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3 in 1 Phonocardiography Module with Data Monitored through IoMT

T. Mbiadoun Lionel¹, Kom Martin²

Lecturer, Department of Electrical Engineering and Telecommunication, PKFIE Engineering College,
Yaounde, Cameroon¹

Professor, Department of Electrical Engineering and Telecommunication, NASEY Engineering College, University of
Yaounde 1, Cameroon²

ABSTRACT:In this work we present a three in one tool that is able to acquire and processed heart vibrations. The device design can help reducing the cost of heart medical exam in country under development. This system is able to acquire PCG signal an enable monitoring using IoMT. The module has a built-in strong automatic gain control and active noise cancellation. It is then possible to use it for fetus, children and adults.

KEYWORDS:PCG, Phonocardiograph, Heart disease, IoMT, AGC.

I. INTRODUCTION

Heart disease is one of the leading causes of disability and death in the world according to WHO [1]. In poor countries such as Cameroon access to medical care is quite difficult. It is particularly difficult for a patient to be consulted by a specialist because of cardiologists scarcity [2]. This research is to bring a solution to this problem while taking into account all categories of people: fetus, children and adult. The study is based on phonocardiography, which is a different process from what is generally known as electrocardiography. Phonocardiography is directly related to the mechanical activity of the heart that produces sounds and / or breaths during its operation. The choice of phonocardiography is justified by the fact that it is possible to perform low cost exams compared to electrocardiography [3] [4] and this asset is crucial for poor countries where the population does not have a great purchasing power. Previous works have produced devices operating solely on each of the three human categories taken separately and are all intended for use in a hospital because incorporating a low-range transmission mode (Bluetooth, wifi, Zigbee). The module presented in this paper is able to produce a strong gain automatically while minimizing noise to the maximum which allowed us to acquire signals from all humans categories mentioned above. This device is intended for remote patients worldwide, so it is possible to perform diagnostics, routine checks and pregnancy monitoring without having the patient coming to the hospital.

Paper is organized as follows. Section II describes relates work, Section III give the methodology followed in this work, Section IV presents experimental results. Finally, Section V presents conclusion.

II. RELATED WORK

In 2003 Ying-Wen BAI and Al developed a stethoscope accessible remotely using internet [5]. It is then possible for the doctors to consult a file recorded on a patient located out of the hospital center. The device shown by the following figure shows that it is based on a personal computer (PC) and it does not include fetus.

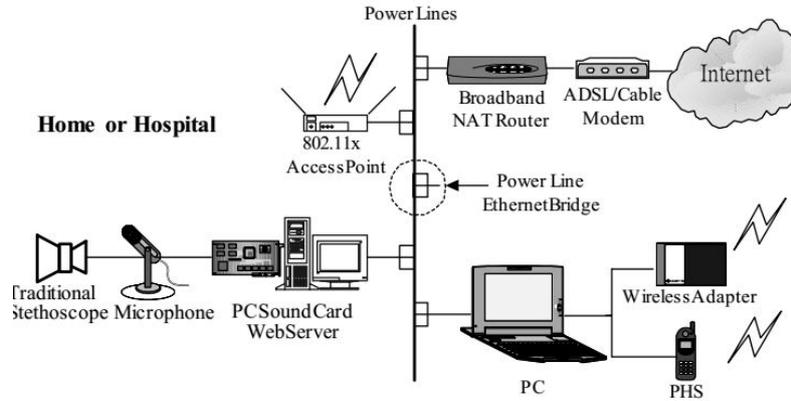


Fig 1: Ying-Wen BAI and AI stethoscope

In 2009, Arun Kumar Mitra et al developed a fetal device for monitoring home pregnancies by acquiring and analyzing PCG signals to reduce the use of ultrasound which is quite harmful to the fetus [6]. The following figure gives the block diagram of the device.

