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## Real-time feature extraction of ECG signals using NI LabVIEW

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### ABSTRACT

This study is based on measuring the Electrocardiogram (ECG) signals from the human body in real-time with the help of the software called NI LabVIEW. Not only the raw ECG signals, the digital filtered version of the ECG signals can also be displayed in real-time by processing the signals using the digital filtering tools of the program. The ECG itself provides various diagnostic information and NI LabVIEW biomedical toolkit offers many tools that helps to process the signals and perform feature extraction. Thus, this software was preferred for the ECG data acquisition. In this project, heart rate of a patient is calculated by detecting R-R intervals on the ECG tracing using the method called Teager Energy. In order to test the system, several experiments have been conducted with 12 subjects (6 non-smokers + 6 smokers). Their ECG signals were taken in relaxed and after running conditions. The experimental results were recorded for the graphical and statistical analysis. According to the results, the effect of smoking to the heart rate was discussed.

**Keywords:** Electrocardiogram (ECG), Feature Extraction, NI LabVIEW

### NI LabVIEW kullanarak EKG sinyallerinin gerçek zamanlı özellik çıkarımı

### ÖZ

Bu proje, NI LabVIEW programı sayesinde insan vücudundan gerçek zamanlı elektrokardiyogram (EKG) ölçümüne dayanır. Sadece ham sinyaller değil, programın filtreleme toolları sayesinde dijital filtrelenmiş EKG de gerçek zamanlı görülebilir. EKG sinyalinin kendisi birçok diagnostik bilgi içerir. NI LabVIEW biomedical toolkit, biyomedikal sinyalleri işleme ve özellik çıkarımı için birçok tool barındırır. Bu nedenle, EKG verilerini almak için bu program tercih edilmiştir. Bu çalışmada, EKG sinyali üzerinden R-R dalgaları tespit edilerek hastaların kalp atış hızı Teager enerji metodu ile hesaplanmıştır. Bu sistemi test etmek için 12 kişi üzerinde birtakım deneyler yapılmıştır (6 sigara içmeyen + 6 sigara içen). Deneye katılan insanların dinlenme halindeki ve koştuktan sonraki EKG dataları ölçülmüştür. Bu deneylerin sonuçları grafiksel ve istatistiksel analizler için kaydedilmiştir. Bu sonuçlara göre sigara içmenin kalp atış hızına etkisi tartışılmıştır.

**Anahtar Kelimeler:** Elektrokardiyogram (EKG), Özellik Çıkarımı, NI LabVIEW

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## 1. INTRODUCTION

The ECG is defined as recording of the heart's electrical activity. In the normal state, cardiac cells are electrically polarized. Inner sides of the cardiac cells are negatively charged whereas the outer sides are positively charged. The essential activity of the heart is called depolarization. In the process of depolarization the cardiac cells can lose their normal negativity. This depolarization spreads out from cell to cell, generating a wave of depolarization that can be transferred through the entire heart. A flow of electric current is produced by the wave of depolarization. With the help of electrodes on the body, this current can be detected. When the depolarization is completed, the cardiac cells restore their normal polarity by a process called repolarization which is also sensed by the electrodes [1].

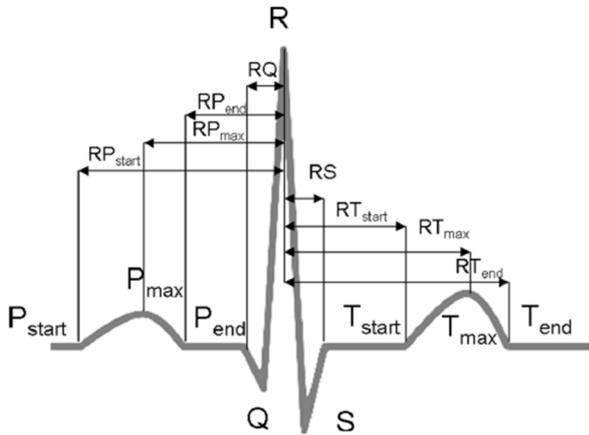


Figure 1. Peaks and valleys of an ECG signal

In the figure above [2] a sample of ECG is displayed which is characterized by five peaks and valleys labeled by the letters P, Q, R, S and T. The ECG analysis depends on the correct and reliable detection of these peaks. In the ECG analysis, the QRS complex detection is an essential task. When the QRS complex is identified and detailed accurately, then the heart rate can be calculated and some other analysis such as ST segment can be performed.

