Analysis of a Low Cost Numeric Blood Pressure Meter

A. YOUMSSI, *Member, IEEE*

***Abstract*— An easy and personal measurement of the blood pressure may help avoiding stroke, and controlling some health parameters in general. A low cost accessible electronic device could be useful in that aim for many people and for statistics studies. We would like to propose a study that could lead to the building of such device. The methodology used has firstly consists in studying with the help of a cardio physician how the pressure behaves in the human body, then we establish the algorithm and the flow chart of the method, the synopsis of the device, from which the different schematics could be drown. The main results are constituted by the analog and the numeric deduced schematics, their implementation and the issued measurements. We can then conclude that our objectives have been achieved, in this study we have made possible an easy and low cost personal numeric blood pressure meter.**

***Index Terms*—Electronics, Electricals, Automation, Applications in Medicine**

I. Introduction

THE individual control of Blood Pressure might certainly help medical diagnostics. If that follow up can possibly be individually registered and easily computerised; this could Lead to a précised, quick and best study of the health of a person and even of part of a population. Many cases of stroke,

And other diseases could then be easily detected and beaten through a quick medical consultation, or even prevented by the analyses made on blood pressure data of a patient or a population. It can also be noticed that one of the first actions on patients in all hospital is taking their blood pressure. That information is usually written on sheets with a great possibility of errors, and almost no possibility for the computation of great data. There exist numeric blood pressure meters, but they still expensive and of difficult access [1-5]. We would like in this study, to propose an easy, low cost one, with the possibility to transfer the data into a computer. The device will then measure, detect, and register, the systolic and diastolic pressures, with the possibility to register other data, like the dates and the time.

Corresponding Author—Andre YOUMSSI, ing.Ph.D, Senior Lecturer in Electrical Engineering University of N'gaoundere P.O.Box 455 N'gaoundere –Cameroon-.
Emails: andre.youmssi@yahoo.com / ayoumssi@yahoo.fr

II. Methods and Materials

The methodology we have used for this study consists in examining the existing solutions and their limits, and after that deciding what the best method to used, and which types of materials will be involved. These are explained in the following subsections (*A; B; and C*).

A. Comparisons with any existing solutions

There exist many types of blood pressure meters that can be grouped in mainly three categories: Analog Blood Pressure Meters without electronic treatments, Analog Blood Pressure Meters with electronic treatments, and digital ones [6-11]:

-Analog Blood Pressure Meters: These are the most common and most uses ones especially in almost all hospitals underdeveloped countries. It comprises a flexible air sheath, an analog manometer, and a stethoscope. The sheath applies the pressure around the patient arm, while the stethoscope is used to detect the pulses, the manometer being used to indicate analogically the instantaneous value of the pressure established in the flexible air sheath. This type of blood pressure meter needs to the physician to have keen ears, and not to have any eye trouble. This type of blood pressure meters are so subject to Parallax errors and to errors that may come from the difference between persons.
-Analog Electronic blood Pressure that contain some electronic treatments, but with analog displays. These types are still subject to Parallax errors.
-Digital Blood Pressure Meters: These ones are more modern. They are out of price. They cheapest ones are around a thousand us $, in much underdeveloped countries, and the technologies are of no access.

The proposed Blood Pressure Meter in this article can be classified in the third class. It has the particularity to be ten time cheaper, with simple and accessible schematics.

B. Methods

In order to tackle this problem, we have tried to understand what an arterial pressure is, and how it is brought into an electronic signal. After that, we have used electronic methods and components to find the solutions.

We would like to base our study on a medical understanding of arterial blood pressure. It is explained that the blood circulates in the arteries and the veins due to contractions and relaxations of the heart. That blood then circulates by fits and starts and so applies a physical pressure, so called blood pressure, on the internal face of the veins and arteries. The value of that pressure should always remains between two limits, an upper limit P_2 called systolic pressure, and a lower one, called diastolic pressure. Those two values are generally detected owing to stethoscopes equipped with analog manometers. This method can often only be used by physicians. The issued measurements are then written down, and analysed after with great possibilities of errors. Some detectors [12, 15] could deliver electronic signals. Our approach will be the search of P_1 and P_2 which will be electrically treated, displayed, and registered for future uses such as computations. The principles that can read on the following flow chart (fig.1) consist in detecting P_2 and P_1, then display and register them respectively.

The whole system can then be described by the synopsis on fig.2. The pressure applied on the arm of the patient is through a flexible air sheath, is converted into an electric voltage by a pressure sensor. The obtained voltage is then amplified and filtered, before being converted into numeric values for displays and registration. The two last operations are performed simultaneously under a control command system (fig.2).

The proposed system will used logic and analog integrated circuits that should be fed by DC voltages. In order to assure the electric autonomy of the system, it should be incorporated DC feedings of different types. The classic Diode rectifiers are not sufficient because the rectified voltages are not constant, and slights variations of the AC part have repercussions of the obtained rectified voltage at the output. In order to avoid such problems, the rectified DC voltage needs to be stabilized. So after the rectifier, we must place a filter, and after a filter, a regulator. Among the different ways of regulations, we have chosen a linear series regulator mainly because it seems more robust; it more assures a constant value of the output voltage whatever the running conditions. It needs for the task, a voltage reference, an error amplifier, and a series element (fig.3). The input voltage should remain into two limits (a minimum, and a maximum). A maximum delivered current should also be respected.

