Digital Fotoplethysmograph

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Abstract. You should leave 8 mm of space above the abstract and 10 mm after the abstract. The heading Abstract should be typed in bold 9-point Times. The body of the abstract should be typed in normal 9-point Arial in a single paragraph, immediately following the heading. The text should be set to 1 line spacing. The abstract should be centred across the page, indented 17 mm from the left and right page margins and justified. It should not normally exceed 200 words.

1 Introduction

A component of biomedical engineering that involves the use of electronics in the medical field for investigation, diagnosis or treatment is called medical electronics.

Because we are talking about electronics, it means the processed signal is electrical. But in reality, biosensors can be of both electrical nature and often non-electrical nature such as temperature, flux (eg brightness), deformation, displacement, pressure, electromagnetic field, chemical structure, etc. From the point of view of electronics, in order to be measurable, all these signals have to be transformed into electrical signals. The main role in this conversion process to electrical signals is provided by the device called the transducer(I think the sensor is a component of the transducer).

Without entering into the details of the vast array of biosource sources, and bearing in mind that these (biosensors) underlie the processes that ensure the functionality of the bio-systems, we can say that a biosystem is actually a mechatronic system.

From a functional point of view, the structure of a mechatronic system can have the following components, shown in the following figure:

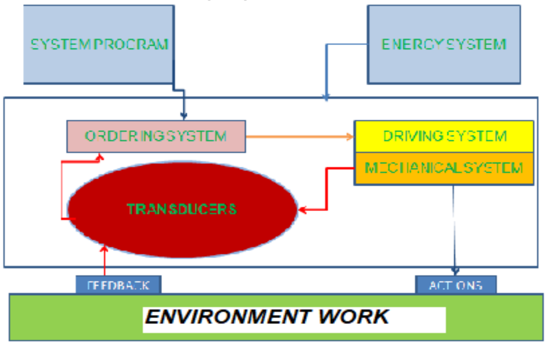

Fig.1. Functional structure of a mechatronic system

One of the most complex mechatronic systems can be considered a biosystem called the human body.

It is interesting to establish (or impossible) how many processes of electrical, physical, chemical, etc. take place in the human body in the time unit (in one second), as it is said that in a vegetable (eg carrot, celery) occur around approx. 50.000 processes per second.

For a human system, a simplified customization of the mechatronic system scheme shown above may look like this:

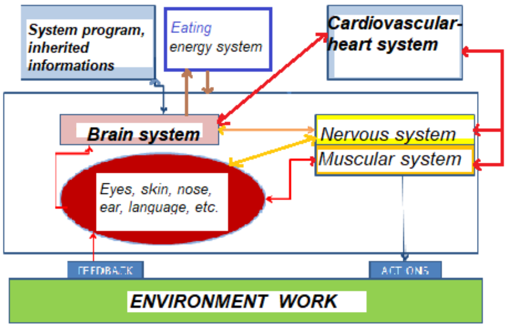

Fig.2. Simplified customization of the mechatronic system

In fact, it has been shown that each of the brain, heart, nervous and muscular systems generates biosignals that are electrically (electrodes) and mechanical (received with transducers).

So, the electronic equipment must be appropriate / adapted to the spectra of frequencies and amplitudes of the electrical signals generated by the above mentioned biosystems [4], as follows:

- brain -10 μV ... 100 μV and a frequency spectrum of 0.1 Hz ... 100 Hz, signal represented by electroencephalogram;
- heart - 100 μV ... 4 mV and a frequency spectrum of 0.1 Hz ... 100 Hz, signal represented by electrocardiogram;

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- neuromuscular system - 100 µV ... 4 mV and a frequency spectrum of 5 Hz ... 2 KHz, signal represented by electromyogram.

Electroencephalogram, electrocardiogram, and electromyogram are actually graphical representations, which at the abscissa have the frequency (where the time results), and on the ordinate they have the amplitude of the electrical signal obtained.

The raw signal spectrum collected by the transducer is very rich (many spectral components), besides the signal of interest that contains other signals generated by the human body or the environment in which it lives / works. At the same time, the raw signal amplitude is often very small.

