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Physics

Application of the Peltier-Seebeck effect for termical-electrical energy conversion as source for mobile device charging

Aplicação do Efeito Peltier-Seebeck para conversão de Energia Térmica-Elétrica como fonte de carregamento de um dispositivo móvel

Lucas de Goes Muniz[I], **Rita de Cássia Mota**[I]

[I]Universidade Federal do Amazonas, Manaus, AM, Brasil

ABSTRACT

This work states a viable option, using low-cost components and renewable energy, of building a phone charger with main source of energy from the difference of temperature between a human body and a heat sink, free of wires and/or external connectors. Using the Peltier-Seeback effect, to produce a potential difference from the broker junction in different heats, stabilizing and amplifying this with a circuit composed by simple components and of easy access, getting as the circuit output the average values of 5,02 V and 1.1A Such values may be taken in consideration as enough to recharge a smartphone battery, which the output values vary between 3.3V-5V and 0.7A-2A. This way, this shown study demonstrates the application of a thermal-physical effect on a common accessory of daily use, using as intermission the basic concept of engineering in what it refers to solving problems. Therefore, on electric energy shortage situations in remote places without electricity, there will be new search fronts, academic or not, that might be used as a broad way to allow the energy supply in home appliances of high tension, bringing energy supply to remote areas of any origin and contributing to the development of research on this area.

Keywords: Renewable energy, Applied Physics to engineering; Peltier Effect

RESUMO

No presente trabalho, apresenta-se um meio viável, utilizando componentes de baixo custo e energia renovável, de construir um carregador de celular com fonte principal de energia obtida a partir da diferença de temperatura entre um corpo humano e um dissipador de calor, independente de fios e/ou conectores externos. Utilizando o efeito Peltier-Seeback, para produzir uma diferença de potencial a partir da junção de condutores em temperaturas diferentes, estabilizando e amplificando esta com um circuito composto por componentes simples e de fácil acesso, obtivemos como saída do circuito os

valores médios de 5,02 V e 1.1A. Tais valores podem ser considerados suficientes para recarregar uma bateria de smartphone, que variam seus valores de saída entre 3.3V-5V e 0.7A-2A. Desse modo, o estudo apresentado demonstra a aplicação de um efeito termo-físico a um acessório de uso cotidiano, utilizando como intermeio o conceito básico de engenharia que se refere a solução de problemas. Assim, mediante a situações de escassez de energia elétrica surgem novas frentes de pesquisa que poderão ser utilizadas de forma ampliada para permitir o abastecimento de energia em eletrodomésticos de alta tensão, levar suprimento de energia a locais remotos e contribuir para o desenvolvimento de pesquisas nessa área.

Palavras-chave: Energia renovável; Física aplicada; Efeito Peltier

1 INTRODUCTION

Coming from the advancement of the materials science, caused by the revolution of the semiconductors, the thermoelectric applications became one of the most important technological potencies in history, being classified as fundamental for the evolution of researching and the developing of science. Among the most notable ones, it is possible to highlight the use of the Peltier Effect in domestic fridges coming from the electricity and the inverse operation, proposed by Thomas Seebeck, who reefers to the obtaining of electric current from a gradient of temperature submitted in a junction of two different metals (MACDONALD, 2006, p.5).

Parallel to this, the revolution on mobile communication also tops as the technological pillars of the second decade of the 2000s: the main adornment of market research, nowadays the cell phones represent way more than only a simple electronic device – being a way of life, a incoming source and mainly a human body cell, being able of organizing task – exchange messages – taking pictures and a sequence of functions which they hold and constantly grow for the sake of commodity (DUTRA, 2016, p.13).

The industry follows this growth, releasing each time newer models with different functions and with new improvements added, as strong processors and exclusive dedication to different modalities, so these can have an excellent performance and retiring a lot of other devices which held only one of these

functionalities which the cell phone has now, such as landlines, photographic cameras, MP3 players and so (DUTRA, 2016, p. 11).

With such complexity and countless functionalities, it is comprehensible that the energy sources of the device, the batteries, have duration lower than the expected, becoming one of the main problems of the device (HOFFMAN, 2016). The simpler solution found by the companies aims to lower the use of that, but not modify it, bringing only a temporary solution, with the continuity to moderate durations and making their users hostages of wires and chargers.

Using that premise and considering the diffusion in large scale of the use of cell phones, from this research is settled to search for technological solutions that attend this demand and solve partially this error, making as the target audience the assiduous users of the device, to make an alternative of use of renewable energy and at low cost, proportioning a bigger lifespan to the battery and more available time for the general use.