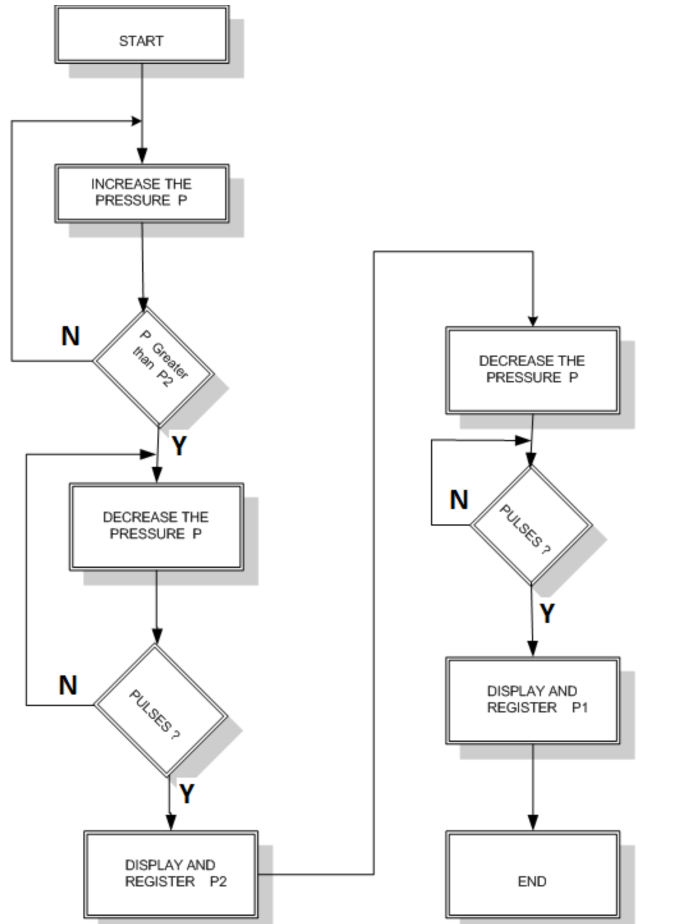

Fig. 1 The Flow-Chart of the detection of the Systolic (P_2) and Diastolic (P_1) pressures.

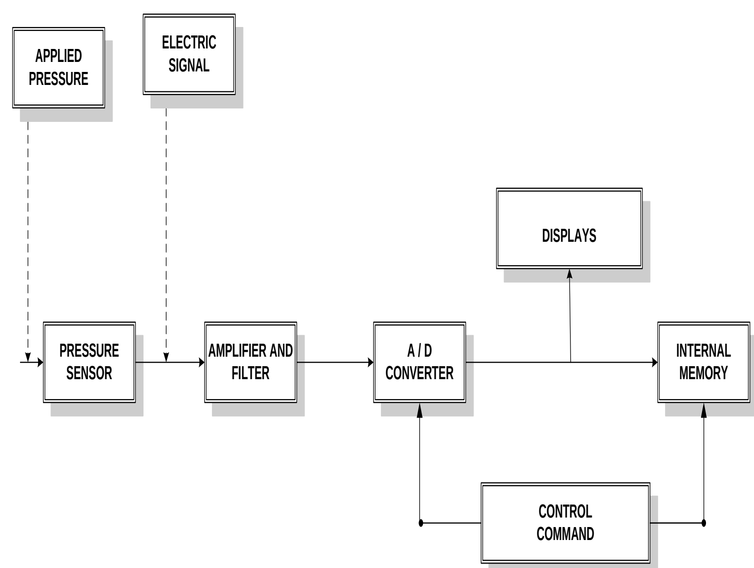

Fig.2 Synopsis of the Blood Pressure Meter

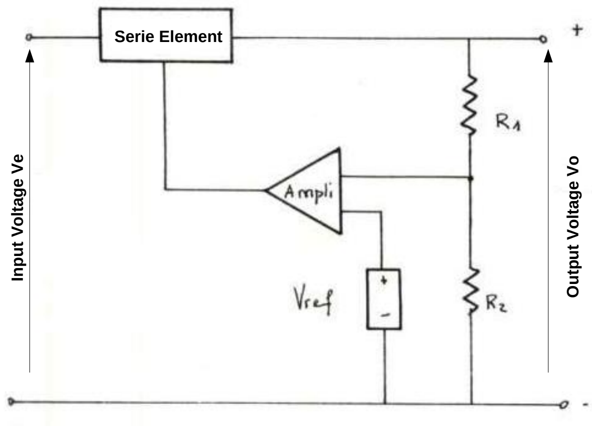

Fig.3 Principle of a Serie DC Linear Voltage Regulator

In order to adjust, the output voltage, a potentiometer could be used as indicated on fig.4. The current I_B flowing through R_2 then gives the needed reference voltage V_{ref}. C_1 and C_2 remains the high frequency filters.