In electronics, these two issues represent two of the biggest problems in converting the biosemnal into the desired electric signal that correctly describes the behavior of the biosystem under study.

Mathematically, over the raw electrical signal is applied the Fourier transform which will highlight the signals that make up the raw signal, where normally the recovered signal will be found. Basically, in the case of the heart, a low pass filter (with a cutting frequency between 2 - 3 Hz) is applied to the signal obtained.

In this case, in figure 3, is represented the schematic diagram of a biomedical equipment:

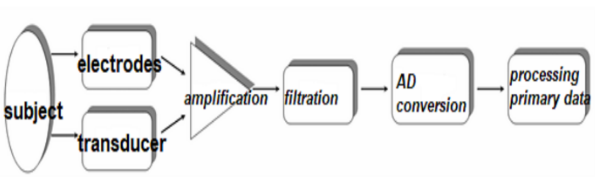

Fig.3. Schematic diagram of a biomedical equipment[5]

Note that the first basic electrical signal obtained is analogous, and it, according to needs, undergoes an analog-to-digital conversion (digital technology offers the benefit of a "noise protection").

As a result, the more we can get a "cleaner" analogue signal, that is, a very low noise, the more realistic the signal to be processed, and we can get the most accurate measurements.

The noise has two components, one internal (overlapping of different biosensors of different nature: eg ECG signal noise from muscles - 10 kHz noise-or breathing - low frequency 0.15 - 0.3 Hz) and an external (discontinuous contact between electrodes and tissue, change of electrode impedance to subject movement, network noise - 50Hz, noise of components and electronic circuits of transducer equipment, working temperature, etc.).

2 Cardiovascular system – arterial pulse

Blood circulation in the human body is based on the mechanical activity of the heart that works as a two-phase pump: suction and discharge.

Through blood vessels, the cardiovascular system (made up of the heart and blood vessels) is designed to transport / evacuate nutrients / residuals to the cells of the entire body, and to achieve oxygen intake and the removal of carbon dioxide in the lungs.

Blood vessels that carry blood from the heart to cells are called arteries, and those that provide circulation to the heart are called veins. The communication between the two networks of "ducts" (arteries and veins) is provided by the capillary vessels.

Capillary vessels have a diameter of µm and are spread throughout the body so that each cell is exactly in the vicinity of a capillary vessel.

The heart is seen as an electrical system that generates stimuli and works in tandem with a mechanical system (the muscles of the heart) that reacts by mechanical contraction to these stimuli. The occurrence of mechanical contraction takes place after an electromechanical latency time.

From a mechanical point of view, heart activity takes place over five stages: atrial systole, ventricular systole (when blood is pumped into the arteries), atrial diastole, ventricular diastole, and general diastole.

Normal blood circulation ensures optimal functioning of other vital organs (Figure 2).

The heart has a lot of functional parameters, one of which is the heart rate or the number of beats per minute, well-proven by the arterial pulse.

With the mechanical contraction of the ventricular systole phase - pumping blood into the arteries, arterial blood flow spreading along the artery walls also occurs.

At the level of the human body 9 points of arterial pulse have been established which, by a slight pressure of the artery, can be perceived as a mechanical "twist" at the respective points[6] (fig. 4).

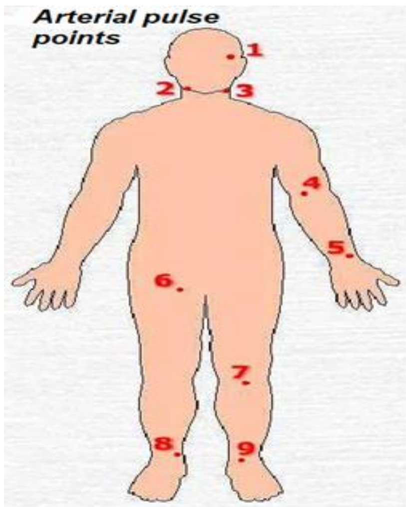

Fig.4. Arterial pulse points of human body
1.Temporal artery;
2. Facial artery;
3. Carotide artery;
4. Brachial artery;
5. Radial artery;
6. Femoral artery;

7. Popliteal artery;
8. Posterior tibial artery;
9. Dorsal pedi artery.

Taking the form of the electrical signal (ECG) of the QRS complex (picked up by electrodes as a result of the electrical activity of the heart), in the following figure one can see the latency of occurrence in relation to the P wave (triggering the cardiac cycle) of the arterial pulse collected from the artery carotid.

