



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6

Issue: II

Month of publication: February 2018

DOI:

www.ijraset.com

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Real Time Bio-signal Acquisition System

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Abstract: In this paper, the design and development of a bio-signal data acquisition system has been discussed. The system is based on ADS1299 (Integrated Circuit) IC from Texas Instruments, which is the frontend IC for bio-signal amplification and digitization. The system is integrated with Arduino UNO based microcontroller board and Lab VIEW based PC control for various processing. In this paper ECG signal has been acquired using the ADS1299 IC and designed PC software. The acquired raw and noisy ECG signal has been processed to remove various noises to obtain a clean ECG signal for further processing and storage.

Keywords: ECG, data acquisition, bio-signal, Lab VIEW, embedded system

I. INTRODUCTION

The human body is a complex integration of a number of biological systems with several ongoing physiological, functional and pathological processes simultaneously. Because of these interdependencies, the extraction of the specific signal of interest from complex environment becomes a challenging task. Biomedical signals are very low amplitude signals which needs proper signal conditioning for data acquisition [1-3]. Various data acquisition setups has been reported in the literature. In [4], a wireless based biopotential acquisition system has been presented for non-invasive brain signal acquisition. In [5], a wearable wireless data acquisition system has been reported. The system was build using CC2510 IC from Texas Instruments. Wireless data was received, processed and displayed in a mobile plate form. In [6], another Bluetooth based ECG monitoring device was developed which can transmit date to a remote computer for processing and monitoring. In our present work, our mail objective is the design and development of a battery operated bio-signal acquisition system that can work on the four most “popular” bio-signals, namely EEG, ECG, EOG and EMG. This allows for better analysis of subject’s and also has a real time waveform display feature. In this present work, we are focusing on acquiring and displaying ECG signal on real time basis using one channel. The system setup is represented by the block diagram shown in Figure 1. Data acquisition is based on ADS1299 IC and Arduino UNO board. The data is received by a PC where it is processed and displayed in a LabVIEW based program.

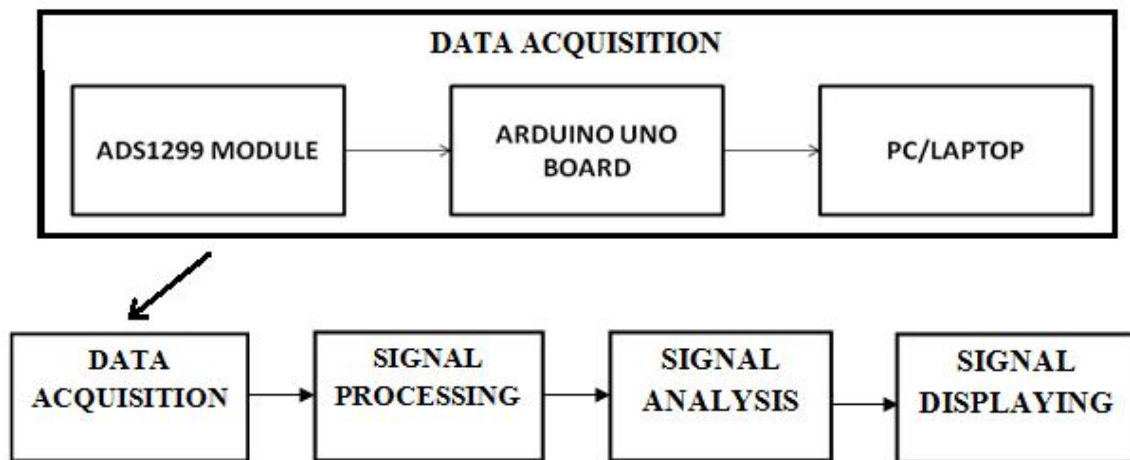


Fig.1: Process flow of proposed model

II. SIGNAL CONDITIONING AND DATA ACQUISITION SETUP

The purpose of a signal conditioning and data acquisition setup is to amplify analog signals and subsequently digitize the analog signals and store in computer in digital form, so that digital processing and analysis can be performed on the signals. A bio-signal and data acquisition system has been reported in [7]. In their system a general purpose National Instruments based DAQ card has been used as backbone for bio-signal acquisition. In [8], a low cost PIC microcontroller based data acquisition system has been

