ORIGINAL ARTICLE

# ELEMENTS TO STUDY CORPORAL TEMPERATURE'S SENSOR

**Mohamed Rezki[1], Mouloud Ayad[1] and Kamel Saoudi[1]**
[1] University of Bouira / Department of electrical engineering / Bouira / Algeria/mohamedrezki197@yahoo.fr

## ABSTRACT
**Background:** Measurement of a temperature's body -skin surface of human tissue- is very significant for the human healthy, that for the diagnosis (detection of hypothermia or hyperthermia) or for the therapeutic reason during a heat therapy, also called thermotherapy . **Objectives**: This work relates to study of some elements which one must take into account during a corporal temperature measurement. **Methods:** We resolve Penne's equation which traduce the bio-heat transfer taking into consideration physiological properties of human tissues ad also measure the dynamic's characteristic of a temperature' sensor. **Results:** The study expose that we have a pseudo uniform distribution of temperature if we use a metal plate and for the dynamic's characteristic of a temperature' sensor we get rapid response to a dynamic stimulation in burning (heating) which is well explained by calculating the rise time. **Conclusions:** Some elements of corporal temperature's sensor were studied and from the good dynamics characteristic we can ascertain that for measuring temperature is not necessary to get a monitoring system, a static device is sufficient -because also of the slowest change of temperature's body in general.
***Keywords***: Bio-heat transfer, temperature' sensor, Penne's equation, dynamic's characteristic.

## 1. INTRODUCTION

Although the measurement of corporal temperatures was known by the human being since antiquity that did not prevent the non benefit of the amazing electronics progress in order to have more powerful measuring temperature devices with acceptable accuracy. The problem it is that this measurement is discontinuous from where need for knowing the distribution of the temperature, which leads us to know for each moment the manner of progression of the thermal transfer in biological tissues "bio-heat transfer". Moreover this latter show how heat moves within the body or external to the body [1].
Various mathematical models of bio-heat transfer were developed, the famous one is the Penne's model–published in 1948 - [2]. We will briefly describe this model and solve some cases of heat transfer numerically. But also see some characteristics of a temperature's sensor.

### -Description of bio-heat's problem

There are some mechanisms –known- of the heat transfer applied for all the systems (biological included) which are [3,4] [5]:

-Radiation: it's an energy produced by an electromagnetic wave action. The Stefan-Boltzmann equation, which describes the rate of transfer of radiant energy, is as follows for an object in a vacuum:

$$Q = \epsilon\sigma T^4 \qquad (1)$$

For radiative transfer between two objects, the equation is as follows:

$$Q = \epsilon\sigma(T_a^4 - T_b^4) \qquad (2)$$

Where Q is the rate of heat transfer, ε is the emissivity (unity for a black body), σ is the Stefan-Boltzmann constant, and T is the absolute temperature (in Kelvin). Radiation is typically only important for very hot Object, or for objects with a large temperature difference.

- Convection: It's a transfer of thermal energy through a fluid due to bulk motion of the fluid. It's formula is called Newton's law with the expression as below:

$$q^{\cdot\prime\prime} = h\,(T_{surf} - T_{fluid}) \qquad (3)$$

Where q is the convective heat flux x (W/m$^2$) and "$T_{surf}$, $T_{fluid}$ "are the surface and fluid temperatures respectively. 'h' (W/m$^2$ .K) is termed the convection heat transfer coefficient

- Conduction*:* It means that the gradient in temperature within the tissue itself drives the flow (Fourier's law):

$$q^{\cdot\prime\prime} = -k\nabla T \qquad (4)$$

If we take the 'x' direction:

$$q''_x = -k\frac{dT}{dx} \qquad (5)$$

(dT/dx) is the temperature gradient in 'x' direction and $q_x$ is heat flux x (W/m$^2$), the parameter k the thermal conductivity (W/m.K).

- Advection: It's the transport mechanism of a fluid substance. This phenomenon can be described by the formula:

$$Q = v\rho c_p \Delta T \qquad (6)$$

Where Q is heat flux (W/m$^2$), ρ is density (kg/m$^3$), $c_p$ is heat capacity at constant pressure (J/(kg*K)), ΔT is the change in temperature (K), v is velocity (m/s).

– Blood perfusion: the blood vessels especially inside tissues and organs cause the modification of the heat transfer process. This latter is affected by vessel geometry, local blood flow rates, and thermal capacity of the blood.

