A Real-Time Pulse-Wave Data Acquisition System Based On Arm Processor

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***Abstract*—:** This paper reports the design and development details of an embedded system for real-time pulse-wave data acquisition. Based on the BCM2835 Raspberry Pi Single board computer with an ARM11 Processor, this system simultaneously acquires pulse-waves from both the hands in real-time. The acquired data is analyzed and as well presented on a GUI for visual diagnosis.

Keywords— Single Board computer, Real-Time, Pulse-Wave, data acquisition.

Introduction

The number of patients suffering from cardiovascular diseases is on a constant rise in recent times and hence there is a lot of scope for the development of reliable advanced-microprocessor based pulse-wave data acquisition systems. Since the pulse of the human body plays a major role in the cardiovascular system diagnosis, it has attracted great attention from medical professionals [1-2].
Though a range of embedded systems have occupied significant space in the medical equipment market today, most of them require personal computers to compute and/or to display the analyzed data or waveforms [1]. Further, the challenge of accurate analysis along with visual display of pulse wave in real-time is still interesting.
In this paper, the design details and results of the dual-channel pulse wave detection system are reported. The pulses are detected and conditioned before applying to the quantizer. The acquired information is processed using an ARM processor which has a direct interface to a monitor unit to display the pulse-waves of right and left hands simultaneously. The possibility of direct interface of the display unit to the high-end processor eliminates the necessity of a personal computer for processing/presentation. In other words, the use of a Single Board Computer (SBC) offers great advantages in embedded applications of this kind.

PULSE TYPE	PHYSIOLOGICAL CAUSE	POSSIBLE DISEASES
Weak	Decreases Stroke volume	Heart failure
Large & Building	Increased Stroke volume	Fever, Bradycardia, Heart block
Bisferiens	Increased arterial pulse with double systolic peak	Hypertrophic, Cardiomyopathy
Pulse alternans	Non-uniform Pulse amplitudes	Left ventricular failure

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I. SYSTEM COMPONENTS

Figure-1 depicts the system components which are described in the subsequent sub-sections.

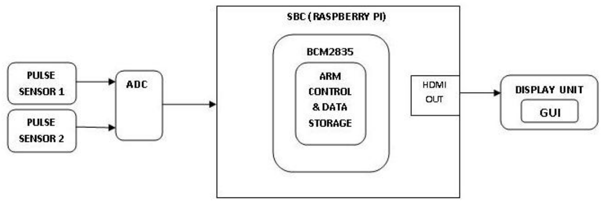

Fig. 1. *System Block diagram*

The system mainly consists of two pulse sensors to acquire the pulse signals, a multichannel ADC for conversion of the acquired analog signal, an ARM1176JZ-S Processor to realize acquisition and processing. Finally, the processed signals are reconstructed on the display monitor for visual monitoring. Furthermore, two time-stamped pulse signal sequences are extracted and processed separately to determine similarities.

A. Pulses and Pulse Sensor

The blood forced into aorta when heart pumps it not only moves the blood into the vessels forward but it also sets a pressure wave that travels along arteries, the pressure wave which travels it expands the arterial wall and this expansion is palpable as pulse[8].
The characteristics of pulses have been well known to be relatable to ailments as depicted in table 1 and figure-2 [8, 9,10].

Table 1. Possible diseases which are based on pulse shapes[8]

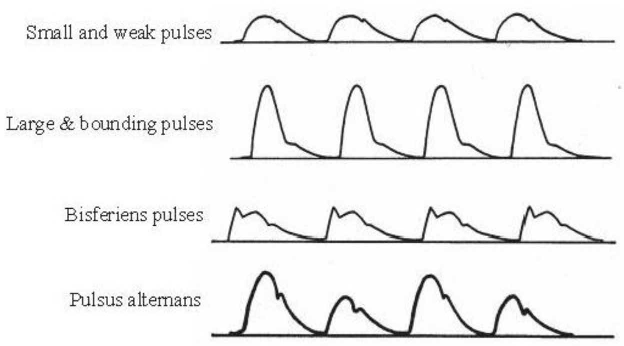

***Fig. 2.** Pulse wave classification [8]*

Here, we use an optical sensor at the finger tip to detect the alterations in volumetric blood flow with heart beats. The sensor unit consists of an infrared (IR) light emitting diode (LED) and a photo diode (PD). The IR-LED transmits an infrared light into finger tip (placed over the sensor unit) and the PD senses the portion of the light that is reflected back.