Also, the figure contains the cardiac signal phonogram (FCG) - fig.5:

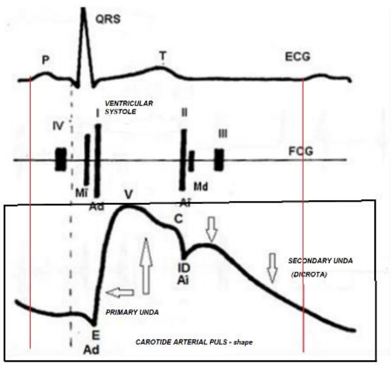

Fig.5. Arterial signal pulse EKG, FCG, carotid –point 3(see fig.4).

All this time, in a rhythmic motion - generated by the contractions of the heart, the blood circulates through arteries, capillary vessels and veins. As a result of the rhythmical flow of blood, the vessels suffer certain physical deformities (normally imperceptible).

3 Plethysmography – fotoplethysmography

The non-invasive technique that highlights the change in physical size as a result of blood flow is called pletismography[5].

From the point of view of biosignal collection, it can be "mechanically" picked (using a mechanically fixed pneumatic cuff) or using a reflexive photoelectric transducer that highlights the absence / presence of blood flow in a tissue containing capillary arteries and vessels.

Using a photoelectric transducer, we are talking about electrical photoplethysmography that measures the degree of absorption of blood flow (located at the extremities of the body - fingers, ear lobe) passing through a tissue exposed to a light source. The photoplethysmograph offers data on heart rate and oxygen saturation of the blood (we use the term pulsoximeter).

In the following we will discuss the use of photoplethysmograph for establishing heart rate. Suggestively, this is represented in the following figure:

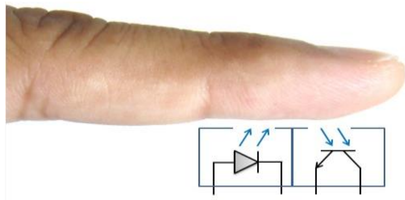

Fig.6. Principle of the fotoplethysmography.

The main component underlying the photoplethysmograph is the reflexive photoelectric transducer. It is based on the principle of transmission, absorption-reflection and the reception of a luminous flux, its variation being emphasized by changing the values of an electric current.

Fig.7. Fotoplethysmograph.

3.1 Practical aspects

A. Experiment I

From an electrical point of view, using a software simulation application (Spice, Orcad, Protel, LiveWire, etc.) of the behavior of a photoelectric transducer (phototransistor) we get the following:

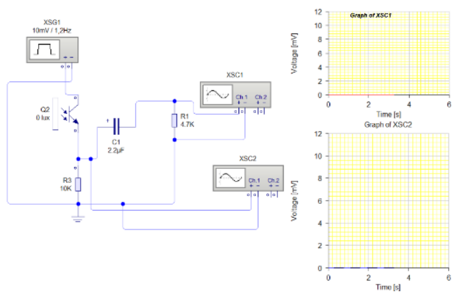

Fig.8. Light intensity has 0 lx, output signal is 0 mV.

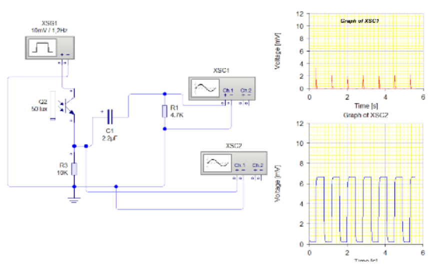

Fig.9. Light intensity has 50 lx, output signal is 6.5 mV.