As the main base of research in sources and ways of energy, and using as foundation the theory proposed by Peltier-Seebeck, the research relates two important technological revolutions, so it can purpose an alternative manner of feeding a cell phone device, with no major damages to the ambient and bigger mobility feature and practicality to the user, once such device will be portable to be installed on the back of the phone. The main advantage of this device is that the energy coming from the Peltier cells, in a small size, being have as clean energy and has a great potential to be explored (CEKDIN, 2020). Such fact, makes its projection of using not only for emergencies, but it is had as more viable to transformation and use as an alternative source.

2 THEORETICAL FOUNDATION

Physics are defined as the study of the nature and its processes of transformation, being one of the bases to any proposal of technological innovation,

which in general terms, is connected directly to the creation and application of concepts (FEYNMAN, 1964). The knowledge given by physics allowed the human being, from the beginning, a series of progresses in all of the sectors – engineering, health, astronomy, computing and such – being a base to any project from the area and having its phenomenon quantified by engineers and researchers, contributing to the development not only conceptual, but also critical: represented in this project by the application of physical effects in the gaining of energy and derivations from these already applied to the electronics, as in the using of specific components and calculations.

2.1 Renewable Energy

The Brazilian production of renewable energy and from biomass has grown in the latest years, following the world line of constructing the economies of clean energy of the future (PISCHKE, 2020). Although the country has as potential source the solar energy, the search for the called renewable energy follows in constant growth, aimed to mobilize great sectors of the society including companies, governments and investors to lower the cost of energy and making it less pollutant (MACDONALD, 2006, p.3). An acute solution to this problems is on the converted energy from the temperature difference, represented mainly by the Peltier cells which allow the obtaining of energy with the minimum of aggression as possible to the environment and minimal cost, obtaining a cheap and sustainable source of energy, supplying the costs and attending the goal (TELKOMNIKA, 2020).

2.2 The Peltier-Seebeck Effect

The thermoelectric effect represented by the Peltier-Seebeck effect reefers to the obtaining of electricity from the difference of temperature: to create a heat flux, it becomes necessary the existence of a temperature difference between the facets of the thermoelectric pair – in this case, coming from a heat sink and the

human body (MOURA, 2010). The electric potency coming from these is denominated the resulting electromotive force, being directly proportional to the obtained difference (SPRY, 2013, p. 34). Considering that in the Equation (1) is:

$$\Delta E = E_2 - E_1 > 0 \quad (1)$$

Where, the electromotive force ΔE depends directly from the nature of materials and the difference between their temperatures, being formally presented in the Equation (2) as:

$$\Delta E = \alpha_{ab} \cdot \Delta T \quad (2)$$

In the way that α_{ab} is the thermodynamic coefficient of Seebeck and ΔT the temperature difference between the conductors.

When associated to a thermocouple, the union between two distinct metals aiming to obtain a potential difference, the electromotive force obtained can be given in the Equation (3), where:

$$E = \int_{T_1}^{T_2} (a_b\,(T) - a_a(T))dT \quad (3)$$

Being possible, like that, to estimate the quantity of thermal energy converted in electric energy (SPRY, 2013, p. 35).

2.3 Peltier Cells

The Peltier Cells represent the most practical way of demonstration of the Peltier Effect, as for the Seebeck Effect, once that it can be commonly used as a refrigerator and converter of thermoelectric energy. Its physical nature consists in a little arrangement of bismuth telluride blocks – (Bi2Te3) doped of type N and type P semiconductors and welded between two ceramic plates, connected electrically

in series and thermally in parallel (KUMAR, 2019). When a DC current is applied to one or more parts of elements from type-n to type-p, there is the inversion of junction temperature, resulting in an absorbing of heat from the ambient and transferring from the padlip through electron transportation. The capacity of heat bombing from a cooler is proportional to the current and the number of pairs of elements type-n and type-p (KUMAR, 2019).

The inverted effect is possible creating a gradient of temperature from the extremities of the Cells, the hotter extremity holds the electrons from that region with bigger kinetic energy and transfers then to the coldest side, generating a difference of electric potential among the extremities of the conductors in the order of some mV (KUMAR, 2019).

