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Conception and Realization of a Biomedical Acquisition System Dedicated to Measuring the Oxygen Saturation Pulse by Photo Plethysmography Red and Infrared: Application to theCardio-Respiratory Functional Exploration

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Abstract: *We present in this paper a system for detecting the photoplethysmographic signal (PPG) dedicated to the measurement of functional oxygen saturation in the blood.*
The system is designed by means of a suitable non-invasive optical technology. The device realized can detect the PPG signal.It includes an optical contact sonde applied during the measurement (sensor), a circuit for shaping the signal (PPG), an interface for the acquisition and digitization in connection with a serial communication port beneath RS232 protocol and a local computer terminal hosts a graphical user interface (GUI) implemented as Integrated Development Environment Visual Basic for displaying, archiving, digital signal processing photo plethysmography and its transfer through telemedicine networks for exploration or remote monitoring of cardiovascular and respiratory function.

Keywords:*Beer Lambert, microcontroller, PPG, RS232, SpO_2 , Visual Basic(VB).*

I. INTRODUCTION

The simultaneous display in real-time of vital physiological quantities allowedmore accurately and more efficiently to know and monitor the pathophysiological state of the patient. In this context, we indicate oxygen saturation (SpO2) as an important parameter for the control of the cardiovascular-respiratory system.
To approach thearterial oxygen saturation(SaO2), the pulse oximeter (SpO2) must constantly determine the content of oxyhemoglobin(HbO2) and reduced hemoglobin (Hb) in arterial blood. We need asystem that can:

- Continuous measure in real-time of the HbO2 and the Hb.
- Recognize the pulsatility signal with demonstrating its arterial origin [4].

As part of this work, we performed a technical platform for collecting photoplethysmographic signal based on molecular absorption spectrophotometry in the red and infrared light.Thistechnical platformworksby applying thesensortoaninterestingarteriolar vascular bed, such asthefinger.The sensor containsaduallight source LEDs IR-R (infrared - red)anda photodetector(phototransistor) which receives thesignalafter its passagethrough the finger. The final result ofourdesignyieldeda string ofelectronic measurementnecessaryto extract and processthePPGsignal,while being compatiblewithan acquisition cardcarried around aPIC16F876Amicrocontrollerand softwareto managethedisplay and processingofthis physiologicalvariableat alocal post.

II. PHOTOPLETHYSMOGRAPHY ORIGIN

A signal may be defined as the physical support of information, represented by a function of one or more variables [9]. If the time is the variable (one-dimensional signal) the signal represents the temporal evolution of a physical quantity, in our case the volume variation of arterial blood.
The photoplethysmographic trace results from the attenuation modification of the light energy transmitted through or reflected by the tissue on which the light was applied.Hemoglobin isthemainlight absorberin human blood.
ThePPGmeasuring systemis based onthepropertyof hemoglobinto absorb lightemittedwhenoxygenateddifferentlythan when itisnot.Theoxyhemoglobinabsorbs moreinfrared light,whilereduced hemoglobinabsorbs morered light"Fig.1", Overthisabsorptionvariesby pulsatilemanner at eachcardiac cyclewith asystolicflow of thearterializedblood in finger[1].

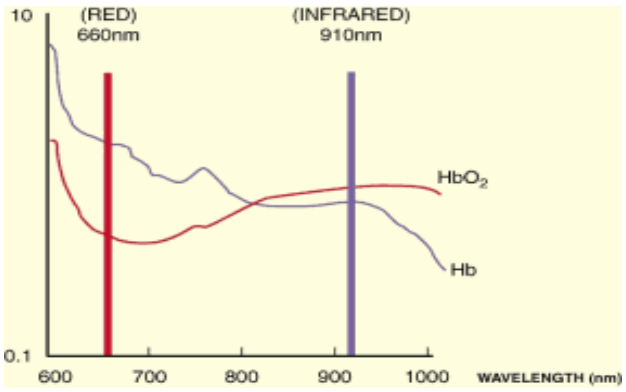

Figure.1 Light absorption by Hb and HbO2[6].