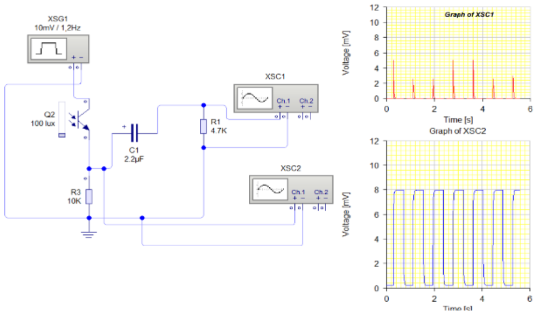

Fig.10. Light intensity has 100 lux, output signal is 8 mV.

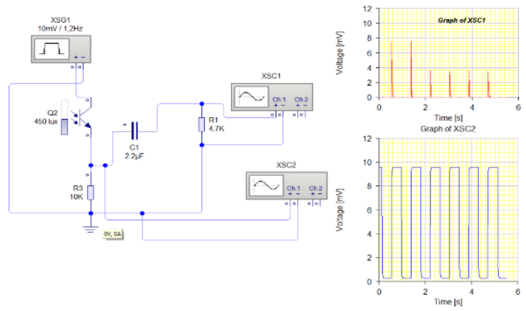

Fig.11. Light intensity has 450 lux, output signal is 9 mV.

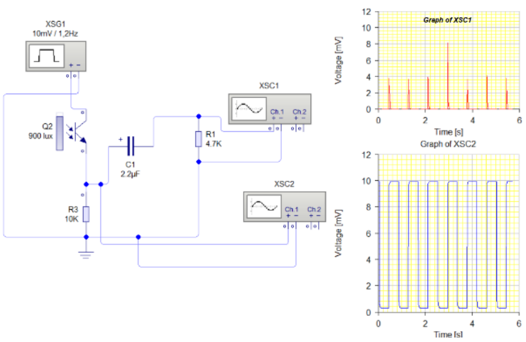

Fig.12. Light intensity has 900 lux, output signal is 10 mV.

A rectangular signal with a frequency of 1.2 Hz was selected, which coincided with a normal heart rate (60 - 75 beats per minute). Taking into account the values in the experiment, the characteristic of the output signal according to the intensity of the light flux has the form:

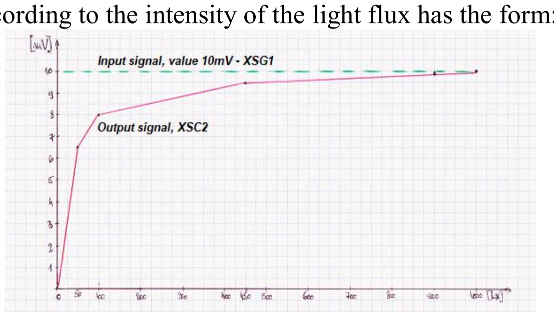

Fig.13. The graph of the output signal level according to the light intensity (applied to the phototransistor) .

In the above figures, with the increase of the intensity of the light flux, it is observed: the signal level increases from the transducer, the first pulses (the red signal - XSC1) which in practice coincide with the heartbeats and, importantly, waveform (XSC2) obtained directly from the transducer.

An example of a reflexive photoelectric transducer is the TCRT1000.

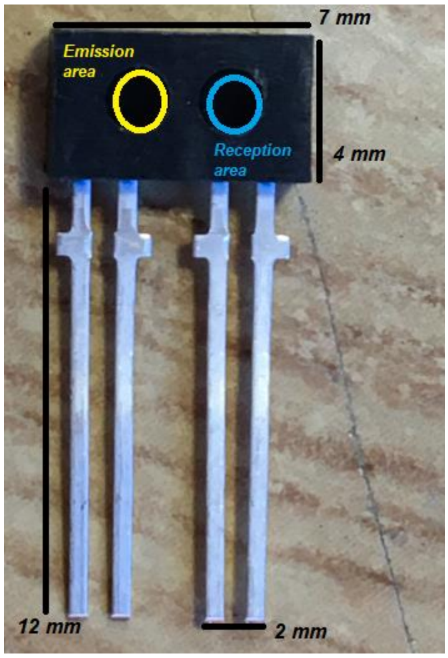

Fig.14. The TCRT1000 reflexiv photolectric transducer.

