Proposal for a teaching demonstration Stand Thermoelectric Effect

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Abstract

This article presents a proposal for development of a didactic strand for demonstration of the Seebeck, Peltier effects and for testing to obtain performance curves of the modules and thermoelectric materials. Thermoelectric materials have the property that when subjected to a potential difference to generate a temperature gradient between its faces (Peltier) and subjected to a temperature gradient, generating a potential difference between their terminals (Seebeck). The stand proposal is composed of a thermal system that has the functions of heating and cooling followed by a data acquisition system (temperature, voltage, current and power output) which will allow the visualization of measured quantities in the form of graphs and a software developed in Delphi® that enable monitoring the effects during the experiments and obtain the performance curves of thermoelectric materials. Ends up presenting a prototype of the bench didactic proposal and the validation results of the bench.

Keywords

Didatic Stand, thermoelectric, Peltier Effect, Seebeck Effect, Learning.

Introduction

One of the major paradigms of education is to attempt to change the archaic form of the learning process. As can be seen in most educational institutions a lesson always comes down to the traditional method, students listening and speaking teacher, very few times using other tools to verify the contents assimilated. Like for example, through practical examples, use of teaching resources technological interaction and direct contact with the student. [1]

One way to check the level of learning in the classroom is through the use of teaching resources technology that enables academic develop practices or experiments related to the content covered in class, and one of these ways is the use of didactic countertops.

The object of this paper are thermoelectric materials, these materials when subjected to a temperature difference generates electricity. So as we can see there are several quantities that can be analyzed to confirm these effects, such as temperature, voltage and current generated. [2]

To visually analyze all this greatness, we need to measure this information, in this case, there will be a didactic stand for the academic and perform tests by varying temperature proves the power generation, the effect of thermoelectricity.

Therefore, this paper presents the development of a didactic stand low cost to enable the student to prove the concepts discussed in the classroom through practical experiments.

It is noteworthy that the thermoelectric materials can be applied in various branches of engineering as: renewable energy, the very study of physics, among other applications. Therefore, using the counter proposal able to demonstrate that the student from thermal variations on the thermoelectric material has as a result the variations of electrical measurements, such as voltage, current and power.

Thermoelectric effects

The thermoelectricity is the property that some materials have to generate electricity based on the temperature difference applied to its terminals and vice versa. Two phenomena can be studied to better understand the functioning of these materials, the Seebeck effect and the Peltier effect.

Seebeck Effect

The thermoelectric effect was discovered in 1821 by Thomas Johann Seebeck (physicist born in 1877 and died in 1831), which states that: when two distinct conductive material is applied to a temperature difference can generate a potential difference (voltage) between their terminals, as is shown in Figure 1A. If there is a load on the output of this material an electric current is generated, as shown in Figure 1B.

This phenomenon is called the Seebeck coefficient (α), one can observe this phenomenon in a well-known device, the thermocouple element used for temperature measurement:

$$\alpha = \frac{\Delta V}{\Delta T} \qquad (1)$$

$\alpha \Rightarrow$ Seebeck Coeficient

$\Delta V \Rightarrow$ Voltage Range

$\Delta T \Rightarrow$ Temperature Range

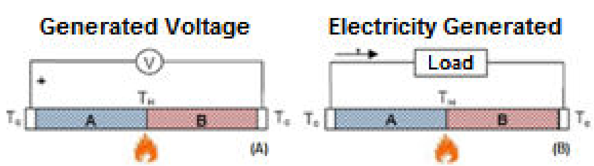

FIG. 1 SEEBECK EFFECT [3]

Years later, another physicist, Jean Charles Athanase Peltier (born in 1785 and died in 1845) described a metal junction can produce cold or heat, the Peltier effect. The Peltier effect provides that two distinct materials when subjected to a potential difference does occur producing temperature gradient, namely the inverse process to the Seebeck effect.

Depending on the direction of current heat can be released or absorbed, as can be seen in Figures 2A and 2B.

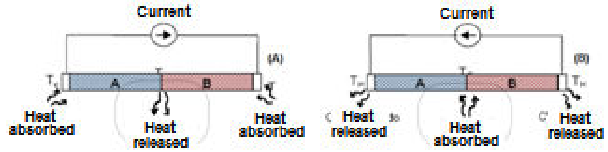

FIG. 2 PELTIER EFFECT [3]

The quantification of this effect is the Peltier coefficient (π):

$$\pi = \alpha . T \qquad (2)$$

Thermoelectric Materials

Thermoelectric materials are semiconductors that formed when applied to temperature differences can generate energy in the form of electrical voltage. Thermoelectric modules are typically formed of semiconductor materials, and has its structure formed to increase the current density and hence the output power. Are manufactured from materials such as tellurium, antimony, germanium and silver, with high doping to create semiconductor materials. These in turn are welded in a sandwich of two ceramic plates, ensuring heat transfer and sufficient mechanical strength. Figure 3 shows how the formation of the tablet, with PN junctions connected in series.

