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Extraction and Conversion of Exhaust Heat from Automobile Engine in to Electrical Energy

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ABSTRACT: Energy is vital for the progress of the nation and it has to be conserved in an efficient manner. Nowadays increasing worldwide problem is shortage of energy. In an Automobile out of the total heat supplied to the engine in the form of fuel, approximately 30 to 40 percent is converted into useful mechanical work and the remaining heat is expelled out as waste heat. This paper focus on the recovery and utilization of waste heat into useful electrical energy by using See back effect where in Thermoelectric Generators (TEG) are placed on the exhaust surface for converting heat directly into electrical energy. Thermoelectric generators are highly doped semiconductor solid state devices. The output voltage of the thermoelectric generator is given to a dc super lift converter circuit. The output of the super lift converter is used for battery charging.

INTRODUCTION

A. General

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. 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. This effect can be used to generate electricity. It is based on the Seebeck effect, Peltier effect, and Thomson effect. This 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. Thermocouples are based on the effect that the junction between two different metals produces a voltage which increases with temperature. They are frequently used in ovens, furnaces, flue gas measurement and other areas with temperatures above about 250°C.

B. Thermoelectric Effect

When two metals are connected together, a thermoelectric voltage is produced due to the different binding energies of the electrons to the metal ions. This voltage depends on the metals themselves, and in addition on the temperature. In order for this thermal voltage to produce a flow of current the two metals must of course be also connected together at the other end so that a closed circuit is formed. In this way a thermal voltage is produced at the second junction. If there is the same temperature at the two junctions there is no flow of current since the partial voltages produced at the two points cancel each other. With different temperatures at the junctions the voltages generated are different and a current flows.

The measurement point is the junction which is exposed to the measured temperature. The reference junction is the junction at the known temperature. Since the known temperature is usually lower than the measured temperature, the reference junction is generally called the cold junction.

C. Possibility of Heat Recovery and Availability

The heat depends part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. The availability of waste heat from some various sources are tabulated as follows

TABLE - I: AVAILIBILITY OF WASTE HEAT

Types of Device	Temperature (^{0}C)
Steam boiler exhausts	230-480
Nickel refining furnace	1370-1650
IC engine exhausts	120-250
Gas turbine exhausts	370-540
Heat treating furnaces	425 – 650
Steel heating furnaces	925-1050
Air conditioner condenser	32–43

Benefits of waste heat recovery can be broadly classified into two categories.

D. Direct Benefits

Recovery of waste heat has a direct effect on the combustion process efficiency. This is reflected by reduction in the utility consumption and process cost. Possibility of Waste Heat from Internal Combustion Engine greatly depends on automobile engine, i.e. Internal Combustion engines. The majority of vehicles are still powered by either Spark Ignition (SI) or Compression Ignition (CI) engines. CI engines also known as diesel engines have a wide field of applications and as energy converters they are characterized by their high efficiency.

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Small air-cooled diesel engines of up to 35 kW output are used for irrigation purpose, small agricultural tractors and construction machines whereas large farms employ tractors of up to 150 kW output. Water or air-cooled engines are used for a range of 35-150 kW and unless strictly air cooled engine is required, water-cooled engines are preferred for higher power ranges. Earth moving machinery uses engines with an output of up to 520 kW or even higher, up to 740 kW. Diesel engines are used in small electrical power generating units or as standby units for medium capacity power stations.

E. Indirect Benefits

The indirect benefits of heat recovery are:

1) Reduction in pollution-A number of toxic combustible wastes such as Carbon Monoxide (CO),Hydrocarbons (HC), Nitrogen Oxides (NO2), and Particulate Matter (PM) releasing to atmosphere. Recovering of heat reduces the environmental pollution.

2) Reduction in exhaustion of waste heat and increase in efficiency of battery.

2. BLOCK DIAGRAM AND COMPONENT DESCRIPTIONS

In this chapter, the block diagram of a thermo electric converter to convert waste heat obtained on exhaust surface is discussed and the working of various blocks in block diagram is explained in detail. Thermoelectric Generators are devices that convert heat directly into electrical energy, using a phenomenon called the Seeback effect. Thermoelectric Generators can be applied in a variety of low power remote applications. The thermal to electric energy conversion can be performed using components that require no maintenance, have inherently high reliability and can be used to construct generators with long services free lifetimes.

A. Existing System

Fuel cells and solar panels are used to generate the electricity to the vehicles. The Cost of this system will be high. Regenerative braking system is applied to generate the power. The output voltage is very low in regenerative braking system.