reported. The analog to digital conversion was done using the microcontrollers inbuilt ADC chip. The digitized data was transmitted to PC using serial communication and displayed in PC using Matlab software. In our present work the main goal is the acquisition of bio-signals, which are of low amplitude and noisy. Hence these signals have to be amplified to a proper level and eliminate noise present in the signals. In our present work, the heart of the developed signal conditioning system is the ADS1299 integrated circuit (IC) and data acquisition system is the Arduino UNO board.

A. ADS1299 Module

The heart of the bio-signal data acquisition circuit is the IC from Texas Instruments called ADS1299. The ADS1299 module performs analog signal acquisition, its subsequent amplification and conversion into digital form. The other important components are the Zener diodes connected back to back for each channel for additional electrostatic discharge (ESD) protection. A low pass RC circuit is also connected at each of the 8 channels. An important connection made is that all the supplies of ADS1299 are bypassed with 10 and 0.1µF solid ceramic capacitors. The ADS1299 IC consists of eight programmable gate arrays that are highly resistant to noise along with the eight 24 bit resolution delta-sigma analog to digital converters that can sample simultaneously. The IC has in total eight channels each with one PGA and an A/D converter. The IC works with a very low power of 5mW per channel and an input bias current of 300pA. The internal noise is also low and is 1 micro-Volt peak to peak. The data rates of the IC can be programmed between 250 SPS to 16 kSPS so as the gain that can be configurable at 1,2,4,6,8,12 and 24. The CMRR is -110 dB and thus the system can highly reject common mode signals [9]. The ADS1299 IC is controlled through serial peripheral interface (SPI) consisting of four signals: CS, SCLK, DIN, and DOUT. The output data is placed on DOUT pin: in the following format:- MSB bit first+ 24 status bits+ 24 bits per channel for 8 channels in binary two's complement format.

B. Arduino UNO Board

The ADS1299 has a built in SPI compatible serial interface for serial data transmission between a specific microcontroller. The microcontroller on board of the Arduino module is ATMEGA 328P which acts as the master and controls the slave device ADS1299. Arduino acts as the interface between ADS1299 and PC [10]. The Arduino used is Arduino Uno which is programmed by Arduino IDE software. Its main function is to provide timing and other necessary control commands to the ADS1299. The registers of ADS1299 are read and written through Arduino and the digitized data from the ADS1299 is received and stored in the internal registers of Arduino. This communication is serial which is via SPI. This stored data is then sent via pre-installed USB-UART port of the Arduino to the PC where it is further analyzed and displayed.

III. SIGNAL PROCESSING AND ANALYZING

The serial data from Arduino is received by PC in a LabVIEW based program. The program serially reads the digital data and performs the extraction of channel data and conversion of two's complement data to voltage form for further processing and display. The signal processing and analysing is performed by the same LabVIEW program. The detail block diagram of the LabVIEW based program is shown in Figure 2. In this block diagram of LabVIEW program, the serial port is configured according to the configuration of the UART of the Arduino. The baud rate should be always kept same with that of the Arduino. Data transmission occurs in the form of one byte at a time and thus the data bits are configured to 8 bits of the VISA SERIAL. Timeout is set to stop the process if there is no read or write process is being performed. The input buffer size is also set in this block. The digitized data received by the Arduino from the ADS1299 is in the form of 2's complement which is converted to decimal equivalent for further processing. The decimal value is then converted to its equivalent voltage by using resolution of the ADC, given reference voltage and PGA gain and is given by equation 1.

$$V = \left(\frac{D}{R} \times V_{ref}\right) \div G \quad (1)$$

Where,

V= Voltage (mV)

D= Decimal equivalent of input string.

V_{ref}= Reference voltage=4.5V

G= Gain of ADS1299=24

R=Resolution of ADC

The LabVIEW program also performs the task of processing the signals. Various signal processing blocks have been implemented in the LabVIEW program such as notch filter, high pass filter, low pass filter and median filter. Finally the signals are displayed in the output graph.

