Design and development of flexible boards and their application to biomedical engineering

Diseño y desarrollo de placas flexibles y su aplicación en la ingeniería en biomédica

José Luis Ordoñez-Ávila[1], Luis Eduardo Martínez Osorto[2], Fernanda Cáceres Lagos[3]

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1 Universidad Tecnológica Centroamericana (UNITEC). Honduras.
jlordonez@unitec.edu
https://orcid.org/0000-0002-3537-1739
2 Universidad Tecnológica Centroamericana (UNITEC). Honduras.
leduaro1006@unitec.edu
3 Universidad Tecnológica Centroamericana (UNITEC). Honduras.
fernanda_lcl@unitec.edu
https://orcid.org/0000-0002-8663-9854

Keywords

Fabrication; flexible circuits; incremental methodology; materials; wearable technology.

Abstract

Wearable devices in the healthcare industry require to be easy to use, comfortable to handle, and reliable in their operation. This article presents a study on the design and manufacture of flexible circuits and their applications in the field of biomedical engineering. The methodology used in this study is the incremental methodology, which implies a step-by- step approach of the design and fabrication process. The study focuses on the fabrication of a flexible circuit using conductive ink and a flexible substrate. The results showed that the Voltera V-ONE printer can be used to create these circuits with a high accuracy and precision. Various substrates were used for the testing process due to their different characteristic. The final circuit was tested and found to be functional for applications in biomedical engineering.

Palabras clave

Circuitos flexibles; fabricación; materiales; metodología incremental; tecnología vestible.

Resumen

Los dispositivos vestibles, o wearables, en la industria de la salud deben ser fáciles de usar, amigables con el usuario y confiables en su funcionamiento. Este artículo presenta un estudio sobre el diseño y la fabricación de circuitos flexibles y sus aplicaciones en el campo de la ingeniería biomédica. La metodología utilizada en este estudio es la metodología incremental, que implica un enfoque paso a paso del proceso de diseño y fabricación. El estudio se centra en la fabricación de un circuito flexible utilizando tinta conductora y un sustrato flexible. Los resultados mostraron que la impresora Voltera V-ONE puede utilizarse para crear estos circuitos con una gran exactitud y precisión. Se utilizaron varios sustratos para el proceso de prueba debido a sus diferentes características. El circuito final fue probado y resultó ser funcional para aplicaciones en ingeniería biomédica.

Introduction

Flexible circuits have emerged as a promising alternative to traditional rigid circuit boards due to their unique properties. In recent years, flexible circuits have been increasingly used in various applications including aerospace, automotive, and consumer electronics. However, the field of biomedical engineering has also been greatly impacted by this technology. The design and fabrication of flexible circuits for biomedical applications has proven to be challenging and requires specialized knowledge, materials, and equipment [1].

Another important aspect of flexible circuits is the conductive material. In traditional rigid circuit boards, copper is commonly used as the conductive material. However, copper is not suitable for flexible circuits as it can easily crack or break when the circuit is bent or stretched. Conductive ink is an alternative solution for flexible circuits. Conductive inks are typically made of metallic nanoparticles dispersed in a solvent and can be printed onto a flexible substrate using a variety of printing techniques [2].

The Voltera V-ONE printer is a novel tool that allows the creation of printed circuit boards in-house, providing a cost- effective and efficient solution for small scale prototyping. [3]. The Voltera V-ONE printer uses conductive ink to create printed circuit boards on different substrates. The printer allows for the creation of complex circuits with a high degree of accuracy and precision. It has been used in various applications, including robotics, aerospace, and consumer electronics [4].

Our study aimed to demonstrate the feasibility of using the Voltera V-ONE printer for the fabrication of functional flexible circuits. The circuit was then tested for its functionality, and the results were analyzed to get to know how it could be implemented in the biomedical engineering field.

State of the Art

To prepare for the creation of the flexible research, a literary review was done and consisted of 25 articles related to the different types of methods used for the manufacture of circuits, sensors, and the implementation of the internet of things (IoT). These topics are essential to understand how to create flexible circuits and their possible application in healthcare. Articles were chosen based on their relevance, number of citations and recent publication date.