The normal heart rate range lies between 60 and 100 beats per minute (bpm). The heart rate depends on the time between two R waves. In the formula below [3] calculation of heart rate is shown:

$$\text{Heart Rate} = \frac{1}{R-R \text{ interval (sec)}} \times 60 \quad (1)$$

Since the ECG signals are generated by human body, biomedical instrumentation play an

important role for the ECG measurement. The ECG signals are low in amplitude and contaminated by several noises. Therefore, it is not easy to obtain smooth ECG signals.

In this study, an ECG module AD8232 and its surface electrodes were used to measure the signals from the body. NI myDAQ card was used as a data acquisition platform. In addition to that, NI LabVIEW application, which is especially design for data acquisition, was used for data recording and visualization due to its useful tools. In order to obtain ECG signals without any noises, digital filtering tools that is provided in LabVIEW was used.

## 2. MATERIALS AND METHODS

In this project, firstly the raw ECG signals were obtained using AD8232 ECG module through surface electrodes. This module is an integrated signal conditioning circuit for bio-potential measurement applications. It is designed to extract bio-potentials and perform amplifying and filtering the signals as well [4]. In order to measure the signals, the electrodes are placed on the skin of patient. Locations of the electrodes are specified by Einthoven triangle which refers left and right arms and the left leg as well.

Laboratory Virtual Environment Workbench (LabVIEW) is a software that is provided from the National Instruments Company. In recent years, LabVIEW has become a very popular programming language for measurement and automation [5]. It functions as virtual instrumentation. This software provides a platform that has several tools to perform applications especially in real-time [6]. In order to develop an algorithm in the program, all required functions must be performed in the block diagram. There is also a platform called GUI to control the block diagram. Figure 2 shows the block diagram environment and the GUI as well.

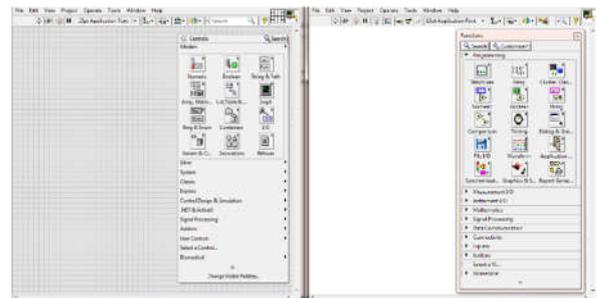


Figure 2. GUI and block diagram of the program

NI myDAQ card is an acquisition platform that converts the analog signals into a digital form. This card provides digital input and output (DIO), analog input and output (AIO), audio, power supplies and digital multimeter (DMM) functions in a compact USB device. It allows user to measure and analyze real-world signals. Combined with NI LabVIEW on the PC, the user can process and analyze acquired signals anytime [7].

In order to obtain waveform of the ECG in this project, the AD8232 module was connected to the card. The card and its connections to the ECG module is displayed in figure 3.



Figure 3. AD8232 ECG module and NI myDAQ card

In LabVIEW, DAQ Assistant tool was used to acquire data from DAQ card into the program. Acquisition mode was chosen as continuous mode in configuration settings of the tool. Additionally, sample rate was 1k (Hz) and sample to read was 3k for the signal. In the figure below, DAQ Assistant and its connection is shown.