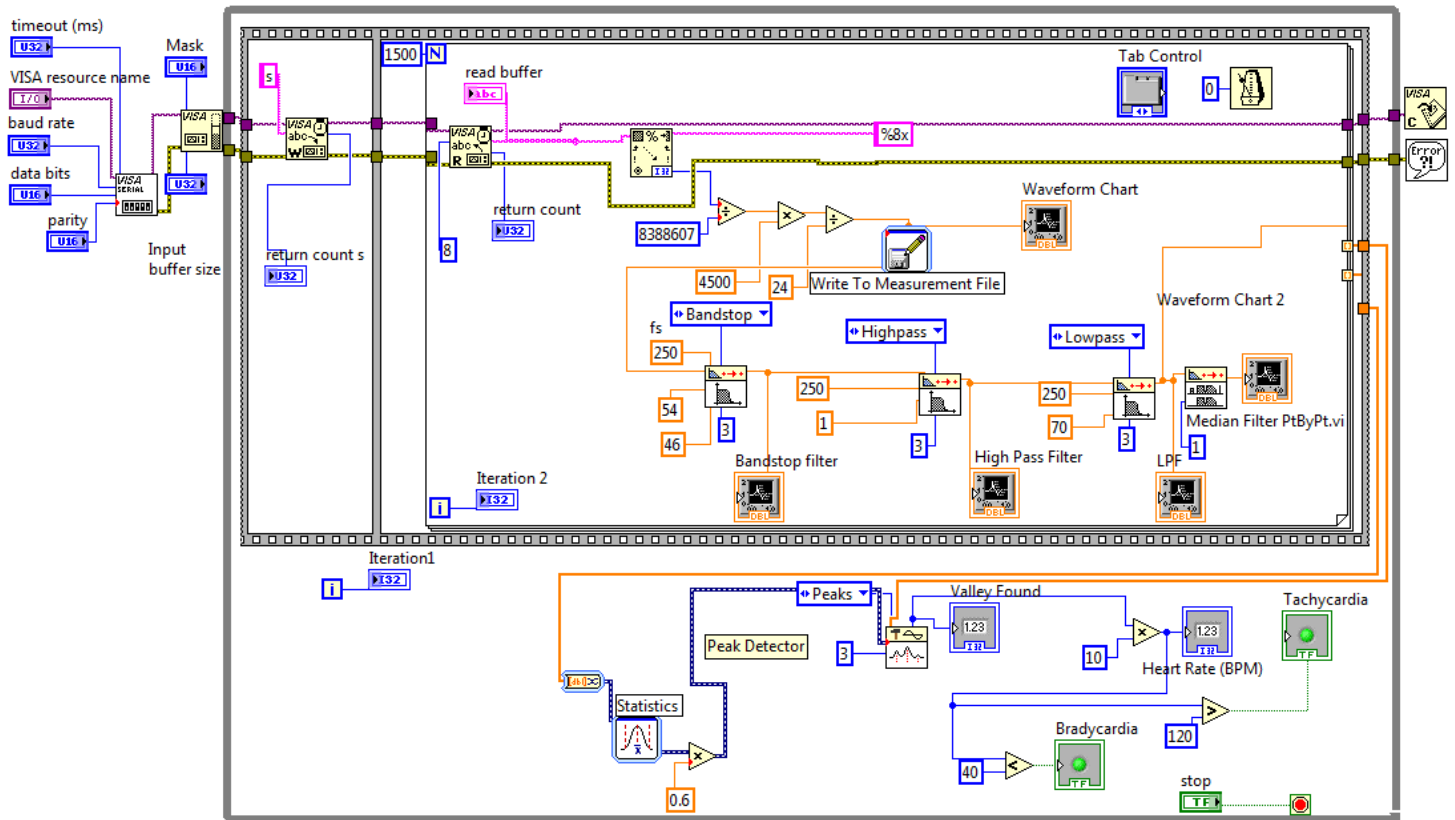


Fig.2: Block diagram design of Lab VIEW based DAQ PC software

IV. RESULTS AND DISCUSSIONS

In this section the results of various stages of processing the ECG signal is presented. First the raw ECG signal is passed through a notch filter to eliminate the 50Hz AC voltage noise of domestic supply. The signal is then passed through a high pass filter to eliminate the slow drifting of the ECG signals from baseline. The notch and high pass filtered signal is then passed through a low pass to eliminate all the high frequency noise present in the signal. The ECG of a normal person was measured from lead II position that is the positive electrode was placed in the left leg and the negative electrode was placed in the right arm's wrist. The electrodes were connected on channel 1 and the raw waveform obtained is shown in Figure 3.

