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BRAILLE READING DEVICE BASED IN ELECTROCUTANEOUS STIMULATION

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ABSTRACT

This work aims design and implementation of a device, which allows blind users to read digital material from the PC through a Braille display electrodes. With this device and after further training, the user will be able to access a huge amount of digital material, achieving higher performance in studies, work, etc., thus achieving greater social inclusion. The prototype accepts plaintext, loaded from a computer, which is transmitted to a Braille display electrode, where the surface of the finger is stimulated electrically with the purpose to simulate the same pressure and embossing of braille paper. This prototype is an initial project, which will serve as a starting point for improving the same and the development of multiple applications.

Keywords: braille, cutaneous, electrode, electrical stimulation,prototype.

INTRODUCTION

In social terms, the development of a technology depends on the definition or the model used. Assistive technology promotes greater independence by enabling people to perform tasks that were previously unable to achieve or had great difficulty in compliance. If an approach within a social model, where the problem of disability in considered to society rather than to the person is done, must be designed devices or technologies that are accessible and usable by the widest range of possible population, including disabled people, to thereby extend their opportunities and chances. (Hersh and Johnson, 2008).

One of the major limitations of the visually impaired people is to access to reading material. This problem has been addressed through the development of numerous practical solutions within a wide range of technologies and research processes (Asamura, *et al.*, 1998), (Asamura, *et al.*, 1999).

For example, a touch display, as the equivalent of a visual display, presents information that is perceived through the sense of touch. Thus, through electrical excitation (Rollman, 1974) of the inner skin afferents (Vallbo and Johansson, 1984), the user is given the possibility of interpreting codes such as Braille reading. This stimulation is done through electrodes placed on the surface of the skin and by which currents flow with specific waveform, to cause various tactile sensations (Kajimoto, *et al.*, 2002).

Based on the concept of *activation function*, Kajimoto (1999), McNeal (1979), Rubinstein (1988) show that it is possible to selectively stimulate each one of the tactile nerve fibers in the skin separately, by considering the orientation of axons; horizontal or vertical.

Observations by Sato (2010) mention that anodic and cathodic stimuli activates nerve fibers connected to different tactile receptors responsible for feel pressure and vibration sensations. Additionally, the mathematical analysis reveals that anodic electrical stimuli triggers efficiently nerve axons with orthogonal directions to the skin surface, while cathode stimuli properly stimulates those nerve fibers with directions parallel to the skin surface. This situation is represented in Figure-1.

By careful choice of parameters of the current waveform injected to the skin (pulse width, current amplitude, duration and repetition rate), it is possible to induce to the user a feeling of vibration or pressure on the stimulated site. The sensation intensity can be controlled better by varying both the pulse width and amplitude; further refinement in the sense of texture can be achieved by varying the repetition rate (Rollman, 1974).

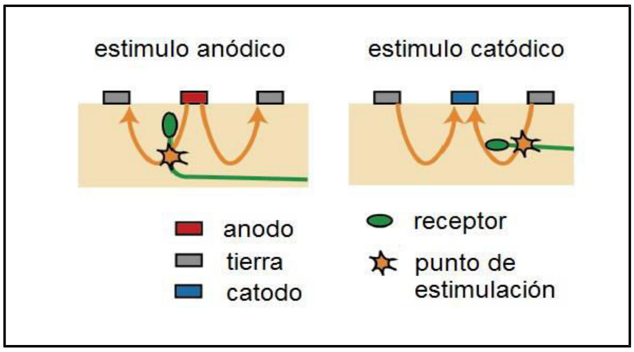

Figure-1. Selective stimulation using anodic and cathodic electrodes.

On the basis of research in the area of electrical stimulation, such as (Kajimoto, *et al.*, 1999) and (Echenique, *et al.*, 2011), the stimulation signal shown in Figure-2 to achieve a feeling of pressure is proposed.