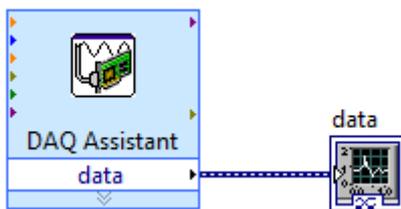


Figure 4. DAQ Assistant tool in the block diagram

When the measurement started from the body, firstly the analog signal was sent to the DAQ card and then the signal was converted into a digital form. With the help of DAQ card tool, the data was acquired. After the data was taken, as a next step signal processing was performed. Therefore, the signals could be seen on the GUI of the program in a smooth waveform. Finally, according to user choice the data was recorded. Figure 5 shows the flowchart of the program.

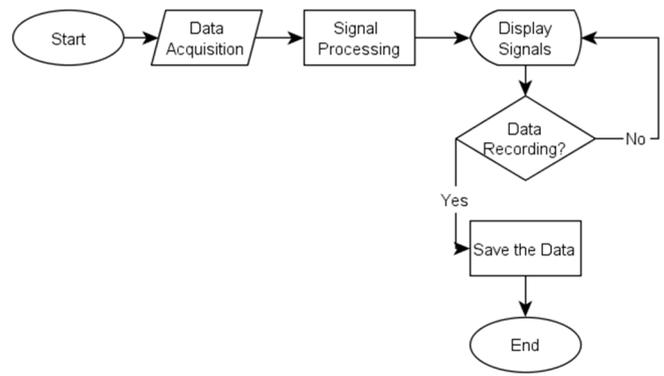


Figure 5. Flowchart of the program

Filtering is one of the most important task in bio-signal processing. After receiving the raw bio-signals from human body through electrodes, it has to be processed in order to bring the signal in detectable form. Since this task is focused on the ECG signals, first step was setting the bandwidth of the signal. To do so, firstly band-pass filter was used. After that, band-stop filter, detrending and wavelet denoising have been performed on the signal.

Band-pass filter is a combination of low-pass and high-pass filter. It basically attenuates lower and higher frequencies from the desired signal frequency range [8]. For the extraction of ECG signals, 0.01 Hz was chosen as low cut-off frequency whereas 120 Hz was high cut-off frequency. The type of filter was Butterworth filter which makes the frequency response of the signal smoother [9]. Additionally, the band-pass filter order was 7.

Band-stop filter is a series combination of high and low-pass filter. This type of filter eliminates the noise which lies in the specific range such as 50 Hz power line interference [10]. Notch filter is a special type of band-stop filter that eliminates power line noise. In the band-stop filter tool of the program, cut-off frequencies were chosen 49 Hz and 51 Hz. Therefore, 50 Hz was removed. Figure 6 shows the band-pass and band-stop filter tools and their connections in the block diagram.

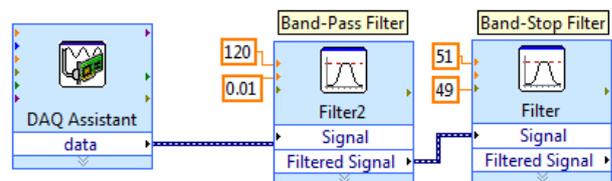


Figure 6. Band-pass and Band-stop filters in LabVIEW

In recent years, wavelet transform became one of the most powerful time-frequency analysis and signal coding tool. It has been particularly useful to process bio-signals especially in case of ECG signals [11]. Wavelet transform represents functions with discontinuities and sharp peaks. This is based on distributing continuous time signals into different scale components. Therefore, after reconstruction of the signal, this non-stationary and non-periodic signal can be seen smoothly [12]. In order to obtain ECG signals accurately, Wavelet transform approach was used in LabVIEW.