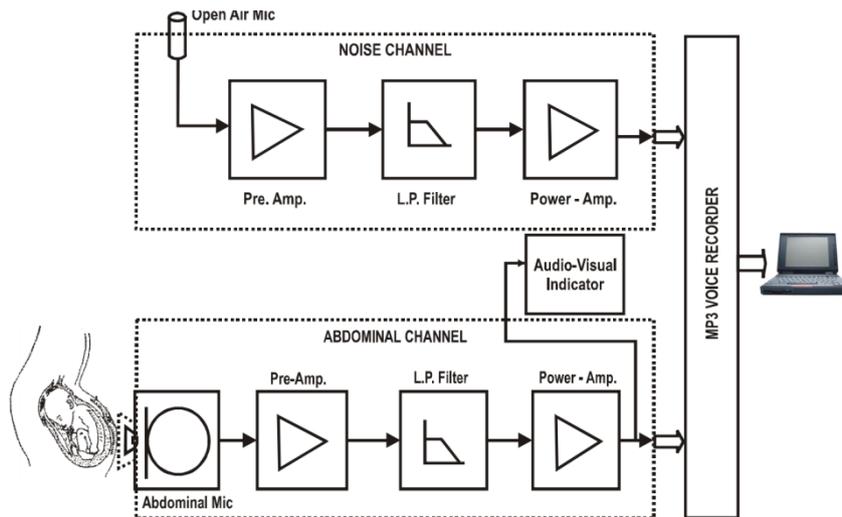


Fig 2: Arun KumarMitra et al device

In 2014, R. Nivethika et al developed a digital stethoscope based on the adaptation of a traditional stethoscope with an electret microphone and a digital electronic processing card making it possible to automatically detect certain heart defects [7]. The card in question is based on the TMS320C5515 which is a microcontroller specializing in digital processing. They have thus demonstrated that it is possible to develop a high-performance device at low cost and small in size. The block diagram is shown in the following figure.

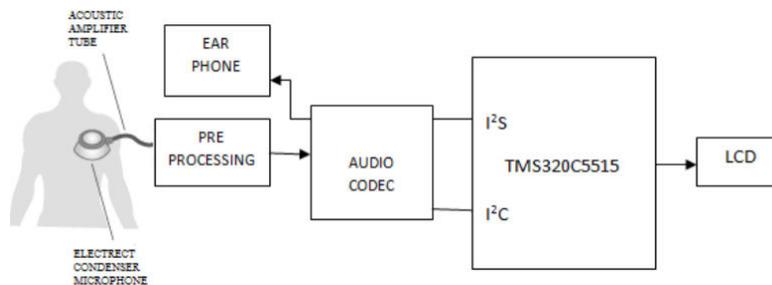


Fig 3: R. Nivethika et al device



In 2017, Lars-JoschenThoms et al invented a miniature device for acquiring PCG signals directly on a smartphone for educational purposes. The device is capable of picking up cardiac signals in the range of 10 - 250Hz [8]. The received signal is transmitted to the phone through the jack and the phone is responsible for amplifying and displaying through a computer application installed there.

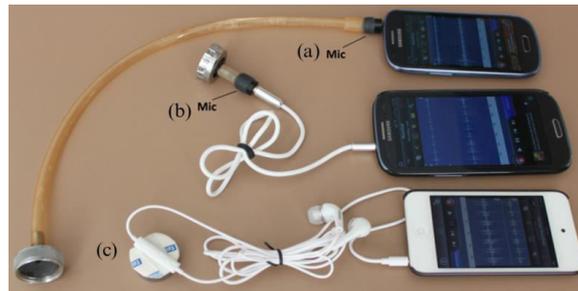


Fig 4 :Lars-Joschen Thomsdevice

III. METHODOLOGY

Current technology in medical instrumentation is based on the precision, reliability and robustness of various devices [9]. We present here a model based on a microcontroller from the manufacturer microchip. This microcontroller is responsible for coordinating and controlling tasks necessary for the acquisition of the PCG signal. This device is made to be able to work with adults, children and fetuses. Thus we have the PCG sensor, the pre-amplifier module to ensure a good signal level before filtering, the pass band filter to circumscribe the useful range of the signal, the automatic gain control (AGC) for ensure the right level of amplification, active noise cancelling (ANC) to reduce ambient noise, the processing unit which coordinates the entire system, the transmission module, the LCD display.