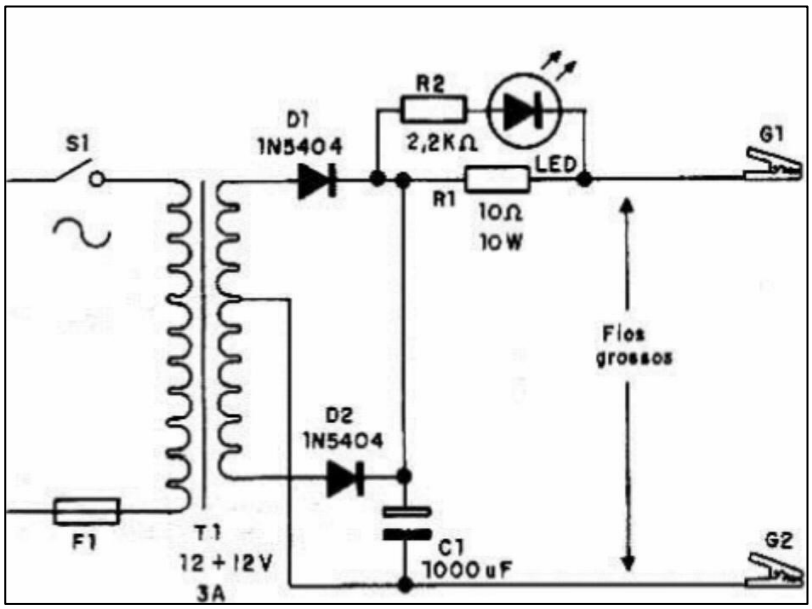
2.4 Tension Regulator 78XX

The tension regulators have as their main function to attenuate the tension produced by the generated in the demanded limits by the battery that is feeding (REIS, 2013). The ones from the 7800 series can provide tensions from 5 to 24 volts typically with a current of 1 ampere and are extremely attractive to low cost projects, specially by its small size and high trust, having high internal protection to short circuits in its output, not having the need for any external component, having only the premise of 2 volts feeding bigger than the desired to its output, for this case, trafficking between 5,5 V and 7,5 V (SCI LLC, 2014).

2.5 Convencional Chargers

A simple charger consists in a source that establishes a current in the contrary way that needs to be recharged. Since the internal resistance of a battery varies of charge and is normally very small, it is needed to aggregate to this source some device to limit to a safe value the charge current, as presented on the circuit on the Figure (1) (BRAGA, 2010):

Figure 1 – Schematic representation of a circuit present in phone chargers with an energy transformer and electrolytic capacitor for transformation and stabilization of the input energy



Source: (BRAGA, 2010)

Then, a simple first resource to the charge consists in using the regimen of constant current. In a cell completely uncharged the tension on their terminals is low: when applied to the tension of the charger feeding, the difference of potential between that and the one from the battery is high, making it circle an initial current greater than the recommended and making its circuit more complex to apply a current in the inverted way for a certain time.

3 PROPOSAL

The main proposal of this project is the developing of a portable charger using new methods to feed a cell phone device, supplying the need of users during their whole days, without the use of wires or external connectors, using for it the thermal energy conversion, coming from the temperature difference, in electric energy.

3.1 System Architecture

Its construction differs from the old chargers, because in these there where only one current limiter with a value that determined the needed time to fill all of the charge, where the current not only charged the energy on the cell but also, due to the electric resistance, generated heat, warming the battery and lowering the lifespan of its components.

For the modern batteries, the chargers have become more complex, where a simple first resource for the charge consists in using the continuous current regimen. In a completely uncharged cell the tension in its terminals is low. Then, when applying the tension to the charger, the difference between its tension and from the battery is high, having the need to circle an initial current proportional to this one. In that way, considering the functioning of the current chargers and supplying the electric needs of the cell phone device, it is possible to have as a viable alternative, following as a prerogative the use of Peltier Cells and the integrally portable way, organize through a simple functioning diagram:

a) Conversion of Thermal Energy to Electric Energy from the difference of temperature;

b) Amplifying of the electric potency obtained, using a electric circuit;

c) Transferring of the signal amplified to the cell phone.

Where it is possible to define the steps of simulation, mounting, tests and enhancement.

3.2 Energy Capture: Body Heat

The body heat is a way of energy coming from the transformation of food in glucose, which allows the formation of ATP molecules and has energetic molecules to allow that the human being realizes daily activities, being part of that energy transformed in heat, which is potentially distributed, having small divergences to more exposed parts, where there is higher heat exchange with the environment, and less exposed parts (WANG, 2019).

To obtain a body heat base and the amount of energy that could be used, there were picked samples of temperature from three distinct volunteers, using a contactless thermometer G-tech thgtsc1 to obtain a standard average of the population.

The obtained results had as their average value the ones of 34,8 °C to the temperature of 17 °C, 35,4 °C to the temperature of 25 °C and 36,9 °C to the room temperature, summarizing the available temperature available to work with in 35,7 °C, with variations of ±1 °C.

