Use of Peltier Cells in the Cooling Process

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Abstract— *Peltier cells represent an interesting alternative to conventional cooling methods and are currently being used in areas where conventional cooling methods are not suitable. They can produce heat and cold when supplied with electricity. The article discusses the possibilities of using Peltier cell technology in the cooling processes of electronic components in an environment where it is not possible to use conventional cooling methods due to their size or the inappropriateness of the given type of cooling. It compares cooling options and describes basic power calculation procedures to cover cooling power needs. Thermoelectric cooling has several advantages, including the absence of a cooling medium, the possibility of precise temperature regulation, small dimensions and a relatively long service life.*

Keywords*— *Peltier cells, thermoelectric device, heat transfer.

I. INTRODUCTION

With the development of science, technology and the use of advanced technologies, new software applications are constantly created with increasing requirements for hardware, and the associated constant increase in computer performance. As power increases, so does the thermal power produced by electronic components, whether in computers or mobile devices, which must be removed from the device to ensure the required power. To prevent the system from malfunctioning, it is necessary to improve the heat dissipation. The need for heat dissipation adjustments arises due to the increasing performance of cooled parts of the computer and other semiconductor components. While in the past only one fan, usually located in the power source, or passive coolers placed on the surface of the most heated elements was sufficient to cool the computer, nowadays most components are supplemented with a cooler and often this cooler is also supplemented with an active part, a fan or water cooling and a heat exchanger , through which the heat accumulated in the coolant is removed to the surroundings.

Radiant heat is generated on the surface of the printed circuit board fitted with semiconductor components and power components, the effects of which on the power components and individual processors of desktop computers and mobile devices affect their proper work. These semiconductor power components produce radiant heat during their operation, so we can consider them as heat sources. Effective cooling makes it possible to use the maximum power of the transistor, processor and thus also the performance of the given components. Performance growth also results in an increase in processor temperature ratios and the related need for better heat dissipation. In addition to the standard method of cooling processors, which is soon a thing of the past, new cooling methods with new cooling elements and technologies are coming to the fore. The use of the Peltier cell in the field of computer technology and primarily mobile technology brings the advantage of the compactness of the cooling device, but at the cost of additional energy consumption compared to passive heat removal systems. The most interesting nowadays is the use of small Peltier cells in the cooling of powerful mobile devices, where there is no possibility of water cooling and air cooling is not a sufficiently efficient way of cooling due to the poor transfer of heat from the core of the device through the plastic protective covers. In such a case, direct contact of the cold side of the Peltier cell provides a better cooling method, while only a passive heat exchanger or a small fan is sufficient to cool the heated side.

II. THE PRINCIPLE OF THE PELTIER CELL FUNCTION

A Peltier cell is a thermoelectric device that, when an electric current flows, develops different temperatures on the contact surfaces of two conductors, whereby one surface cools and the other heats up (Peltier phenomenon), or vice versa, when different temperatures are supplied, an electric current is generated (Seebeck phenomenon). Peltier cells are most often constructed in such a way that a larger number of elements, mostly made of semiconductor materials, are connected in series in terms of electric current flow and in parallel in terms of heat flow.