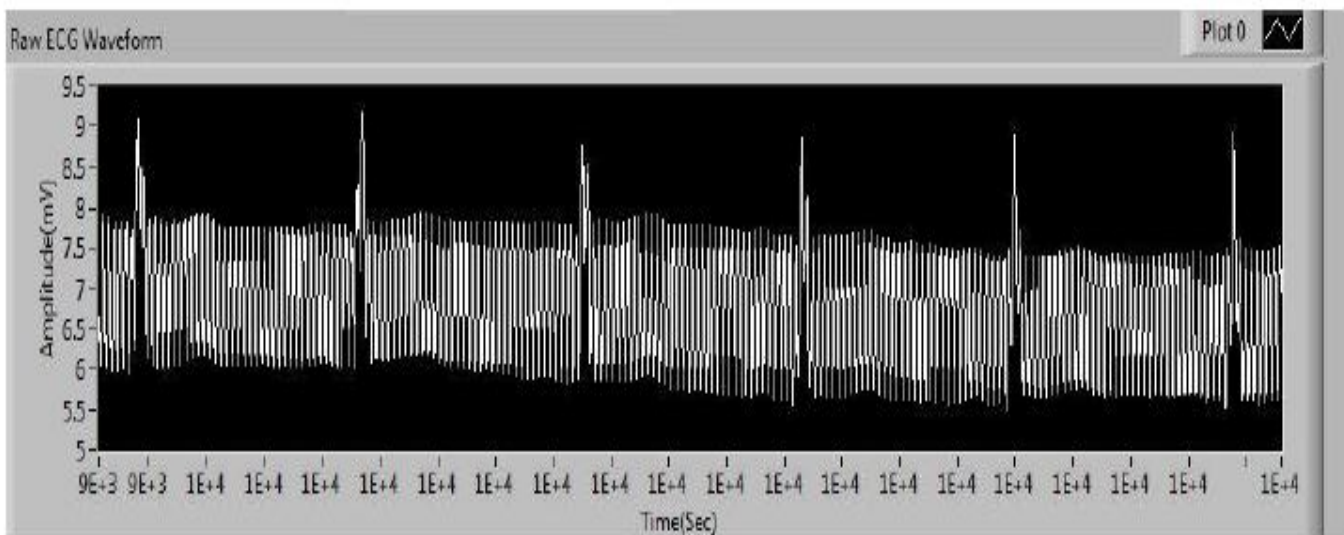


Fig 3: Original raw ECG waveform obtained from channel 1 using Lead II Configuration

Since we are dealing with real time acquisition of data in order to enhance the processing speed(as compared to an array based filter) a point by point filter has been utilized. ECG suffers from power line interference which introduces unwanted peak at 50Hz; this artifact is removed by the use of a notch filter of cut off frequency $f_L=46\text{Hz}$ and $f_H=54\text{Hz}$. Figure 4 shows the notch filtered ECG signal.