Assuming that everyone consumes 2000 kCal, we have: , that is, there are consumed and expended per Day, and part of that is dissipated in the heat. To calculate the potency in W there is the need of the division of that energy by the number of seconds in a day, obtaining the Equation (4) (OGIN, 2011):

$$P = \frac{8.37x10^6}{24x3.600s}\ 97W \tag{4}$$

In that way, a regular human being, in regular activities, dissipates around 100 W of potency, which would feed through the electricity of a regular light bulb (OGIN, 2011).

Considering that, in case there would be transformed internally around of 100 W, there is the need to eliminate the same 100 W so that the body temperature would keep stable. Without clothing, and by irradiation, a person dissipates around 10 W for each degree of difference of temperature between their body and the ambient, being that heat liberated by the skin.

If the skin of a adult human measures approximately 1,7m, we have the Equation (5):

$$Dissipação = \frac{97}{1700} = 57\frac{mW}{cm} \tag{5}$$

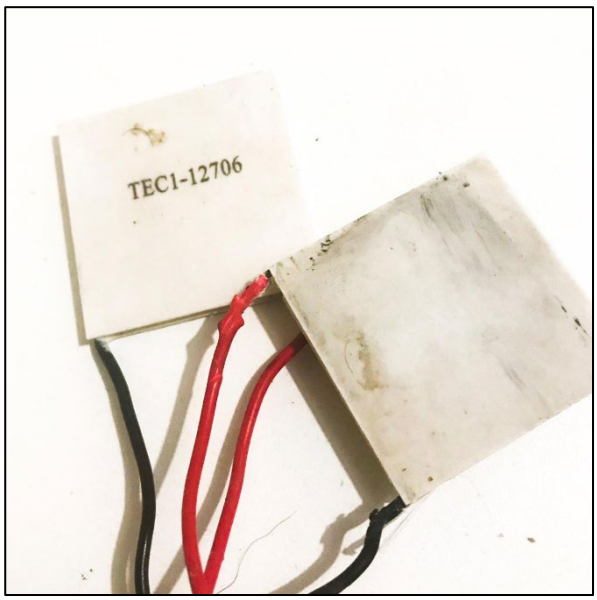
Having the human hand, a measure of approximately 10cm, there is 0,57 W available for use in its best condition – which is considered little for the goal

of the project, having the need to intensify the heat and increase the capture, optioning for the use of aluminum paper as a coating for the cells with the objective of increasing the heat, once that as higher it is, the greater the vibration of particles interfering on the electrons movement. This influence causes loses on the electrons movements and, consequently, warming of the conductor body, generating more energy and potency (GOLDSMID, 2017).

3.3 Energy capture from the Peltier Cells

The choice for the cells came through the mean of sensitivity of temperature capture, being from the TECI family, represented in the Figure (2), the most efficient to this. Although, even they work fastly, they uncharged very fast, having the need of something that stabilizes the present energy, such as a capacitor to be included in the circuit.

Figure 2 – Thermoelectric modules that can operate as heat sources and heat receptors. Associated to ceramic plates filled with small cubes of Bi2Te3 (bismuth telluride). For this experiment there were used five plates of (4x40x40 mm)



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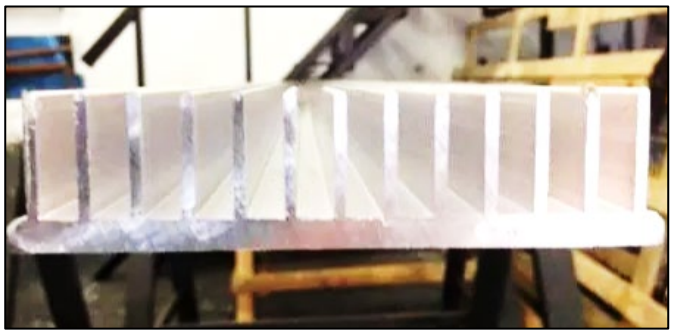
The difference of temperature is given by the heat of the hand and an aluminum heat sink, represented on Figure (3):

Figure 3 – Thermal heat sink made of aluminum (12x120x80 mm), responsible for the increasing of the thermal dissipation rates, and consequently the cooling of the contact surface, through the phenomenon of the thermal conduction



