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Design and Development of Standard 12-Lead ECG Data Acquisition and Monitoring System

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Abstract

This paper presents a low cost and portable 12-lead ECG data acquisition and monitoring system based on microcontroller. Surface mount devices (SMDs) are used to realize a compact system. The system consists of two parts, analog pre-data acquisition part and digital data processing part. In analog pre-data acquisition part, it composes of three channels measuring circuits and lead selector. Each channel includes analog 0.7Hz to 20Hz band pass filter and amplifier with the overall gain of 900. In accordance with the tested measurement, percent gain error is low. In digital data processing part, the microcontroller is programmed using C-language. USB interfacing is also used to transfer the data to PC. The 12-lead ECG system can be performed by using the lead selector which is controlled by the microcontroller.

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*Keywords:*12-lead; ECG; data acquisition; USB

1. Introduction

In medical services, the signals from human body are important for diagnosing the diseases. One of the most interesting signals is electrocardiogram (ECG). ECG can be measured as a voltage with amplitude of a few mV, normally in the range between 1mV and 4mV on the human body. Therefore, it requires a high amplification to identify it clearly. It is known that the frequency bandwidth of the ECG is in the range of 0.05Hz to 100Hz[1]. Basic features of the ECG wave are P, Q, R, S and T wave. Sometimes U-wave is also observed however it is not clear

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and not so significant. P-wave is appeared when the left and right atria are activated and atrial depolarization occurs. QRS complex can be seen when the ventricles are stimulated and ventricle depolarization occurs. Ventricular re-polarization can be recorded as the ST segment, T-wave and U-wave[2].

Many techniques have been proposed for ECG measurement and monitoring systems such as the use of minicomputer and microprocessor[3]. Tape based recording and monitoring ECG systems are large, heavy and expensive for home care. To get more advantage than the tape based ECG recording systems, Fezari, Bousbia-Salah and Bedda[4] described a single chip microcontroller based ECG monitoring system. PC based ECG monitoring systems for home health services have also been proposed[5, 6]. Most of the systems are expensive and limited to use. Ali S. AlMejrad[7] proposed the design of single channel ECG based on standard 8051 microcontroller. However, those systems could perform only single lead.

2. Experimental Method

System block diagram for the overall system is shown in Fig. 1. Standard 12-lead ECG data acquisition and monitoring system is generally composed of seven stages. From the first stage to the fifth stage can be called as analog data acquisition unit. The last two stages are digital data processing unit. Each stage is as follow:

Stage-1: Ten disposable electrodes, Stage-2: Lead selector, Stage-3: Three channels differential amplifiers, Stage-4: Three band-pass filters, Stage-5: Offset level shifter, Stage-6: Digital data processing using microcontroller and Stage-7: Personal computer or notebook computer.

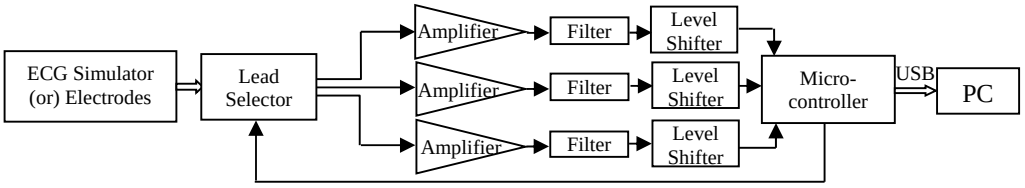

Fig. 1. System Block Diagram

2.1. Analog data acquisition unit

Analog data acquisition unit has five stages. In the first stage, ten disposable electrodes were put on the related body surface, which include six chest electrodes (V1 to V6) and four limbs leads electrodes (left arm, right arm, left leg and right leg). Electrode at the right leg was used as a reference electrode and connected to ground. Shielded cable and DB15 connector were used to link with those ten electrodes and lead selector stage.

The second stage, lead selector acts like a multiplexer for selecting a proper lead measurement. Solid stage switches, 74HC4316 were used in that stage. By using solid stage switches, it can also reduce the switch contact noise which occurs when using the mechanical switches. Switches were controlled by microcontroller to select the lead automatically at each fifteen-second interval. This will rotate to measure all twelve channels.

In the third stage, three instrumentation amplifiers (INA121) were used to take the three channels ECG data simultaneously. Surface mount device type, INA121 amplifier is a low power consumption amplifier with high impedance FET input. It also has excellent accuracy. Gain can be set from 1 to 10,000 with a single R_G resistor. Adaptor (220V AC/+9VDC), ICL7660S converter IC, 7805 and 7905 regulator IC were used to get +5V and -5V dual power supply for this stage.

Fourth stage is band-pass filter. Band-pass filter with gain control for one channel is shown in Fig 2.a. Frequency response curve for overall gain = 900 (59dB) is shown in Fig 2.b. In this stage, band-pass filter was implemented by cascading first order passive high pass filter, second order passive low pass filter and first order active low pass filter with gain control. Surface mount device (SMD) type, TL082 Op-amp and RC components were used to design the filter in this stage. Gain can also be changed. The magnitude of the voltage gain in low pass filter is a function of the feedback resistor divided by its corresponding input resistor value. Its gain equation is shown in Eq. 1.