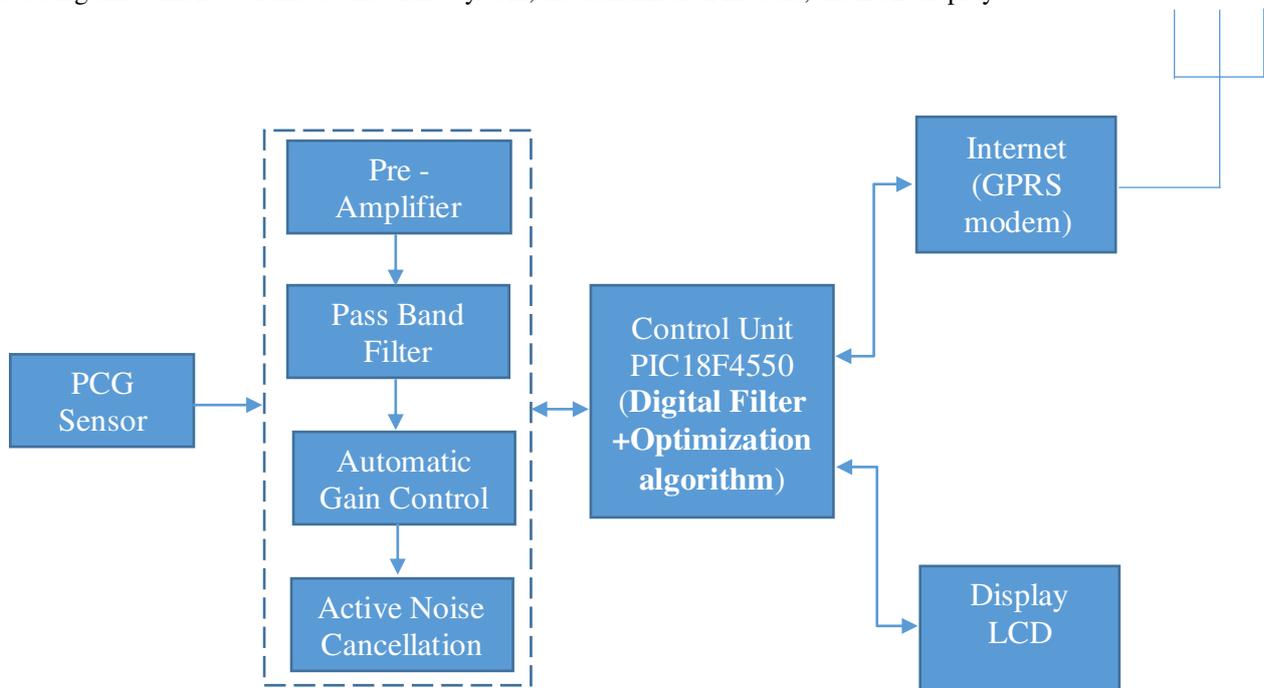


Fig5:Block diagram of the system

The key part of our module is the preamplifier + AGC. Both are working together to come out with a huge gain enabling the device to work in the range expected. It consists of two identical cells calibrated at a gain of $G = 106$ and activated by the microcontroller. The automatic gain control circuit is achieved by the MCP41100 which is a digital



potentiometer manufactured by Microchip. It is widely used in digital electronics because of its stability and especially its low cost [10]. The figure below illustrates the amplification chain of our module. The preamplifier part is done with two AD620 (which has a good ratio quality/price for biomedical applications) and the Automatic Gain Control is with a non-inverting amplification built around the LM358 which is an operational amplifier suitable for on-board applications [11].

