
International Journal of Physical Sciences and Engineering
Available online at www.sciencescholar.us
Vol. 5 No. 2, August 2021, pages: 25-33
e-ISSN : 2550-6943, p-ISSN : 2550-6951
https://doi.org/10.29332/ijpse.v5n2.1359

Design and Construction of a Thermoelectric System for High Performance Computers

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Manuscript submitted: 09 April 2021, Manuscript revised: 18 May 2021, Accepted for publication: 27 June 2021

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Keywords

control;
cooling;
heatsink;
thermo sensors;
thermoelectric;

Abstract

The objective of the project is to develop a cooling system as a new alternative to improve the efficiency of desktop-type computer equipment, allowing to extend the useful life of the computer processors more and to obtain a better performance. In manufacturing the system, the thermoelectric cooling technique was used, using components such as Peltier cells, heat sinks, axial fans, and thermal paste in the mechanical section, and temperature sensors were applied to control them. In this sense, it was possible to reduce hot temperatures from 33°C to 20°C on average while maintaining adequate temperatures for the processor, among its characteristics is the energy consumption of 0.18 kWh, the temperature of the hot unit 38.67 ° C, heat to dissipate 132.27 W, cold unit temperature 2 ° C and airflow temperature at the outlet of the system of 19.6 ° C, results obtained in real-time during the practical experimentation phase in various system testing tests Cooling. In conclusion, it is this system that allows reducing temperatures through the delivery of air at a temperature lower than the ambient temperature, unlike active cooling systems that deliver airflow at an ambient temperature of 30 ° C.

Contents

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1 Introduction

Currently, the use of computers is an essential part of daily activities, especially in the growing virtuality that is being experienced, becoming an indispensable work tool, whose benefits go from the collection of information to its processing, that is why that are linked to most institutions, companies, and homes. The progress generated from studies in the technological field in computer cooling systems, such as computers that provide essential resources or methods that provide improvements in data collection time.

Studies such as that refer to work proposals for the design of a Peltier cell system that allows maintaining temperatures, where mathematical formulas are used to determine computer temperatures, which is related to algorithms running on the present system. Research by based on the Le Chatelier-Braun theory, and the energy balance equation in the presence of electric current and heat flow. Likewise, establishes the cooling and cooling needs of spaces to increase comfort have increased, and the technology based on the Peltier effect presents more interest every day (Maury, 2010; Rota et al., 2006).

The fact of being able to cool a space with little noise and low mechanical wear due to friction parts allows opening the doors to thermoelectricity. In this document, the analysis of the assembly of a refrigeration module using Peltier cells is presented. The proposed system has two thermal energy dissipation modules, 12 Volt 0.6 Amp fans for airflow, and 6 6 Amp Peltier cells, connected in parallel. For the system test, two power sources are used, one with a capacity of 15 Amps and 12 Volts and the other with a capacity of 14 Amps and 12 Volts, but despite this, the cooling capacity achieved is low. for the space in which the test was carried out, which is why it should be noted that it is possible to optimize the design and improve the performance of the proposed system (Gould et al., 2011; Rahman & Shuttleworth, 1995).

The present study consists of the development of a liquid cooling or water-cooling system that is more effective and economical than conventional and commercial cooling systems for the application of overclocking to computer equipment in gaming and rendering situations, said system consists of various radiators or water blocks, which will have the function of regulating the high temperatures produced by the integrated circuits of the CPU and GPU. The hydraulic circuit of this system will consist of a water store where it will be driven towards the different water blocks that are in charge of cooling the liquid with the use of the Peltier effect and in turn, this will be in charge of cooling the microprocessors, the heat emanated by the cells. of Peltier will be compensated by heatsinks with fans or coolers (Sepúlveda et al., 2018).

2 Materials and Methods

This study is developed in the city of Portoviejo - Manabí - Ecuador located at a latitude of 1.0546 ° S, 170 feet above sea level, at the facilities of the Paulo Emilio Macías Higher Technological Institute; to develop a prototype of an automatic cooling system for desktop computers in the computer lab. Given the design of a thermoelectric cooling system is proposed, because it is possible to lower the air temperature below the ambient temperature, it is designed based on the experimental method.

3 Results and Discussions

For design purposes, the nominal temperature of the ambient air will be evaluated and a series of tests with the automatic thermoelectric cooling system will be evaluated to lower the temperature to 10 ° C as the output flow of the system. the static pressure drop of the SP fans is low due to its direct installation (without ducts). To obtain data as part of the information gathering, digital measuring instruments such as the temperature meter (hygrothermal) were used in various intervals of time, which will be recorded in an experimental observation file (Wiriyasart et al., 2019; Choi et al., 2012).

