THERMAL ENERGY HARVESTING AND MANAGEMENT

[1]K. SUDHA, [2] K.VIBHA, [3]S R KABHILESH KUMAR, [4]MELVIN CHARLES S

[1]Assistant Professor II, Department of Electronics and Instrumentation, Velammal Engineering College, Chennai
[2]Assistant Professor, Department of Electronics and Instrumentation, SRM Institute of Technology, Chennai
[3'4] UG scholar, Department of Electronics and Instrumentation, Velammal Engineering College, Chennai
Email: sudha1384@gmail.com@gmail.com*

***Abstract* - The Conventional sources of energy like, coal, petrol, natural gas are limited and will soon be exhausted. The rapid depleting of fossil fuel reserves and increasing concern towards global warming have created the need to surge for the alternative power generation options. Non conventional methods of energy harvesting are gaining eminence nowadays, as they are more energy efficient, reduce pollution and also they serve as a promising solution to the toughest energy crisis faced during the recent years. Energy harvesting (or) scavenging is a process that captures small amount of energy that would otherwise be lost as heat, light, vibrations, RF, movement. Thermal energy harvesting is one of the popular methods of capturing waste heat from the environment and converting it into electricity. Easy maintenance, less weight, Environmental friendliness, High reliability and Availability of power throughout the day are some distinct advantages of thermoelectric generators compared to other energy harvesters. This paper focuses on the modelling of thermoelectric power generation. The simulation of the system is done using MATLAB/Simulink software and prototype of the same is implemented. ATMELAT89S52 microcontroller is used because of its flexibility and cost effectiveness. The coding is written in EMBEDDED C and compiled using KEIL software. The implemented prototype is tested and it is found that the output power generated is capable of powering mini home appliances.**

Keywords— *Energy Scavenging, Hybrid energy harvesting, thermoelectric generator, Peltier sensor.*

I. INTRODUCTION

Energy is the cornerstone of our modern society. It permits services and opportunities that range from the simple to the profound, from cooking meals to education. Without electricity, we are denied healthcare, sanitation services, and the social, educational, economic, scientific, and agricultural progress. As the demand for power and energy is increasing rapidly and depletion of natural resources is taking place with the same pace, the emergence of environmental friendly and pollution free non-conventional energy resources has become a viable alternative. There are wide spectrums of alternative energies like Solar, Wind, RF, Vibrations, Biomass, and Tidal which are environment friendly and are available in abundance. Thermal Energy Harvesting is based on Thermoelectric Effect which is direct conversion of temperature differences into electricity. In 1820 Thomas Seebeck discovered that if two metals at different temperatures touch it is possible to create an electric current. Jean Peltier discovered that the opposite was also true. Seebeck coefficient is given by $S = -\Delta V/\Delta T$ where ΔV is the voltage difference and ΔT is the temperature difference between hot and cold sides. The negative sign comes from negative charge of the electron. The device which converts temperature differences into electricity is called as Thermo Electric Generator (TEG) [2]. There are many sources for thermal energy found in the environment like Waste heat from Automobiles, Waste Incinerators, Home appliances, Factories (Glass, Al) etc.

II. GENERAL BLOCK DIAGRAM

The block diagram of the implemented Thermal Energy Harvester is shown in the figure 1. The various components used for designing thermal energy harvesters are explained below.

1. PELTIER SENSOR

A thermoelectric cooling (TEC) module [2] is a semiconductor-based electronic component that functions as a small heat pump (transfers heat from one plate to another).

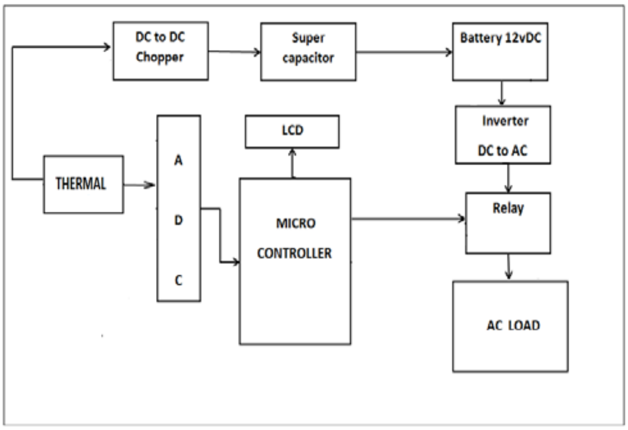

Figure 1 Block Diagram of the proposed Thermal Energy Harvester

A Peltier [6] has two plates, the cold and the hot plate. Between those plates there are several thermocouples. By creating temperature differences electricity can be generated. This is based on Seebeck effect and can be used for power generation. Peltier thermo-elements are mainly made of semi conductive material. They have a lot of P-N contacts connected in series which are heavily doped. Usually P-type and N-type materials are alloys of Bismuth and Tellurium. The specification of the Peltier sensor used is given in table1.