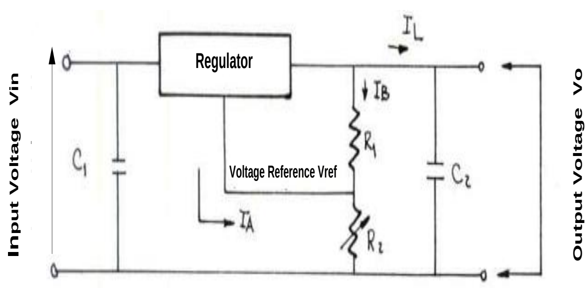

Fig.4 Adjustment of the Output Voltage Vo

C. Materials

The choice of the materials is based on the principles that we remind here. A classic air flexible sheath can be used to apply the pressure on the arm of the patient at the adequate place. The physical parameter, which is the applied pressure, is transformed into an electronic signal through a detector. That electronic signal needs to be amplified and filtered, before it is converted into a numeric value, and then displayed and registered at adequate time. The two last operations the display and the registration, being performed under a control command system [14].

We then need the following equipments and components:

-A pressure detector

-A classic air flexible sheath equipped by a manual or automatic pressure generator

-Circuits to detect the pulses, to amplify, filter, and deliver the electronic signal representing the detected blood pressure pulses.

-Circuits to transform the analog signals into numeric ones: some analog to numeric electronic converters, and many flip flops.

-Circuits to display the value of the blood pressure: numeric segments displays

-Circuits to register the different values of the blood pressure: decoders, counters, and Random Access Memories.

-Circuit for the control command that could help the transfer of data for computations

-Circuits to generate the DC power used for the treatment: a mono phase bridge diodes (Graetz rectifier), mono phase AC transformers, and cables for the connections.

-Other circuits if necessary, for instance based capacitor filters

III. RESULTS AND COMMENTS

A. Analog Schematics and Comments

The physical applied pressure is transformed into an electric signal by the sensor LX0503A (Fig.5) which is a piezoelectric integrated circuit of SENSYM Family. This device needs an additional offset compensation circuit, made here by a follower and two resistors (2.8 MΩ and 8.2 MΩ). The compensation circuit delivers a low voltage of around a 100 mV at the output of the first amplification stage. The 100 kΩ potentiometer helps to superpose a voltage of opposite phase to (V1-V2). Many stages of amplifiers should be used due to the fact that when considering one stage the product of the voltage magnification by the bandwidth is constant (Fig.5 & Fig.6).

At the output of the last amplification stage, the electric signal holds no wanted components that should be eliminated. At that last stage, the signal must then be filtered in order to remove the DC component and the noises. The here proposed filter is a band-pass type constituted by both a lower and a higher pass filter. The normal rhythm of a human being heart when he or she is at rest corresponds to 0.2 to 2 Hz (Fig.6). The obtained filter bandwidth for the pressure signal is shown on fig.9, the frequency to detect being around 0.2-2 Hz, that corresponds to 70 to 75 pulsations per minute (Fig.9).

The analog signal at the output 2 (Fig.6) is now ready to be converted into numeric one through an Analog to Digital converter for the registration and the computations (Fig.7). The same signal from the output 2 can be detected by a pulse circuit detector for the displays. That circuit is mad of a comparator, a 5 V Zener diode and a mono stable flip flops of type 74 121 or equivalent (Fig.8).