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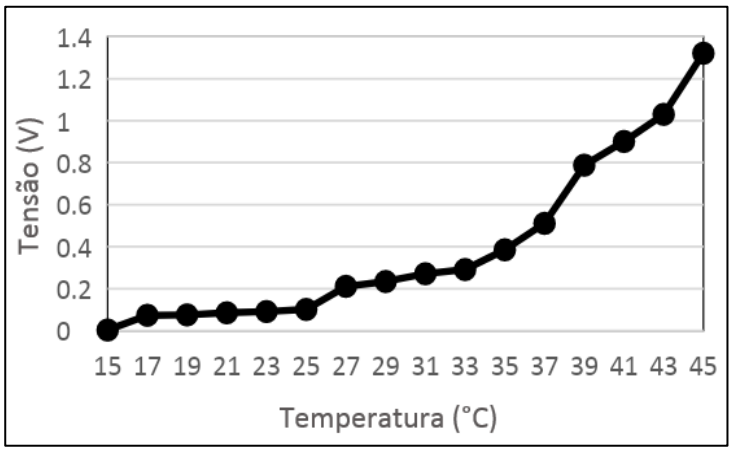
When associated and submitted to a temperature variation of 15 ºC to 45 ºC, with the use of a stabilizer circuit, it is obtained an important gain margin, as shown in the chart on Figure (4):

Figure 4 – Temperature versus Tension. On the interval between 15 °C and 25 °C, there is only the discreet change of values of tension, caused, mostly, by the low temperature applied to the cell. Between 27 °C and 37 °C the converted tension rises continuously, but reaches values lower than expected. Only between 39 °C and 45 °C the predicted values for the feeding source are reached



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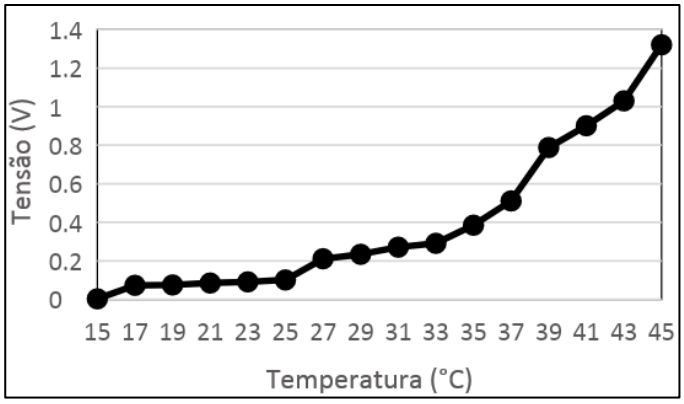
This way, it is implied the need of a rise on the difference of the temperatures available on the Peltier module, that way, the same experiment was realized with the association covered in aluminum paper of 4 mm. Its choice was justified

because it is a conductor of heat of easy access and use and of important gaining. The results obtained are demonstrated on the chart on Figure (5):

Figure 5 – Temperature versus Tension. The interval between 15 °C and 25 °C, there is a discreet gain of tension in relation to the first experiment, in less time of contact with the cell. Between 27 °C and 35 °C the converted tension rises and reaches the expected, but this scenario is excluded since it's a temperature hardly reached by human hand in contact with the device



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Considering the specifications of working and the realized experiments, it is supposed that a Peltier cell provides between 0,9 and 1,2 V available for the use in that situation. To consider that a cell phone needs from 3,5 V to 5 V, a single Peltier cell is insufficient to feed the circuit, having the need to an electric adjustment to energize its functioning.

3.4 Electric Circuit

In the construction of a circuit, there is the need to evaluate the available resources of input and the wanted result to the output, planning its composition in a way to obtain the wanted result: Pretending to charge a cell phone, there is a need to supply the market specifications, where most of it defines from 3.5 V to 5 V DC and a current over 500 mA, inducting to the treatment in amplification and stability of the values obtained from the source outputs.

The cells generate a DC tension signal, not having the need of transformation. Although, since its capacity of energy generating depends on the difference of temperature, there is an intense variation of tension, after all, it depends on the intensity of the heat from where the plate is.

To solve this problem, there is the need to filter these tension fluctuations, that is, using an electrolytic capacitor, which impedes its rough changes, in a way that in case the cell rises or lowers its tension quickly, the capacitor will keep it stable, generating a signal with fewer oscillations, only with soft *ripples*.

With that, the circuit starts with an electrolytic capacitor of a considerable value in parallel with the output signal of the Peltier board. In this case, it was designed the value of 100uF/25 V for not working with an elevated current and being a value easily found in the market.

Parallel to that, there is the need to watch out for the specifications of the plate. Between the important data there is that the plate abstracts a maximum value of tension of 7 V and current of 0,43A, and with that, in its maximum efficiency, is projected a potency of 3 W and a tension signal that even going through a filter capacitor, it still has fluctuations.