Model number	TEC1-12706
Voltage	12V
Umax (V)	15.4V
Imax (A)	6A
QMax (W)	92W
Max. Temperature	68°C
Internal resistance	1.98 Ohm +/- 10%
Dimensions	40mm x 40mm x3.6mm

Table 1 Specification of the Peltier Sensor

2. MICROCONTROLLER

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller [2] with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non volatile memory technology and is compatible with the Indus-try-standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in- system or by a conventional non volatile memory programmer. Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

3. ANALOG TO DIGITAL CONVERTER

The ADC0808, ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic [1]. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals.

4. DC TO DC CHOPPER

Chopper is a static power electronics device which converts fixed dc voltage/power to variable DC voltage or power. It is nothing but a high speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output. Step up chopper or boost converter [1] is used to increase the input voltage level and deliver at its output side.

5. SUPERCAPACITORS

Super capacitors [6] are also known as Ultra capacitors. Capacitors charge and discharge very quickly. On the other hand batteries can hold a large amount of power. The super capacitor [4] combines the merits of both battery and capacitor. It has higher power density, high efficiency (97-98%), much faster charge and discharge rate, environmentally friendly, extremely low internal resistance or ESR

ISSN 2229-5518

6. BATTERY

An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode, and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work.

7. INVERTER

An inverter is an electric apparatus that changes direct current (DC) to alternating current (AC). Direct current is created by devices such as batteries and solar panels. When connected, an inverter allows these devices to provide electric power for small household devices. The inverter does this through a complex process of electrical adjustment [6]. From this process, AC electric power is produced. This form of electricity can be used to power an electric light, a microwave oven, or some other electric machine.

8. RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal or where several circuits must be controlled by one signal. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

III. GENERAL WORKING

Thermal energy is supplied as the input to one side of the Peltier sensor. As the heat moves from hot side to cold side, the charge carriers also move inside which gives rise to a voltage [4]. This voltage increases when the temperature difference increases. The output voltage is then given to a DC-DC converter (boost chopper). The boosted voltage from the chopper is stored in a super capacitor and finally in a 12V battery which is used to store the charges for future purposes. The DC output produced is converted to AC supply using an inverter. In order to convert the AC Voltage to usable range (180-230V) a step up transformer is used. The AC supply after conditioning is given to the load. (Here the lamp acts like the load.)

IV. SIMULATION

The simulation done using MATLAB software is shown in fig 2 and fig 3. A constant temperature of 115 deg is assumed at one side while the temperature on the other side is varied from 65 deg to 90 deg. The difference in temperature is directly proportional to the output voltage . The output voltage from the voltage scope is given to the boost converter and then is given to the load. In the same way the graph for different temperatures are obtained.

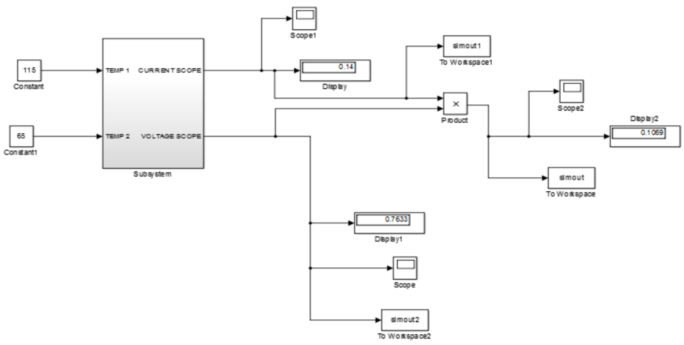

Figure 2 TEG Model implemented using MATLAB/Simulink

Inside the subsystem of the TEG model [1] the following equations of the voltage and current are implemented.

CURRENT EQUATION $I = \alpha \Delta T/(1+m)R$

VOLTAGE EQUATION $V = -R(I - I_{shortckt})$
Where $I_{shortckt}$ is the maximum current of TEG $I_{shortckt} = 2 I_m = 2W_m/V_m$.

The values of the parameters used in the above equations are listed in the table 2.

PARAMETERS	DESCRIPTION	VALUE
α	Seebeck coefficient of TEG	0.031 V/K
ΔT	Difference in temperature	115-t1
m	Ratio between load resistance and internal resistance	1
R	Matched load resistance	0.5 Ω
W_m	Matched load output power	5 W
V_m	Matched load output voltage	6 V

Table 2 Shows parameters used in current and voltage equations

The boost converter designed using MATLAB/Simulink is given in fig 3.