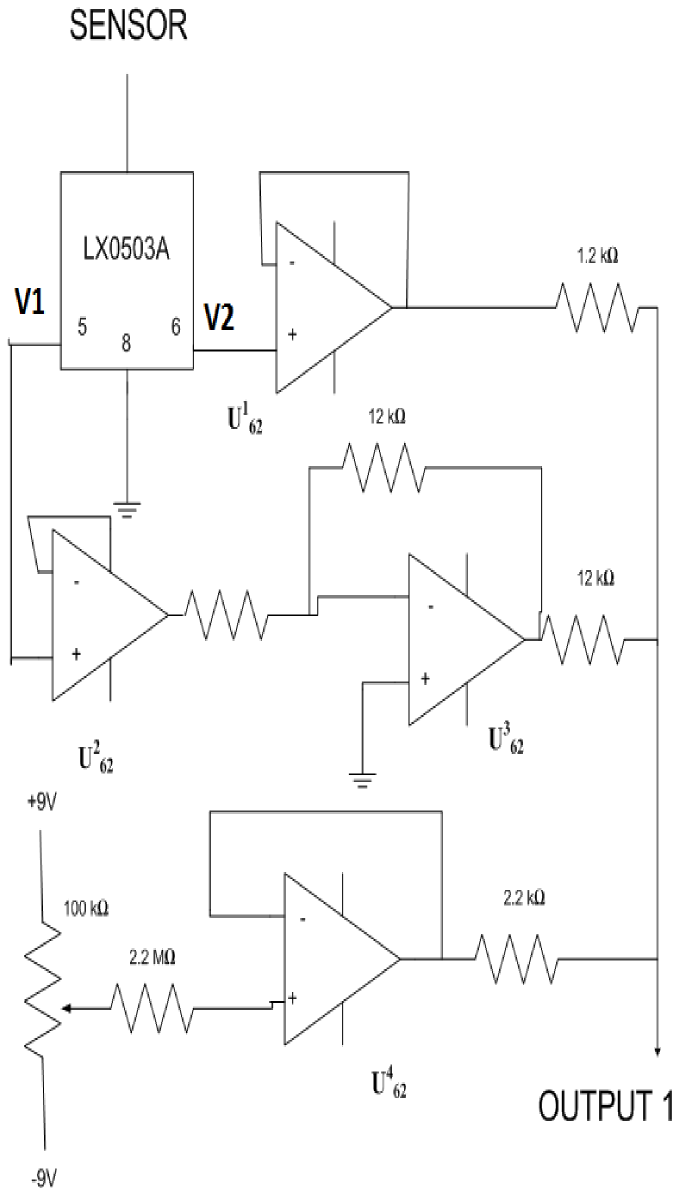

Fig.5 the Blood Pressure Analog Schematic (Part 1)

A. *Numeric Schematics and Comments*

The signal from the output of the A/D Converter (Fig.7 and Fig.10) is decoded and registered through adequate numeric circuits one of those could be seen on fig.10. A really simple A/D converter is used 3500/ADD 3501. Only the positive values are converted, which called unilateral conversion. The conversion command order is given by the pulsations derived from the pulses. A 500 kHz oscillator fixes the conversion frequency. That frequency has been calculated based on the pulse frequency and the capacity of the A/D converter. So the A/D converter is managed to achieve one operation before the next one (Fig.10). After the conversion, the signal is decoded through an adequate binary-Binary Coded Decimal decoder, and then registered according to the memory capacity. There are two important information to be registered the systolic blood pressure and the diastolic one. The signal from the output 4 (Fig.8) needs to be hold for a while in some registers before it is displayed on two chosen decimal number under the control command circuit on Fig.11.

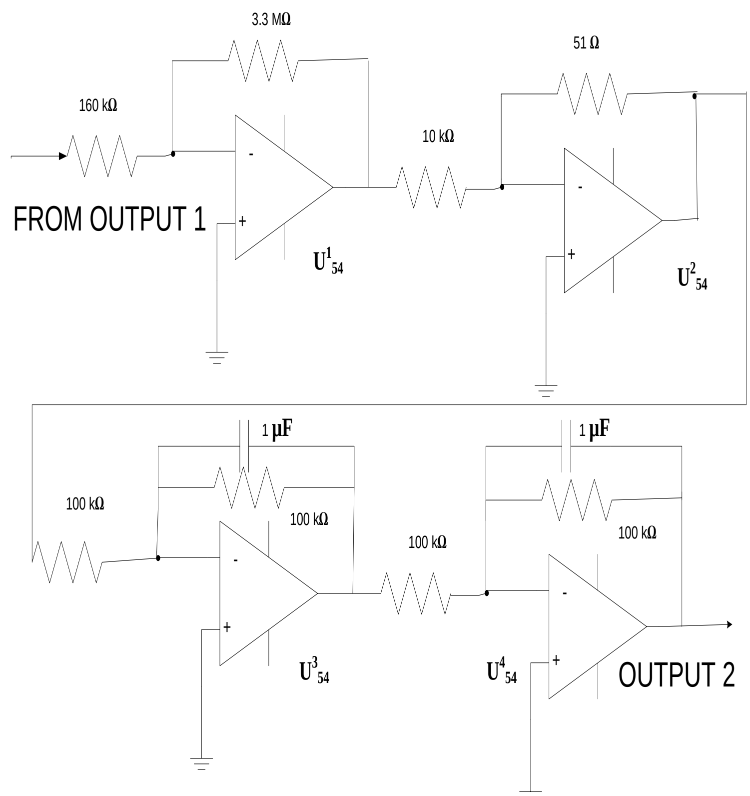

Fig.6 the Blood Pressure Analog Schematic (Part 2)

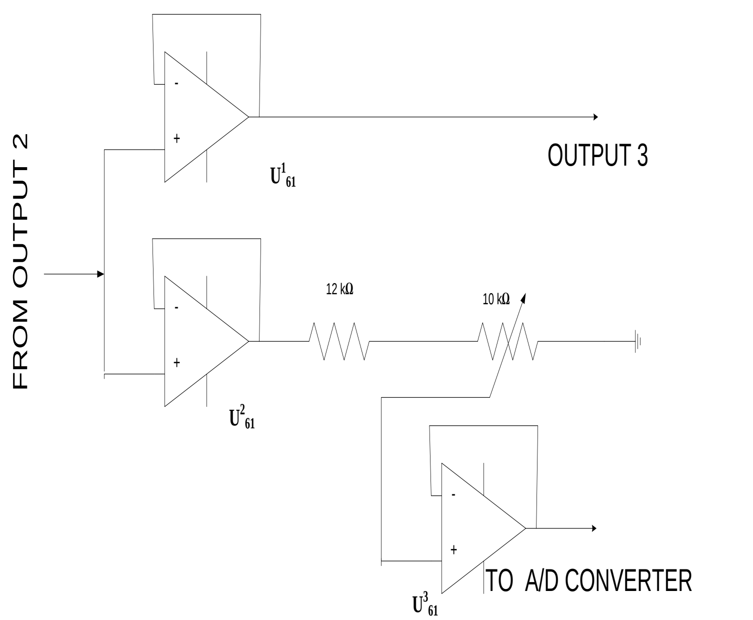

Fig.7 the Blood Pressure Analog Schematic (Part 3)