One of the ECG contaminants is known as baseline wandering. This noise lies in the frequency range of 0.15 Hz and 0.3 Hz. Baseline wandering can be removed by eliminating the trend of the ECG signal [13]. In the formula below, where t is sampling duration and N is number of sampling points of the signal, the trend level calculation is given:

$$trend\ level = \frac{\log_2 2t}{\log_2 N} \quad (2)$$

According to the formula, trend level of the ECG signal was found 0.7 and wavelet was chosen db06. After removing baseline wandering, the ECG signal was clearer than the original form. Nevertheless, some type of noises, such as wideband noise, might still effect to the signal. Therefore, the wavelet denoising tool was used to remove such artifacts. This method is based on decomposing the ECG signals and then by applying threshold modifying each wavelet coefficient, and finally reconstructing the denoised signal. Therefore, thresholding the wavelet transform will remove the low amplitude noise or undesired signals. In fact, it can remove any noise overlap as little as possible in the frequency domain [14]. In the program, the type of wavelet was set to undecimated wavelet transform (UWT) and db06 was chosen as wavelet [15]. Additionally, soft thresholding was used. Figure 7 displays the detrending and denoising tools and their connections in LabVIEW.

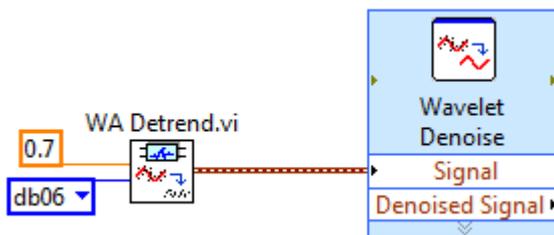


Figure 7. Wavelet Detrending and Denoising in LabVIEW

In order to extract any information from an ECG trace, the signal must be obtained clearly. After completing the filtering process, the next step was focusing on feature extraction.

In this study, the algorithm was made according to R-peak detection. Since the time interval between two periodic R peaks is key issue for the heart rate calculation, firstly amplitude information of the ECG peaks was used. Compare to the other peaks, R peak has the highest amplitude. By using Biosignal Rate Extractor.vi in LabVIEW, firstly low and high threshold values were defined. According to the formula 1, heart beat per minutes could be calculated. Because of the risk that other peaks might reach that threshold values, the results were not reliable. To get rid of this problem, another method called Teager Energy was implemented to the algorithm.

R-peak detection is an essential task in feature extraction. There are several methods for detecting R-peak [16]. In this study, Teager Energy Method, which is based on squaring the signal amplitude, was used. Therefore the peaks which have amplitude in the range of 0-1mV, will be attenuated. Since R-peak has the highest amplitude and it is greater than 1mV, R-peak will be detected more accurately [17]. Figure 8 shows the determination of the heart rate with Teager energy method.

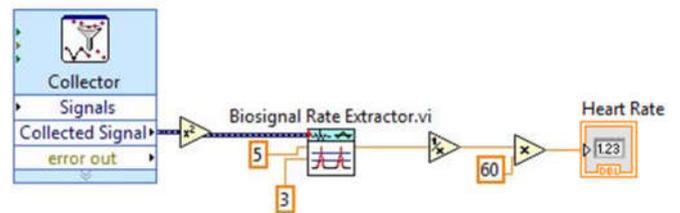


Figure 8. Determination of heart rate using Teager energy method

To use the ECG data for further analysis, it has to be recorded. Therefore, another small algorithm was implemented to the main program. This allows user to record the data on the pc during measurements.

After completing the entire program, the results were displayed on the GUI of LabVIEW. Figure 9 shows the measured signals in three different form. First one is the original noisy signal. The second one is the filtered signal. The last one shows the signal with Teager energy method. Additionally the heart rate can also be seen in real-time.