III. SYSTEM CONCEPTION

The PPG signal obtained used two Light Emitter Diodes (LEDs), one red and the other infrared,thesetwoshould lightalternately andfor that weneed adriver circuittoactuatetheLEDs,this circuit isrealized onbasics of aPIC16F84Amicrocontroller.

The sensoris composed of aface which is consistedofLEDs (red andinfrared) connectedto the control circuitwhich controlsthe emission, and asecond facethat is a phototransistor (sensor), theselatterareconnectedto the electronic circuitforshapingsignal. The phototransistor used BPX43 to its higher sensitivity to detect the light passing through the finger.

IV. MEASURING PRINCIPLE

The principle is basedon the emission oftwo lights(red andinfrared)respectively660nmand940nmandmeasuring theirabsorptionbypulsatilebloodflow. Theabsorptionofthered and infrared lightthatwill varyaccordinglytomeetthereduced hemoglobin(Hb-R) unoxygenatedor oxyhemoglobin(HbO2).

Thephysical lawwhichisbasedonthecalculationofSpO2by the systemisthe Beer-Lambert law, thatis,insynthesis, that the absorption variationsof the light wavesare a variations function intheconcentrationofasolute [4] [7]. The onlyvariableexistingin stable conditionsisthesystolicarterialflow"Fig.2", which can be analyzedin termsof amplitude,duration, and especially respiratory changes due to failures of pulmonary interchange at the alveolar-capillary territories.

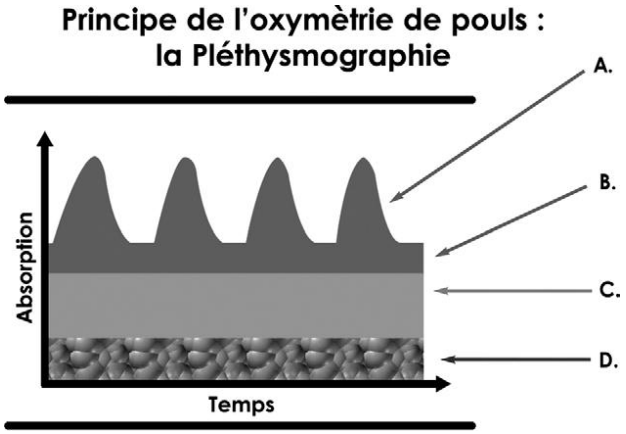

Figure.2 Principle of pulse oximetry. A: variable light absorption due to the change in arterial blood volume. B: constant related to light absorption part of the non-pulsatile arterial blood. C: constant light absorption related to venous blood. D: constant light absorption associated with the tissue, bones ... [4]

The oxygen concentrationis determinedby differencesof light intensitytransmittedto the photodetectorcaused by variationsinthelightabsorptionbyoxygenatedanddeoxygenatedhemoglobincontainedinthevascularbed.

The arterial oxygen saturation (SaO2) was measured in percentage and determined by the concentration of oxygenated hemoglobin (HbO2) relative to the total amount of hemoglobin (Hb). The functional SpO2 mathematically corresponds to the percentage of hemoglobin can carry oxygen effectively, i.e., (1).

: $Spo2 = \frac{Hbo\ 2}{Hbo\ 2+HbR} * 100$ …(1) [3][10][11]

The arteriolar bed beats and absorbs normally variable amounts of light during the pulsations.The ratio of the absorbed light is translated in a measurement of functional oxygen saturation (SpO2).
Duringthe systole, a newpulseofarterialbloodintothevascularbed, theblood volumeandtheabsorptionof lightincreases.Duringthe diastole, theblood volumeandtheabsorptionof lightreachtheir lowestlevel.
SpO2 measurements are based on the difference between the maximum and minimum absorption (measures at the systole and the diastole).In doing so, it focuses on the absorption of pulsatile arterial lumen, eliminating the effects of non-pulsatile absorption such as tissue, bone, and venous blood [2].

V. THE REALIZED SYSTEM

The classicalprinciple ofphysiological measurementis to capture, amplify, formatand view the variations of physical quantitiesfrom the differentorgans of the humanbody.
In this sectionwe presentthe practical implementation ofvarious electronicdevicesthatwe have realized.
The following blockdiagram showsthe practical realizationof aphotoplytesmogramme (PPG),through this block diagram four main parts are distinguished, asensor, the command circuit, the forming circuit and finally thesignal acquisitioninterface. All circuits are alimented by the same supply source.