The signal conditioning circuit consists of dual-opamp LM358 as depicted in figure-**3**. The 1st stage is a transconductance amplifier which converts the photo current into voltage. This voltage is further amplified using the 2nd stage variable gain amplifier.

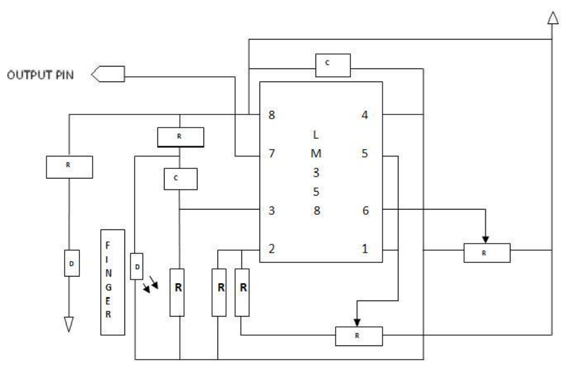

***Fig. 3.** Pulse Sensor Circuit*

B. ADC

This module uses 10bit A to D converter in ATmega328. The essential features are low power consumption, 6 multiplexed single ended input channels, 0.5LSB integral non-linearity, ±2LSB absolute accuracy, 13-260µs of conversion time and a maximum sampling rate of 76.9Ksps. In this work, using the GCC cross compiler it's programmed in C to perform A/D conversion of the two input channels.

C. Single Board computer

The single board computer is as depicted in figure-4. It consists of the Ethernet port, two USB2.0 ports typically for Keyboard and Mouse, CSI Camera interface, GPIO headers, Audio Jack, DSI connector display and HDMI &Composite as two main options for the display device. In this work, the HDMI out is used for display using HDMI-DVI (Digital Video Interface) adopter. The resolution is automatically set to the connected display unit [4,5].

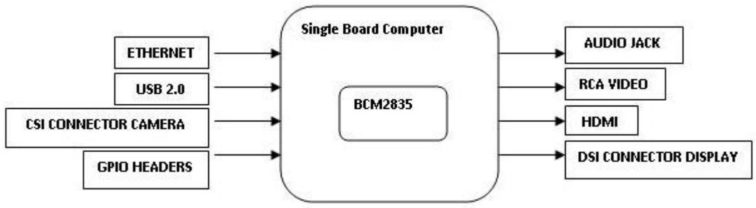

***Fig. 3.** Single board computer (Raspberry pi)*

The SBC is based on BCM2835 which has the ARM 11 series processor (Broadcom). V6 architecture, an inbuilt RAM of 512MB, Operating frequency of 700MHz, a range of DSP instructions, 32-bit Arm and 16-bit thumb instruction set are the important specifications of the processor [6]. The SBC supports upto 32GB and in the present work, an 8GB SD card is used and is loaded with an embedded Linux based Debian Wheezy operating system (ubuntu flavor).

II Software Design

The figure-5 depicts the flow chart of the software design. The Equation (1) gives the relation to convert the digital data into corresponding voltage levels

$$V\_x_i = \frac{(y_i \times 5)}{1024}$$

Here V_x_i corresponds to the voltage value of ith channel of ADC i= 1& 2 and Yi corresponds to the digital values for channel 1 and 2 respectively.

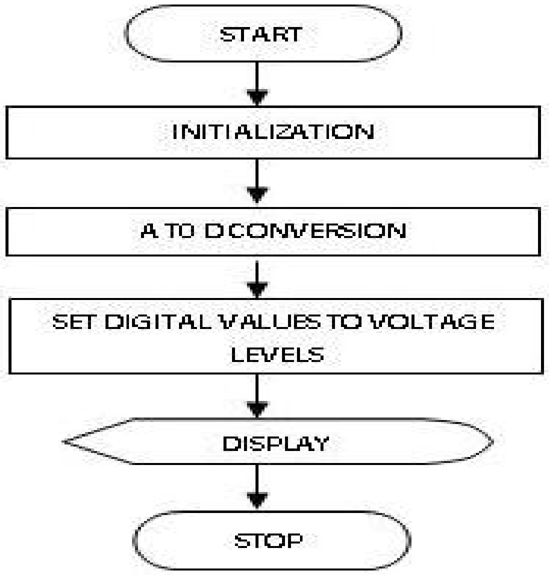

***Fig.** 5 System Flow chart*

The converted voltage level values are taken to display the pulse wave on the designed GUI. The GUI built using Qt toolkit is a C++ library and set of tools for building multiplatform GUI program [7]. The embedded Qt is an integrated development environment used for building GUI using a C++ interface.