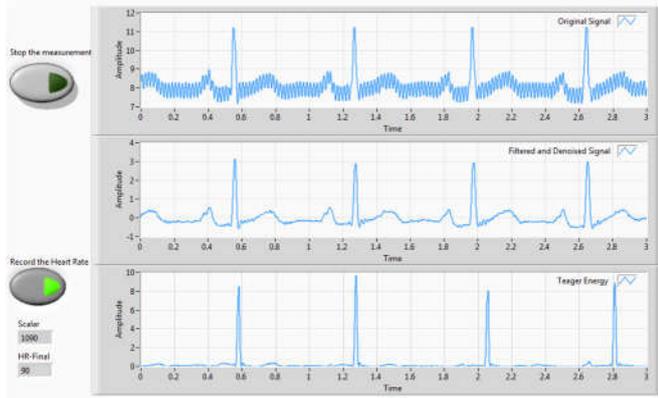


Figure 9. ECG Signals on GUI of the program

After completing the program, the next step was testing the system. In order to test the application, several experiments have been run. During the experiments ECG signals and heart rate values were recorded for each participant. In total, 12 person were participated to the trials. 6 of them were smokers and other 6 of them were non-smokers. All of them were male and their age range lies between 21 and 27.

Firstly, the participant was asked to sit and close their eyes for the relaxing period. Their signals were taken for 2 minutes and recorded. Later on, the participant was asked to run on the smooth floor for 2 minutes as well. After he run, another measurement was performed and the signals were recorded. These steps were repeated for each 12 participants. The recorded data was loaded to MATLAB for the graphical representation and loaded to Microsoft Office Excel 2013 for the statistical analysis.

### 3. RESULTS

In this study, the ECG signals of 6 smoker and 6 non-smoker subjects were measured and their heart rate values were calculated in relaxing and after run condition. The heart rate values were calculated for each subject and the results were represented graphically. Figure 10-a and 10-b represent the graphical results for the non-smoker and smoker subjects.

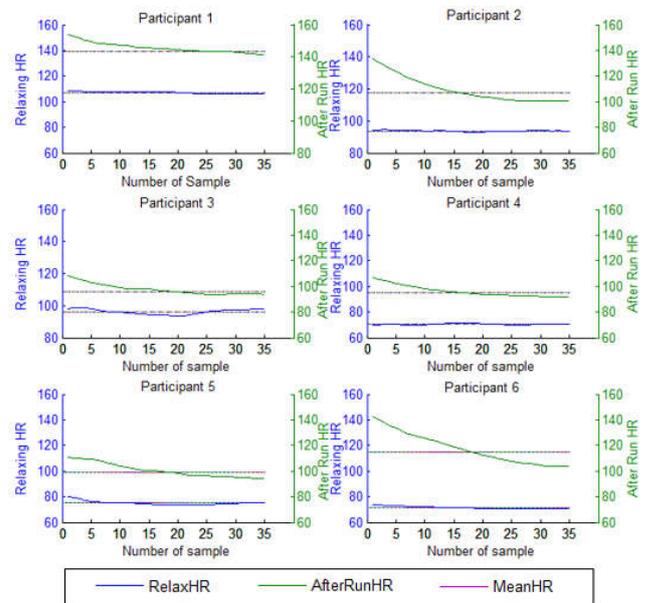


Figure 10-a. Experimental results of non-smoker subjects

The left y-axis of the graphs, which is in blue color, represents the heart rate values when the participant were relaxing, whereas the right y-axis, which is in green color, shows the heart rate values after the participant run. Moreover, the x-axis represents the number of sample, which means 35 different calculated heart rate value. In addition, the smooth lines on the graphs stand for the mean values for both relaxing period and after run. The legend of the graphs are displayed on bottom of the graphs.