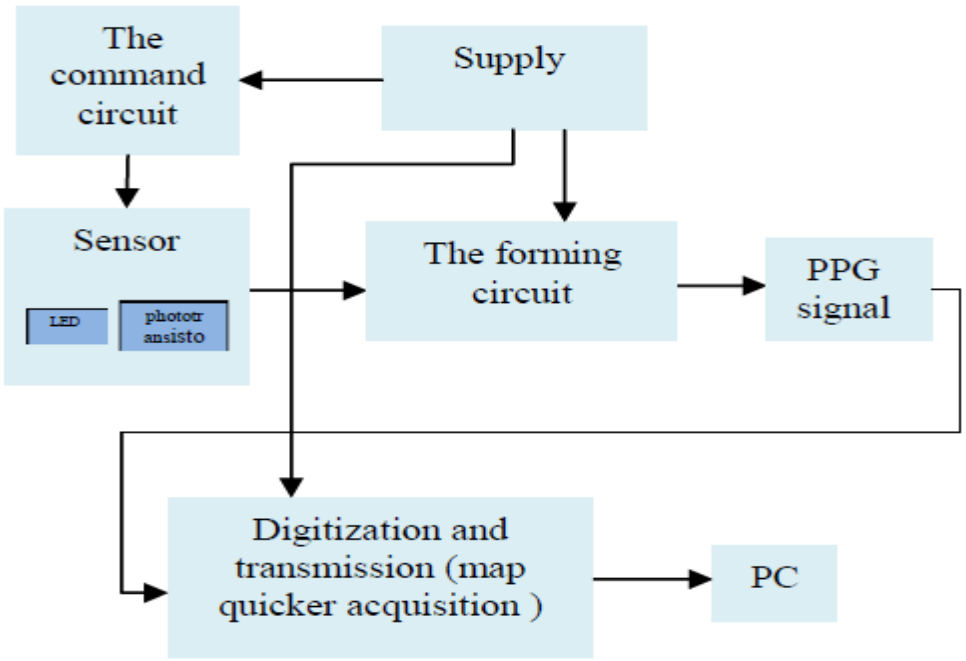

Figure.3The diagram of realized system.

V.1 LEDs driving circuit

The circuit of "Fig.5" shows a control circuit for operating the LEDs red and infrared which light alternately for a period of 10s. Two signals are obtained from a different wavelength corresponding to the color R (red) and IR (infrared)lengths. This circuit is realized based microcontroller from Microchip Pic 16F84A.

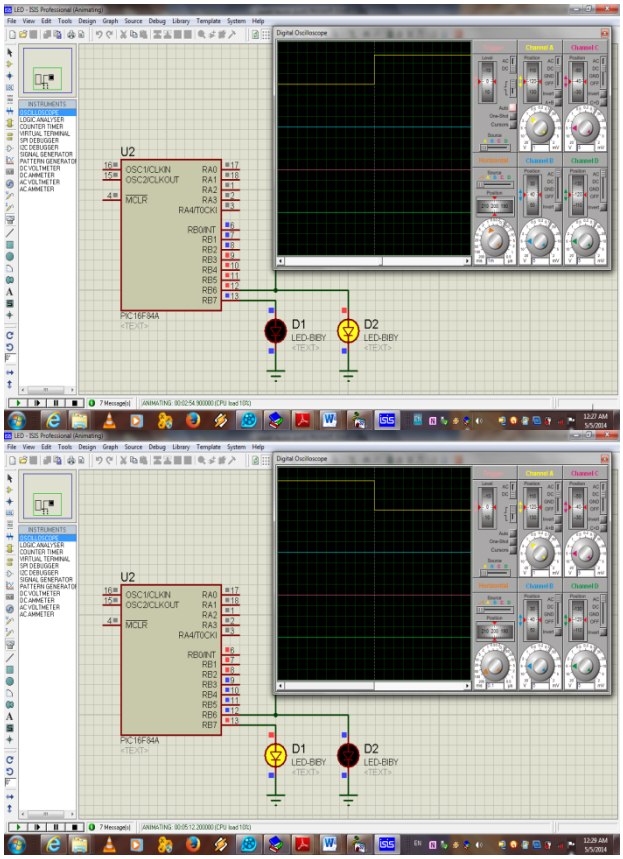

Figure.4 The LEDs actuating with frequency 0.1HZ by the Pic 16F84A microcontroller.