B. Proposed System

The proposed system is used to generate the power from heat energy using Peltier device. Proposed system is interfaced with super capacitor and super lift converter. By using this system, it will distribute the power to the rechargeable battery. The charged Power is distributed to the vehicle power supply such as lamps and etc.

C. Block Diagram Description

The thermo electric energy harvester device used is peltier. The peltier is used to convert heat energy into electrical energy and the piezoelectric sensor is used to convert vibration energy into electrical energy. These electrical energies have been stored in super capacitor. The super capacitor works like a battery. The super capacitor is a fast charging and slower discharging capacitor than other types of capacitor. The super capacitor output is given to the Boost converter. The Boost converter is a type of dc to dc converter. The function of Boost converter is to convert the output voltage higher than the input voltage. The Boost converter output is given to the battery for battery charging purpose. The battery power is given to the Inverter. The Inverter output power is distribute to the load. In this project; we can sense the input and output power to maintain the constant output power with the help of Analog to Digital converter (ADC).

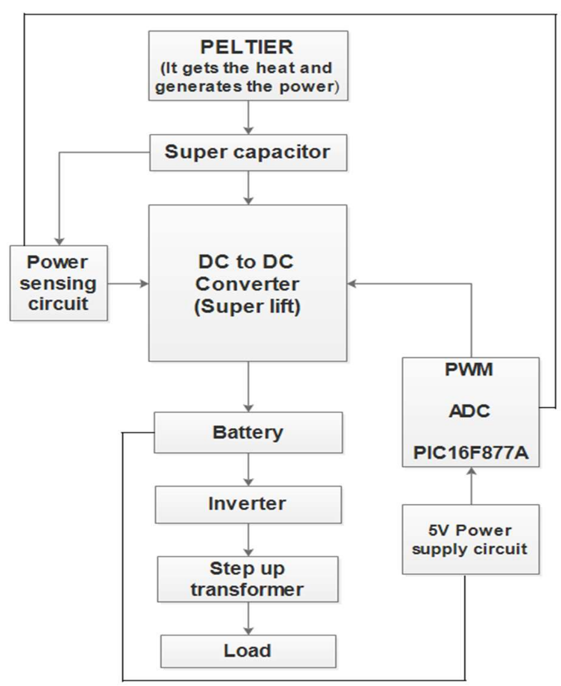

Fig. 1 Block diagram of Heat to Electrical Energy Converter

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D. Component description

The System consists of Thermo Electric Convertor (TEC 1-12706), Power Mosfet-IRFP460, Boost Converter, Super Capacitor, Voltage Regulator-7805, Max232 IC,6V Battery,PIC-16F877A Microcontroller, Single Phase Inverter using IGBT(FGA25N120ANTD) ,Single Phase Transformer and an LCD display.

E. Thermo Electric Generator (TEC 1-12706)

TEG is an acronym for „Thermo Electric Generator". A TEG is a device utilizing one or more thermoelectric models as the primary components, followed by a cooling system that can be either passive or active. Such as an open air heat sink, fan cooled heat sink, or fluid cooled. These components are then fabricated into an assembly to function as one unit called a TEG. When heat is applied to the hot side of a TEG, electricity is produced. Almost any heat source can be used to generate electricity, such as solar heat, geothermal heat, even body heat. In addition the efficiency of any device or machine that generates heat as a byproduct can be drastically improved by recovering the energy lost as heat. TEC1-12706 is 40mm x 40mm size module, it is a single stage module which is designed for cooling and heating up to 90°C applications it is also Known as Thermoelectric cooling modules. They are widely used in industrial areas, for example, computer CPU, coffee maker, portable refrigerators, medical instruments. The Following Figures describes its internal view, working principles and commercial product.