Other than fluctuations, the feeding of the cells is subjected to peaks of energy, able to damage the device and the components of the circuit, making it necessary the use of a tension regulator to establish it: since there is the need to adjust to 3,5 V – 5 V, it was designed the CI7805 (WIDLAR, 1971), which as recommended by the fabricant, is indicated its use with two capacitors: one of polyester of 330nF on the input and another ceramic of good quality with 100nF.

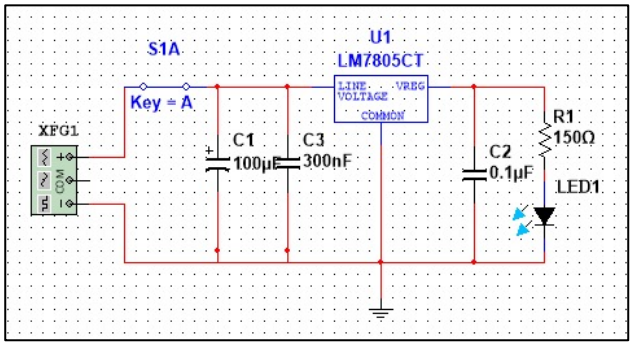
Such capacitors are important so the 7805 can deliver a stable signal on the output independent of input variations or variations of charge requests on the output: The polyester capacitor of low capacitance is ideal for high frequency noise filtering that the electrolytic capacitor cannot filter and the ceramic capacitor has the function to lower the ripple of the regulator itself, regulating the output that is

being generated and with that adapting dynamically in its internal circuits to keep it stable and in the suitable value.

That way, other than the regulator, it is included in the project the needed capacitors. And in that way there is finally the regulator output the needed DC value to charge a cell phone.

Based on the theoretical concepts, there is on Figure (6) the simulation of the proposed circuit.

Figure 6 – Simulation of the proposed circuit, using the CI7805 and its specified peripherals components, besides a function generator to simulate the obtained values by the Peltier module



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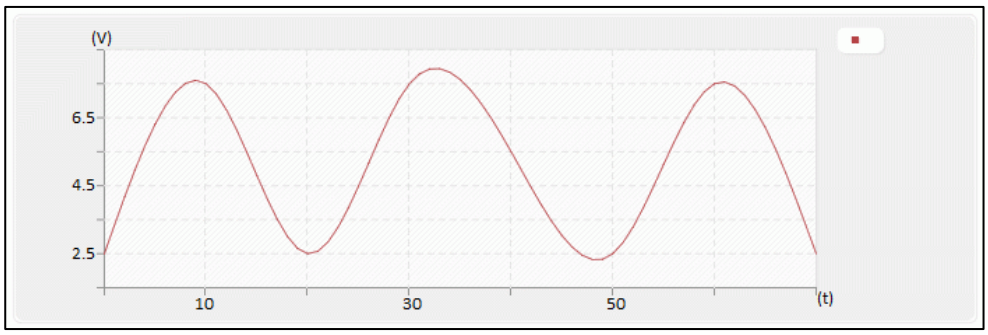
It is chosen for use by its versatility, paying attention to the minimum and maximum values of tensions of input and current considering that the CI7805 has in its specifications inputs over to 7-34 volts, being an integrated circuit with energy dissipation proportional to the difference of tension between input and output, in a way that as higher the tension of input, the CI will get warmer, and it will take down its performance.

3.5 Electronic Circuit Simulation

The simulation is a fundamental step to precede the assembly of the practical tests of the Project, being able to prevent possible errors of planning in material damage.

To simulate the Peltier board, it is generated a DC signal with soft ripples, it was used a function generator with a AC wave of 1Vp and an offset of 6V with low frequency. On the Figure (7), there is the representation of output wave from the function generator.

Figure 7 – Wave pf output of the function generator, similar to the signal expected on the output of the Peltier Module. Amplitude (V) x Time (s)



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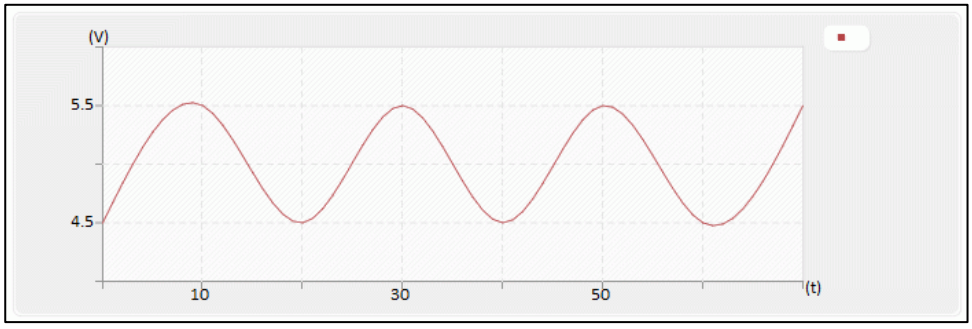
To demonstrate the filtering effect of the capacitors, there is the wave form that is possible two view after the C3 capacitor on the Figure (8):