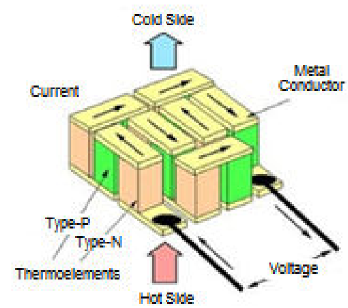

FIG. 3 FORMATION OF THE THERMOELECTRIC MODULE [3]

By applying a temperature greater on one side there is a current flow constant over the semiconductor material, and therefore a voltage formed by the association of several elements.

All commercial thermoelectric modules are based on the principle mentioned above, these modules are manufactured for different values of temperature, size and power, Figure 4 shows a commercial tablet.

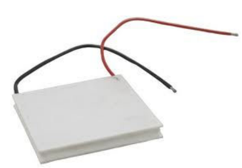

FIG. 4 COMERCIAL THERMOELECTRIC MODULE [3]

Among the advantages of thermoelectric materials, we can list the high reliability, low maintenance, application versatility, size, lightness, is silent and highly secure. [5]

With the development of thermoelectric materials, one can apply it in various areas where there are operating conditions. For example, can be used for power generation in industries where heat loss is present (thermoelectric power plants, foundries), or even in the exhaust of a car. In these two cases, there may be a considerable increase in overall system efficiency.

In other cases its use applies in cooling of foodstuffs, electronics and air conditioning systems (but we should consider that the cooling efficiency is still low compared to existing devices today such as compressors). [6]

Brief State Of The Art

We highlight below some work related to the measurement of thermoelectric phenomena.

Study platform for intelligent control applications and embedded systems

The platform studies in question proposes the remote programming of a microcontroller to perform the temperature control, which via a thermoelectric module makes it possible to remotely check the heating of an aluminum disk and cooling module through a blower , it will be possible to apply some theories as PID or fuzzy control. Figure 5 shows the schematic of the process.[7]

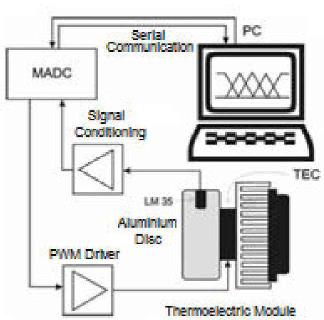

FIG. 5 PLATFORM FOR INTELLIGENT CONTROL APPLICATIONS [7]

Didactical Stand For The Study Of Thermoelectric Generators

The counter of didactic for the study thermoelectric generators has the function check the power output signal and monitor the temperature gradient. The system comprises a thermoelectric module, heat sinks and resistors calibrated load, and by measuring signals through analogue instruments (multimeters), a power source and a thermal camera can make the analysis of thermoelectric effects. Figure 6 shows the bench and equipment used. [8]

FIG. 6 DIDACTICAL STAND FOR THE STUDY OF THERMOELECTRIC GENERATORS [7]

Mini-laboratory educational for experimental studies to the concept of renewable energy

As can be seen in Figure 7, this bench has the function to study the various phenomena of renewable energy, such as thermoelectric, photovoltaic, solar, among others. As this bench encompasses many different technologies, there is also the possibility of the study of thermoelectric materials for waste energy, even where there is the possibility of combining other renewable energy technologies for analysis. [9]

FIG. 7 MINI-LABORATORY EDUCATIONAL FOR EXPERIMENTAL STUDIES TO THE CONCEPT OF RENEWABLE ENERGY

Propose Didatic Stand

The proposed workbench is that it is mobile, easy installation and configuration, and has concentrated all measurements in one device, ie, a complete system (hardware and software).

With the proposed bench you can monitor the following thermoelectric effects, among which we can highlight the Seebeck effect, Peltier and Thomson. While in the area of testing will allow the lifting of the curve real performance thermoelectric modules for various applications for cooling and power generation, since the proposed system will have the ability to make the purchase and storage of test data for future comparative analyzes.