In "Fig.5", the two transistors Q1 and Q2 are used as a switch to turn the LEDs in working state or stopping. The microcontroller generates a square wave of period 10 seconds to the on state and 10 seconds to shutdown state"Fig.4".We get LEDs actuating,which are in turn placed in a state on and off every 10 seconds.

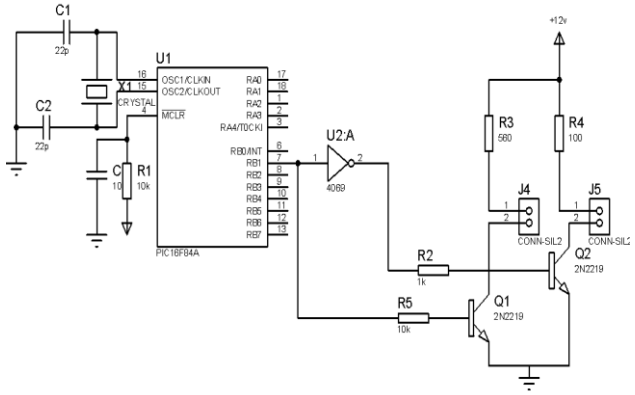

Figure.5 Command circuit.

V.2Theprobe

The probe part contains the light source and the photodetector, The LEDs that we used is a red light source R and infrared IR. Aphototransistorsensordetects the changesin light intensityandconverting them intoan electric current. All in a suitably designed casing (shape and dimensions) "fig.6".

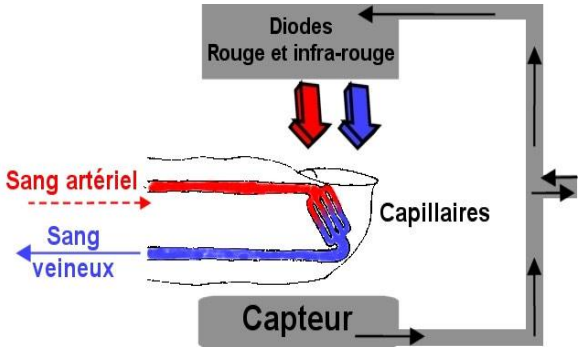

Figure.6 The finger into the probe between the transmitter and receiver[5].

V.3 Formatting circuit

The formattingof the signal isa measurement chain that beginning with the sensor and ends with the last element necessary to get the desired signal. The "Fig.7" shows an electronic system for the analog processing (amplification, filtering andcalibration)of the signal.