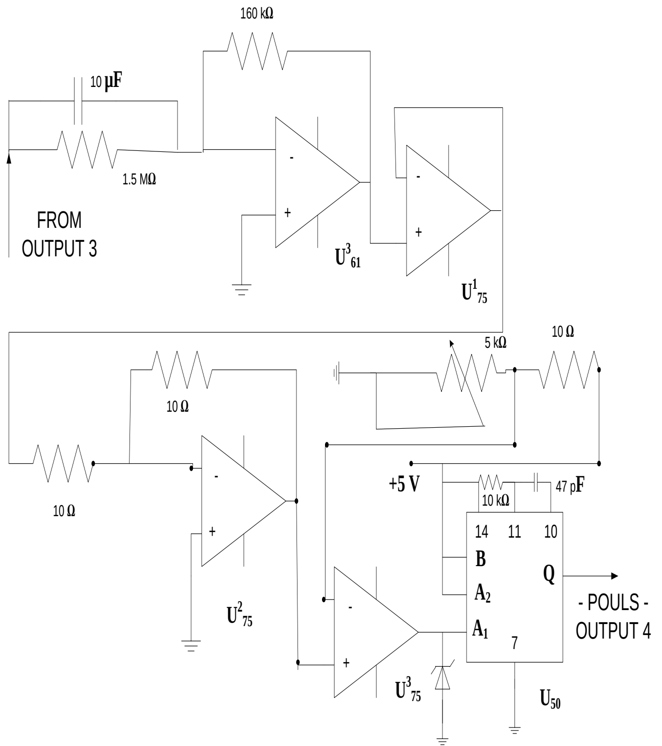

Fig.8 the Blood Pressure Analog Schematic (Part 4)

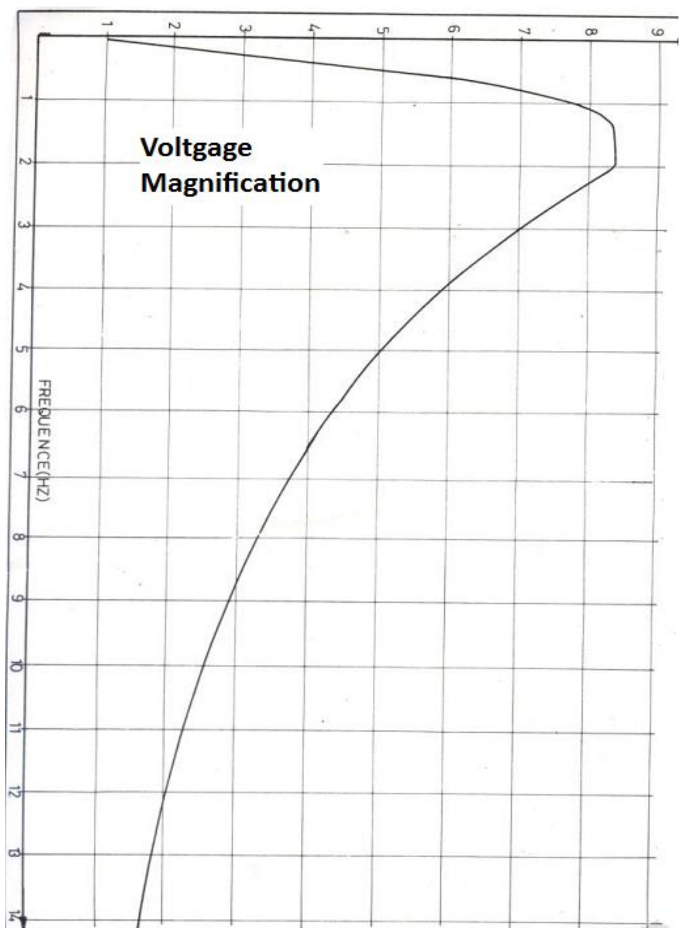

Fig.9 The obtained characteristic of the bandwidth filter for the pressure signal treatment