Among the possible configurations possible and experiments to be carried out with the counter proposal is the schematic layout shown in Figure 8, in this case the application is to use thermoelectric modules for power generation. Where one can see the existence of a power source which can be obtained from waste energy, for example, and a cold source system that may be a finned heat transfer or heat pipe, and finally a thermoelectric module that loads can feed as resistors or battery charging systems and LED lighting.

The experiment consists in checking the electrical signals of the generator (voltage, current and power) as a function of temperature variations, which through the system data acquisition countertop (dotted lines) you can take a measurement and demonstrate the effectiveness of this application.

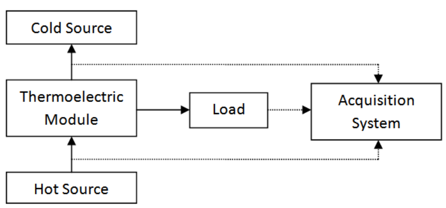

FIG. 8 INSTALLATION METHOD OF STAND

To study the effect thermoelectric some quantities must be considered, for example the temperature gradient, the voltage generated, current generated, and thus the generated power.

The proposed acquisition system is shown in Figure 09, which basically consists of the following parts:

- Electronic System Microprocessor for temperature acquisition;
- Electronic microprocessor system for acquiring electrical quantities (voltage, current and power);
- Software acquisition.

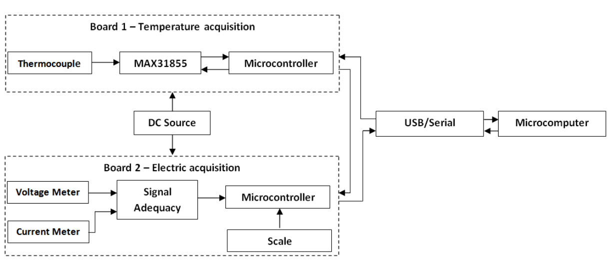

FIG. 9 SYSTEM OVERVIEW

Temperature Acquisition

According to Figure 9, the plate 01, possesses certain temperature for acquisition of thermocouples, the design idea is that up to eight temperature measurements are divided into four channels, namely a signal for temperature and one for high temperature.

These temperature sensors operate on the Seebeck effect to generate, when subjected to certain delta temperature, a small amount of voltage (usually at the home of mV), a value proportional to the temperature. [10]

Operation Of Temperature Board

For this project we will use a type K thermocouple, which can handle temperatures from -270 to 1200 ° C. As the thermocouple generates very small voltages, in his mili volts and also does not have a linear curve, you need a signal conditioner, which linearize and amplify the signal. [11]

In the market there are some types of conditioners, amplifiers, for this project we opted to use the MAX31855K of Maxim, which captures the signal from the thermocouple and through synchronous serial communication microcontroller sends the temperature signals and failure, as shown in table 01.

TABLE 1 SENT BIT MAP [12]

	14-BIT THERMOCOUPLE TEMPERATURE DATA				RES	FAULT BIT	12-BIT INTERNAL TEMPERATURE DATA				RES	SCV BIT	SCG BIT	OC BIT
BIT	D31	D30	...	D18	D17	D16	D15	D14	...	D4	D3	D2	D1	D0
VALUE	Sign	MSB 2^{10} (1024°C)	...	LSB 2^{-2} (0.25°C)	Reserved	1 = Fault	Sign	MSB 2^{6} (64°C)	...	LSB 2^{-4} (0.0625°C)	Reserved	1 = Short to V_{CC}	1 = Short to GND	1 = Open Circuit

Electric Aquisition

To acquire the electrical signals need to raise the voltage and current of differential form, ie, the reference signal is different plate reference signal measurement. For this you will need to design an electronic circuit with operational amplifiers in setting Subtractor in order to adjust the gain value pair that the microcontroller can start reading.

For measuring the electric voltage was made adjustment gain amplifier for the same voltage input is placed at the output, besides the possibility of scaling, making possible to measure voltages up to 15V.

As for the electric current, can be used the same circuit, only using a charging resistor (shunt) and by adjusting the gain can be measured at the output of the circuit the same value of input current, for example, if the current is 100mA, the output has a voltage of 100mV. In this case we can measure currents up to 5A generated by the thermoelectric modules.

Acquisition System

To total data acquired visually, is a software developed in Delphi© visual environment that will capture information from microcontroller through the serial port, it will show through graphics can still save these acquisitions for future research or compare values.

Main Display

Figure 10 shows the main screen of the software, it shows four different graphs, the first shows the temperature value, in this case the temperature of the joint red hot in blue and black CJ the resultant of these two values (gradient) .