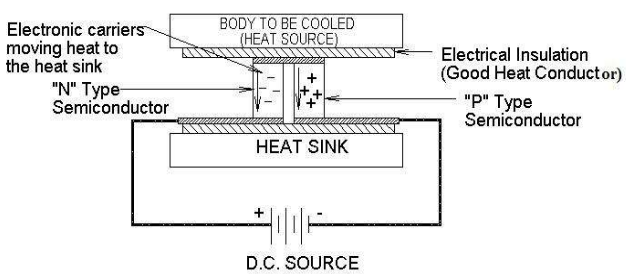

Fig. 2 Thermoelectric Generator Working Diagram

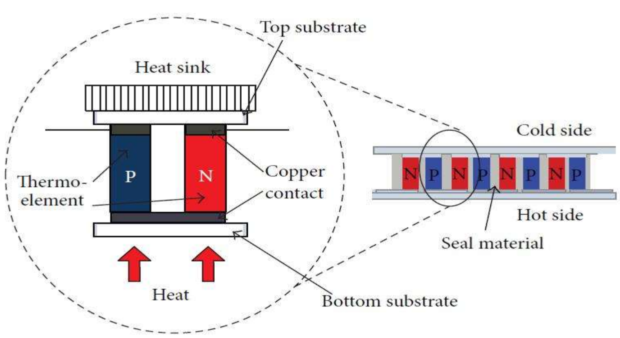

Fig. 3 Thermoelectric Generator Internal View

When any electrical conductor is subjected to a thermal gradient, by heating one end while maintaining the other end at a low temperature, it will generate a voltage between the hot and cold ends. This is known as the SEEBACK EFFECT and this principle used for the direct conversion of heat energy into electrical energy.

F. Super lift Converter

Super lift converter is a new series of DC/DC converter possessing high voltage transfer gain, high efficiency, reduced ripple voltage and current. Super lift technique armed by split capacitors increases the output voltage in higher geometric progression. It is a class of Switched-Mode Power Supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

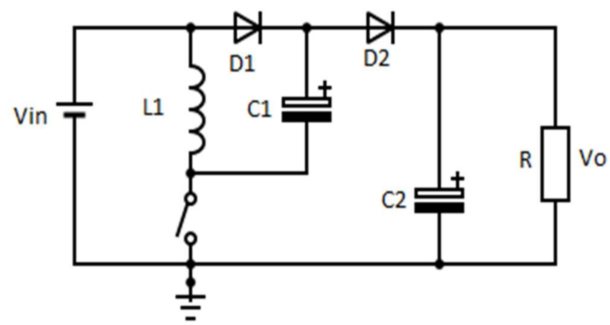

Fig. 4 Super lift converter

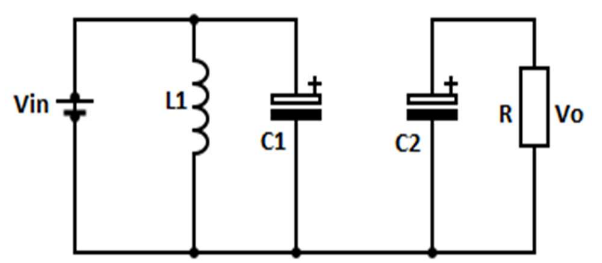

Fig. 5 ON state working diagram

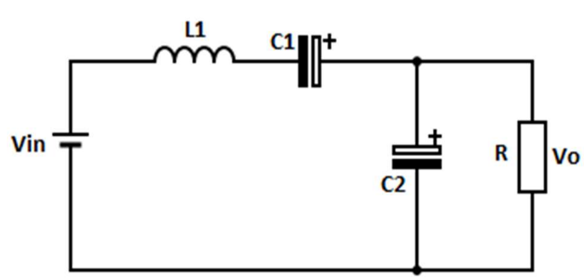

Fig. 6 OFF state working diagram

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Transfer gain of super lift converter is given by,

$$G = \frac{V_0}{V_{in}} = \frac{2-K}{1-K}$$

Where G – Transfer gain

V_0 – Output voltage

V_{in} – Input voltage

3. TEG POWER AND EFFICIENCY CALCULATION

The conversion efficiency η is defined as the ratio of the generated electrical power P_T and the heat input into the module Q_H, Q_c – heat removed from the cooled side.

$$\boldsymbol{\eta = \frac{P_T}{Q_H} = \frac{P_T}{Q_C+P_T}}$$

There are four basic physical entities that are involved in the operation of Thermo Electric Generators (TEG), namely, the Thomson effect, the Joule effect, the Seebeck effect and the Peltier effect. Under steady state conditions, these entities together explain the phenomena of energy flow below.

$$TJ\frac{da}{dx} + \tau J\frac{dT}{dx} - \rho J^2 - \frac{d}{dx}\left(k\frac{dT}{dx}\right) = 0$$

Where T - temperature

J – electrical current density

α – Seebeck coefficient

τ – Thomson coefficient

ρ – electrical resistivity

k – thermal conductivity of the material

The equation of heat flow at hot side is :

$$Q_H = K_T.(T_H - T_C) + S_T.T_H.I - \frac{1}{2}I^2R_T$$

Where $K_T = N(k_n + k_p)G$ – total thermal conductance of N couples.

$S_T = N(a_n + a_p)$ – total seebeck coefficient.