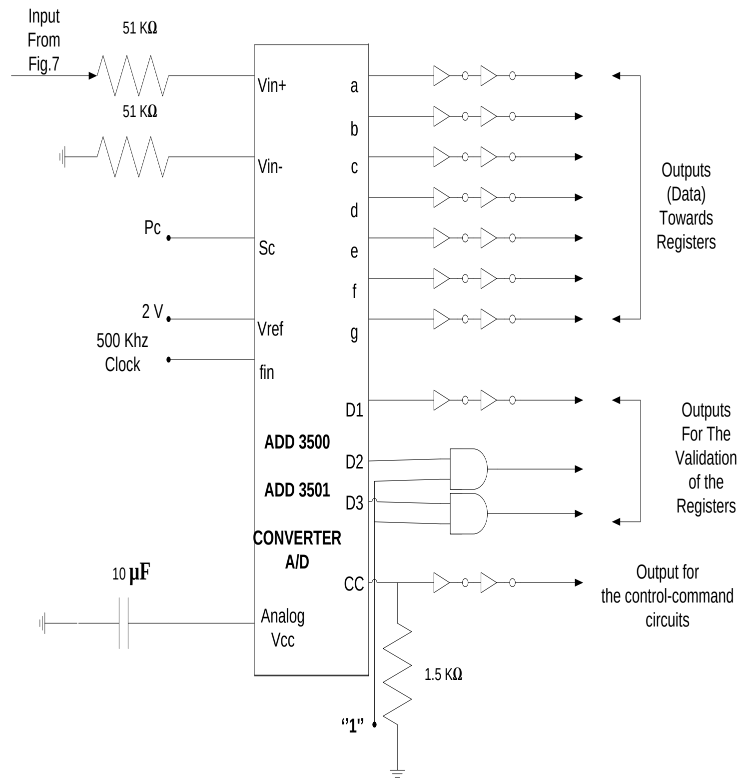

Fig.10 Analog to Digital Conversion of the Blood Pressure Electronic Signal

In order to be display, and registered, the analog signal is converted into an equivalent digital signal through an A/D converter (Fig.10). Here lowest cost A/D converter 3500/ADD 3501 has been used. The reference DC voltage has been fixed to 2 V. The DC polarization voltage is 5 V, and is none isolated, which means a unilateral conversion, the only positive values are then converted. The conversion command signal is the pulse. An oscillator of frequency Fin gives the conversion frequency. Fin has been calculated and is here 500 kHz. In fact, Fin is linked to the time conversion t, and should satisfy other criteria as indicated by its builder: Fin = 64.256/t and should be between 100 kHz and 640 kHz. In the other hand, knowing that a normal human earth at rest beats at 75 pulses per minute, its frequency is 1.25 Hz, with the corresponding period of 0.8 s. The conversion time t should then be smaller than 0.8 s to bring the A/D converter achieves one conversion before the next one. All those considerations lead t = 0.12 s, and we then have the frequency conversion Fin = 500 kHz. It should be noticed that the follower at the outputs D1, D2, D3, and CC give more power to those signal enabling them to drive many TTL inputs (fig.10).

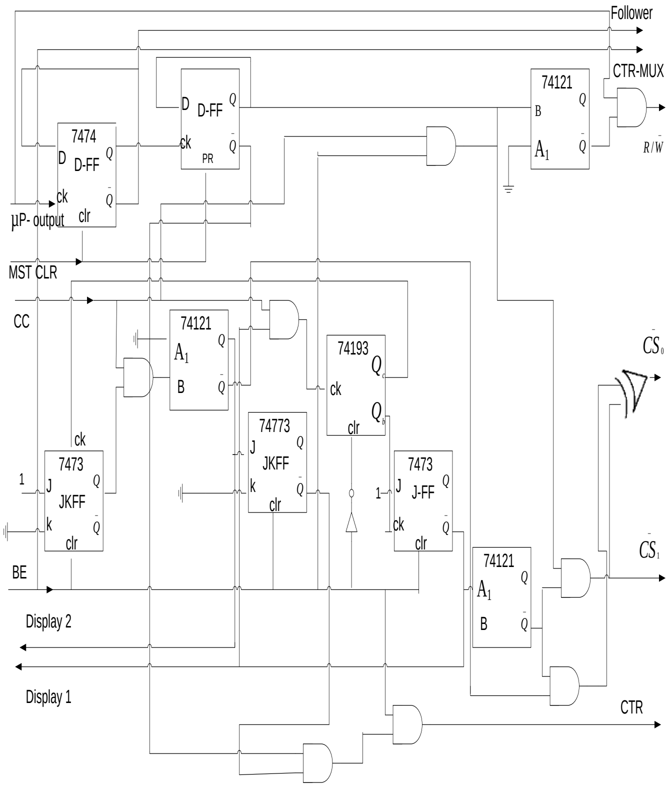

Fig.11 Control Command Circuit

The digital readout is performed through six seven segments displays with each preceded by two registers which roles are to hold the information for a while for the reading (Display 1 and display 2, Fig.11). Those registers are initialised by couple with the command signals coming from the A/D converter at the outputs D1, D2, and D3, the data to display being the digital value of the arterial pressure at the outputs a to g (Fig.10). We have a multiplexed display, so those signals from D1, D2, D3 and CC help positioning each digit at the correct place (Fig.11). The display is made off with three digits, with the highest weight be not greater than 3 since the systolic human blood pressure is always smaller than 300 mm Hg.