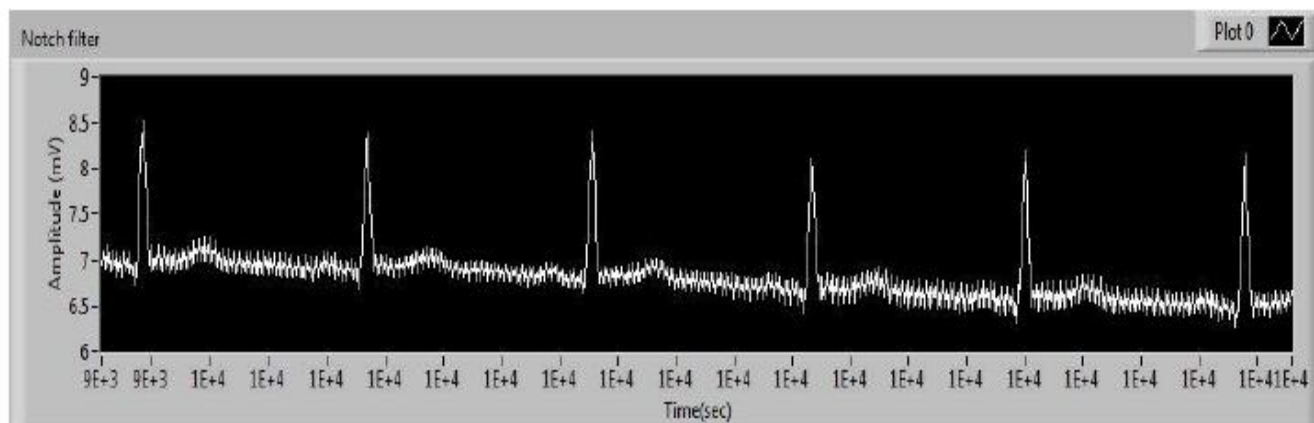


Fig 4: Point by point notch filter output using lead II configuration

The notch filtered ECG signal slowly drifts over time with a low frequency. We have used a high pass filter to nullify the effect of baseline wandering with high cut off frequency of $f_H = 0.7\text{Hz}$. The high pass filtering is also done point by point. Figure 5 shows the high pass filtered signal where the base line wander is removed.

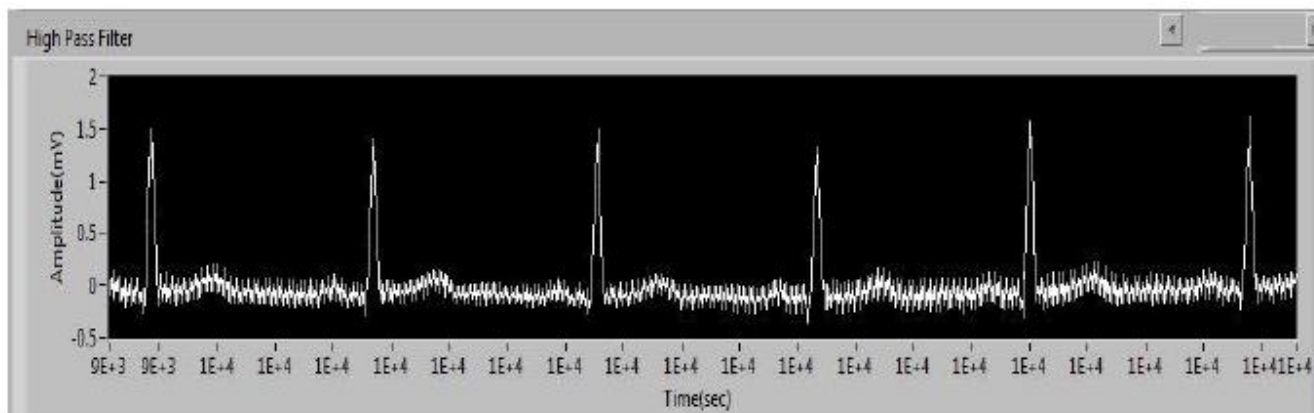


Fig.5: Point by point High pass filter waveform using Lead II Configuration

The ECG signals also contain high frequency noise like Electromyogram noise and noise due to movement of ECG electrodes. To reduce the high frequency noises, due to EMG artifacts, movement of leads etc, a low pass filter is applied with low cut off frequency $f_L= 70 \text{ Hz}$. This removes the high frequency noise present in the ECG signal. Figure 6 shows the high pass filtered signal.