The compilation of articles was carried out in the IEEE Xplore, IOP and MDPI libraries. The library in which the largest number of documents related to circuit fabrication, sensor integration and implementation of IoT was found in the IEEE Xplore library.

The articles that were published within the last 6 years were the ones considered for the review. Fig.1 shows the countries of origin for the articles. The country from which more number were found was India with 24%, this is due to its large population and the need for innovation to become a developed country. The countries where we found one or 2 articles, which are quite diverse and correspond to 60% of the articles found. The wide variety of origins reflects the interest around the world in the topic.

Table I shows a summary of the topics of interest. Sensor research articles indicate that ultrasonic sensors are the most widely used technology for obstacle detection systems. In terms of circuit fabrication, traditional circuit printing is still the most widely used method, but there is growing interest in additive printing in various materials for circuit fabrication. Additive printing involves building up layers of material to create a circuit, which offers greater flexibility in design and material selection.

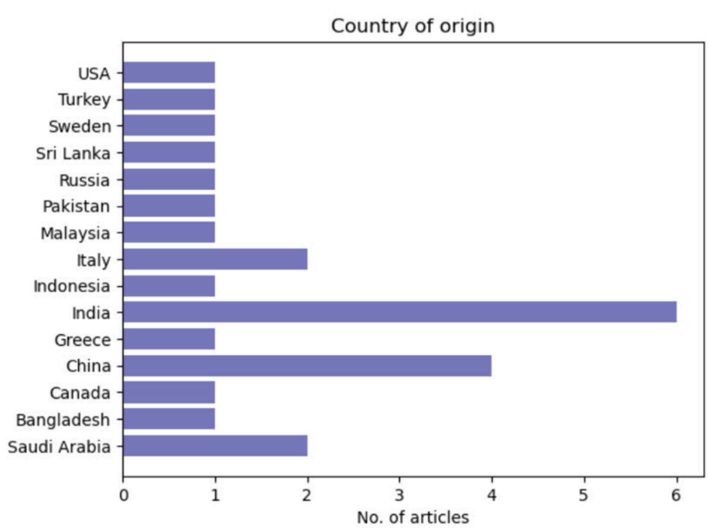

Fig 1. Country of origin of articles.

Table 1. Comparison of Topics of Interest

Topic	Summary
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Internet of Things [11], [12] [27], [28]	IoT implementation has been mainly for data monitoring purposes followed by remote device control, and lastly for communication
Wearable design [29], [21], [5], [6], [7], [9], [10], [11], [12]	Some examples of wearbles are mostly different types of tools, a wearable pair of shoes with integrated sensors and IoT implementation using Bluetooth, a harness carrying the circuit on the chest and lastly a bracelet with movement detection and audio feedback.

Methodology

For this project the incremental methodology was used to create a prototype that could be implemented in a real environment. The incremental methodology, as seen in Fig.2, is based on creating a complete product at each stage of the project and improve the product within each cycle. The analysis takes in consideration what has been learned from previous increments. The design is based the literature review done previously. The code section integrates what is designed to make a complete and functional product for the research. Before creating a deliverable product, testing is done to understand where the objective was met, where it failed and, where it can improve [30].

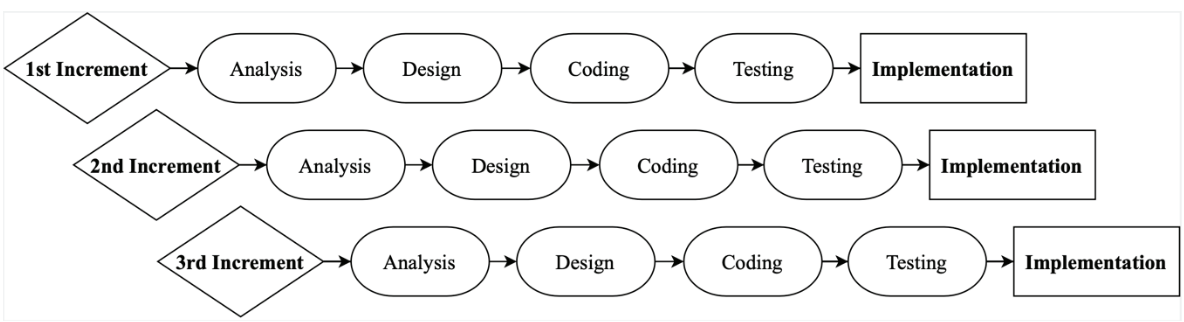

Figura 2. Incremental Methodology Diagram.