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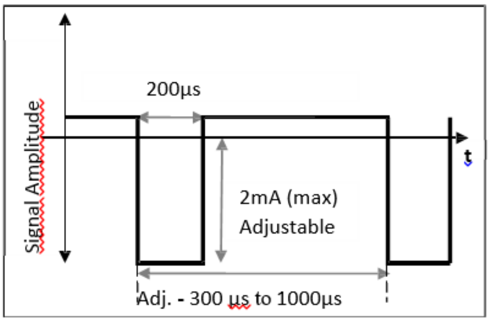

Figure-2. Current waveform of stimulation signal.

Some restrictions are necessary to prevent damage to the skin tissue. Specifically, the maximum stimulation current flowing from the electrode should be limited to 2 mA. Similarly, the average load current (pulse duration x pulse amplitude) of the two alternations of the biphasic pulse should be zero, meaning that the geometric area of the positive pulse must be equal the geometric area of the negative pulse, this in order to avoid accumulation of electric charge on the skin.

Grimes (1983) states that a puncture sense is a warning prior to the destruction of skin tissue. This effect occurs because the current is concentrated in pores with very high local current density and a high probability of nervous excitement. Thus an electric current is more dangerous on moisten skin than on dry skin. With lines of potential in the range of 110-250 volts, the dielectric breakdown of the skin remains still slow, with thresholds for a slight feeling of 1mA or dangerous level of 20mA, the latter critical value is seen in situations of electric shock.

SYSTEM DESIGN

This device converts digitalized letters and numbers to "tactile characters," which can be perceived through the Braille display electrode designed for the prototype. This situation is illustrated in Figure-3.

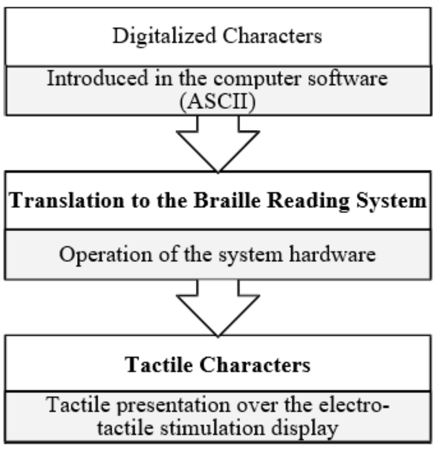

Figure-3. Prototype operation sequence.

The prototype corresponds to the block diagram shown in Figure-4, wherein the functional system modules grouped into three operational sections are shown.

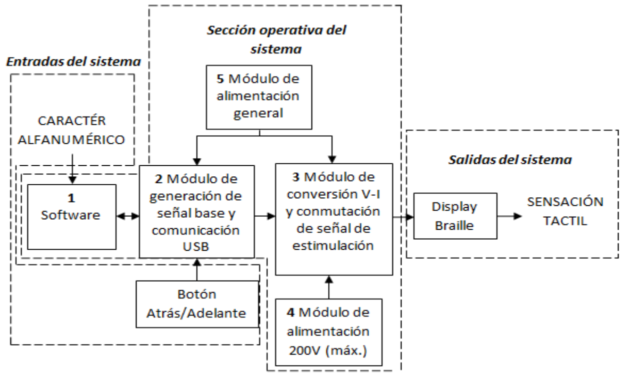

Figure-4. System block diagram.

Input section

The system is fed with digitalized alphanumeric characters entered from a computer. Two buttons back / forward are willing to allow return or move to an earlier or later one character.

Translation section

This section includes the translation of digital characters to Braille reading system and its presentation as "tactile characters". It consists of four functional modules that interact with each other for the generation of the stimulation signal used in emulation of pressures associated with a Braille symbol.

Base signal generation and USB communications module

The microcontroller receives from the software via USB port, variables such as operating frequency and duty cycle of the signal for the construction of the base stimulation signal waveform (Figure-2).

The microcontroller generates a PWM signal and calculates an offset value based on the received variables. Subsequently the digital-analog converter converts the offset given by the microcontroller to an analog value. Through the operation of these two signals it is obtained the base stimulation signal waveform shown in Figure-5.