In choosing the photo transducer, it is necessary to consider the characteristic transfer area of the photo transducer within a temperature range of the working environment.

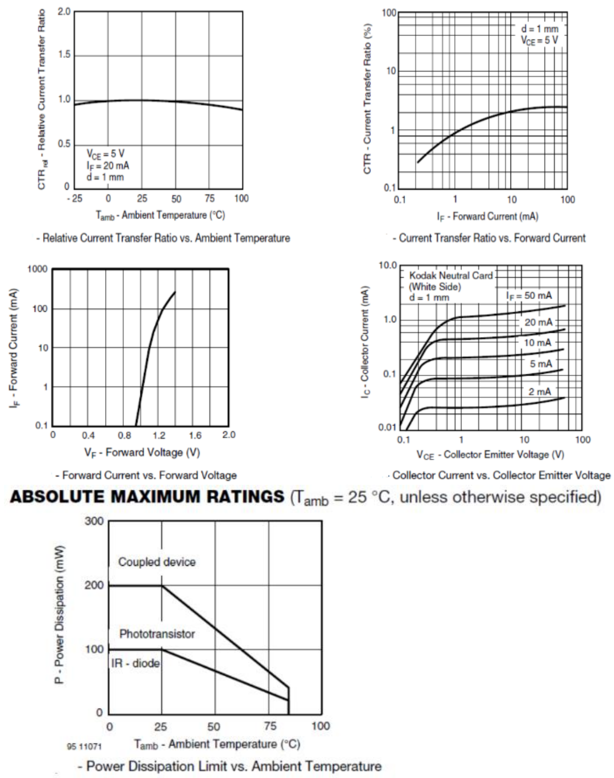

Fig.15. The main transfer features of the TCRT1000.

Using discrete components, various electronic schemes that help determine heart rate can be achieved / used, such as:

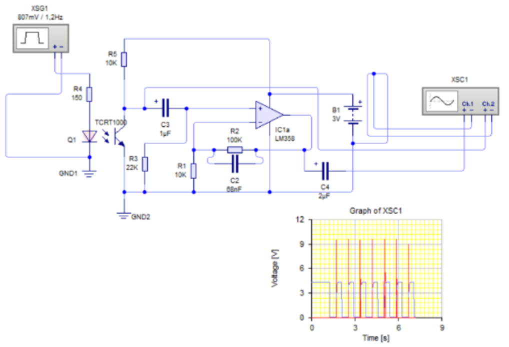

Fig.16. The circuit diagram of a circuit that shows the arterial impulse.

Signal generator XSG1 only simulates the beat of blood flow, not the waveform.

The resulting pulses can be highlighted and counted on an oscilloscope or (by removing the oscilloscope) the impulses (amplified) from the LM358 integrated circuit output are inserted into a counting module (containing time base and display).

The integrated LM358 circuit is used in the configuration shown in the following figure:

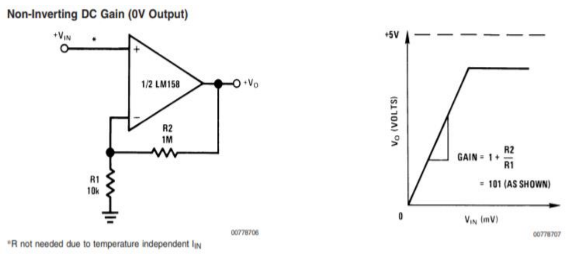

Fig.17. LM358 non-inverse input amplifier base configuration (see fig.16).

B. *Experiment II*

At present, the electronic circuits / components of most modules, equipments, devices are made in SMD technology, allowing for a reduction of external noise (in particular), size, costs and an increase in flexibility / portability (by integrating the IT component) .

In this sense modern / integrated transducers have been made to provide the measurably direct signal output. One such example is the XD-58C pulse sensor that can be used in a photoplethysmograph.