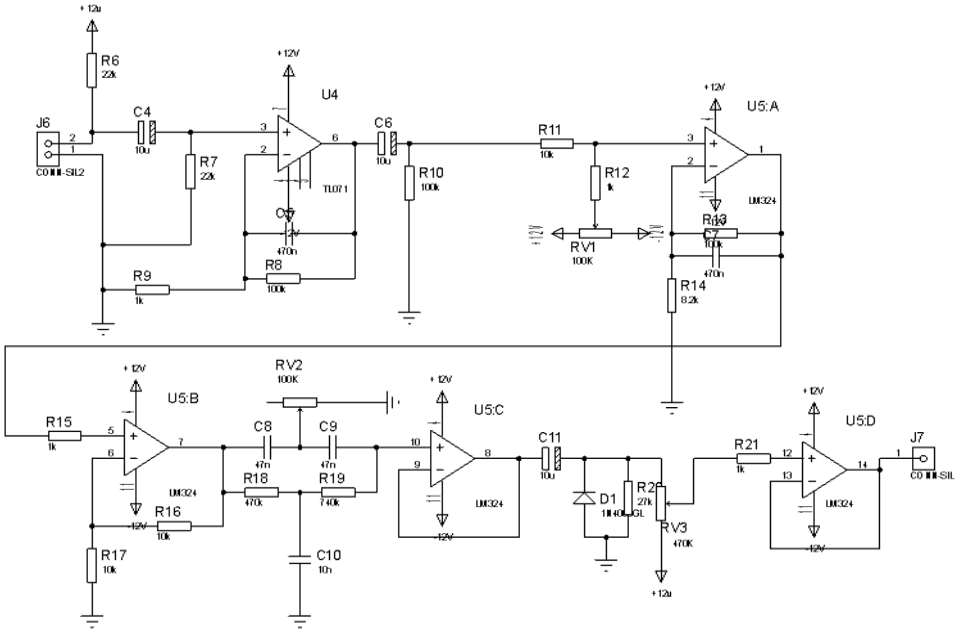

Figure.7 Electrical diagram of the formatting circuit.

Thegain of the firstamplifier isequal to 101, i.e., (2).

$$: A = 1 + \frac{R8}{R9} = 1 + \frac{100}{1} = 101 \ldots (2)$$

This helps to amplify weak amplitude signals of a few millivolts order coming from phototransistor. Thesignalwill beapplied to asecondamplifierconnectedto a potentiometer RV1 for controllingits gain.

The third floor designed with the integrated circuit LM324 allows to implement an operational amplifier and realize a Twain T-filter active adjustable by RV2, to remove noisefrom sector50Hz.The last floor is designed for impedance adaptation and adjusting the DC component. In J7 we have an order signal 1V of amplitude witha frequencyofaround 1HZif we are in presence of a normal signal.

The "Fig.8" representsthe image 3D of thecircuitlayout.

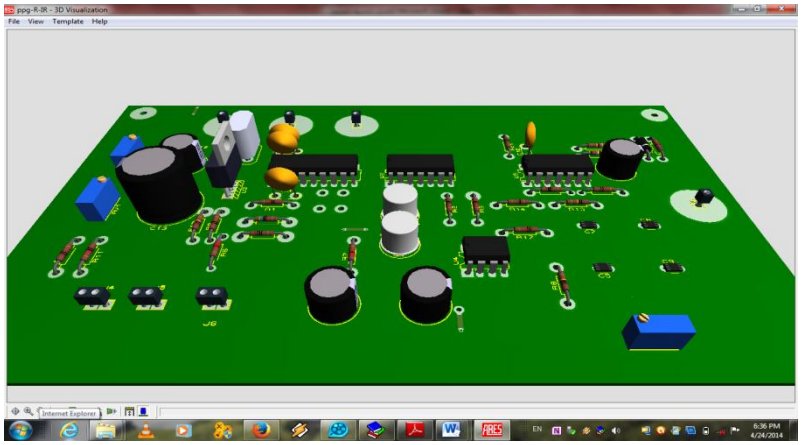

Figure.8 The 3D image of the formatting circuit.

V.4 The signal acquisition circuit

Afterformattingwe reducethe output signalof the circuit to a compatible level to be connected to a microcontroller. This is theparty responsible fordigitizing the signal that allows to make it accessible to a digital system(PC, DSP etc…).

The acquisition circuit is realized around the microcontroller PIC16F876A[6] has an ADC module (Analog to Digital Converter) 10 bits for digitizationand an USART module (Universal Serial Asynchronous Receiver Transmitter) for local communication asynchronous sub protocol RS232,as shown in"Fig.9" and "Fig.10". In factthis component is usedto manageall multiplexing procedures, of sampling, analogue to digital conversion and transmitting data.

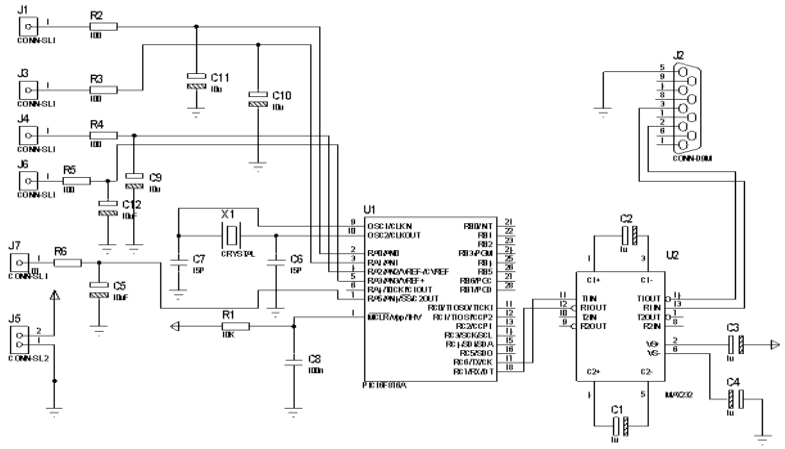

Figure.9 The electrical diagram of data acquisition card.