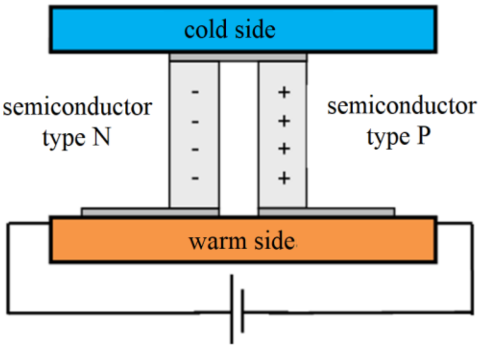


FIGURE 1: One thermoelectric cell

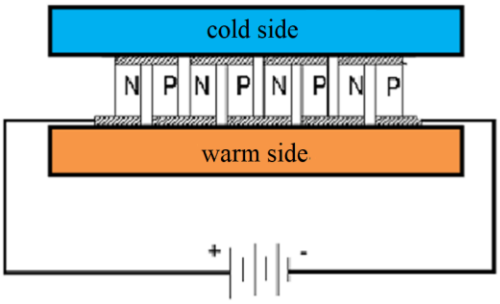


FIGURE 2: Serial connection of thermocouples

Peltier cells consist of several thermocouples connected to a thermoelectric battery. Individual thermocouples are connected using metal bridges that ensure their electrically conductive connection. The mechanical integrity and electrical insulation of the thermocouples are ensured by the ceramic plates on which the thermocouples are fixed. Power supply is provided by two electrodes located on the edges of the cell. Thanks to the process of miniaturization of individual components, including semiconductor parts used in Peltier cells (PC), the thickness of the cell itself and also the weight are reduced, which enables its more comfortable use in the case of mobile applications.

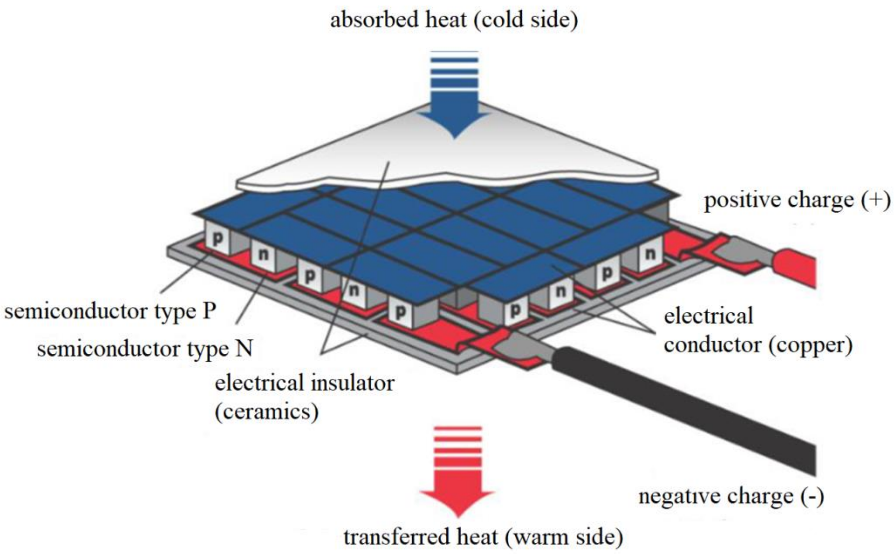


FIGURE 3: Peltier cell

For the heat output entering on the cold side into the Peltier cell PS (fig. 3) this equation applies:

$$P_S = \alpha \cdot I \cdot T_S - \frac{R \cdot I^2}{2} - \lambda \cdot S \cdot \frac{\Delta T}{l} \text{ (W)} \tag{1}$$

where α is Seebec's coefficient ($V \cdot K^{-1}$), R – electrical resistance (Ω), I – electric current (A), T_S – temperature on the cold side of PC (K), T_H – temperature on the warm side of PC (K), λ – the coefficient of thermal conductivity used material ($W \cdot m^{-1} \cdot K^{-1}$), S – total cross-section of all semiconductor pillars (m^2), l – the height of semiconductor pillars (m), $\Delta T = T_H - T_S$.

Thermal power output on the warm side of the PC P_H can be written in the form:

$$P_H = \alpha \cdot I \cdot T_H + \frac{R \cdot I^2}{2} - \lambda \cdot S \cdot \frac{\Delta T}{l} \text{ (W)} \tag{2}$$

After reaching a steady state, when individual quantities no longer change with time, the law of conservation of energy must apply to the electric power supplied to the cell:

$$P_E = U \cdot I = P_H - P_S = \alpha \cdot I \cdot \Delta T + R \cdot I^2 \text{ (W)} \quad (3)$$

The PC cooling efficiency expresses the ratio of the heat removed from the cold side of the cell to the electrical output and can be described by the relation:

$$\eta_{TEC} = \frac{P_S}{P_E} = \frac{\alpha \cdot I \cdot T_S - \frac{R \cdot I^2}{2} - \lambda \cdot S \cdot \frac{\Delta T}{l}}{\alpha \cdot I \cdot \Delta T + R \cdot I^2} \quad (4)$$