Figure 8 – Output signal from the tension regulator, with no ripple variation. It is not expected such mitigation with real components, because although the real conditions applied to the simulation, there is still the use of ideal environments. Amplitude (V) x Time (s)



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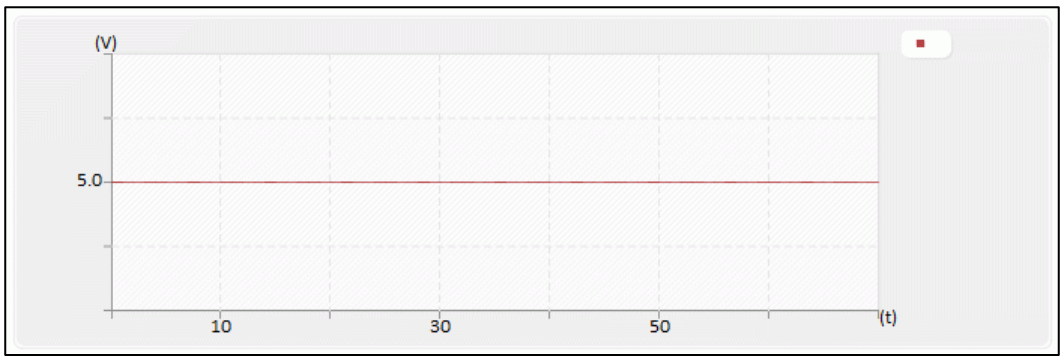
And, finally, the output signal from the regulator, represented on Figures (9) and (10): which is highly stable in 5 V DC:

Figure 9– Output tension from the circuit with the use of a tension regulator, obtaining the needed value for the cell phone feeding



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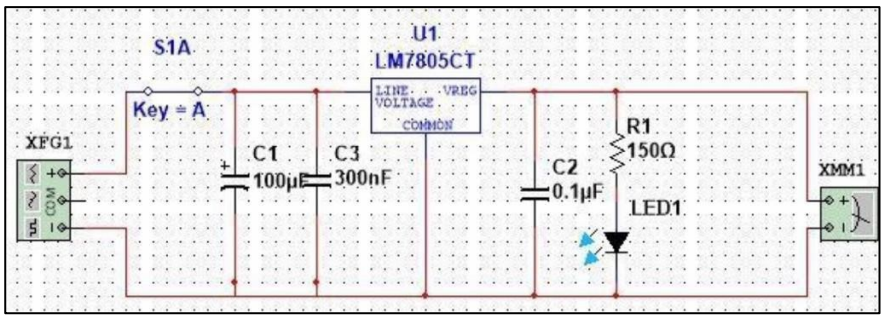
Being the Simulator hypothesis tested, it is possible to go to the prototyping and board construction.

4 RESULTS AND DISCUSSION

Before the prototyping of the board it is needed to simulate the circuit in protoboard, measuring tension and current given by the regulator with the Peltier board from an average temperature and with a resistive charge, it can be able to obtain a tension of 4,98 V and a current peak of 0,94A. Considering the results enough and satisfactory.

Figure 10 – Output tension of the circuit with the use of the tension regulator, obtaining the needed value for the feeding of the cell phone device



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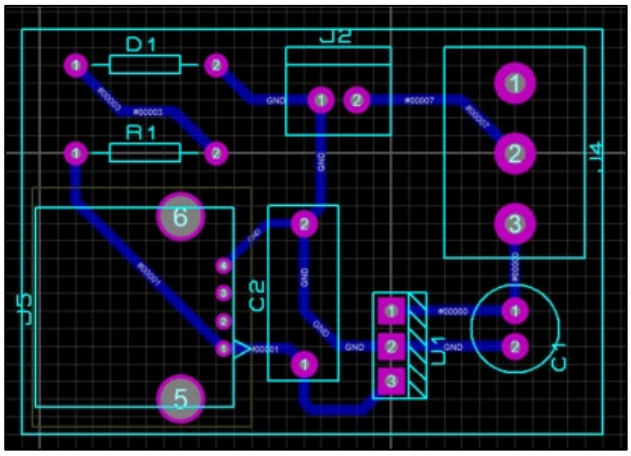
With this, it was mounted a PCB layout, demonstrating on Figure (11), positioning the components in an optimized and strategic form in the way the board could be the smallest as possible. The care was taken in generating the trails only in one side of the board, to make it easy on its printing and, although the use of the automatic trail generator, the manual modeling shown it necessary in the way of optimizing the space.