Results

In the first increment, the design of a functional circuit was pursued to recreate it in a flexible substrate. Based on the literature review, a prototype of an object detection system was designed, with the purpose of indicating the location of an obstacle in front of a person. The circuit design was done in Proteus. The circuit consists of a PIC18F45K22 micro- controller, two sensors (2 ultrasonic range finder). Two vibration motors controlled using a MOSFET transistor modulated by a PWM signal.

The left motor indicates that the object is on the left side of the person, the same for the right side. The intensity of the vibration indicates the proximity of the object to the sensor. A Bluetooth module for the use of IoT implementation. The coding for the system was done in the development tool for micro-controllers MikroC. The flow diagram of the code can be seen in Fig.3. The system was tested resulting in sensors operating correctly and a fast response from the motors.

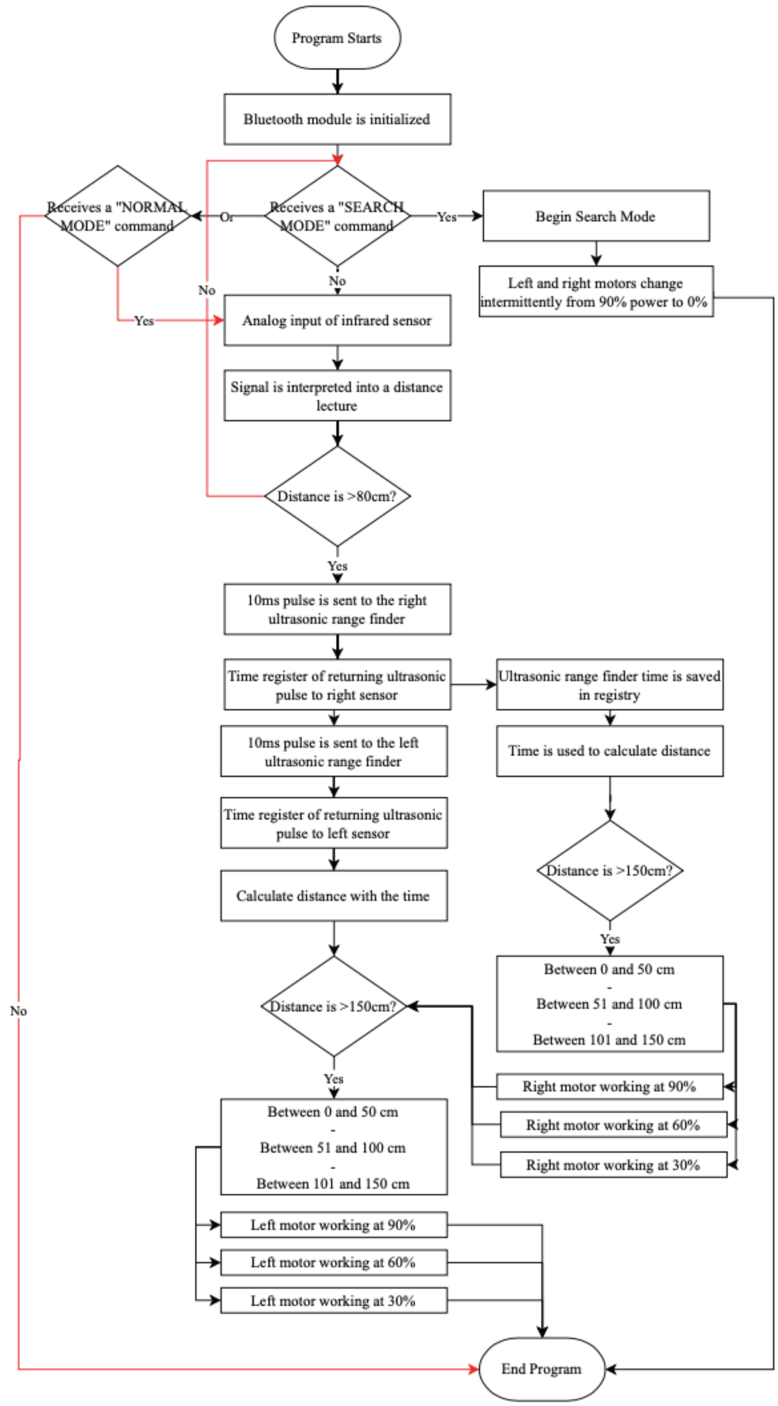

Figura 3. First Increment Code Diagram.

For the second increment, the Voltera V-ONE circuit printer was used. Proteus was used for the design, and board design was also elaborated for the routing of the circuit tracks. Several prints were made to test 3 different soldering methods.

Re-flow soldering using tin paste and a heat gun with air flow regulation and temperature control was successful. The result was a rigid board with the ability to remove and replace important components such as power supply, motors, sensors, and micro-controller. There was an issue with the brittleness of the solder joints. Movement and vibration from the motor was enough to break these solder joints.

On this increment, the circuit was divided into 4 modules due to the difficulty in soldering previously.