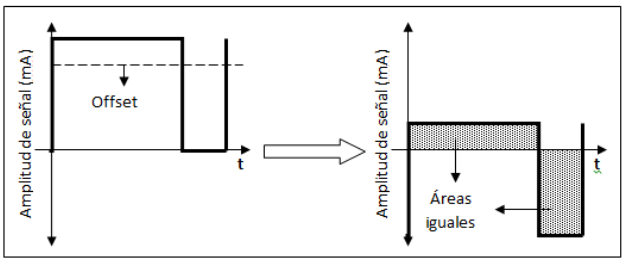

Figure-5. Base stimulation signal waveform.

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The amplifier arrangement of Figure-6, in addition to the operation between the PWM signal and the offset signal, allows adjustment of the stimulation signal intensity by varying the resistors RB and RC.

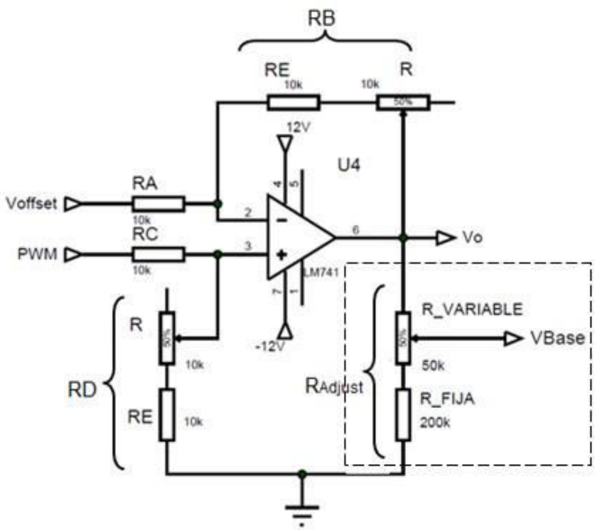

Figure-6. Base stimulation signal generator schematic.

The baseband stimulation signal generated in this module (Figure-7) is converted to injection currents through the next module.

V-I converting and Stimulation signal switching module

This module performs the conversion of the base stimulation signal to stimulation currents by implementing current sources (Sedra, Smith, 1999). Similarly, the stimulation signal is switched to be supplied to each of the Braille display electrodes according to the received ASCII character. Figure-8 describes in general how it is translated and represented a tactile character on the Braille display.

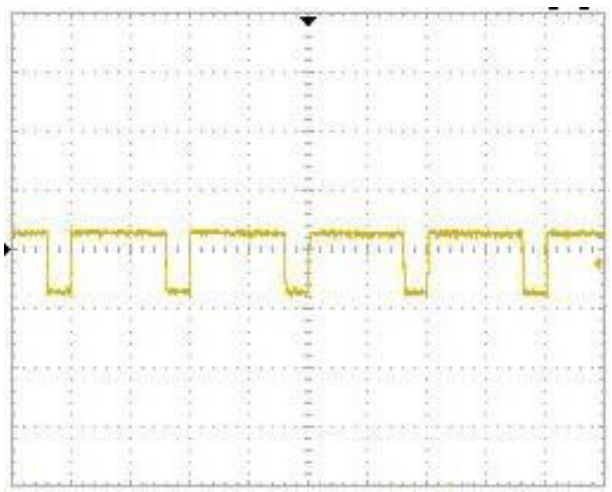

Figure-7. Oscilloscope image of the base stimulation signal.

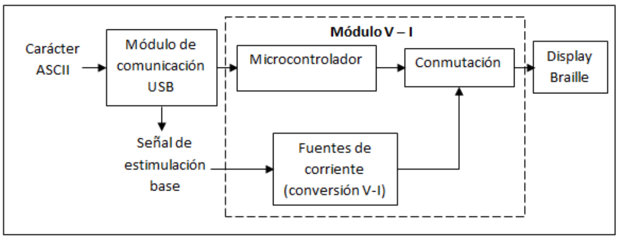

Figure-8. Functional diagram of the V-I conversion module and stimulation signal switching.

