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Development of Portable ECG Measurement Device and PC Software for Automatic ST Analysis

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Abstract: ECG is used on purpose to keep good health or monitor cardiac function of aged person as well as on purpose to diagnose the disease of heart patients. The ambulatory ECG monitoring system under guarantee of safety and accuracy is very efficient to prevent the progress of heart disease and sudden death. These systems can detect the temporary change of ECG that is very significant to diagnose heart disease such as myocardial ischemia, arrhythmia and cardiac infarction. In this paper, we describe the ECG signal analysis algorithm and measurement system for ECG monitoring. The designed small-size portable ECG device consisted of instrumentation amplifier, micro-controller, filter and RF module. The developed device measures ECG with four electrodes in the body and detects QRS complex and ST level change in real-time. Also it transmits the measured signal to the personal computer. The developed software for ECG analysis in personal computer has the function to detect the feature points and ST level change.

Keywords: ECG. QRS complex, ST level, ST shape, myocardial ischemia.

1. INTRODUCTION

Myocardial ischemia is a disorder of cardiac function caused by insufficient blood flow to the muscle tissue of the heart and a prime cause for the occurrence of cardiac infarction and dangerous cardiac arrhythmias. The main ECG symptom related with myocardial ischemia is ST change, and the symptom is transient. Therefore, it is necessary to monitor and analyze the ECG of a person who is suffering from heart disease for 24 hours[1-5].

The ambulatory ECG monitoring system is very efficient to prevent the progress of heart disease and sudden death. These systems developed until now, the so-called holter systems consist of the portable ECG recorder, data reader, analysis software and PC or workstation. User measure and record ECG by oneself as carrying the portable ECG recorder, and analyze the recorded ECG using analysis software based on PC or send that to physician in hospital. ECG analysis process of most holter systems is off-line except several systems that detect QRS by real-time and make warning sound at dangerous situation.

In this paper, we designed the portable ECG measurement device and ST analysis algorithm. The portable ECG measurement device have two channels and communicate to PC by digital radio way. Most portable ECG devices have the functions about real-time ECG auto-analysis, but these are simple analysis such as an abnormal pulse monitoring by detecting QRS complex.

We developed the real-time ECG analysis algorithm for micro-controller and the algorithm could detect the QRS complex and ST-segment level change. The detecting of ST-segment level could be used in the alarm system about ischemic episodes and in the monitoring system about myocardial ischemia. The first step in the detection of ST-segment level is to detect feature points, such as the QRS complex, J-point, etc. In the process of feature point detection, the morphological characteristics of the QRS, such as the steep slope and high amplitude, are used to detect the QRS complex. And then, the developed algorithm detects the level of ST-segment.

ECG analysis software based on PC is developed for the advanced analysis of ECG. The developed software has the function to detect the feature points and ST-segment level and to classify an ST shape type according to its morphological shape difference.

2. ALGORITHM FOR ST SHAPE ANALYSIS

To detect the transient changes of ST, we classify the ST segments by their morphology. First, a set of reference ST shapes is given. An ECG analysis algorithm developed in this study consists of feature point detection and ST shape classification. S wave and J-point detection are performed during the process of feature point detection, and the proposed algorithm classifies the STs into reference ST shapes. To improve the performance of ST shape classification, the rules for the trend of previous beats and the shape type of previous beats are used.

Detection of feature points

The feature points like PR level point, J-point, S wave, etc. are detected by a searching method based on the R peak. (a) and (b) in Fig. 1 show the establishment of detection area for finding S, Q and T wave. The duration of the Q wave detection area is 160ms. Normally, the PR interval is 120ms to 200ms, and the period of 160ms includes the duration of the P wave. Therefore, 160ms includes, at least, the half duration of the QRS complex and the beginning of the Q wave. We divided the Q wave detection area into four parts as shown in Fig 1(c) and found the minimum point or the inflection point as Q wave. After Q wave detection, PR level point is detected by finding the inflection point around for Q wave. S wave is detected by the same method used in Q wave detection as shown in Fig. 1(d). J-point is also detected by finding the inflection point around for S wave[6].

Calculating ST level

The ST level was measured based on the definition of ST episodes in the European ST database[7]. ST segment deviation was measured 80ms after the J-point if the heart rate had not exceeded 120 bpm. The ST segment deviation was measured 60ms after the J-point if the heart rate had exceeded 120 bpm. The beginning of an ST level episode is located by searching backward from the time when the absolute ST deviation first exceeds 0.1mV until a beat is found, for which the absolute ST deviation is less than 0.05mV. We ignore the variation which does not maintain its level for 5sec to produce a continuous section of ST level change. The end of an ST level episode is located by searching forward from the time when the absolute ST deviation last exceeded 0.1mV until a beat is found, for which the absolute ST deviation is less than 0.05mV. And, ST episode section has to keep the absolute ST deviation no less than 0.1mV during at least 30sec.