$R_T = N(\rho_n + \rho_p)/G$ – total resistance.

G = area/length – Geometry factor.

Heat flow at cold side is :

$$Q_H = K_T.(T_H - T_C) + S_T.T_c.I - \frac{1}{2}I^2R_T$$

Thus the net power produced by the module P_T is

$$\boldsymbol{P_T = Q_H - Q_C = S_T.(T_H - T_C).I - I^2R_T}$$

$$\boldsymbol{= [S_T(T_H - T_C) - IR_T].I = V_TI}$$

And the voltage produced by the module V_T is

$$V_T = S_T(T_H - T_C) - IR_T$$

Therefore, the P_T, Q_H, Q_C, η can easily be calculated, if the material properties are known. In practice, it is impossible to measure the temperature of both the hot and cold junction.

$$W_H = (W_{T1} + W_{T2} + W_{T3} + W_{CR})$$

Where W_H - Total thermal resistance between T1 and T_H.

W_{T1},W_{T2},W_{T3} – Thermal conductivity resistances.

W_{CR} – Thermal contact resistance.

The hot junction temperature T_H is given by

$$T_H = T_1 + Q_HW_{TC}$$

Similarly, the hot junction temperature T_H is given by

$$T_C = T_2 - Q_CW_{TC}$$

Where W_{TC} – Total thermal resistance between T_C and T_2.

Thus relating to the power produced by the peltier module with that of the output gain of the super lift converter it gives the improved power from the output of the gain and it is given by the following relation,

$$P_O = P_T.G$$

$$P_O = V_TI.\frac{V_O}{V_{in}}$$

Where P_O – Improved stepped up power of the module from the output terminals of the super lift converter.

4. HARDWARE IMPLEMENTATION

In this chapter, the hardware implementation of a THERMO ELECTRIC CONVERTER to convert waste heat obtained on exhaust surface is discussed and its working is explained in detail.

Figure 9 circuit consists of Peltier device (TEC 1-12706), Boost converter with MOSFET switch IRFP460, PIC-

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16F877A Microcontroller interfaced with MAX232 and 16x2 LCD display, Voltage Regulator 7805 and X1 crystal Oscillator to maintain constant 20MHz frequency.
In below Figure 7 TEC1-12706 is placed on the exhaust surface of automobile two wheeler muffler shown.it is also used to convert waste heat generated in hot waste gas exhaust industrial furnace, air conditioner outdoor unit, laptops, car and so on. We implemented this setup in automobile to utilize waste heat and generated electrical energy is used to charge the battery of the vehicle.