### II. PENNE'S EQUATION

An American physician Harry H. Pennes introduced the two effects quote in top (the metabolism and the blood perfusion) by affecting them terms in its equation, which is written as [6]:

$$\rho c\frac{\partial T}{\partial t} = k\frac{\partial^2 T}{\partial x^2} + \omega_b\rho_b c_b(T_a - T) + Q_m + Q_r(t) \qquad (7)$$

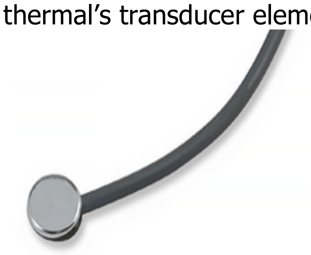
Where $Q_m$ (W/m$^3$) is the metabolic heat generation, $Q_r$ heat generation rate due to volumetric heating (W/m$^3$), $c_b$ is the specific heat of blood, k is the thermal conductivity of the tissue, T is the tissue temperature, Ta is the arterial temperature (assumed to be constant), ρ is the density of the tissue, ρb is the density of blood, and ωb is the blood perfusion. We have two terms added to the heat equation due to the metabolism [Qm] and the blood perfusion [xb.$_{\rho b}$.$c_b$ (Ta−T)].

## 2. MATERIALS AND METHODS

### 2.1. Study of the temperature distribution of a metal plate:

As the principle element in our temperature sensor is a metal (see figure1). We use temperature-analysis-applying-finite difference method in order to give a temperature analysis of a metal plate subjected to heat at one site and open to air at other (inspired from Sidhartha Agrawal technique [7]).

**Figure 1:** The figure presents the thermal's transducer element of temperature measure device.



### 2.2. Study of the dynamical response of temperature sensor*:*

Although the dynamic characteristic is very important for the majority of physiological sensors but it is not enough for diagnostic side against its importance to the therapeutically cure. It's why the interest of our further study. For this study we took a temperature sensor linked to a data acquisition board "Arduino" (see figure 2). Firstly was applied as a corporal temperature sensor by placing it on our finger and then we put it in a bowl of cold water in order to see its dynamical response.

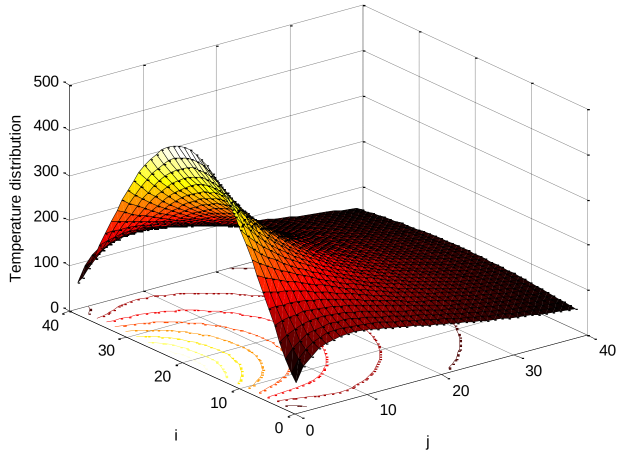
**Figure 2:** The figure presents a type model of Arduino Mega 2560 R3 Front.

## 3. RESULTS AND DISCUSSION

### 3.1. Study of the temperature distribution of a metal plate:

We get the curve shown in the figure 3.

**Figure 3:** The figure presents a temperature distribution of a metal plate

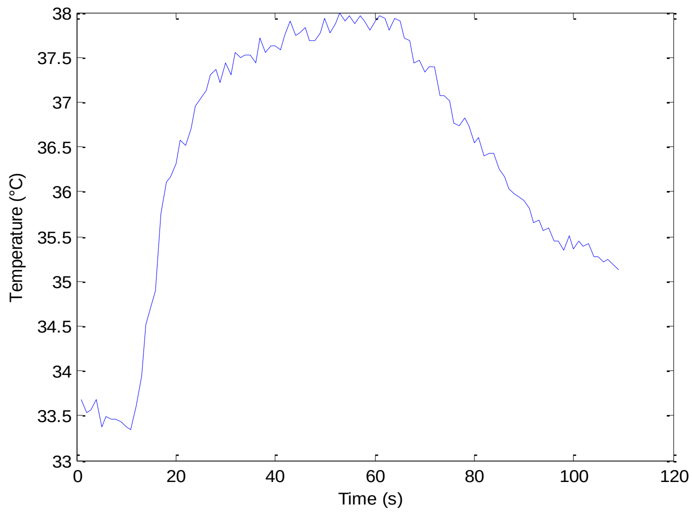



From this figure, we can see a nearly uniform shape of the temperature distribution if we use a metal plate.

### 3.2. Study of the dynamical response of temperature sensor:

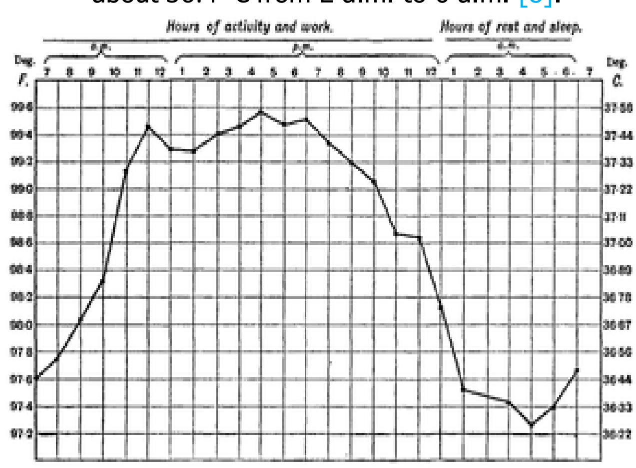
By using the data acquisition board "Arduino", we had this graph (Figure 4):