III. DESIGN OF A COOLING SOLUTION USING PELTIER CELLS

In the experimental cooling design, the used cooling technology and heat removal from the semiconductor component (CPU processor), water in a steel container with a temperature of about 70°C, which was thermally insulated, was used to simulate the supplied heat from the processor. A steel container with a height of 200 mm and a weight of 250.95 g with a diameter of 70 mm was sufficiently insulated with PVC insulation with a thickness of 10 mm and a weight of 36.62 g. The foil served to reduce heat flow by radiation. Sufficient insulation prevents us from transferring energy through thermal conduction, which takes place in solids and liquids. The measurement was based on basic knowledge of the theory of heat and mass transfer.

FIGURE 4: Insulated steel container

The choice of PC was based on parameters such as the size of the maximum supply voltage and the size of the maximum current, cell dimensions, the temperature difference between the hot and cold side and, of course, the power of the cell. The cell used is soldered by the manufacturer with BiSn solder, which has a melting temperature of 138°C. For this reason, it is very important not to exceed this temperature during the experiment, otherwise the solder may melt and the cell may be destroyed.

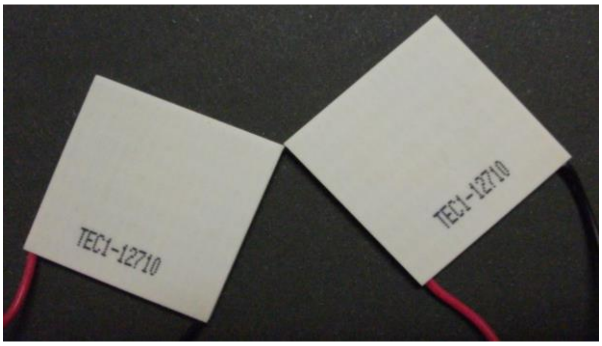


FIGURE 5: Peltier cell TEC1-12710

An 80x80mm fan was used for sufficient heat removal from the cooler, with a DC 12V power supply and a power of 2.3W. The Peltier cell was placed with the cold side on the steel cylinder and the warm side on the radiator. Monitoring of temperatures was ensured by the use of 4 pcs of digital temperature sensors of type SMT160-30 in four places with the help of a computer. One sensor measured the temperature on the bottom of the cooler, the other sensor hung freely in the room to monitor the ambient temperature. The third and fourth sensors were placed directly in the steel cylinder, both sensors monitored the temperature of the heated water and its gradual cooling.

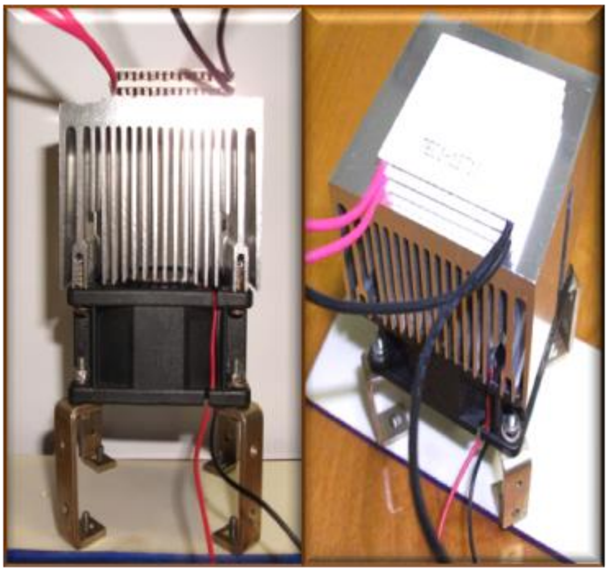


FIGURE 6: Placement of the Peltier cell

Uniform cooling of the water in the insulated container was ensured by mixing the water with a motor with an axis at the end of which there was a propeller.