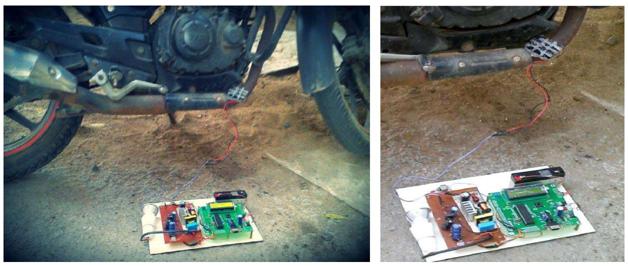

Fig.7 Hardware implementation in automobile two wheeler

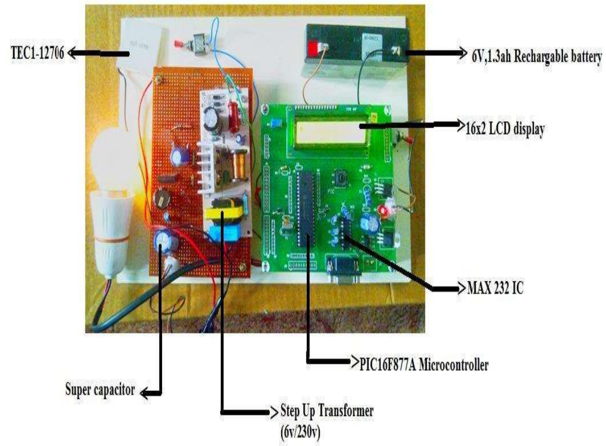

Fig.8 Hardware implementation

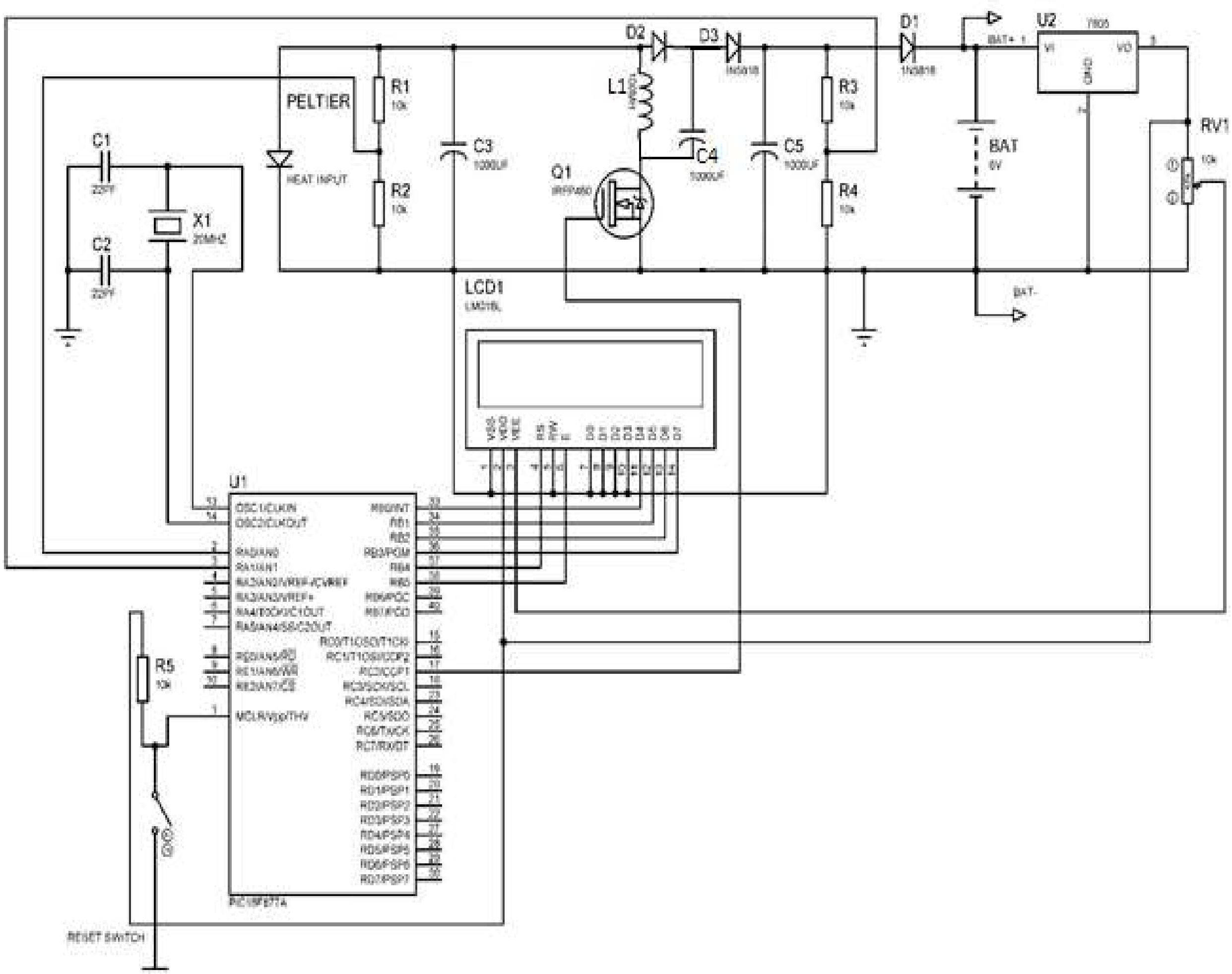

Fig.9 Schematic Diagram of Heat to electrical energy converter

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TABLE-II: Output measurement the temperature measurement is shown below

TEMPERATURE (°C)	INPUT POWER (W)	OUTPUT POWER(W)
42	1.684	2.873
56	1.928	4.973
87	2.4	5.95
71	2.148	5.278
58	1.72	3.554

Fig.10 Temperature Measurement

CONCLUSION

Extraction and conversion of exhaust heat from automobile engine into electrical was successfully implemented using SEEBACK EFFECT. In this project, waste heat obtained in the exhaust surface of the automobile two wheeler are utilized and converted as electrical energy and stored in the battery. This method is more advantageous while we travel longer distance.

The Peltier device (TEC1-12706) can work more efficiently below 150 °C beyond which the power output starts to degrade. The Peltier should be placed on a clean and moisture less surface.

This setup is included in the automobile design and implemented to utilize the waste heat energy and converted as DC electrical energy. This setup can also be used to convert waste heat generated in air conditioner outdoor unit, laptops, car and so on.

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