Figure 11 – The PCB Layout of the proposed circuit. It was chosen the use of this technique as a way to occupy the smallest space as possible and avoid possible noises with problems of corrosion and weld



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On the first done test, with only the Peltier cell, it was obtained a response from the led included, but there was no charge on the cell phone, having the need to test the other four Peltier boards in a row, in the case there is low tension, obtaining the result shown on the Table (1):

Table 1 – Table of values measured in the output of the tension regulator available on the board, where it can be seen the defusal caused by the superior limit of exceeded current

Device Type	**Result obtained with the feeding of the circuit with 1 cell**	**Result obtained with the feeding of the circuit with 5 cells**
GALAXY ACE	0,370 V	2,138 V
NOKIA LUMIA 620	0,574 V	2,986 V
MOTOG3	0,951 V	5,236 V

With the three cell phone devices, it was noted that the 7805 defused and with that suffered a tension fall on its output. An interesting factor is that the more modern the device is, the smaller was the tension fall on the regulator. Associating it to the fact that the more modern devices consume more current and being able to suppose that the defusing of the regulator was because of a current request peak on its output. One more input data was that the three cell phone devices through the test were with less than 50% of charge on their batteries, and by remembering the theoretical part of the working of the batteries we can see that the less the charge the more the current request.

From that, it was added to the project a current limiter circuit with the CI LM317. Because even having a high current request from the cell phones the limiter would not allow to circle a current greater than 1A in the output of the regulator and with that would not defuse it.

In order that the current to be 1A, the resistor used on circuit was of 1,25 Ω and was able to dissipate the minimum of 1,25 W of potency, concluding the efficiency of the Project and measuring 5.5 V at the circuit output, enough to recharge a cell phone battery.

5 CONCLUSION

This research had as its objective to show the development of a portable charger using new methods to feed a cell phone device, supplying the need of users through the whole Day, without the use of wires or external connectors, using for it the conversion of thermal energy, coming from the difference of temperature, in electric energy.

This way, the experience got satisfactory results in a professional and personal character, in a way to reach the proposed goals and to contribute to the professional growth of its idealizer, once it is expected from an electronic, computing, or any other areas engineer to be able to project and develop

components, equipments and electronic systems needed to the general use of society, referring it the basic concept of engineering which is the solution of problems through physical and mathematical concepts.

Like that, upon situations of scarcity of electric energy, new fronts of research appear that could be used in the future in a vast way of allowing the supply of energy on high tension household appliances, taking the energy supply to remote locations and contribute to the development of more researches in this area.

Such contributions are of extreme importance in a world each time more developed and dependable of new technologies as in instance, the cell phone that appeared to supply the need of communication to the man. And, for the performance of this function it not only needed to obtain the cell phone, but to possess enough energy for its execution.

With improvement proposals, it has the using of components of smaller size and better performance, which would result in a final project more compact and with less loss of energy and noise, but that in counterpart would skip from one of the objectives of this project that is the low cost.

Other than that, the intensification of obtaining of energy, with a new architecture and a different planning for the capitation of body heat, would bring a better performance in relation to the time needed for a charge and in a more linear performance of the regulator circuit, once it would reduce the incidence of ripples and consequently increase the lifespan of the proposed circuit.

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Authorship contributions

1 - Lucas de Goes Muniz
Graduando de Engenharia da Computação na Universidade Federal do Amazonas
https://orcid.org/0000-0002-8640-0034 - lucasgmuniz@gmail.com
Contribuição: realizou o projeto de iniciação científica PIB-E/0040/2016 - Carregador Sustentável: carregador de celular alimentado a partir da troca de calor entre corpos, o qual deu base para o artigo. Apoiou desde o planejamento da pesquisa e na coleta de dados, bem como nas análises laboratoriais e dos dados, assim como na redação do artigo.

2 - Rita de Cássia Mota
Docente do Departamento de Física na Universidade Federal do Amazonas
https://orcid.org/0000-0002-2607-9306 - rcmota24@gmail.com
Contribuição: orientadora do projeto de iniciação científica, apoiou no planejamento do estudo, orientou a coleta de dados e parte das análises laboratoriais, bem como apoiou na análise dos dados e redação do artigo.

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