Braille translation and stimulation signal switching

Alphanumeric characters entered into the computer software are serially received by the microcontroller and through routine 'Switch Case' binary values are selected according to the character received. Binary numbers allow switching the signal selected in the display electrodes to thereby present the respective tactile character. For example, the letter 'N' in Braille is represented by points 1, 3, 4 and 5, as illustrated in Figure-9.

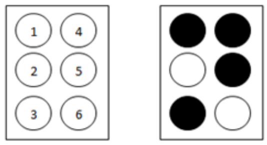

Figure-9. Numeric assignment of Braille points related to the letter 'N'.

The numerical assignment for each of the points corresponds to six pin of the microcontroller for managing optocouplers activation functioning as signal switching devices. Through this IC, stimulation currents to the electrodes of the display Braille are controlled, allowing driving of alternations signal also isolates the low power electronics from the high voltage side.

The time that remains activated a Braille point is 5ms, that is to say the current signal injected into each electrode is at least five cycles of signal when the frequency of the stimulation wave corresponds to the minimum provided by the device, i.e. 1 KHz. This situation is shown in the timing diagram of Figure-10 and the signal in Figure-11.

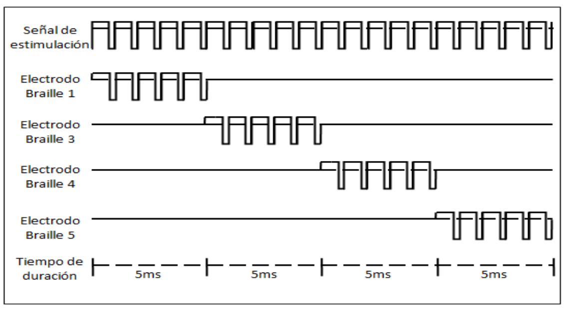

Figure-10. Timing diagram for each point of the letter Braille 'N'.

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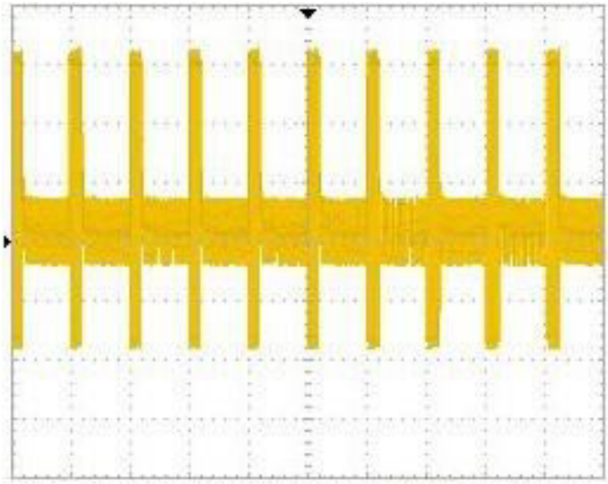

Figure-11. Oscilloscope image for the switched pacing signal on a single Braille electrode.

200V Power supply module

This module manages the constant-voltage values required for skin electrical stimulation. Specifically it comprises two independent switching power supplies (Gamboa, 2008), (Texas Instruments, 2014) connected in series, which raise from 12Vdc up to 200V.

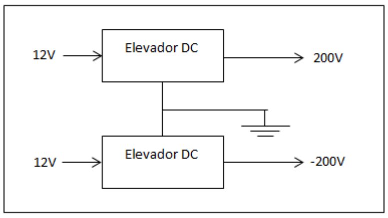

Figure-12. 200V power supply.

Software

The software was designed and implemented over Visual Studio 2013. In this software alphanumeric characters are entered in digital form and are sent to the hardware of the system one by one, at different times, so that only one character is displayed on the Braille display electrode at a particular time. In addition, parameters of stimulation signal waveform are established through the windows that compose the software.

By the two sliders located on top of the setup window shown in Figure-13, it can be varied the parameters of the stimulation signal to set the waveform that best causes a feeling of pressure. Similarly, there are buttons with the letter that make up the Latin alphabet, which when pressed send the equivalent ASCII code. These digital characters are received by the system hardware, interpreted and translated into tactile characters.