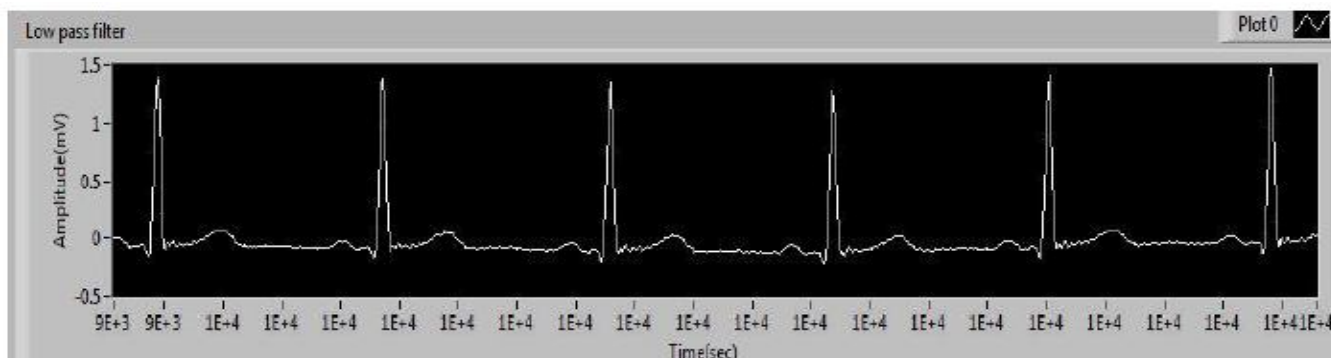


Fig.6: Point by point Low pass filter waveform using Lead II configuration

The high pass filtered signal is then smoothed for signal variations in order to obtain a smooth signal, along with a real time display, a point by point median filter is used of rank 2 is designed and applied to the high pass filtered signal. Figure 7 shows the smoothed ECG signal obtained after the point by point median filter. In the smoothed ECG signal the various features of the ECG signal is clearly visible. The smoothed signal is stored in PC host environment in a file through LabVIEW for subsequent processing.

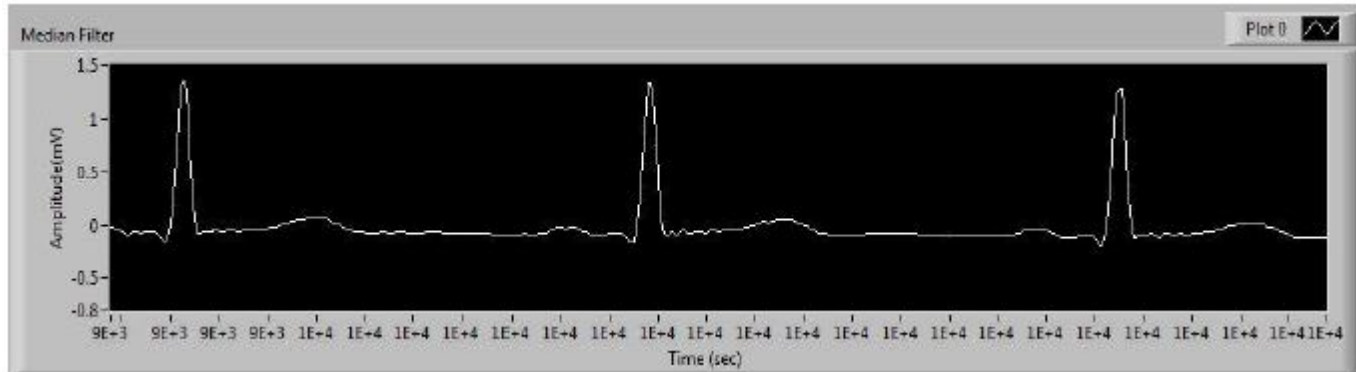


Fig.7: Point by point median filter output using Lead II configuration

V. CONCLUSION

The implementation of a real time bio-signal data acquisition system was not at all easy prior to the extreme nature of concepts related with it. Starting with biological signals, their generation and characteristics, concepts like biomedical instrumentation like Microcontroller programming language like Arduino programming language as well as software platforms like LabVIEW were largely used. In midst of all the hurdles and challenges, we are able to reach towards our objective of implementing a good quality ECG signal acquisition, to a large extent from which observer can derive optimum information with maximal ease.

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