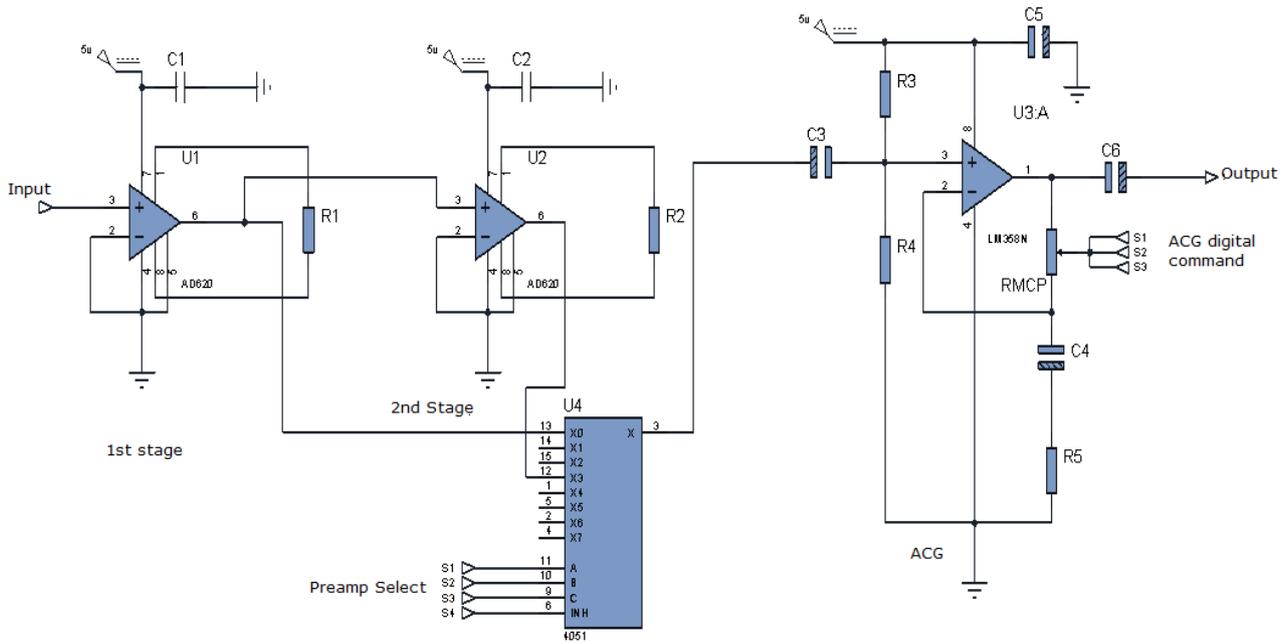


Fig 6: Pre-amp & AGC circuit

Figure 7 gives the AGC algorithm which illustrates how the different stages are activated and the sweep of different gain possibilities up to maximum gain. If at maximum gain the microcontroller still does not pick up a usable signal then an error message is returned and the acquisition process stops. The user will then have to review the position of the sensor and start a new acquisition. We have chosen a minimum voltage margin of 1V at the output of the AGC whatever the input value because from this voltage, future treatments can be carried out without any difficulty by the microcontroller and also, this allows to have a safety margin with regard to the protection of the microcontroller whose maximum authorized value is 5V.

