

Acquisition, Filtering and Analysis of ECG Using MATLAB

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Abstract- This paper deals with the study and analysis of ECG signal by means of MATLAB. Study of ECG signal includes acquisition of real time ECG signal, filtering and processing of ECG signal, feature extraction and analysis of ECG signal. The acquisition of ECG signal is done by the 8-channel system hardware. It is digitized using ADC MAX1112. It offers a serial port interface. The ECG data is processed and analyzed by multipurpose software MATLAB. The MATLAB functions, toolboxes and simulink provide a better environment to process the ECG signal and analyze it. This system is cost effective along with the advantages of digital system.

Keywords: 8-Channel ECG system, MATLAB, ECG signals processing, ECG signal analysis, GUI.

I. INTRODUCTION

Electrocardiography has been in clinical use for the diagnosis and monitoring of heart abnormalities for close to a century. After the initial attempts of automated ECG analysis, there has been a continuous development of hardware and software for ECG signal acquisition, processing, parameter extraction and analysis. Electrocardiography is not only for diagnosis and monitoring of heart but an excellent tool for cardiac analysis [1]. The ECG represents a graph of variations in electrical potential generated by the heart and recorded at the body surface. The contraction and relaxation of the cardiac muscles result in generation of electrical potential which could be used to diagnose various disorders of the heart. These disorders can vary from minor to life threatening. The electrical activity of heart is sensed by monitoring electrodes placed on the skin surface. The electrical signals are very small in amplitude. These signals are within the frequency range of 0.05 to 100Hz.

The volume of ECGs recorded in hospitals is increasing. Although modern electrocardiographs have digital output most of the ECGs are still

recorded on plain paper. Recently, exchanging patients' clinical information between healthcare facilities has become very important. It will be very helpful if plain paper type ECG is replaced by a digital equivalent solution [3].

The system presented in this paper has been designed following the CSE standards. The aim of this project is to design an ECG system which could help the doctors to perform diagnosis and analysis of the heart. The system presented here is a combination of hardware and software. Hardware is used for the data acquisition and signal conditioning. Software is used for further processing of the signals. Since ECG signals are very noisy, usually 50Hz noise, MATLAB is used to test and adjust a digital filter, in order to obtain a good QRS complex. This software is very helpful for ECG data analysis. An attempt of improvement is made in this paper.

II. PROJECT FLOW

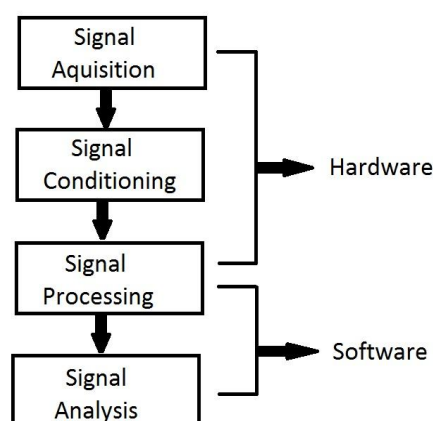


Fig 1: Project Flow

III. HARDWARE

A. Signal Acquisition

The signal is available on the body surface. This ECG signal is of mV range which is picked up by a standard Twelve Lead system with a small exception that the augmented leads and the Lead III

are derived from Lead I and Lead II using the Einthoven Triangle [4]. This reduces the hardware requirements and only eight channels for eight leads (Lead I, Lead II and six chest leads) are needed for a complete ECG [1].

B. Signal Conditioning

The signals from the electrodes are given to the buffer stage. The buffer stage uses OP07 operational amplifier and a common reference for the chest leads is developed. The summation of all the ECG signals is added together and forced on to the right leg for providing a floating ground [5]. Due to this buffer stage the signal is protected from the loading effect. The differential input from the buffers is given to the respective channels that are eight in number (See Figure 2). Channel 1 and Channel 2 measures Lead I and Lead II and remaining six channels are chest leads. The first stage of the module is a simple amplifier using an OP07 IC which provides a gain of 50. A higher gain causes reduction in CMRR. The next stage is a combination of two second order high pass filter at a cut-off frequency of 0.05Hz. In the pass band it gives a gain of 4. The third stage is a notch filter which uses a Twin Tee model providing a power supply frequency (50Hz) rejection ratio of 120dB. The notch filter provides a gain of 1.25 to reduce its bandwidth and to give a sharp dip at the power supply frequency. The last stage of the module is low pass filter which is designed on the same principle as that of the high pass filter. It also provides a gain of 4 having cut-off frequency of 100Hz. This entire arrangement gives a clear ECG waveform with suppressed surrounding and power supply frequency noise [1].