Figure.10 The 3D image of acquisition card.

Thecommunicationof this card withthePC is done through a serial connection RS232 (DB9), connectedto the microcontrollerbyits pins2 and 3 (RX, TX) viaa circuit MAX232 whose role it is the adaptation of the signals TTL/CMOS.

The transmission of asynchronous type (no common clock between the transmitter and receiver), additional bitsarenecessary for the functioning: start bit of word (Start), bit(s) end of word (stop), "Fig.11".

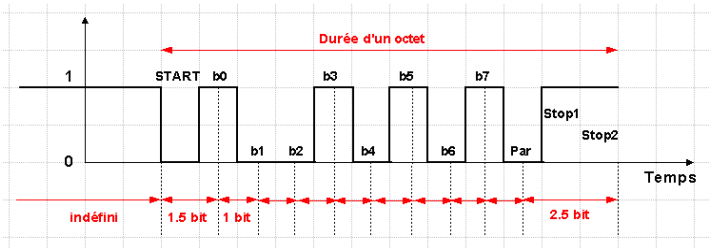

Figure.11 Serial transmission bit by bit [7].

The transmission of characters cannot function properly only if the different variable parameters of this frame are known to both the transmitter and the receiver [8].It is then necessary to adjust the following parameters: the transmission speed, the number of bits of thecharacter tobe transmitted, the parity, the number of stop bits.
In our case:

- Transmission speed 57600 baud (bit / s).
- 8 bits data.
- No parity bit.
- A start bit.
- A stop bit.

V.5 Acquisition interface

The software application reception and display data has been implemented in the environment Visual Basic (VB) by meansof the componentMscomm of VB which allows the asynchronous serial data reception.

VI. RESULTS

"Fig.12" shows the signal recording PPG-IR of a normal subject,representativeof pulsedoxygen saturationof oxyhemoglobin (HbO2). Each wave represents a heart cycle, systolic and diastolic.

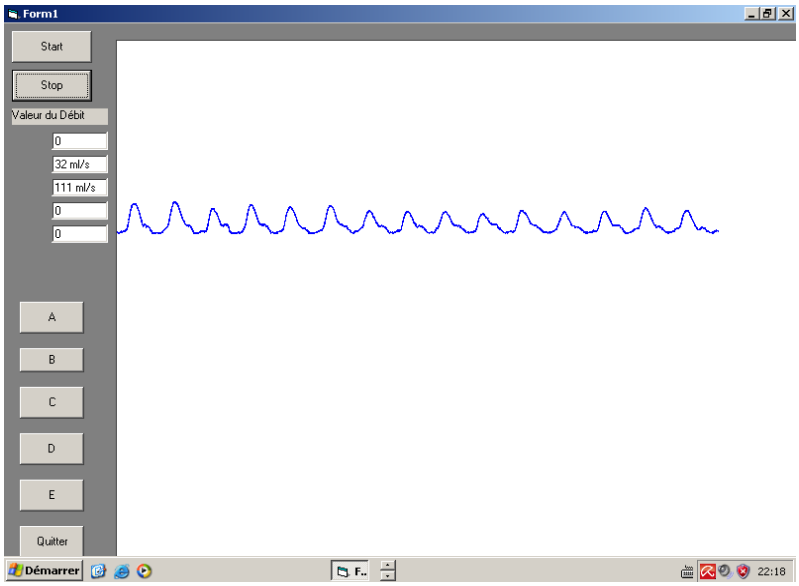

Figure.12 Plot of signal PPG, LED IR.

"Fig.13" showsthesignal recording PPG-R, with the same subject,representative of hemoglobin(Hb-R) reduced.