Design of the thermoelectric cooling system

The design of the thermoelectric cooling system conforms to 3 Peltier cells Model TEC1-12600 fed at 12 volts (V) and 6 amps (A), which allows obtaining 15 ° C (centigrade) at the bases of the heatsinks. On the other hand, it is made up of 2 heat sinks of 12 centimeters squared (cm2), indispensable means to carry out heat transfer and to be able to remove through the 2 axial fans with their measurements of 12 centimeters squared (cm2) and 2.5 centimeters (cm) with a rotation speed of 1200 revolutions per minute (RPM).

For the control of the cooling system, an Arduino Mega 16 board is incorporated, this allows us to program several variables such as control temperatures, and they are also installed DHT11 thermo sensors for capturing physical quantities (temperature) and being translated into electrical pulses as signals for control. In this sense, these temperature values recorded by the system are displayed using 1 liquid crystal display (CD) monochrome, likewise, 4 relays model ESP32 type normally open (NO) and normally closed (NC) powered at 5V are integrated, which is responsible for opening or closing the circuit.

Experimentation

In this phase, the environmental temperature is initially evaluated, then the dissipators with an area of 12 x 12 are selected. x 2.5 the 12 x 12 x 2.5 fan at an angular rotational speed of 1200 revolutions per minute. Table 1 referring to the variable interval test is presented below.

Table 1
Automatic cooling system test data

Test	Operating time		Temp. Ambient	Temp. Heat sink (° C)	Heat to dissipate (W)	Temp. Cold sink (° C)	Temp. System airflow
	Start	End					
1	10:00	12:00	30.1	38.40	131.50	1.96	19.0
2	14:00	16:00	30.2	38.45	131.67	1.99	19.2
3	10:00	12:00	30.3	38.47	131.73	2.10	19.5
4	14:00	16:00	30.5	39.00	133.55	2.15	19.8
5	10:00	12:00	30.3	38.46	131.70	1.965	19.5
6	14:00	16:00	30.1	38.40	131.50	1.96	19.0
7	10:00	12:00	30.3	38.47	131, 73	2.10	19.5
8	14:00	16:00	30.5	38.40	131.50	1.96	19.8
9	10:00	12:00	30.0	39.0	133.60	2.10	19, 0
10	14:00	16:00	30.5	39.00	133.55	2.10	19.8
11	10:00	12:00	30.2	38.46	131.70	1.965	19.2
12	14:00	16:00	30.5	38.90	133.21	2.00	19.8
13	10:00	12:00	30.5	38.40	131.50	1.96	19.8
14	14:00	16:00	30.4	38.75	132.69	2.00	19.7
15	10:00	12:00	30.3	38.40	131.50	1.96	19.5
16	14:00	16:00	30.4	38.7	132.52	2.00	19.7
17	10:00	12:00	30.5	39.05	133.72	2.10	19.8
18	14:00	16:00	30.4	38.75	133.60	2.1	19.8
19	10: 00	12:00	30.5	39.02	133.62	2.00	19.8
20	14:00	16:00	30.5	39.00	133.55	2.10	19.8

As seen the average environmental temperature is 30.35 ºC and the minimum reaches Adopted by the system is 19.6 ºC, in this sense, it was possible to achieve a reduction of 10 ° C as proposed in the study, likewise, its average consumption is 0.13 Kw / h. According to (Villarrubia, 2001), This is justified because thermoelectric cooling is based on the Peltier effect and constitutes a system for direct conversion of electricity into cold, without going through mechanical or thermal energy. completely static, without moving parts, and powered only by direct current, it is very useful in all those applications where the load to be refrigerated is in motion

(Rafati et al., 2012; Qiao, 2006). On the other hand, it is essential to establish heat parameters to be dissipated by the aluminum heatsink to have a balance between the hot and cold zone to obtain adequate operational values of the thermoelectric cooling system. Figure 1 shows the heat to be dissipated versus the temperature of the heat source.

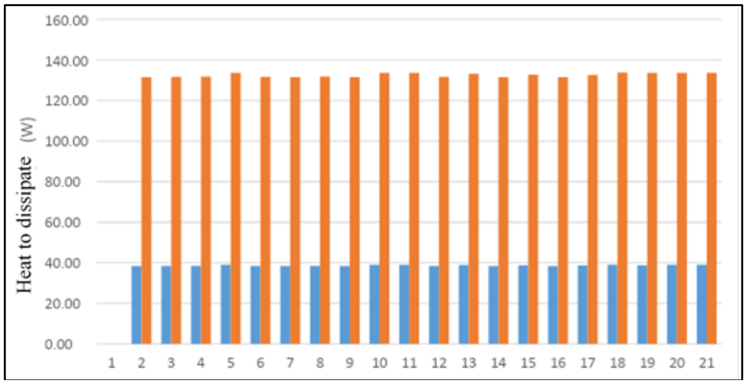

Figure 1. Heat to dissipate versus the temperature of the hot source
Source: Authors of the Project

In another context of the experimental phase, it was possible to obtain data referring to the temperature of the airflow and the system concerning the cold unit of the heatsink where the linear correlation that exists in the face of changes in the physical magnitude of temperature is appreciated, in other words, that the outlet temperature of the airflow from the thermoelectric system depends on the external environmental temperature. In figures 2 and 3 the aforementioned is plotted (Nozariasbmarz et al., 2020).