**Figure 4:** The figure presents a dynamic's characteristic of an Arduino temperatures sensor.




We see from the figure (figure 4) the rapid response to a dynamic stimulation in burning (heating) which is well explained by calculating the rise time. This latter is the time spends when signal progress between 1O percent and 90 % of its maximum level, which is in our case is more or less than five (05) seconds. But it's very slow in the opposite case (see the fall time which is the time spends when signal progress between 9O percent and 10 % of its maximum level).
We can deduce that for this temperature sensor it's better to use it for a heating (burning process such as hyperthermia) but not the freezing case (as the hypothermia) especially when we have a continuous control of corporal temperature to do.
Other ascertainment, the dynamic response for this type of sensor (corporal temperature) can be considered as good for the normal cases despite the slow change of the body temperature during the whole day (see figure5).

**Figure 5:** Diurnal variation in body temperature, ranging from about 37.5 °C from 10 a.m. to 6 p.m., and falling to about 36.4 °C from 2 a.m. to 6 a.m. [8].




Compared to other studies, which for most of them treat the dynamics of thermal sensor (especially with thermocouples) for use in solutions or air [9,10], this part of work had selected as application of dynamics the human body while focused on practice because there are some theoretical studies such as made by YOON, Heenam [11]. So it's one of the practical studies on the dynamics of corporal sensor.

## 4. CONCLUSION

In this article, some elements which are necessary to know when we want to use a corporal temperature sensor is studied. The heat transfer is complicated to study because of its many physical parameters which are implicated and the problem is more complicated when we have biological matter since of its metabolism character and the blood perfusion, the

mathematical equation of temperature distribution requires more simplifications in order to solve it. But studies follow tirelessly in this field with many diversified studies especially in three dimensions (3d).
As a final point, we see more and more to the miniaturization of body's temperature sensors such as integrated circuit thermometers are a wide measurement range (from -50 °C to 125 °C) with good accuracy but their small size (few millimetres) requires additional amplification block.
One problem that has arisen for our dynamic study is not to be able to see this effect on other organs and not just the skin. That is why we have as perspective of this research, the study of more elements such as working on the distribution of temperature inside the sensor and studying bio-heat transfer in different kinds of human tissues.

## 5. REFRENCES


[1] Mst. Nasima Bagum &al. Finite Element Analysis of One Dimensional Bio-Heat Transfer in Human Tissue. IOSR Journal of Engineering, (IOSRJEN). 2013; vol. (3): 43-49.
[2] Pennes HH. Analysis of Tissue and Arterial Blood Temperature in the Resting Human Forearm. J Appl Phys, 1948;1:93–10
[3] Website**:** http://en.wikipedia.org/wiki/Heat_transfer#Advection; Retrieved: February, 14, 2015.
[4] Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt. 2011. Introduction to Heat Transfer. Sixth edition of the book, JOHN WILEY & SONS, 03-12 and 68-70.
[5] Website**:**
http://www.atomic.physics.lu.se/fileadmin/atomfysik/Biophotonics/Education/Tissue_Optics_Lectures/bioheatequation.pdf
[6] A.V. Kuznetsov. Optimization problems for bioheat equation. Journal: *International Communications in Heat and Mass Transfer*. 2006. Vol (33): 537–543.
[7] Website**:** http://fr.mathworks.com/matlabcentral/profile/authors/870603-sidhartha-agrawal. Retrieved: February, 14, 2015.
[8] W. F. Inc. (2013, 10 August). Human body temperature. Available: http://en.wikipedia.org/w/index.php?title=Human_body_temper ature&veaction=edit&section=13.
[9] Liu Lishuang &al. Test of the Dynamic Characteristics of Temperature Sensor Based on Modulated Laser. International Forum on Information Technology and Applications, 2010 IEEE. 156-158.
[10] Tomoki SHIODA, Yoshifumi SEKINE and Hideo OTSUKA. HIGH PRECISION TCXO FOR RAPID ENVIRONMENTAL TEMPERATURE CHANGE. Proceedings of the 2003 IEEE International Frequency Control Symposium and PDA Exhibition Jointly with the 17th European Frequency and Time Forum. 2003 IEEE. 444- 449.
[11] Website: http://www.bth.se/tek/asb.nsf/bilagor/sss_sensordynamics+_vt09_pdf


**Cite this article: Mohamed Rezki, Mouloud Ayad and Kamel Saoudi.** ELEMENTS TO STUDY CORPORAL TEMPERATURE'S SENSOR. *The American Journal of Innovative Research and Applied Sciences*.2015; 1(5):172-176.