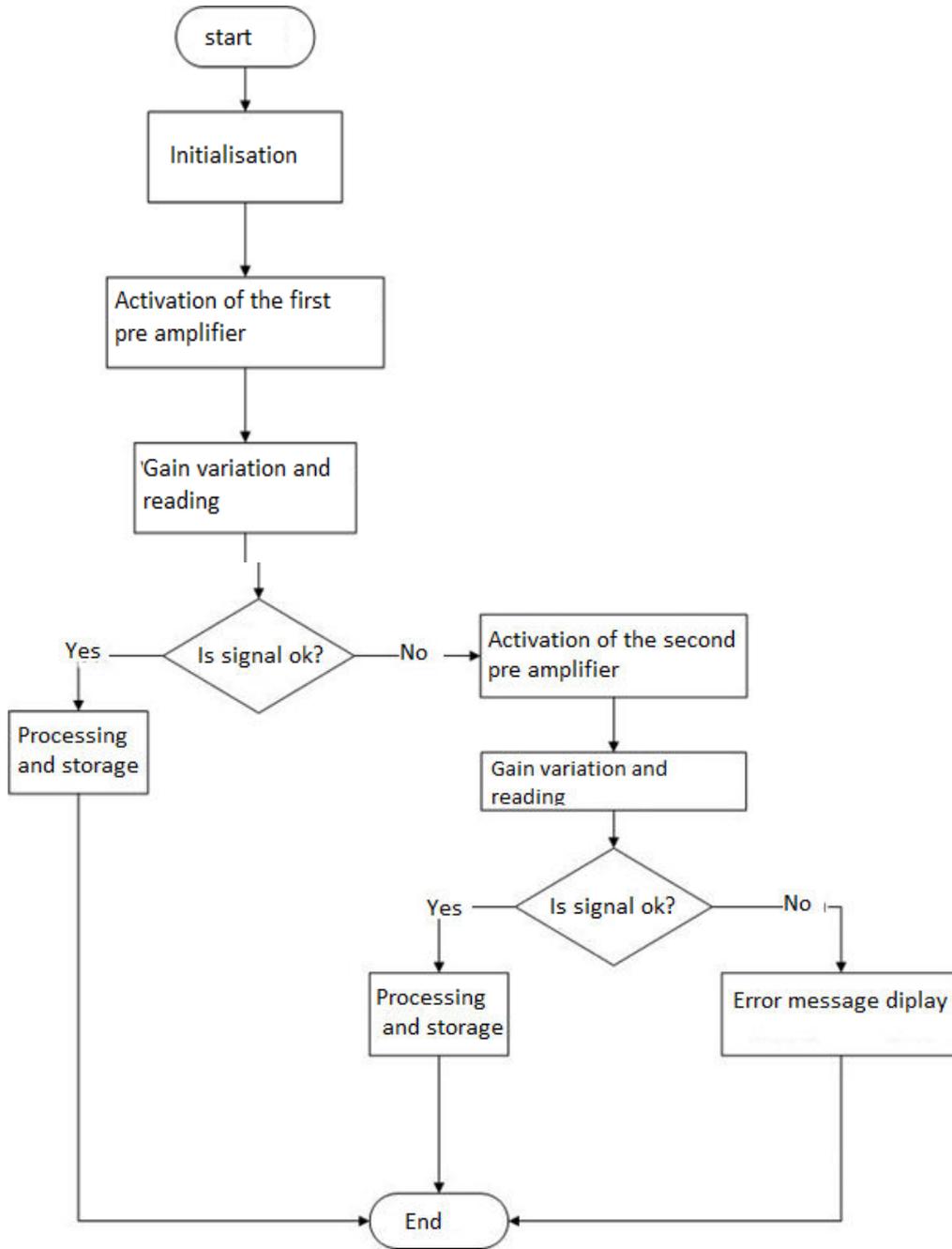


Fig 7:AGC algorithm

IV. EXPERIMENTAL RESULTS

The AGC amplification circuit is the center of our amplification system. It is he who controls the amplification based on the input signal and provides a signal usable by the processing system. It is made up of two stages: the AD620 preamplifiers and an amplifier around the MCP41100. The device has a high gain to amplify a wide range of physiological signals that vary from a few microvolts to a few millivolts. An overview of the amplifier circuit and the internet module is given in figure 8.

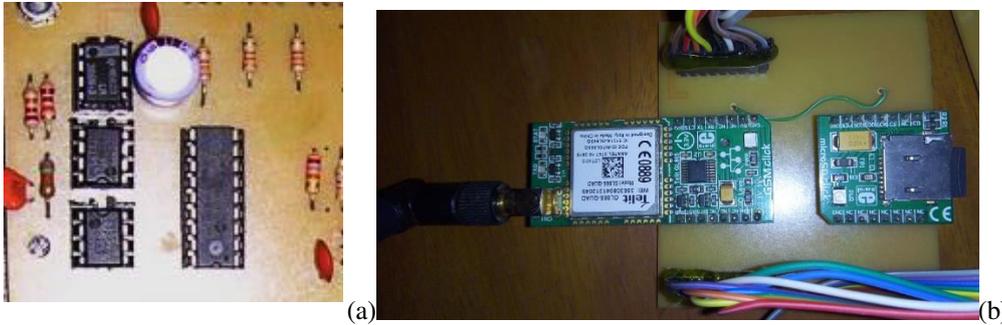


Fig 8:(a) Picture of the AGC circuit (b) Internet module

The operating tests of the CAG card were carried out in the laboratory with an Agilent DSO7014B digital oscilloscope and an Agilent 33220A precision signal generator. We used signals with an amplitude of $100\mu\text{V}$, then an amplitude of 10mV the results obtained are illustrated by the following figures.