Circuits 1 and 2 are for motor control which is designed to have few connections. The tracks and soldering points are large and robust to avoid the fragility of previous circuits as this circuit will be directly exposed to vibrations from the vibration motors. Circuit 3 has the voltage regulation and power distribution.

Circuit 4 has the brain of the operation, the micro-controller PIC18F45K22 and the circuit of its oscillator crystal to have a time control to keep track of the time required for the operation of the system. The Bluetooth module is also found in this circuit.

The test for increment 3 consisted of the fabrication of a flexible circuit. It was necessary to change the substrate on which the conductive ink would be printed. The materials that were chosen for this purpose were polypropylene, which was found in the form of lamination sheets for the plastification of documents and PETG (Polyethylene Terephthalate Glycol) sheets, these materials are resistant to temperatures of approximately 80 °C.

Within the printing process one of the necessary steps to have a printed circuit is to heat the circuit for 50 minutes at 160 °C to adhere the ink to the substrate. In the case of polypropylene during the curing process the deformation due to the high temperature is minimal in comparison PETG.

For soldering we implemented the same method used with the circuit in rigid substrate. The problem in this case is the unevenly application of heat and deformation of the sheets of both polypropylene and PETG. A soldering iron with temperature regulation was needed, due to temperature exceeds 250 °C and the ink begins to lose adhesion. The welding was carried out by hand, to make quick welds and avoid deformation. The soldered circuit can be seen in Fig.4.

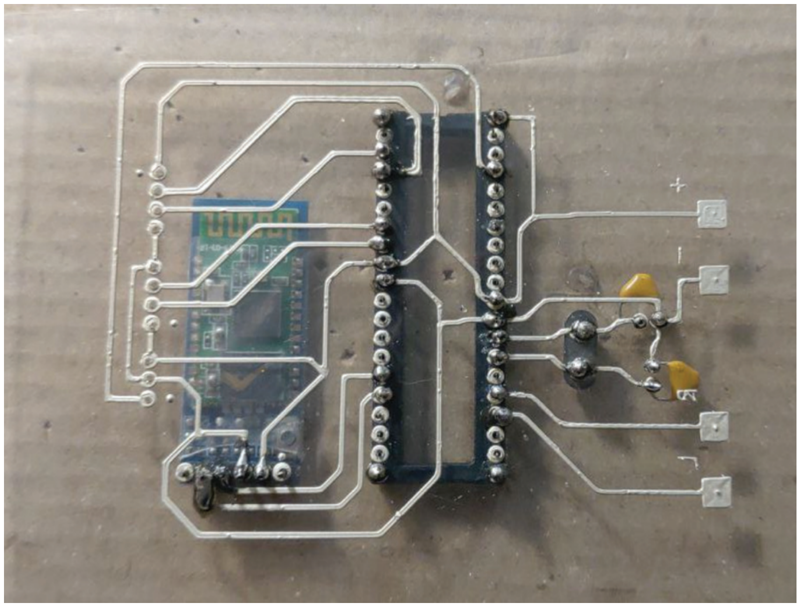

Fig 4. Soldered flexible board.