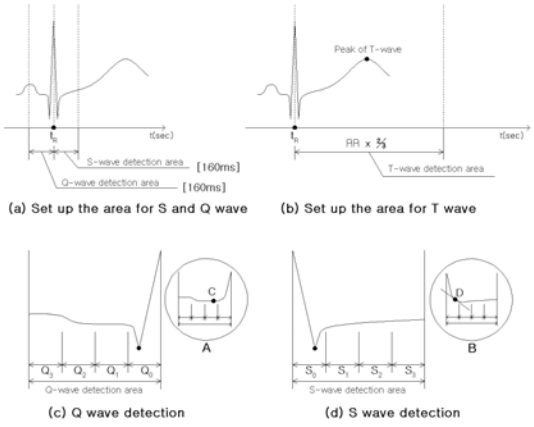

Fig. 1 Detection of feature points

ST shape classification

ST shape classification in ECG data was performed by comparing the four slopes of an ST in ECG data with those in the reference set. Using the four slopes, it was easy to distinguish among concave, convex and negative-T type, and it was easy to distinguish these types from upsloping, horizontal and downsloping. The problem is to distinguish among upsloping, horizontal and downsloping, because the difference among these types is only the slope in the middle region. Therefore, we developed a rule set for improving the performance of ST shape classification among upsloping, downsloping and horizontal. Fig. 2~5 show the results of the ST shape classification.