In the reading window shown in Figure-14 there are three buttons and two text boxes. With the LOAD button you can select a .txt file saved in any location where the computer is running the program. This file must be.txt extension because such documents contain plain text (only characters).

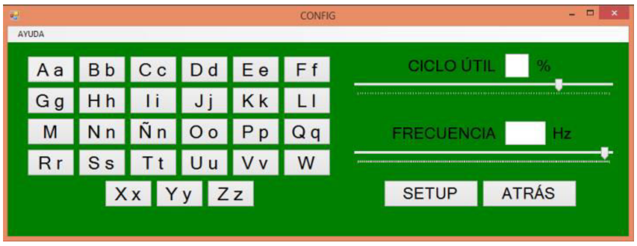

Figure-13. Configuration and training window.

Figure-14. Reading window.

SYSTEM OUTPUT

Braille electrode

Taking into account research papers where it is put in test the concept of electrostimulation (Kajimoto, et al., 1999), (Warren, *et al*., 2008), (Echenique, *et al*., 2011), different Braille display configurations are designed, where the internal electrode distances vary while the electrode size remains fixed.

The route of the stimulation current through the fingertips is determined by the polarity of the stimulation signal (Jawshan, *et al*., 2012). Therefore, it is proposed a larger electrode area which acts as current sink. Designed configurations are shown in Figure-15.

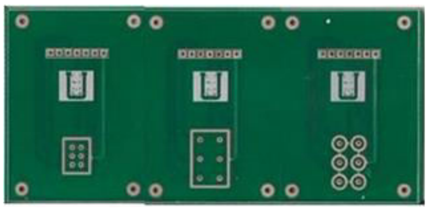

Figure-15. Braille electrode.

The electrodes are made of fiberglass boards. The conductive material is copper. This material is not the best to use because these electrodes may wear in the medium term, but the ease of manufacture, as well as its cost make it the selected material.

Furthermore, for wear, the electrode array is easily replaceable.

Physical assembly

Figure-16 shows the assembly of the Braille electrode array on a foil designed to support it. In the same way, two back/forward buttons are assembled for the navigation of reading characters in the system.

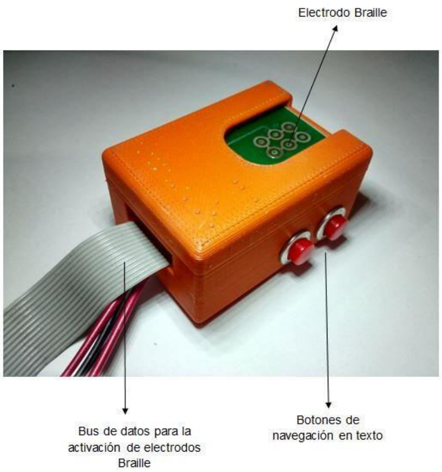

Figure-16. Braille electrode assembly.

RESULTS AND DISCUSSIONS

For the validation of the device a test is applied to a person with visual impairment and a test applied to a healthy person, the latter is bandaged for blindness simulation and evaluated under the same conditions as the blind user. The test consists in the sending of 20 random tactile characters, for which the user must express Braille points (FBU, 2015) where a sense of pressure can be perceived.

For the start of the test, the user is informed clearly what will be done, how the device works and the task that must be performed for the test. In the same way, each user receives a quick training with the device for familiarization with it.

Optimal braille electrode

In the process of rapid training that each person receives prior to the development of the test, it is sought, among other things, that the person identifies which of the three electrode configurations (Figure-15) is best for identifying a tactile character. This way it's obtained that:

- For a person with visual impairment, an electrode configuration where the inter-electrode distances are small, the degree of comfort is greater with respect to a configuration with wide distances. This is due to the greater similarity to the physical representation of Braille characters.
- For a healthy person, a matrix with wide inter-electrode distances represents greater ease in distinguishing one active point from another. This situation could be due to the reduced sensitivity that can be presented by a healthy person to mechanical or electrocutaneous stimuli and to factors such as not being well acquainted with reading the Braille points system.