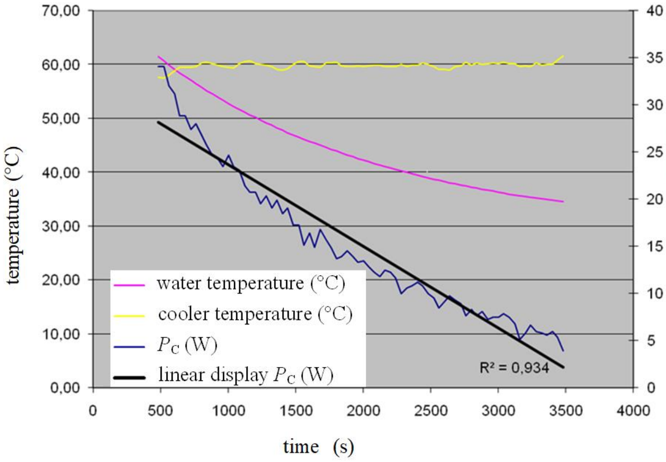
FIGURE 7: A container with a stirrer

The measurement was carried out at values other than those specified by the manufacturer of the Peltier cell, namely at a temperature of T_H = 60 °C (temperature of the hot side of the PC - temperature of the cooler) and a current load of 2A, 3A and 6A, which indicated the working behavior of the Peltier cell in the process of cooling semiconductors parts in conditions other than those specified by the manufacturer himself. A very important part of the measurement was monitoring the temperature of the cooler's bottom, which is the temperature of the hot side of the Peltier cell T_H = 60 °C.

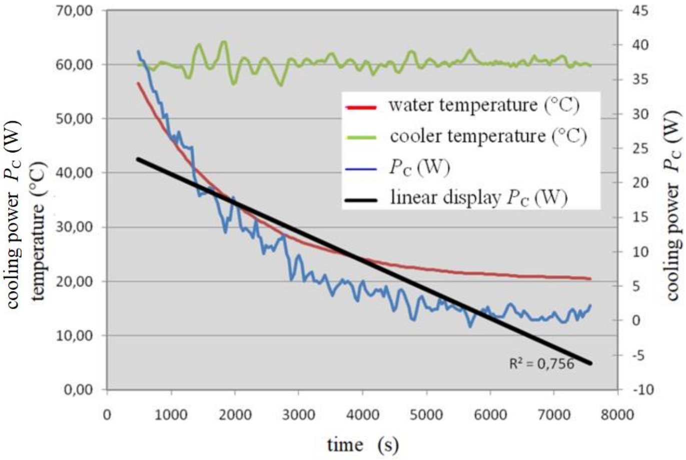
TABLE 1
VALUES OF INDIVIDUAL QUANTITIES DURING EXPERIMENTAL MEASUREMENT

	current load I (A)	cooler temperature T_H (°C)	volume of water in the cylinder $V_{cylinder}$ (ml)	the initial temperature of the heated water in the cylinder $T_{H2O,cylinder}$ (°C)
Measurement No. 1	2	60	380	70
Measurement No. 2	3	60	380	70
Measurement No. 3	6	60	380	70

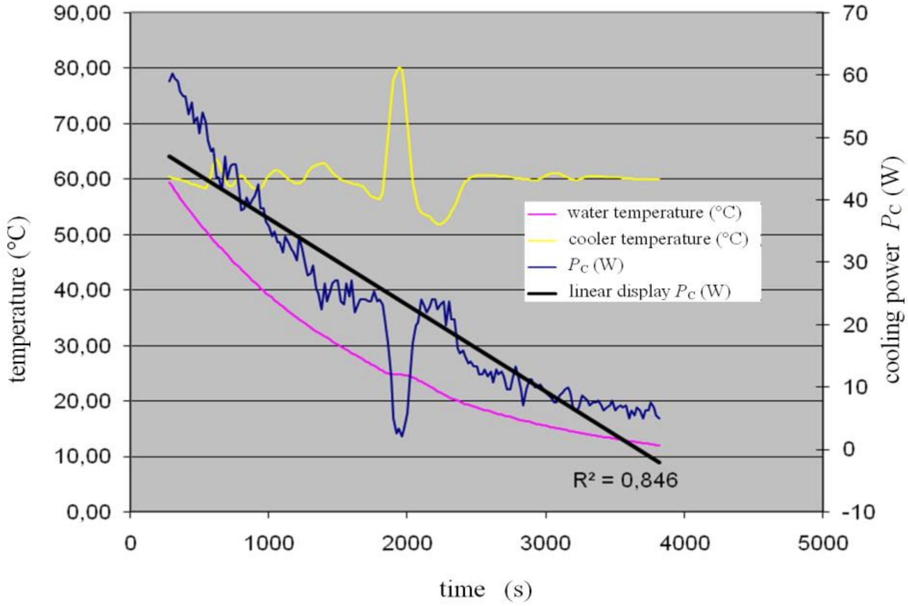
The ambient temperature ranged from 21°C to 23°C (desktop computer conditions). The measurement monitors the cooling performance of the Peltier cell under the given cooling conditions with a constant current load of the Peltier cell and a constant temperature of the cooler. The measured values indicate over what time horizon and at what performance of the Peltier cell the gradual cooling of the heated water in the cylinder (or the PC processor) occurs (fig. 8).