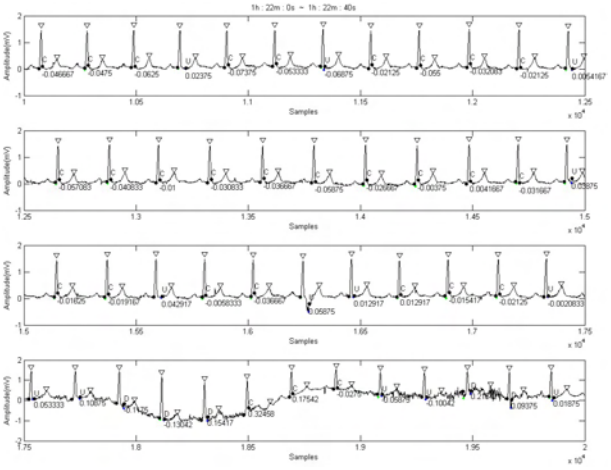

Fig. 2 STs of concave type

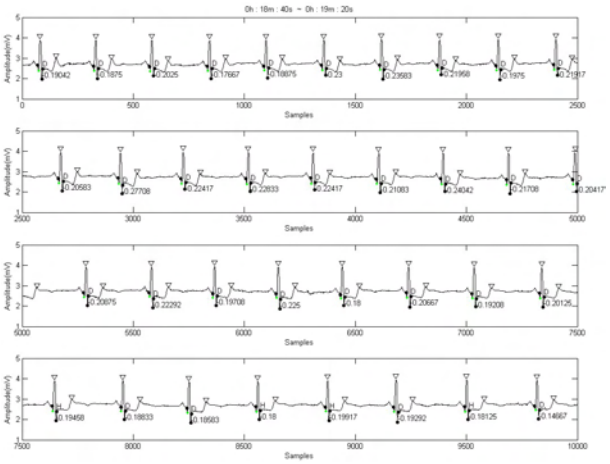

Fig. 3 STs of downsloping type

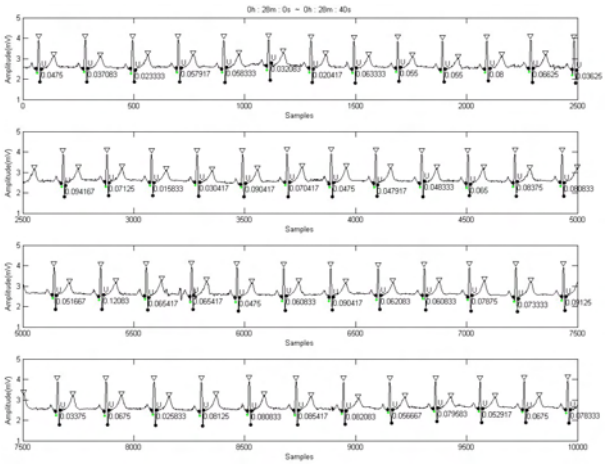

Fig. 4 STs of upsloping type

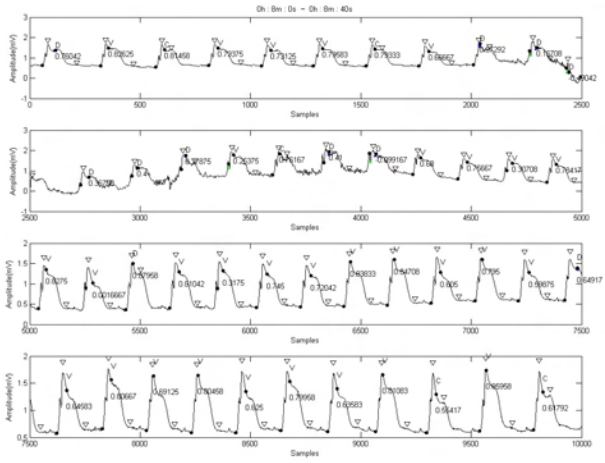

Fig. 5 STs of convex type

3. ECG ANALYSIS SOFTWARE

Fig. 6 is ECG analysis software, which was developed using LabVIEW program. The software displays the results from ECG shape classification. ST level is also displayed below ECG signal. From this window, we can get the information of ST shape and ST level change.

Fig. 6 ECG analysis software

4. PORTABLE ECG DEVICE

The portable ECG measurement device consists of instrumentation amplifier, filter, micro-controller and transmitter module. Hardware configuration of ECG measurement device is shown in Fig. 7.

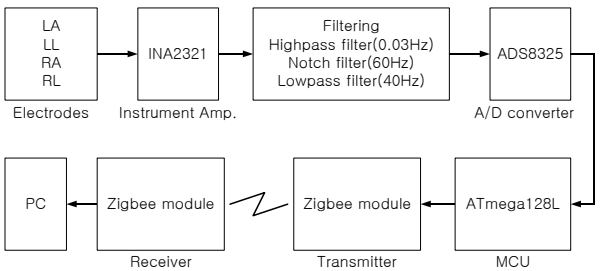

Fig. 7 Hardware configuration of ECG device

After amplification and filtering, the ECG signal is fed through micro-controller. We used ATmega128L for micro-controller, Zigbee module for transmitter and receiver, INA2321 for instrumentation amplifier. INA2321 is a low cost, high accuracy instrumentation amplifier that offers lower power (only 60μA quiescent current), making it a good fit for battery-powered, and portable applications. The low noise, low input bias current and low power of the INA2321 make it well suited for medical applications such as ECG. We composed 40Hz low pass and 60Hz notch filter using OP amp. The device has two channels, and each channel is measured and analyzed simultaneously. Sampling rate is 250Hz and A/D resolution is 15bit. Available distance of transmitter module is 100m but if chip antenna is used, the range could be over 1.6km. The communication with PC is performed through serial port through the receiver module connected in PC. Fig. 8 is the circuit for portable ECG measurement device.

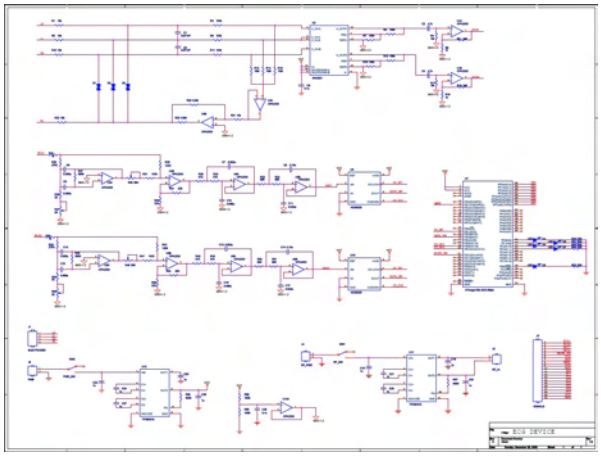

Fig. 8 Portable ECG device circuit

5. CONCLUSION

The ambulatory ECG monitoring systems are very efficient to detect the transient abnormal change like ST-segment level change. In case of myocardial ischemia, it can improve the effectiveness of the ambulatory ECG monitoring systems to give the function about detection of ST-segment change.

The authors designed a small-size portable ECG device. The size of ECG device is 76mm by 59mm. The device measures ECG with four electrodes on the body and available range of RF module is 100m but if chip antenna is used, the range could be over 1.6km.

ECG monitoring and ECG analysis software were developed by using LabVIEW program. ECG analysis software has the function to detect the feature points, ST-segment level and shape.

From the developed device and software, we can monitor an ST level change and irregular pulse in real-time. This can improve the detection of abnormal change which appears transiently in ECG.

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