The welding is composed of three layers: two flexible and one rigid. These being the polypropylene sheet, followed by the conductive ink and finally there is the tin layer that makes up the weld. When the polypropylene sheet is flexed, a force is created that separates the ink from the solder. To prevent this, a resin coating with polyester finish was applied. At last, the fully flexible circuit can be seen in Fig.5. One of the advantages of this resin is that by completely covering the circuit it protects it from damage caused by fluids. Finally, operational tests were done to the final circuit and all components worked according to the coding.

Figura 5. Resin covered board.

Conclusions

A fully operational flexible circuit was created using the Voltera V-ONE to print and cure conductive ink into a polypropylene sheet. Several problems appeared along the process but solved using the incremental methodology. This type of circuits could be beneficial for applications in healthcare, due to its ability to adapt to the patient’s body o garments, making them more comfortable to wear. This could improve the functionality of wearable devices.

Another key benefit of our prototype is the ability to repel humidity thanks to the resin coat. This characteristic is important for patients, who are our final users, because exposure to water and sweat won't generate a problem. In the case of our object detection system, its use won't be limited to only indoors. The patient could wear the prototype even on a rainy day and it wouldn't be damaged.

As mentioned before, the implementation. of IoT in health- care through wearables can help monitor and alert patients about their physiological signals and surroundings using several sensors. The prototype we developed could be the first step to the development of more flexible wearables devices in the industry to monitor patients remotely and help the impaired to perform their daily activities.

Acknowledgement

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Fernanda Cáceres Lagos, Luis Eduardo Martínez Osorto, José Luis Ordóñez-Ávila
Universidad Tecnológica Centroamericana UNITEC, Honduras
fernanda_lcl@unitec.edu, leduaro1006@unitec.edu, jlordonez@unitec.edu

Introduction

Wearable devices in the healthcare industry require to be easy to use, comfortable to handle, and reliable in their operation. This article presents a study on the design and manufacture of flexible circuits and their applications in the field of biomedical engineering. The methodology used in this study is the incremental methodology, which implies a step-by- step approach of the design and fabrication process. The study focuses on the fabrication of a flexible circuit using conductive ink and a flexible substrate. The results showed that the Voltera V-ONE printer can be used to create these circuits with a high accuracy and precision. Various substrates were used for the testing process due to their different characteristic. The final circuit was tested and found to be functional for applications in biomedical engineering.

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Materials and Methods

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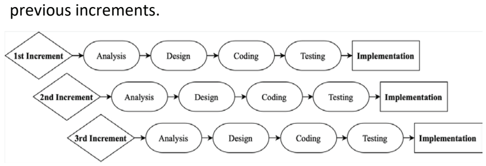

Fig 1. Incremental method.

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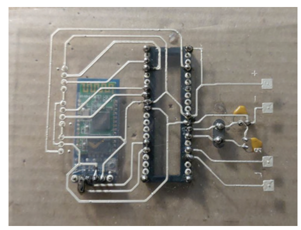

Fig 2. Soldered flexible board.

The test for increment 3 consisted of the fabrication of a flexible circuit. It was necessary to change the substrate on which the conductive ink would be printed. The materials that were chosen for this purpose were polypropylene, which was found in the form of lamination sheets for the plastification of documents and PETG (Polyethylene Terephthalate Glycol) sheets, these materials are resistant to temperatures of approximately 80 °C.

Fig 3. Soldered flexible board with resin protection.

Conclusions / Next Steps

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