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TESTING AND CHARACTERIZATION: BRAIN RECORDING AND MEASUREMENT SYSTEM

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Abstract: - Control and measurement of electrical activities of brain, with implantable devices and systems, have been becoming topics of key interest in physiological measurements even in micro and nanotechnology issues. Implantable devices under the scalp and out of the brain are subject to delicate design and construction. This paper presents a thermal analysis of a designed case for recording signals for EEG applications. The paper also illustrates the materials used for this purpose. The thermal analysis has been performed using Comsol Environment.

Keywords: electroencephalogram, implantable devices, testing, design, biomedical sensors, thermal analysis, nanotechnology.

1. INTRODUCTION

The interest in neuro-recording is very great for long term monitoring in order to help physicians to adopt appropriate therapy [1] [2]. Different authors have been working on implantable devices for neuro-recording of signals but only few numbers are dedicated to the use of special materials based on nanotechnology. If we focus our attention on changes in brain electrical signals, we shall think about mechanisms that are able to overcome pharmacological treatments. Some researchers [3] are developing bio-systems capable of recognizing an epileptic crisis during EEG registration and to stop it during its arising thanks to electrical pulses emitted by the bio-device (sensor) implanted in the cerebral cortex to monitor the medical examination. The main current troubles are due to crisis monitoring and cluttering [4]. This latter could be due by excess of sensitivity. The RNS, implantable device, constantly monitors electrical activity of the brain, gets accustomed to what is normal for that patient and, when it detects activity that is abnormal [5], within a few milliseconds, sends out a small electrical stimulus to stop it. It is very important to recall EEG signal frequencies routed by electrodes that average the action potentials from large numbers of cells, and hence, do not provide action potentials from single cells [6]. In particular, the potentials' frequencies recorded on the scalp of a normal human subject, typically vary in a range of 1-30Hz and there are only few dominant frequency bands that usually arise. They are called alpha (α , 8-13 Hz), beta (β , 13-30 Hz), delta (δ ,

0.5-4 Hz) and theta (θ , 4-7 Hz). Quantitative monitoring is generally used during sleeping [7]. The signal trends are necessary in order to provide a complete overview of the electronic processing and of the Wi-fi electromagnetic transmittivity of the proposed systems. The microcontroller will be programmed and synchronized for this signal elaboration. However, many attempts have been performing to only record EEG signals by means of specific devices, in micro and nanotechnology [8] [9] [10]; thus, they cannot fully be included in the scope of this paper because they only record and monitor [11]. They cannot act as pulse generator. As indicated above, if a system is only dedicated to recording, suffices for it to be a microdevice like an ASIC component but if it has other functions, namely, multi-acquisition, stimulation and transmission. Programmable devices and components are useful in this kind of application. They belong to two categories, namely, standardized components designed for a specific application and others that can be programmed according to desired application. They are for instance ASIC's (application-specific integrated circuit) considered a IC's.. We have plenty of types of ASIC's as full-custom, semi-custom, and silicon compilation. When dealing with ASIC's, problems of trade-offs arise like flexibility, density, cost, and risk. For implantable devices it is mandatory to evaluate the relative costs involved, such as non-standard engineering process costs, and design aspects like architecture and the number of gates. There is also another problem related to the packaging especially for those devices to be included under scalp. It is usually larger than the cost of components included in the packaging- It could reach 80% of the overall cost of the electronic components. That is due to the quality of special materials used for the fabrication of packaging for each component and the overall packaging (enclosure or case) including all components with their local and single packaging. The case must not release and transfer hazardous materials on biological tissues and that is the reason it must be in special implantable materials. Nanotechnology process is a solution that can conjugate dimensions and quality of materials. The first parameter influences the location of the case. Many important metals used for surgical implants are metal alloys based on the combination of Titanium, Aluminum, Vanadium, Nickel, Cobalt and even Iron. But for the case under study it is suitable to use polymeric materials.

2. SYSTEM DESIGN AND MODELING

The main principle scheme of the system data flow is illustrated in Fig.1 where a classical collecting process is shown with additional signal processing and transmission. All the aforementioned units are included and contained in a special case which is the scope of this paper. Once the single subunits have been defined and pre-assessed, and the dimensions of the case have been defined (4 meters x 3 meters), a simulation procedure is started using Comsol simulation environment [12].