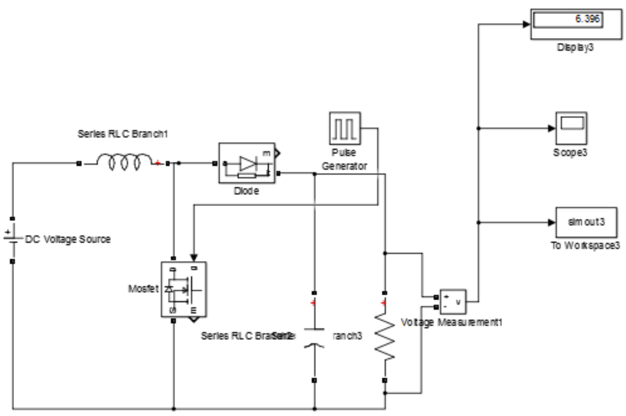

Figure 3 Simulink Model of Boost Converter

V. RESULTS AND DISCUSSION

The simulation results and the implemented model are compared. The graphs obtained for input temperature 65 deg and 75 deg are shown in the figure. Here fig 4 and fig 5 represent the current and voltage scope of the TEG model. Fig 6 represents the final output after boosting.

SIMULATION GRAPHS FOR TEMPERATURE OF 65 DEG

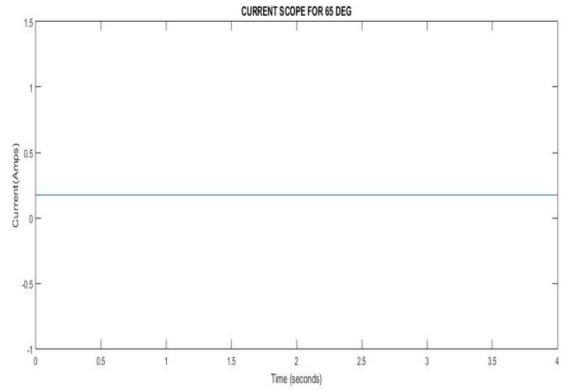

Figure 4 Current Scope for 65 deg

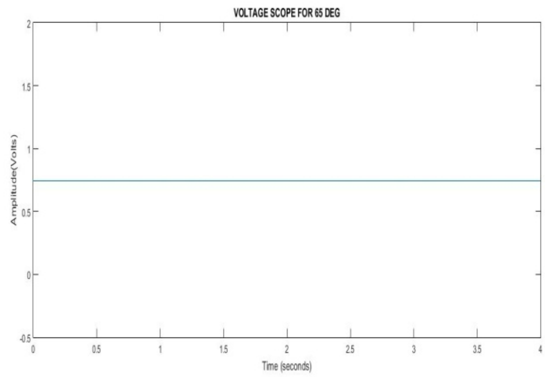

Figure 5 Voltage scope for 65 deg

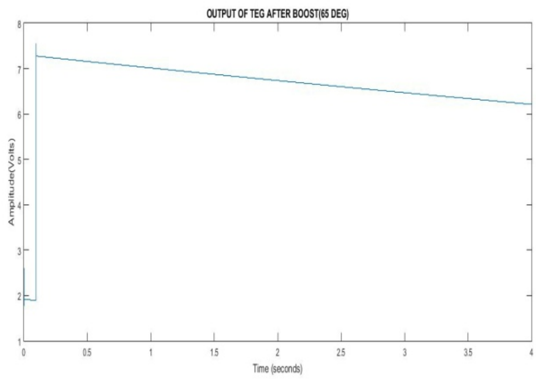

Figure 6 Final output after boost

In the same way as obtained for 65 deg, the simulation output for 75 deg is also obtained. The fig 7 and fig 8 represent the current and voltage scope of the TEG model. Fig 9 represents the final output after boosting.