The second graph shows the voltage generated in Volts, the third current in Amperes and the latter the result of these two values, the Electric Power generated in the module in Watts.

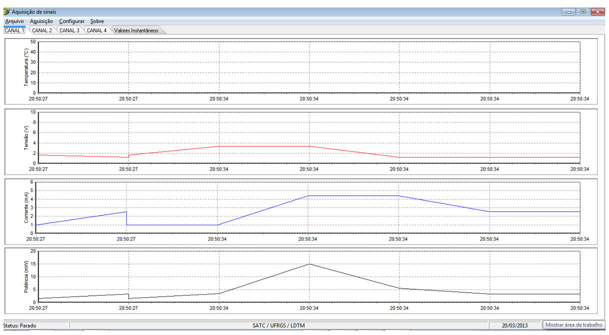

FIG. 10 MAIN DISPLAY OVERVIEW

Software Menus

Through the program menu settings may be made as: save, save as, communication settings and acquisition. Figure 11 shows the configuration screen graphics, which has the function to adjust the full scale of the graphics and qualification or otherwise of each channel individually, because in some cases there will be variations in the magnitude values and measurements that will be made.

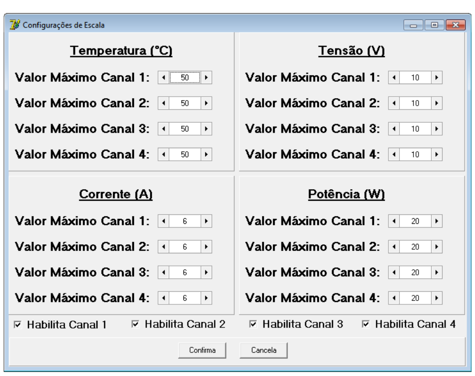

FIG. 11 CONFIGURATION MENU

Flowchart Of Operation

Communication between devices always starts with the computer sending the information to the acquisition boards.

Always one sequence will be performed as described in Figure 12, the first plate receives an information from the computer case if the received information is an application temperature, the card sends a feedback to the microcomputer which makes the analysis of information and aggregation via graphs.

If information is not received temperature value, this is passed on to the next plate, which makes analysis of receipt if a value of voltage or current, as will be sent back to the computer.

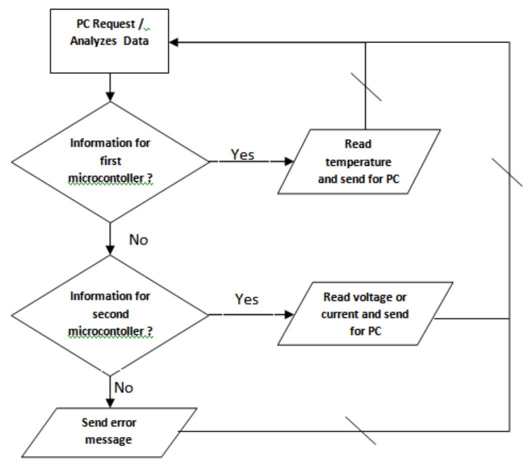

FIG. 12 MAIN DISPLAY OVERVIEW

Expected Results

The tool will become invaluable for experimental analysis of processes related to thermoelectricity because all monitoring will be concentrated in only a system of acquisition, in addition to being mobile, easy to install and use. Another important factor is that the storage of information brings great possibilities for further comparison of tests and analysis for various values of temperature gradient.

One way is to use the bench to obtain efficiency curves of thermoelectric modules. Each type of module can respond developed differently according to the temperature or type of material with which it was manufactured. Through performance tests you can then make comparisons for each type of application and instantly get your performance.

With its use will be possible to create various thermal and electrical arrangements in order to obtain experimentally that the topology with better efficiency for a particular application, either for cooling or generating electricity.

Conclusions

This article presents a proposal for development of a didactic bench for demonstration purposes using thermoelectric thermoelectric modules for this purpose.

Through this workbench the student will have complete autonomy to do practical experiments involving thermoelectric modules, make arrangements thermal and electrical (connected in series or parallel), variation of loads (resistors, motors or LEDs), and through the acquisition system generate graphs tracking and aggregation of data, and demonstrate through experiments the subjects covered in the classroom.

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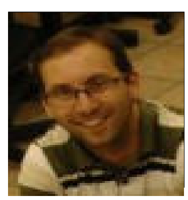

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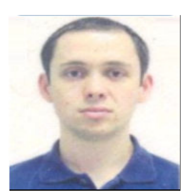

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