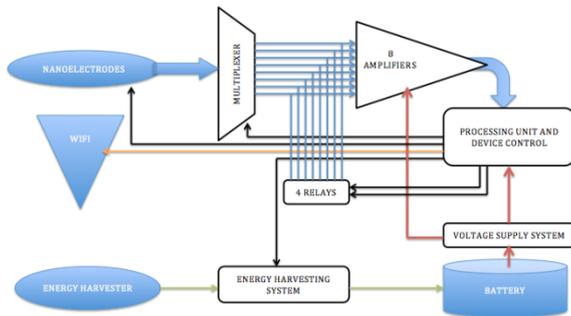


Fig.1: Main components of post sensor circuits

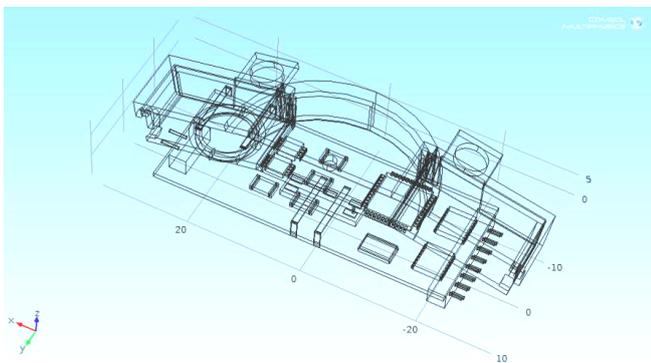


Fig.2: 3D architecture of the system

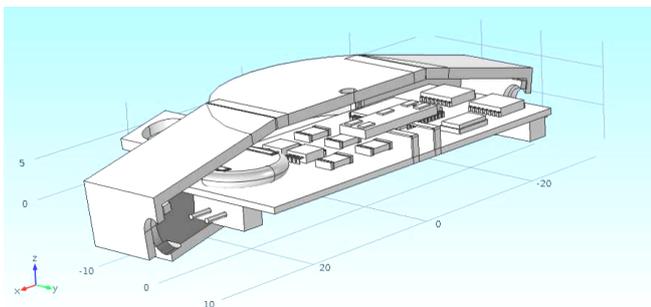


Fig.3: Main components of post sensor circuits

The electronic components are placed on a pcb board for a correct placement and location for minimizing electrical resistance. That is depicted in Fig. 2 and Fig.3. The system has also an energy harvesting unit for converting thermal energy in electric one.

3. SIMULATION AND RESULTS

Since the head is the organ which produces more heat with respect to the other ones, and it is subject to movement, a mechanical simulation is requested for predicting the effect of displacement. According to simulations carried out, a pressure of 100 kPa has been considered to point out a shock on the systems. Deformation is the measure of length variation due to forced stretching or compression. Being deformation, a ratio of two lengths, it is a dimensionless quantity. Given an element subject to an axial exertion, it possible to define a tension

$$\sigma = \frac{P}{A} \quad (1)$$

where P is the pressure applied on 1m^2 and A is the area where is applied the pressure, and a deformation

$$\epsilon = \frac{\Delta l}{l_0} \quad (2)$$

where Δl is variation of the length due to deformation, and l_0 is the initial length. If one measures deformation produced by an increasing and graduated force, this, initially, varies in a proportional way to the force, then it quickly increases. A material is defined isotropic if its behaviour is independent from reference system. An isotropic material gives the same tensional response regardless to direction in which it is deformed, and its properties are the same in all directions.

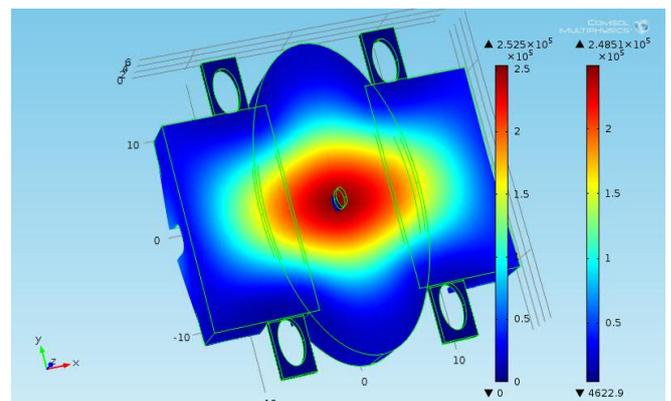


Fig.4: Main components of post sensor circuits

Fig.4 demonstrates the outcomes of the simulation illustrating the deformation of the case due to shocks and external forces. The main deformation occurs in the central parts of the case probably because of a curve is present in that part which corresponds to a special feature of the head.

4. FINAL OUTLOOK

The paper has described preliminary results of designing a bio-implantable neuro-recording system [13]. The main issue is the “reaction” of this kind of apparatus once positioned under the scalp. This design has considered a number of parameters. Most of them are shared with the packaging of electronic circuits. However, some circuits are special for the applications under consideration. Even if not faced in this paper, thermal management is a matter of further investigation. Metals and other materials, like ceramics, make excellent candidate materials for the package housing because of their high thermal conductivity. To ensure unimpeded heat flow from die to the housing, it is necessary to select a die-attach material that does not exhibit a low thermal conductivity. This does not include silicones and epoxies and instead favor solder-attach methods or silver-filled epoxies, polyimides, or glasses.

The described system contains an energy harvester for converting energy from thermal source into electric one. The harvester exploits the thermal stress generated in the case. In any case a hermetic condition is required. A hermetic package is theoretically defined as one that prevents the diffusion of helium. For small-volume packages ($<0.40 \text{ cm}^3$), the leak rate of helium must be lower than $5 \times 10^{-8} \text{ atm} \cdot \text{cm}^3/\text{s}$. In practice it is always understood that a hermetic package prevents the diffusion of moisture and water vapor through its walls. A hermetic package must be made of appropriate materials to prevent contamination and damage on human organs and tissues. Electrical connections through the package must also conform to hermetic sealing. For bio-implantable applications as it is in our case, a hermetic case significantly increases the long-term reliability of electrical and electronic components.

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