ISSN 2229-5518

SIMULATION GRAPHS FOR TEMPERATURE INPUT OF 75 DEG

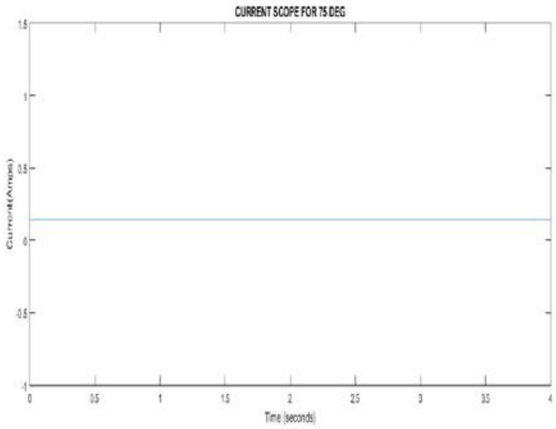

Figure 7 Current scope for 75 deg

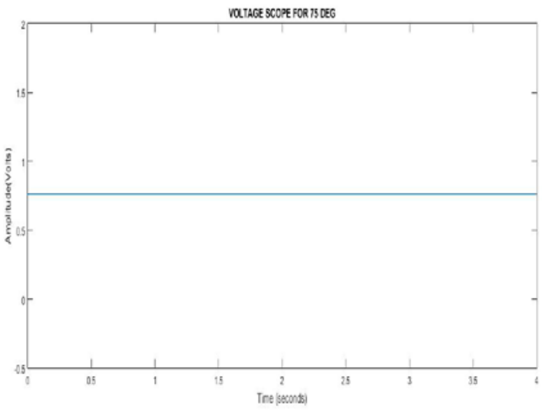

Figure 8 Voltage scope for 75 deg

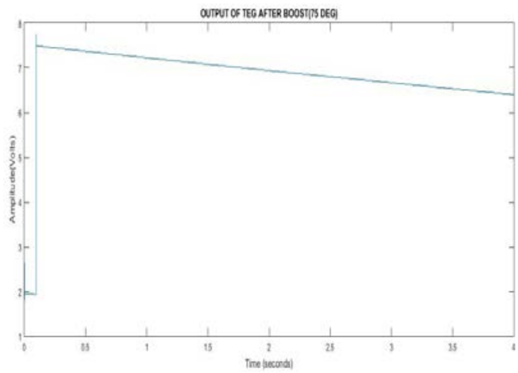

Figure 9 Final output after boost

The results obtained from the simulation model and the implemented prototype is tabulated in the table 3. The fig 10 shows the implemented prototype.

TEMPERATURE (DEG CELCIUS)	SIMULATION RESULTS		HARDWARE RESULTS	
	Before boosting (V)	After boosting (V)	Before boosting (V)	After boosting (V)
65	0.736	6.396	0.54	5.32
75	0.715	6.21	0.51	5.12

Table 3 Results obtained from simulation model and hardware prototype

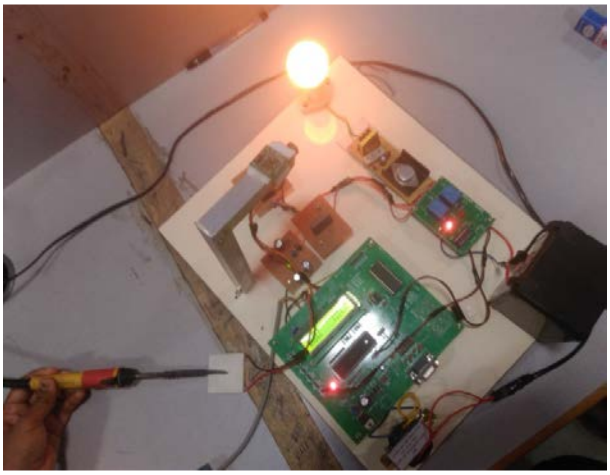

Figure 10 Implemented prototype of the thermal energy harvester

VI. CONCLUSION AND FUTURE SCOPE

Thermoelectric generators have several advantages like easy maintenance, no moving parts, environmental friendly, less weight, high reliability, portable power and it is available 24 hours a day. Because of these distinguished advantages compared to other energy harvesters they find numerous applications like candle operated table light, electricity from tea cup, waste heat from automotive engine can be used for charging battery, glowing indicators, playing music and many more. The future scope aims at developing a hybrid energy harvester including RF and Vibration Energy Harvesters.

BIBILOGRAPHY AND REFERENCES

[1] Carlson, E.J., K. Strunz and B.P. Otis. A 20 mV input boost converter with efficient digital control for thermoelectric energy harvesting. IEEE J. Solid-State Circuits, 2010;45(4):741-750.

[2] Michelle Lim Sern Mi, Sawal Hamid Muhammad Ali, S. Jahariah and Muhammad Shabiul Islam. Modelling of hybrid energy harvester with dc-dc boost converter using arbitary input sources for ultra-low-power micro-devices. IEEE Int. Conf. Semiconductor Electronics, 2014;28-31.

[3] Mayer P M and Ram R J 2006 Optimization of heat sink limited thermoelectric generators Nanoscale Microscale Thermophys. Eng. 10 143–55

[4] Cobble M H 1995 Calculations of generator performance CRC Handbook of Thermoelectrics (New York: CRC Press) chapter 39

[5] Thomas J P, Qidwai M A and Kellogg J C 2006 Energy scavenging for small-scale unmanned systems J. Power Sources 159 1494–509.

[6] D.Samson, M.Kluge, Th.Becker Energy harvesting from autonomous wireless sensor nodes in aircraft IEEE Journal September 2010

[7] L. Bell, "Cooling, heating, generating power, and recovering waste heat with thermoelectric systems," Science, vol. 321, no. 5895, pp. 1457–1461, Sep. 12, 2008

[8] S.Lineykin and S.Ben-Yaakov, " Modelling and analysis of thermo electic modules," IEEE Trans. Ind. Appl., vol.43, no. 2, pp. 505-512, Mar./Apr.2007.