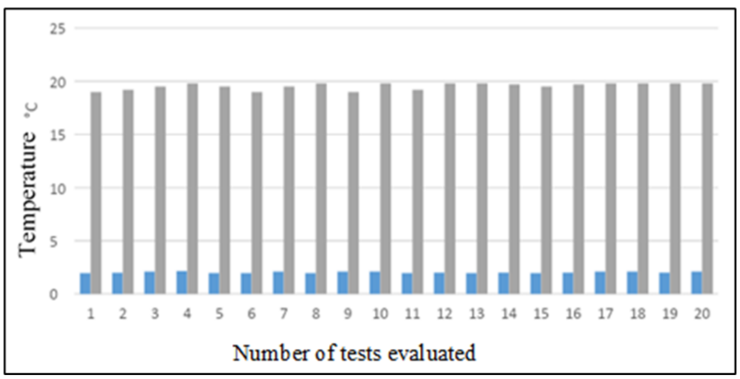

Figure 2. Airflow temperature concerning the heat sink temperature of the cooling unit

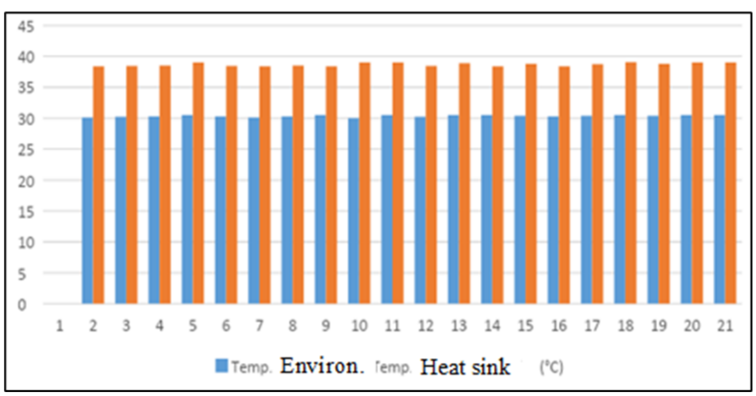

Figure 3. Airflow temperature concerning the heat sink temperature of the heating unit.

Source: Authors of the Project

Given the above, the linear correlation of the ambient temperature with the airflow temperature of the cooling system is graphically evidenced, the relationship being strongly positive with r2= 0.9. It is represented in figure 4.

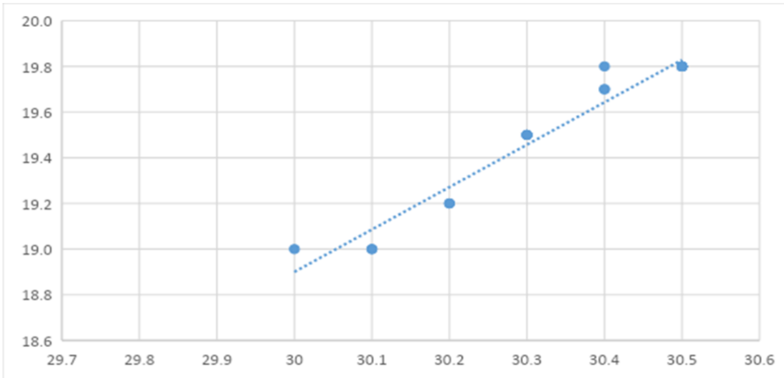

Figure 4. Correlation between ambient air temperature concerning the system
Source: Authors of the Project

Energy costs

Table 2 shows the total cost of energy consumption of the cooling system with Peltier technology, concerning the number of hours in operation. On the other hand, Table 3 shows the characteristics of the thermoelectric system.

Table 2
Annual consumption of the thermoelectric cooling system

Energy Consumption per cell (kW-h)	Peltier Cells	Total Energy Consumption Kw-h)	Cost Kw-h	Total Cost per hour ($)	Hours of operation	Total Cost per day ($) - 8 hours
0.06	3	0.18	0.08	0.0144	8	0.11

Table 3
Operating characteristics of the cooling system

Characteristics of the Thermoelectric system			
Temp. Heat sink (° C)	Heat to dissipate (W)	Temp. Cold sink (° C)	Temp. System airflow
38.67	132.4795	2.0285	19.6

As part of the automatic design, the cooling system works concerning the increase in temperatures that are generated in the processor, through electrical signals that are measurable and interpretable to electronic components such as the Arduino, activating or deactivating the thermoelectric system (Omer, 2015; Hong et al., 2020). For this purpose, the components used are described, described in table 4 below.