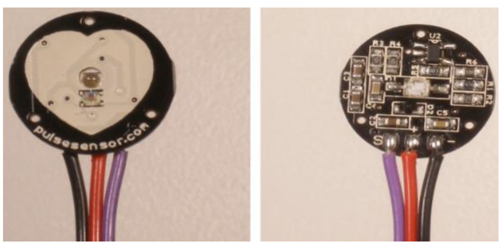

Fig.18. The XD-58C sensor pulse.

With the help of an oscilloscope connected direct to the output of the XD-58C sensor pulse, the waveform of an arterial pulse collected by the finger plethysmography method is obtained.

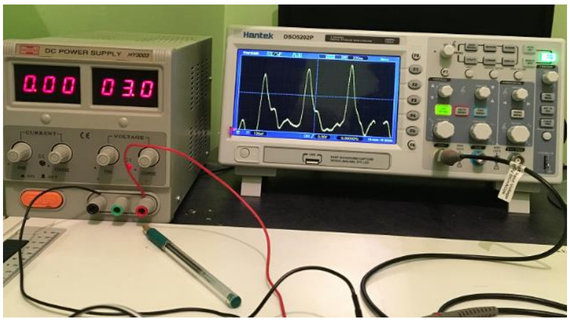

Fig.19. The waveform of arterial pulse using the XD-58C pulse sensor connected to an oscilloscope.

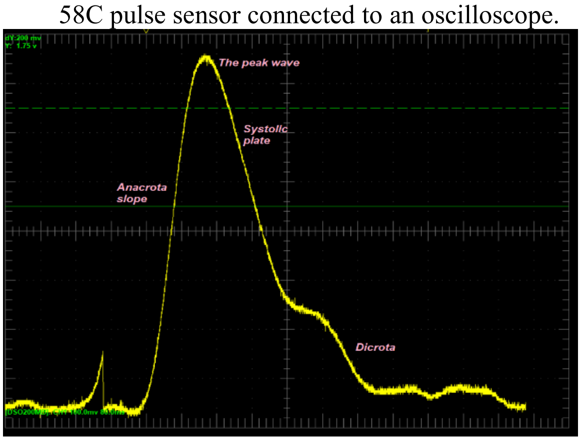

Fig.20. Arterial pulse signal, 45 years, male.

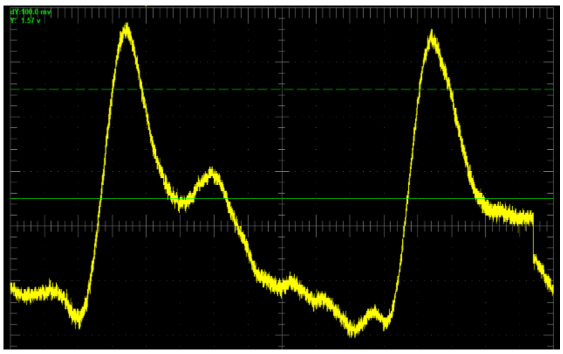

Fig.21. Arterial pulse signal, 17 years, female.

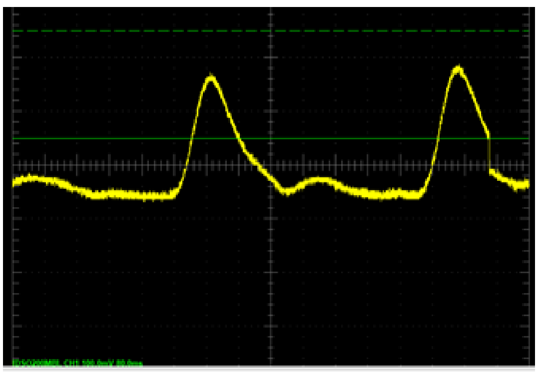

Fig.22. Arterial pulse signal, 11 years, female

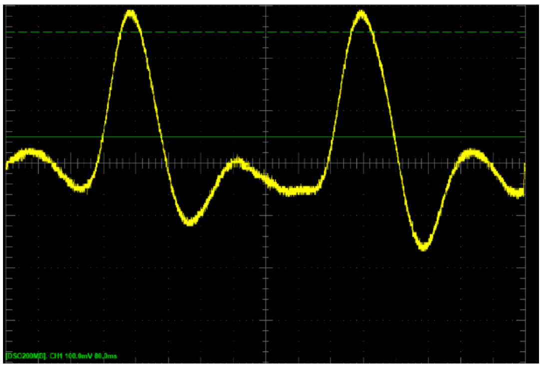

Fig.23. Arterial pulse signal, 45 years, female.

