To measure blood volume flow, a method known as Transit Time Flow Measurement (TTFM) is used, regarded as one of the most accurate. It is currently employed as an essential complement in the verification of coronary implants (by pass) during the surgery process. Accordingly, this paper presents a technical solution to measure the blood flow, which consists of an analog card, a USB interface card and a personal computer. The USB interface receives signals from the analog card; it converts them into digital signals and finally, are sent to the computer via USB port. By means of LabView software, the data is processed and the results are exposed in a display. The signals are displayed and the value of blood volume flow is shown, which are of vital importance during coronary bypass surgery.

Keywords: Transit time method; blood flow measurements; coronary implants.

Para medir el flujo volumétrico sanguíneo se emplea un método conocido como Medición del Flujo Mediante el Tiempo de Transito (TTFM), considerado como uno de los más precisos. Se emplea con frecuencia como complemento esencial en la verificación de los implantes coronarios (by pass) durante el proceso operatorio. Consecuentemente, en este trabajo se presenta una solución técnica para medir el flujo sanguíneo el cual se compone de una tarjeta analógica, una tarjeta de interfaz USB y una computadora personal. La interfaz USB recibe las señales de la tarjeta analógica, las convierte en señales digitales y finalmente, se envían a la computadora a través del puerto USB. Mediante el programa LabView los datos se procesan y los resultados se exponen en un display. Se muestran las señales y los valores de flujo volumétrico sanguíneo, los cuales son de gran importancia durante el implante de vasos coronarios.

Descriptores: Método de tiempo de tránsito; medición de flujo sanguíneo; implantes coronarios.

PACS: 07.05.HD; 07.05.WR

1. Introduction

Cardiovascular diseases are one of the main causes of death globally, being well known the occlusion of blood vessels and in Cuba, there are also reported similar rates. Consequently, during cardio-vascular surgery process, it is very important to know the value of blood volume flow through the grafted vessel (by pass), which represents a quality rating of the implants.

In this paper, the fundamental characteristics of a system that measures blood volumetric flow are described, employing the measurement method known as “Transit Time Flow Measurement”. It let to know the value of volumetric flow of a fluid (blood) that flows through a vessel [1-3].

2. Materials and methods

2.1. Sensor characteristics

The employed ultrasonic sensor is composed of different parts (see Fig. 1):

1. Two rectangular ceramic elements of area 30 mm$^2$ and frequency of 2 MHz.
2. Acrylic stand, where ceramics are glued.
3. Thin copper wires.
5. Rod holder.
6. Shielded cable and stereo jack [1].

2.2. Implementation of the method

Figure 2 shows the block diagram of the proposed circuit that appears in 4, 227.407 U.S. Patent [2-3,5]. In this patent, the detailed operation of each block present in Fig. 2 is shown.
2.3. USB port interface

The USB interface constitutes a development kit that acquire analog signals with amplitudes of 0-5 volts and frequencies between 0.5 and 120 Hz. It uses a DS87C550 microcontroller which is responsible for the conversion of analog signals into digital format, with a minimum conversion time of 16µs and it has also serial transmission. Thus, data is transferred from the microcontroller to the integrated circuit FT232BM employing the serial port. This device sends the data to the PC by means of the USB port, see Fig. 3.

2.3.1. Conversion stage, processing and serial transmission

This stage comprises the DS87C550 Maxim Semiconductors microcontroller, a M2764A EPROM memory and a 74ACT373 latch, as shown in Figure 4.

The processing of the data is done with the use of the microcontroller (see flowchart in Fig. 5). The flow analog signal is applied to microcontroller’s A/D converter (10-bit) and as a result, two bytes are generated and transmitted by one of the microcontroller’s serial ports towards the FT232BM device [4].

The architecture of the microcontroller is designed so that its A/D can be connected to an external 5 V reference. It features a 12 MHz crystal for its operation. First, the least significant byte is sent and after the most significant byte. This process of acquisition, conversion and serial transmission is initiated after receiving 0FH serial code.

2.3.2. Serial-USB conversion stage (IC-FT232BM)

In this section, the configuration of FT232BM integrated circuit is described. This device is capable of receiving information in serial format and convert it into USB format (in our case, the information is sent towards a personal computer). Its supply is 5 Volt that comes from the computer’s USB port. It has a 6 MHz crystal oscillator and operates at the same frequency. It also gives the possibility to incorporate two LEDs to indicate when it is transmitting or receiving information (see Fig. 6). This device also allows us to incorporate a memory, but in our design, it was not necessary [6].

2.4. Implementation of the LabView designed software

2.4.1. Front panel

In order to visualize the signals from the analog module, and convert them into digital signals which are sent to the PC via USB, it became necessary to design LabView software to provide several important services during the surgery process, as shown in Fig. 7.

The front panel consists of a screen that displays the blood flow signal in real time (constantly updated) with a voltage scale on the Y axis, corresponding to volume flow.
in ml/min, and the X-axis corresponding to time values. It has two buttons, the first (REC), located in the upper right, is used to store signal values during a period of time.

The second button (REPORD), gives the possibility to display signal values previously stored. It also presents a numerical indicator that shows the average blood flow in ml/min and finally, a button (STOP) to stop the display of said signals.

3. Validation of Results

To validate the results, three sensors were used for different preset flow values. Table I shows the corresponding measured voltage values and their statistical representation appear in Figs. 8, 9 and 10, respectively.

<table>
<thead>
<tr>
<th>Flow (ml/min)</th>
<th>SAO(V)</th>
<th>SAC(V)</th>
<th>Gris (V)</th>
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<tbody>
<tr>
<td>136</td>
<td>1.48</td>
<td>1.43</td>
<td>1.43</td>
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<tr>
<td>131</td>
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<tr>
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<tr>
<td>106</td>
<td>1.26</td>
<td>1.275</td>
<td>1.2</td>
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<tr>
<td>95</td>
<td>1.2</td>
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<tr>
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<tr>
<td>0</td>
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</tr>
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</table>
where exist similarity between the curves, giving a standard error of 0.099, 0.094 and 0.093, with correlation coefficients of 0.997, 0.998 and 0.996 respectively, which demonstrates the reliability of the measurements.

3.1. Checking the operation of the USB interface

To check the USB interface, it was applied to its input different voltages from 0 to 5 Volt, which were acquired and processed by a LabView program, showing the results in Fig. 11 and Table II.

Figure 11 shows a linear behavior over the range of tenasions, which denotes a faithful reproduction of these values. The reference tension and supply of the A/D comes from the PC’s USB interface. It were selected twelve values of tension in the USB ports of different computers, obtaining the mean value of 5.03 Volt and a confidence limit of ± 0.058 Volt, which introduces a variation of ± 1.1%.

4. Conclusions

It has been obtained an equipment that is able to measure and assess the value of blood flow by the ultrasonic transit time method (TTFM), that is of vital importance in cardiovascular surgery.

The system can be obtained by means of an acquisition module and a personal computer; it has a great demand in Cuba, is easy to use and has the possibility to be marketable.

It was possible to measure with three sensors, the dark blue, the light blue and the gray, giving standard errors of 0.099, 0.094 and 0.093, respectively, which is acceptable for measurements of blood flow.

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