Table 4
Description of the elements of the system

Description	Model

Cell Peltieer	TEC1- 12706)
Power supply Altek	P4-750W
Heatsink	Al RE
fans,	Axial 1200 RPM, 12 cm
Arduino	Mega 16
Monochromatic	Lcd I2c 1602
Temperature sensors	AM2301
Relays	5VDC. V-12

On the other hand, the mechanical design of the prototype of the automatic cooling system is shown in figure 5.

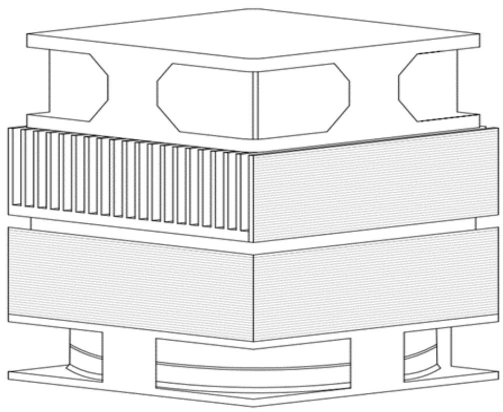

Figure 5. Design of the prototype of the cooling system
Source: Project authors

The calculations are based on the methodology and the results are adjusted to the objective of the research, thus, during the information gathering process through the baseline, it was possible to know the types of cooling applied in processors of desktop computers. Through the review of specialized sources, the design criteria involved in the thermoelectric cooling system were selected as mechanical components, citing heatsinks, thermal paste with a high coefficient of thermal conductivity (K) of 0.9 W/mK, fans low static pressure (SP), and rotation speed according to low sound decibels (dBA), heat sinks with high thermal conductivity (K) such as 205 W / mK aluminum, Peltier cells with technical characteristics of Operating voltage: 0 to 15.2 VDC, operating current of 0 15A, maximum power consumption of 231 Watts, thermosensors in the range of 10 to 90 ° C of operation and Arduino Mega 16 for the programming of the system regarding control (Pourkiaei et al., 2019; Chiu et al., 2011).

The characteristics of the prototype automatic thermoelectric cooling are the hot unit temperature of 38.67 ° C, heat to dissipate of 132.4 watts, cold sink temperature 2.1 ° C and the system outlet volumetric flow temperature. it is 19.6 ° C. The findings indicate that the thermoelectric cooling system in its operation is essential for the integral care of the processor, in conditions of correct use or conditions that are demanding. The statements are related to the analysis of (Gonzalo Toledo, 2020) and (Mariscal et al., 2011) in their research on a thermoelectric cooling system with Peltier cells mention that the magnitude of thermal resistances influences the performance of the Peltier cell, it is also mentioned that to keep the help of a control system is needed to maintain it regardless of the temperature variations of the external environment.

In this sense, the technology of the Peltier effect was used by applying a potential difference to the electrical circuit which creates a cooling effect, in this context the equation 1, design conditions applied by Jean Charles Athanase Peltier. On the other hand, the SETA prototype installation has elements of reduced dimensions compared to other systems that require other bulky elements to reach temperatures below ambient, which is articulated with other studies carried out by MC Higinio Acoltzi Acoltzi on cooling systems thermoelectric.

P=Qh-Qi (1)

Where:
Qh Heat that moves to the interior or focus to cool

Ql heat displaced to the environment.

As part of the calculation methodology, Fourier's law was used considering the difference in temperature from the outside with the other medium to be cooled (processor), the thermal conductivity, thermal resistance between the hot and cold unit, the electrical power supplied to the Peltier cells. , thickness and area and coefficient of thermal conductivity of the heatsinks; agreeing with the calculations developed by a thermoelectric refrigeration system of Ing. José Luis del Río Valdés This agrees with the analysis of results, through the analysis and verification of the process in the experimentation phase, allowing the decrease of temperatures, providing reliability to the processor throughout the running computational operations (Eom et al., 2017; Saber et al., 2019).

4 Conclusion

The contribution of a prototype of an automatic cooling system is the reduction of the ambient air temperature and adaptable to the installations of a desktop computer, using aluminum heatsinks due to their high heat transfer coefficient, allowing to cool the processor in specific design tasks, reducing overheating, delivering stability, and extending its useful life.

Acknowledgments
We are grateful to two anonymous reviewers for their valuable comments on the earlier version of this paper.

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