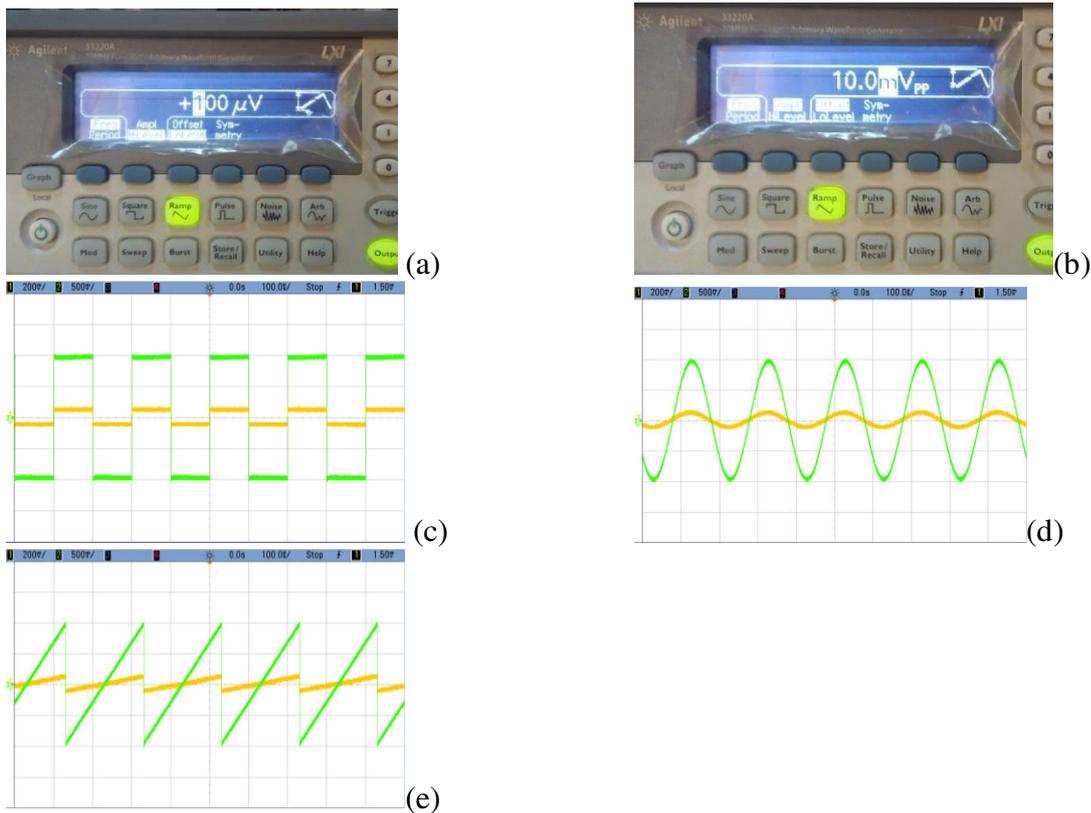


Fig 9: Result of the AGC module (a) signal of $100\mu\text{V}$ (b) signal of 10mV (c) square signal (d) sinusoidal signal (e) saw tooth signal

The active noise reduction device we achieved is essentially digital and is performing well till a maximum surrounding noise of 60dB . The following figures give a representation of the result obtained.