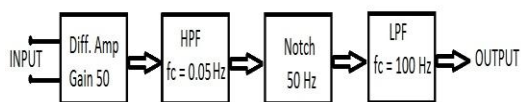


Fig 2: Block diagram of signal conditioning module

C. Signal Processing

The data from all the eight channels is now ready to be processed. For sending data to the computer, software. The software scheme is more powerful and feasible for offline ECG signal processing.

it should be converted into digital form. All the eight signals are therefore given to MAX1112. It is a low cost, low power, multichannel, serial 8-bit ADC. It is a self programmed ADC which has an 8-channel multiplexer inbuilt. This ADC is bipolar which is useful for the conversion of ECG signal as it is a bipolar signal. The 8 analog inputs are software configurable. It operates from a single 4.5V to 5.5V supply and consumes only 135uA while sampling at 50ksps. The output of one channel can be received in one byte. The maximum speed of the ADC MAX1112 is 50k conversions per second which is more than required 4k conversions for all the eight channels. The converted digital data is then serially sent to the computer. A simple program can control multiplexing, analog to digital conversion and the data acquisition. After converting into 8-bit data, it is ready to be read by the computer through serial port. After receiving the 8-bit data, next channel is selected and the conversion cycle is repeated. This process is repeated for all the eight channels. The data is immediately stored in file for signal analysis.

IV. SOFTWARE

From these eight leads the Lead III, aVr, aVl and aVf are calculated in software [6].

$$\text{III} = \text{II} - \text{I} \quad (1)$$

$$\text{aVr} = -1/2(\text{I} + \text{II}) \quad (2)$$

$$\text{aVl} = \text{I} - 1/2\text{II} \quad (3)$$

$$\text{aVf} = \text{II} - 1/2\text{I} \quad (4)$$

All the twelve leads are then stored in file for analysis.

The recorded ECG signal is often contaminated by noise and artifacts that can be within the frequency band of interest and manifest with similar characteristics as the ECG signal. In order to extract useful information from the noisy ECG signals, we need to process raw ECG signal [7]. Even though the ECG signal is filtered in hardware there is an amount of noise remaining in it which may cause a false information extraction. Usually the power line interference is suppressed in hardware but it can be removed completely in software. The software used for the signal processing and further analysis is MATLAB. This software works in windows environment.

A. Signal Processing

For removing the remaining power line noise digital filter is used in MATLAB. There is variety of techniques and algorithms which are used for the filtration of the noisy ECG signal. The DFT of the noisy signal gives the normalized frequency of the signal. Different design techniques are studied and compared to get the optimum results. Using Butterworth design technique a low pass filter and band stop filter is designed. A combination of both the filters results in a clean ECG signal (See Figure 3)

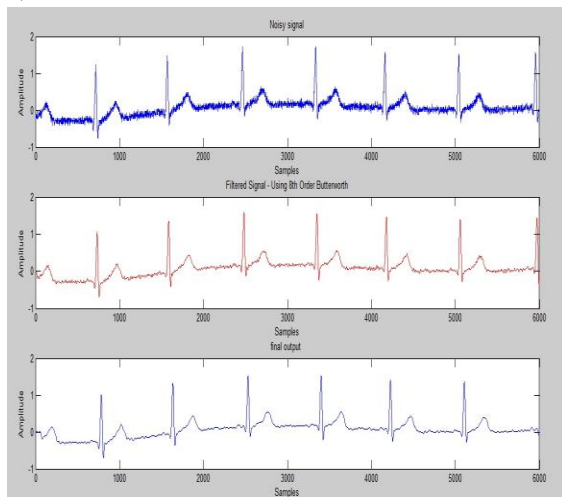


Fig 3: Noisy ECG signal, Filtered signal using 8th order Butterworth filter, Final output

B. Signal Analysis

For the purpose of diagnosis, we need to extract various features from the processed ECG data, including QRS intervals, QRS amplitudes, RR intervals, PR intervals, ST intervals, heart rate etc.

1) Heart Rate Calculation

The normal value of heart beat is in the range of 60 to 100beats/minute. A slower rate than this is called bradycardia (slow heart) and a higher rate is called tachycardia (fast heart). We can calculate heart rate of the given ECG signal with a simple algorithm used in MATLAB. After calculating heart beat RR interval can be calculated. With the help of the heart rate the condition of heart is estimated. A GUI (Graphical User Interface) is designed in MATLAB to perform the above analysis by the user (See Figure 4).



Fig 4: GUI in MATLAB for ECG processing and analysis

V. CONCLUSION

Both hardware and software have effect on signal processing. Real time ECG data is acquired and a clean ECG waveform is obtained for analysis. MATLAB is a very effective tool for ECG data analysis and abnormality detection. The whole system is very useful for monitoring the ECG signal and self diagnosis of the heart.

VI. REFERENCES

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