A normal pulse rate of cardiac impulse and implicitly blood flow through the arteries (capillaries, veins) is considered to have a value of 4-5 m / s, corroborated with the heart electro-mechanical system to provide a heart rate of 55 - 75 beats per minute.

Because we are talking about wave / impulse, the efficiency of their transmission depends crucially on the quality of the propagation medium, in our case the elasticity of the walls and the diameters of the arteries. To preserve the above values, the heart, with an extra effort, is the main organ that tries to make corrections in the event of occurrence of propagation abnormalities.

These additional efforts of the heart are manifested by a too high or too low heart rate (measurable with a photoplethismograph), a situation that signals the existence of cardiovascular system dysfunctions. In such cases, additional investigations (EKG, Doppler, etc.) must be carried out.

At the same time, the data provided by the sensor / transducer can be processed within a digital system. One of the simplest such systems involves connecting the XD-58C pulse sensor to a computer system (a purchase card from a microprocessor motherboard - eg Arduino, etc.) and an LCD display (in this case PC1602)[6].

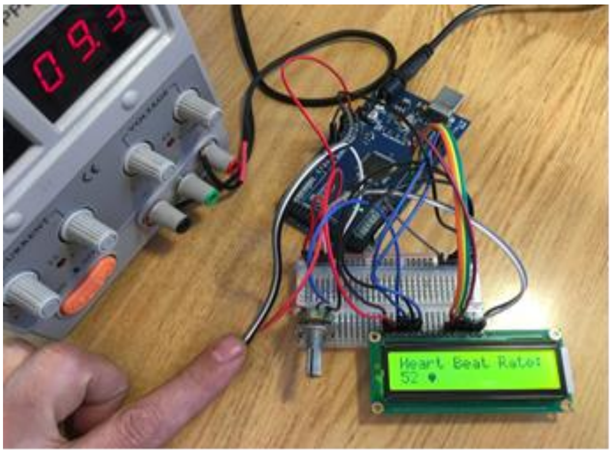

Fig.24. Digital photoplethysmograph with the XD-58C pulse sensor connected to a ArduinoMega 2560 motherboard

4 Considerations

Information about the arterial impulse can be collected from all nine points, fig. 4. The amplitude - frequency (or time) charts will not be the same, but they will have a common look, that during a cycle, the waveform will contain a pulse that can be electronically counted. In fact, it is the pulse perceived by pressure (mechanical picking) that coincides with the rhythm of the blood flow - collected by the photoplethysmograph.

In pathological situations, the morphology of the curve is profoundly altered, in chronic peripheral arteriopathies (atherosclerotic or diabetic), the wave becomes symmetrical, rounded, rectilinear or convex upward, small oscillations, sometimes visible.

Data collection systems can be integrated into a monitoring (local) or telemonitoring (remote monitoring) network. The main physiological parameters (heart rhythm, blood pressure, oxygen saturation, respiratory rate, etc.) are taken from the patient, stored and then analyzed for different periods of time. Telemonitoring represents 25% of the European telemedicine services market.

References

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4. https://dokupdf.com/queue/dizertatie-burja-_5a02de23d64ab2b9bddfed74_pdf?queue_id=-1;
5. http://www.new-wave-concepts.com/lw_dl_st.html - livewire sof;
6. http://www.umfcv.ro/files/p/u/PULS%20ARTERIAL%20PLETISMOGRAFIE%20FINAL(1).pdf;
7. TCRT1000.pdf;
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10. http://www.ace.tuiasi.ro/users/103/Rotariurezumat.pdf.
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