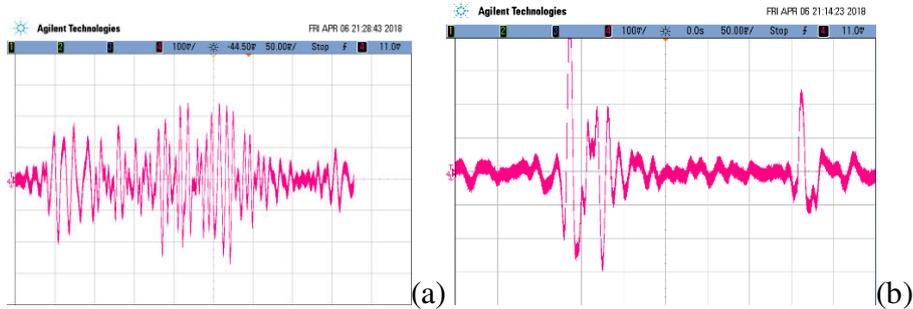


Fig 10: Result of the RAB module with a 60dB noise

The following figure gives a representation of the PCG signal obtained after filtering and acquisition. The signal is viewed on the oscilloscope Agilent DSO7014B.

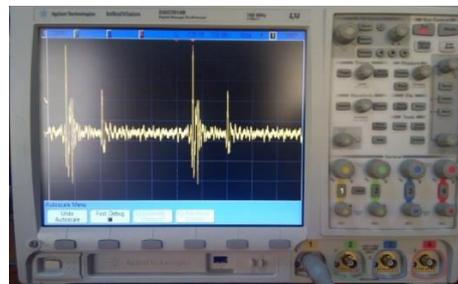


Figure 11: PCG Signal after acquisition

The prototype realized is made of a solid plastic box which serves as protection for electronic circuits. Figure 9 gives several views of the prototype produced.



Figure 12: Different view of the prototype

For the evaluation of this prototype we performed a heartbeat measurement test with a digital blood pressure monitor and the prototype under the same conditions on two groups of 25 people each. The first group consisted of men, and women aged from 18 to 45 years old. The second group consisted of children boys and girls aged from 3 to 12 years old. The following figures present the acquisition with the prototype and a digital blood pressure monitor, then results are marked in the next tables.



Figure 13: Signal acquisition (a) with the prototype (b) digital blood pressure

Tableau 1: Heart bit rate of adults(18 to 45 years old)

Patients	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Tensiomètre	70	75	73	80	77	71	75	96	83	84	86	70	79	77	75	82	76
prototype	70	76	73	79	77	70	78	95	84	84	85	70	79	77	76	82	77

S18	S19	S20	S21	S22	S23	S24	S25
74	77	79	83	76	80	77	72
74	77	80	83	76	80	77	72

Tableau 2: Heart bit rate of children (3 to 12 years old)

Patients	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Tensiomètre	110	102	103	95	90	96	101	89	95	115	92	94	89	89	92
prototype	109	102	102	95	90	95	100	90	95	115	93	93	90	90	92

S18	S18	S18	S19	S20	S21	S22	S23	S24	S25
93	95	97	94	97	102	110	90	93	97
94	95	97	94	95	102	112	90	92	98

Reading these tables shows that the prototype gives satisfactory results and fairly close to reality. It is however good to note that the error compared to the reference value (digital blood pressure monitor) increases a little more when one tends towards a large heartbeat value greater than 100bpm but the maximum difference observed is 3bpm.

V. CONCLUSION

In order to help heart patients who are more and more numerous in the world and in developing country in particular, we have worked in this paper on PCG signals which are signals resulting from the mechanical activity of the heart and which give the patient's heart health status as well as ECG signals. The device produced was tested in laboratory with signals ranging from 100µV to 10mV and the results obtained are quite satisfactory. A test on a population of 25 adults and 25 children was carried out, and results obtained are satisfactory with an accuracy of 1 to 3bpm. The device allows us to have information on the number of heartbeats, signal's spectrum, signal's graphical representation and listen to the heartbeats. The device is able to send the acquired signal anywhere on the national territory and even in the world through IoMT which allows internet communications to be established with a remote server. The device as a whole



gives satisfactory results and the objectives set at the beginning of this work have been achieved but certain points need to be improved.

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