Here is how the display is concretely performed. During the increasing of the pressure, the two groups of digital readouts display at the same time the converted pressures till the pulse stops. When the systolic (the highest) pressure of the patient is read, the physician plots the bit BE at 1 and then begins to decrease the applied pressure. The role of the state bit BE consists in fixing the first group of displays that is the systolic displays. In fact that state bit (BE) put at logic 1 and inversed allows a 74193 counter to detect the height pulse that will enable a JK flip-flop fixing its $\bar{Q}$ output at zero logic. The linked registers are then locked on fixing by this fact the systolic displays, display 1 on figure 11 (Fig.11).

The second group of the digital readouts display instantaneously the converted pressures. In fact the registers which feed those displays are controlled by a combination of the signals D1, D2, D3 and CC coming from the A/D converter (Fig.10). A 74121 flip-flop is then enabled by the pulse which is the signal CC from the converter. That flip-flop that has the same frequency as Fin of the A/D converter remains activated by each pulse. After the last pulse, that flip-flop returns to its initial state. The resulted negative transition sets a J-K flip-flop which $\bar{Q}$ bit goes to zero, then locking on the diastolic registers under its control (Fig.11).

B. DC Feeder Schematics and Comments

The number of numeric and analog integrated circuits is important. It is so crucial to provide the blood pressure meter with its proper DC sources. We have then designed a DC feeder of (- 9 to +- 9V); (0 to 5V); and (0 to 2V). The design has involved a diodes rectifier, and adequate filters and regulation circuits, the regulator LM209 could be replaced by LM307 or an equivalent cheaper regulator (fig.12).

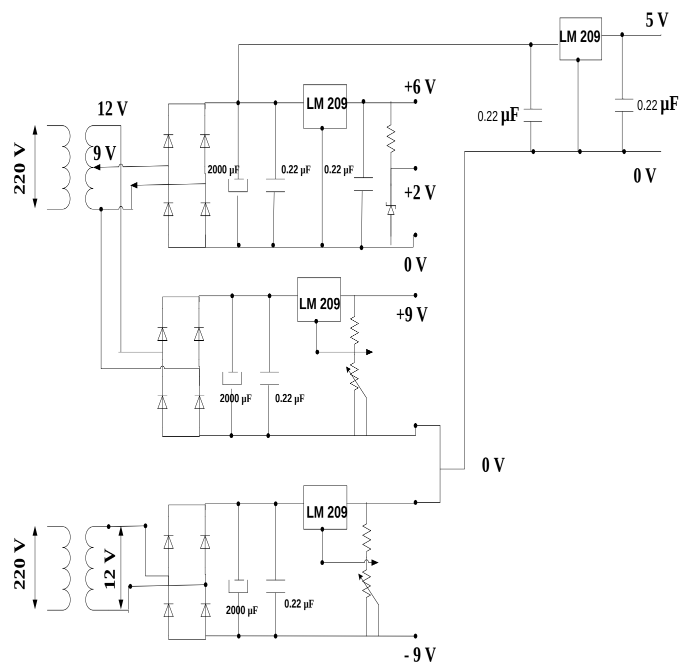

Fig.12 DC Feeder Schematics

C. Technical details and performance of the system

The designed system will cost ten times less than the cheapest ones now on the market. Its manipulation has been made easy. The technology is accessible, and the realisation has been mad the easiest. It could register more than two thousands value for each patient, and that information can be computerized.

IV. CONCLUSION AND PERSPECTIVES

We have then contribute to analyse an easy and personal blood pressure meter that will be of easy access and will help avoiding stroke, and controlling some health parameters in general. The following results have been reached:

-The design and realisation of stabilized DC sources

-The design and the realisation the detection, the transduction and the treatments of the blood pressure signal

-The design and the realisation of the displays and the numeric treatment of the electric signal corresponding to the blood pressure

-The design and the realisation of the control command circuits

We can then conclude that we have made possible a prototype of a low cost numeric and computerised Blood Pressure Meter. All the schematics have been designed, and realised. The measurements have been obtained with satisfaction. The next step could be in one hand the optimisation of each part with the possibility to treat errors, and in the other hand the building and the experimentation of an industrialised example with economic parameters taken into account.

We can also notice that the Blood Pressure Meter we present needs to be calibrated. In fact the reference voltage from which the electronic pulses are generated through a mono stable flip-flop should have an adequate value to bring the generated pulse to correspond to the real pulse of the patient. That reference voltage is in fact a DC signal while the input voltage varies as the real pulse of the patient. So an adequate limit should be found for the DC reference voltages, which limit meaning that we effectively have a pulse. A way to solve this problem of calibration could consist in taking the arterial pressure of a group of patients by different other existing methods and by different physicians, and then calculating the average values for each patient, and finally try to approach with the smallest error that average value using the Blood Pressure Meter presented in this article. This problem of calibration might need profound research in conjunction with a medical team [13, 16].