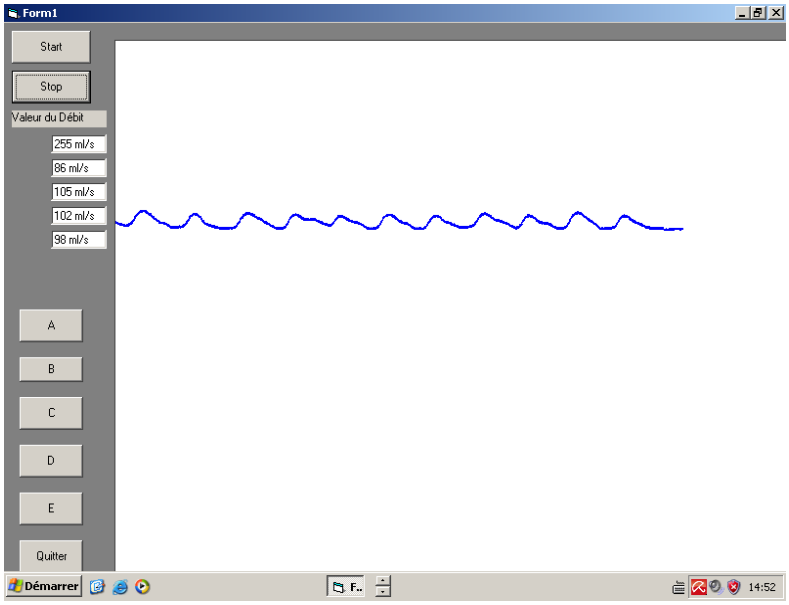

Figure.13 Plot of signal PPG, LED R.

"Fig.14" showsthesignal recording PPG-R and IR, with the same subject, representative of oxyhemoglobin(Hbo2) andreduced hemoglobin (Hb-R) successively, withdecimal valuesofamplitudein volts andtime in seconds. We observe thatthe signal amplitudeofinfrared absorptionisalmosttwice of the signalabsorptionin the red.

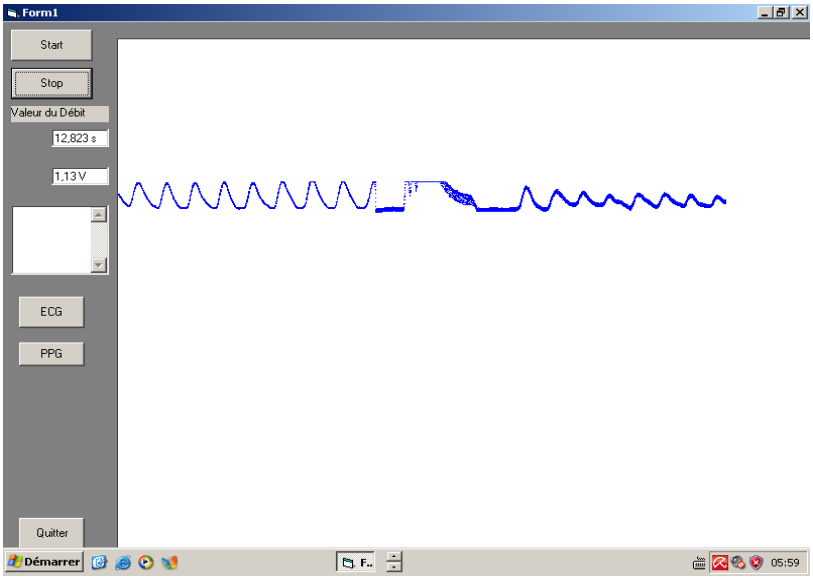

Fig.14 Plot of signal PPG, LEDs R-IR with numerical values.

VII. CONCLUSION

This study is an opportunity for us to present the works that revolves around the implementation of a multiparameter exploration of the cardiovascular and respiratory system. This work was realized with a practical development of a technical platform for the detection initially of the signal PPG, followed by an analog and digital processing dedicated to transmitting data to a local computerviathe serial port throughprotocol RS232 and finalized by the implementation under integrated development environment(IDE) Visual Basic(VB)allowing display, archiving, the digital signal processing photoplethysmographyand its transfer through telemedicine networksfor the purpose of exploration ortelemonitoring of cardiovascular and respiratory function.

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