Percentage of success

The data reported in Table-1 and in Table-2 are the results of the tests applied to the blind user and to the healthy user respectively.

The percentage of success of points measures the number of points that the user perceives correctly, without failing the position in which they are located. Corresponds to the number of correct points correctly on the total number of points representing a character in Braille.

Table-1. Result of the test applied to blind user.

Braille character	Success Points/Character (%)
Z	83.3
P	50.0
A	66.6
E	83.3
R	66.6
G	83.3
F	100.0
A	83.3
Q	33.3
O	83.3
I	0.0
Y	50.0
B	100.0
R	83.3
D	83.3
S	66.6
C	100.0
K	83.3
J	66.6
T	50.0

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Table-2. Result of the test applied to not blind user.

Braille character	Success Points/Character (%)
O	83.3
I	0.0
U	83.3
M	83.3
K	100.3
P	83.3
B	66.6
E	83.3
Q	100.0
L	100.0
T	66.6
D	66.6
S	83.3
J	66.6
H	83.3
R	100.0
G	100.0
X	66.6
Z	33.3
E	50.0

The percentage of correctness of a tactile character is a consequence of the previous measure, that is to say, when a person correctly perceives the position of all the points of the character, therefore the letter Braille is correct. If, on the other hand, the user fails at least one point, then the character is incorrect. This percentage is the number of Braille letters correctly perceived over the total number of characters in the test.

In this way, when analyzing the data collected in the validation tests, a similar percentage of correct Braille points is presented for the two users of the test; Greater than 70 percent. This value is reflected in the percentage of success of a tactile character, which is 15% in a blind person and 25% for a healthy person.

False feelings

In the test performed with the blind person, a common pattern found is the sensation of tactile points where there is no stimulation.

This could be happening because of the reduced inter-electrode distances and the shape of the electric field distribution according to the configuration (Figure-15). It could then be assumed that the use of a concentric electrode (Figure-15, right) has more accurate sensations with respect to a non-concentric electrode configuration (Figure-15, left and center).

It can also be observed that when the stimulation is very strong, the sensation of stimulated area increases, making the perception of the points can overlap between them, which leads to misinterpretations.

Location

A relevant factor in the erroneous reading of the points, and therefore in the misinterpretation of a tactile character, is the physical location of the surface electrodes.

The electro stimulation electrode is a sufficiently smooth surface so as not to correctly distinguish the numerical allocation of the points. The user, not observing where his finger is located, may find it difficult to determine which of the Braille points corresponds to the stimulation.

This situation is presented in both users, being something recurrent. Sometimes the points read are correct, but not the position in which the user assigns them. This is why for future work it is necessary to place at least one physical point in relief that serves as a reference for the location of Braille points.

This suggests that the low percentages in the accuracy of a tactile character, for both users, can be optimized if the percentage of success of Braille points is improved.

Training

For the correct use of a new technology in any individual, it is necessary a stage of adaptation and learning in which the user becomes familiar with the device, realizing a process of recognition and preparation that allows him an appropriate use of this one.

For this reason, in order to be more successful in the use of the experimental prototype developed, it is inherently necessary to have a previous training that guarantees the correct interpretation of the tactile characters presented by electro stimulation.

CONCLUSIONS

Sensitivity and response to electro stimulation vary considerably from person to person. The structure of the cutaneous tissue influences factors immersed in the process of electrical stimulation as the impedance of the skin, which represents an important variable in provoking tactile sensations through constant electric currents and voltages. As the skin structure of each person is different, a particular person may need different stimulation profiles than those used by another person.

The configuration of surface electrodes used for the presentation of a tactile character represents an important factor in the effectiveness of a device as developed in this work. Specifically, the electric field lines generated in the cutaneous tissue by the injection of currents are what actually stimulate the different nervous units. In this way, it is assumed that a tactile sensation provoked will be slightly different for the different configurations proposed in this work.

People who are blind from an early age are significantly more sensitive to electro stimulation than those who are less likely to have a disability. While a range of stimulation currents and voltages hardly provoke slight tactile sensations for a person with recent disability, this same range can create discomfort and even sensations of pain for a person with premature visual impairment. This situation often implicitly evidences the need to modify or adapt electro stimulating devices to meet the individual needs of each user.