QT Designer expands the options available for programmers, allowing them to combine which is designed visually with their source codes. The Algorithm for creating the GUI with QT Designer is listed below.

Step1: Create and initialize the child Widgets in parent Widget.

Step2: Put the child Widget in layouts.

Step3: Set the tab order.

Step4: Establish signal-slot connections.

Step4: Implement the dialog custom slots.

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III Results And Discussions

The pulses of a volunteer whose health condition is normal are acquired at two different times of the day (10 a.m. and 12 Noon). Figure-6 shows a snapshot of such two signals displayed (after acquisition and reconstruction) on the GUI.

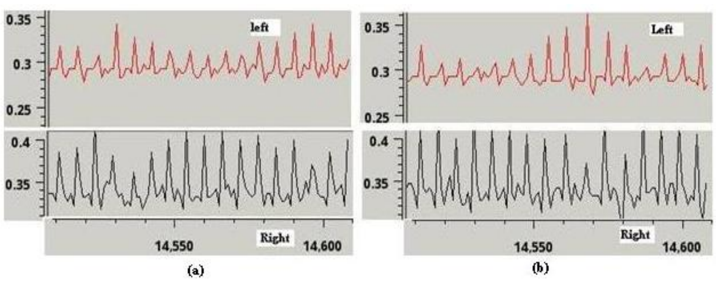

***Fig.** 6. (a) Pulse Wave at 10am of both hands. (b) Pulse Wave at 12 Noon of both hands.*

Characteristic differences/similarities between two signals acquired for the same patient at two different times can provide vital information to the doctors. A measure of similarity between signals is given by the correlation sequence [11]. In this work, pulse sequence acquired at 10 am is used as the reference signal while the pulse acquired at 12 Noon is taken as the current signal.

A measure of similarity between a pair of signal between x(n) & y(n) is given by the cross correlation sequence is given by equation (2) [11,12]

$$r_{xy}(l) = \sum_{n=-\infty}^{\infty} x(n).y(n-l), \quad l = 0, \pm 1, \pm 2, \dots \qquad (1)$$

$$r_{xx}(l) = \sum_{n=-\infty}^{\infty} x(n).x(n-l) \qquad (1)$$

After Acquisition of the pulse wave at 10am & 12 Noon, the text files are extracted and imported to LABVIEW. The LABVIEW tool is used to compute the Amplitude Auto correlation (AAC) & Amplitude Cross Correlation (ACC) and the results are depicted in figure-7. It shows a strong peak when they are correlated, the amplitude are considerably smaller when they are un-correlated

The peak amplitude values in the pulses give the systolic amplitude and depend on the blood volume.

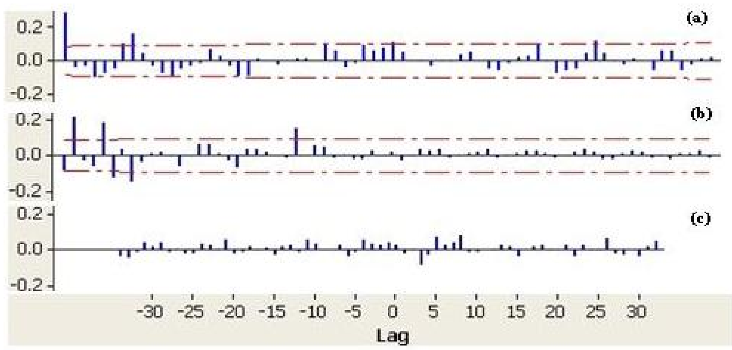

***Fig.** 7. (a)AAC of Left hand at 10am, (b)AAC of Right hand at 10am and (c) ACC of Left hand at 10am & 12 Noon.*

IV Conclusion

The SBC based pulse-wave data acquisition has been designed and tested. Pulses simultaneously acquired in real-time were displayed on the GUI, in addition to determining the AAC and ACC sequences post-acquisition. Only the initial results have been reported in this work and in future advanced algorithms will be realized to better analyze the health conditions.

References

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