ACKNOWLEDGMENTS

Authors would like to acknowledge the University of Ngaoundere, in Cameroon, for leave of absence to Andre YOUMSSI, and respectively to “Ecole Polytechnique de Montreal”, in Canada, through its Department of Electrical and Computer Sciences and its Laboratory in Electrical Energy, and to “Ecole Nationale Supérieure d’Electricité et de Mécanique de Nancy”, France through its Laboratory “Groupe de Recherches en Electrotechnique et Electronique de Nancy”, G.R.E.E.N, both for visitor ships and facilities to Andre YOUMSSI.

REFERENCES

[1] Masao Tsuji, Old Lyme, Conn. United States Patent, «BLOOD PRESSURE METER »; Patent Number: Des. 289,082n; Date of Patent: March. 31, 1987

[2] C.S. Chua and Siew Mun Hin,« Digital Blood Pressure Meter » Freescale Semiconductor-Application Note; May, 2005

[3] KINOSHITA, Hiroyuki; (JP). SATO, Hironori; (JP). FUJII, Kenji; (JP). SAWANOI, Yukiya; (JP) , WO Patent, «BLOOD PRESSURE METER », International Application No.: PCT/JP2012/076230, Publication Date: 02.05.2013

[4] ASHIDA, Tameo; (JP), WO Patent, «BLOOD PRESSURE METER »,Pub. No.: WO/2011/010686, International Application No.: PCT/JP2010/062320, Publication Date: 27.01.2011

[5] OMRON HEALTHCARE CO., WO Patent, «BLOOD PRESSURE METER », Pub. No.: WO/2009/060850; International Application No.: PCT/JP2008/070102; Publication Date: 14.05.2009

[6] Nitzan, Meir « Automatic non-invasive measurement of arterial blood pressure », IEEE Instrumentation & Measurement Magazine, DOI: 10.1109/MIM.2011.5704808, 2011

[7] Sahoo, A. ; Manimegalai, P. ; Thanushkodi, K. «Wavelet based pulse rate and Blood pressure estimation system from ECG and PPG signals », Computer, Communication and Electrical Technology (ICCCET), 2011 International Conference on, DOI: 10.1109/ICCCET.2011.5762486 , 2011, pp 285 – 289.

[8] Van Moer, W. ; Lauwers, L. ; Schoors, D. ; Barbé, K. Linearizing Oscillometric Blood-Pressure Measurements: None Sense? Instrumentation and Measurement, IEEE Transactions on , Vol. 60, DOI: 10.1109/TIM.2010.2090703, 2011, pp 1267 – 127

[9] Barbe, K. ; Van Moer, W. ; Schoors, D. Analyzing the Windkessel Model as a Potential Candidate for Correcting Oscillometric Blood-Pressure Measurements », Instrumentation and Measurement, IEEE Transactions on, Vol 61 DOI: 10.1109/TIM.2011.2161933, 2012, pp: 411 – 418

[10] Chandrasekaran, V. ; Dantu, R. ; Jonnada, S. ; Thiyagaraja, S. ; Subbu, K.P. Cuff less Differential Blood Pressure Estimation Using Smart Phones » Biomedical Engineering, IEEE Transactions on, Vol 60 DOI: 10.1109/TBME.2012.2211078 , 2013 , pp: 1080 – 1089

[11] Kittipiyakul, S. ; Charoenkul, S. ; Pornsukjantra, W. ; Udomsaph, P. ; Woradet, J. ; Plongmai, V. ; Sartsatit, S. « An automatic biomedical acquisition system for hospital registration » Industrial Electronics and Applications (ISIEA), IEEE Symposium on DOI: 10.1109/ISIEA.2011.6108804 , 2011 , pp: 692 – 695

[12] Spulak, D. ; Cmejla, R. ; Fabian, V. «Parameters for mean blood pressure estimation based on electrocardiography and photoplethysmography » Applied Electronics (AE), 2011 International Conference on, 2011, pp: 1-4

[13] Manimegalai, P. ; Jacob, D. ; Thanushkodi, K. Estimation of cardiovascular parameters from ECG and PPG signals, Bioengineering Conference (NEBEC), 38th Annual Northeast, DOI: 10.1109/NEBC.2012.6207051, 2012, pp: 237 – 238

[14] Lee, Y. « Personal Medical Monitoring System Based on x73-PHD Standards, IT Professional, DOI: 10.1109/MITP.2012.90, 2012

[15] Kornain, Z. ; Abdullah, M.R. ; Abu, M.A. « Telemedicine system: Development of wireless healthcare units with GSM and Bluetooth link Industrial Electronics and Applications (ISIEA), IEEE Symposium on , DOI: 10.1109/ISIEA.2012.6496675, 2012 , pp: 72 – 77

[16] Affanni, A. ; Specogna, R. ; Trevisan, F. Electrical Impedance Spectroscopy on flowing blood to predict white thrombus formation in artificial micro channels, Electrical Impedance Spectroscopy on flowing blood to predict white thrombus formation in artificial micro channels, Instrumentation and Measurement Technology Conference (I2MTC), IEEE International, DOI:10.1109/I2MTC.2012.6229295, 2012, pp: 1477 – 1480