For the effectiveness in the use of devices based on electrical stimulation, regardless of its application, it is necessary a previous training process that facilitates the adaptation and easier interpretation of the information presented in a surface electrode array.

In order to optimize the success rates of a tactile character, it suffices to improve the user's ability to locate the Braille points that are activated in the array of electrical stimulation electrodes.

REFERENCES

[1] Asamura N., Tomori N., Shinoda H. 1998. Tactile Feeling Display Based on Selective Stimulation to Skin Receptors. Proc. IEEE Virtual Reality Annual International Symposium. Atlanta, Georgia. pp. 36-42.

[2] Asamura N., Yokoyama N., Shinoda H. 1999. A Method of Selective Stimulation to Epidermal Skin Receptors for Realistic Touch Feedback. Proc. of IEEE Virtual Reality Conference. pp. 274-281.

[3] Echenique A. M., Graffigna J. P., Mut V. 2011. Selección de Parámetros Óptimos para la Electroestimulación Cutánea en Personas Ciegas. V Latin American Congress on Biomedical Engineering CLAIB, Habana, Cuba. pp. 607-610.

[4] FBU. 2015. Alfabeto Braille.

[5] Gamboa Q., J. L. 2008. Guía de Diseño y Análisis de Convertidores Conmutados de Alta Frecuencia.

[6] Grimes S. 1983. Skin Impedance and Electro-Osmosis in the Human Epidermis. Medical & Biomedical Engineering & Computing. pp. 739-749.

[7] Hersh M. A., Johnson M. A. 2008. Assistive Technology for Visual Impaired and Blind People. Springer limited.

[8] Jawshan A., Hwang S. H., Khang G., Song T., Bae T. S., Park S. 2012. Effects of the Polarity and Waveform of the Stimulus Pulse Train on the Electrically-Elicited Pressure Sensation. IEEE EMBS International Conference on Biomedical Engineering and Sciences, Langkawi, Malaysia. pp. 175-179.

[9] Kajimoto H., Kawakami N., Tachi S. 2002. Optimal Design Method for Selective Nerve Stimulation and Its Application to Electrocutaneous Display. Haptic Interfaces for Virtual Environment. pp. 303-310.

[10] Kajimoto H., Kawakami N., Maeda M., Tachi S. 1999. Tactile Feeling Display Using Functional Electrical Stimulation. International Conference on Artificial Reality and Telexistence (ICAT).

[11] McNeal D. R. 1979. Analysis of a Model for Excitation of Myelinated Nerve. IEEE Transactions on Biomedical Engineering. 23(4): 329-337.

[12] Rollman G. B. 1974. Electrocutaneous Stimulation. Conference on vibrotactile communications, Austin, Texas. pp. 37-51.

[13] Rubinstein J. T., Spelman F. A. 1988. Analytical theory for extracellular electrical stimulation of nerve with focal electrodes I. Biophys. J. - Biophysical Society. 54, pp. 975-981.

[14] Sato K. & Tachi T, 2010. Design of Electrotactile Stimulation to Represent Distribution of Force Vectors. IEEE Haptics Symposium, Massachusetts, USA. pp. 121-128.

[15] Sedra A. S. & Smith K. C. 1999. Circuitos Microelectronicos (4 ed.). (E. Ramirez G., & J. E. Romo M., Trads.) México: Oxford University Press.

[16] Texas Instruments. 2014. Application Report. Basic Calculation of a Boost Converter's Power Stage.

[17] Vallbo A. B., Johansson R. S. 1984. Stanford University. Properties of Cutaneous Mechanoreceptors in the Human Hand Related to Touch Sensation.

[18] Warren J. P., Bobich L. R., Santello M., Sweeney J. D., Helms T., S. I. 2008. Receptive Field Characteristics under Electrotactile Stimulation of the Fingertip. IEEE Transactions on Neural Systems and Rehabilitation Engineering. pp. 1-5.