a) $I = 2$ A



b) $I = 3$ A



c) $I = 6$ A

FIGURE 8: Graphical dependence of individual characteristics at different current loads

The goal of the measurements was to achieve the largest possible temperature difference between the temperature of the cooler (the temperature of the warm side of the Peltier cell) and the temperature of the cooled water in the cylinder. The temperature difference is a direct indicator of the cooling of the water by the Peltier cell (fig. 9).

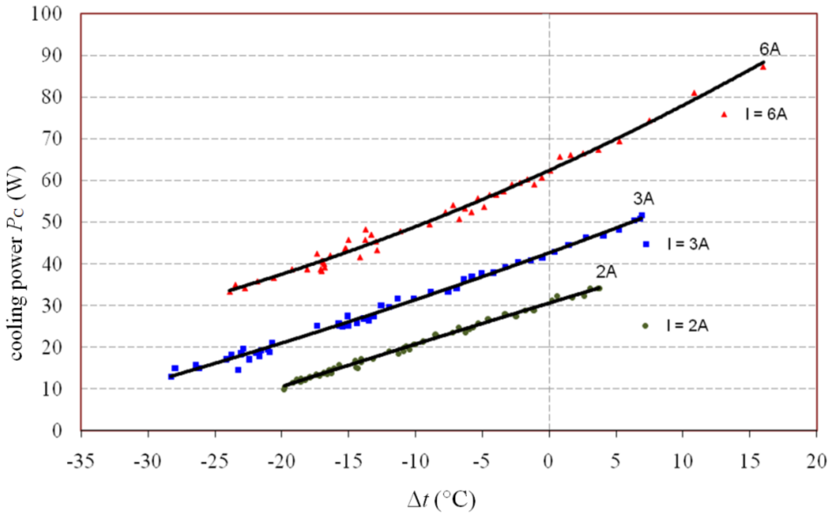


FIGURE 9: Comparison of PC cooling performance at different current loads

As the temperature of the water in the cylinder changes, so does the cooling capacity. The warmer the water in the cylinder, the more cooling power is needed to cool it. The colder the water in the cylinder, the less power the Peltier cell operates.

IV. CONCLUSION

The heated water itself simulates the temperature of the processor working in the given conditions. In fact, the more the processor is loaded, the more it heats up, which means it produces more heat into the computer environment, which must be perfectly dissipated. Imperfect removal of heat from the surface of the processor leads to a decrease in performance, frequency speed and, in case of long-lasting high temperature, to its destruction and deterioration. Therefore, the combination of cooling, which was discussed in the article, is the suitable alternative to the possible cooling used in the process of cooling semiconductor components with a Peltier cell. With its properties, the Peltier cell absorbs the heat of the heated water in the steel cylinder (or the processor), thereby cooling it (or the processor). The heat generated on the other side of the Peltier cell is removed by the cooler, i.e. heat is transferred between the warm side of the Peltier cell and the cold surface of the cooler. The heat dissipation is enhanced by the used fan for perfect heat dissipation from the cooler and into the surroundings. This method of combining cooling with subsequent heat removal makes it possible to use the processor at higher frequency speeds.

Cooling with Peltier cells represents a progressive way of implementing a cooling system. It is a suitable alternative wherever it is necessary to extract a large heat flow from a small area or where emphasis is placed on the small dimensions of the cooling system. Peltier cells also play an important role in temperature regulation.

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