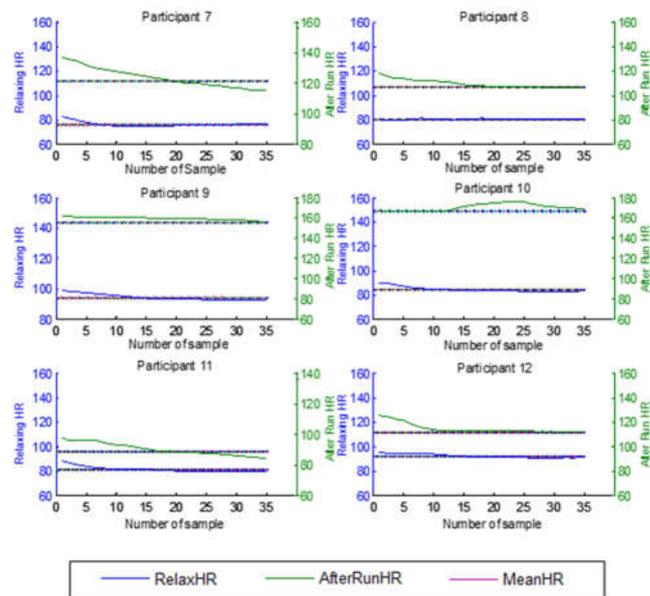


Figure 10-b. Experimental results of smoker subjects

As it can be seen on the results that heart rate values are individual for each person. Therefore, it is not possible to say direct results just by looking at the graphs. Thus, addition to the graphs, statistical analysis were performed. Firstly, mean,

standard error, median, standard deviation values were calculated. Moreover, range, minimum, maximum, count and summation values of the total data were obtained and the results are displayed in a tabular form. Table 1 shows the statistical results of the all subjects' data.

Table 1. Statistical Analysis of the results

	Relaxing	After Run
Mean	85.25	119.53
Standard Error	03.29	07.48
Median	82.96	112.05
Standard Deviation	11.43	25.94
Range	36.63	80.6
Minimum	70.48	90.09
Maximum	107.11	170.69
Sum	1023.09	1434.43
Count	12	12

In order to analyze the experimental results, t-test was used. A t- test is a statistical test that follows t- distribution. The reason to use t-test in this project was to determine if two sets of data (relaxing- after run) are significantly different from each other. Statistical analyses were performed in the Microsoft Office Excel 2013. The t-test results of the subjects are displayed in Table 2.

Table 2. Results of the t-test

Relax.HR	AfterRun.HR		Relax.	AfterRun
107.11	145.62			
93.78	109.12	<b>Mean</b>	85.25	119.53
96.21	97.63	Var.	130.64	673.10
70.48	96.18	Obser.	12	12
75.17	100.53	Pear.Cor.	0.37	
71.38	117.37	Hyp.M.Dif	0	
76.12	123.51	df	11	
80.39	109.48	t Stat	-4.93	
94.39	159.53	<b>P one-tail</b>	0.0002	
84.64	170.69	t Crit.one	1.7958	
81.27	90.09	P two-tail	0.0004	
92.11	114.63	T Crit.two	2.2009	

In Table 2, first and second columns represent the mean relaxing and after run heart rates of each participants. In t-test, p value is a key issue to obtain any results. In this test, p value was considered as 0.05. To understand whether there is significant different between two data sets, the p value should be less than 0.05. In fact, if it is less than 0.001, it is considered as high significant difference. Our results show that the p value in this test is less than 0.001. Therefore, it can be determined that there is high significant difference between the mean heart rate values when they were relaxing and after they run.

In order to understand if there is significant difference between non- smokers and smokers data, another t-test was performed. Firstly the difference between relaxing heart rate and after run of non-smokers was calculated. This calculation was repeated for the smokers as well. Secondly, these two set of difference values were used for the t-test. The results were displayed in Table 3.

Table 3. Results of the t-test for Non-smokers and smokers

NonSmok.					
Relax.	Aft.Run	Diff.		Diff.	
107.11	145.62	38.50		<b>N.Smok</b>	<b>Smok.</b>
93.78	109.12	15.34	<b>Mean</b>	25.38	43.16
96.21	97.63	1.42	Var.	254.37	828.72
70.48	96.18	25.70	Obser.	6	6
75.17	100.53	25.36	Pear. Cor	-0.32	
71.38	117.37	45.99	Hyp. M. Dif	0	
			<b>Smok.</b>	df	5
76.12	123.51	47.38	t Stat	-1.17	
80.39	109.48	29.08	<b>P one-t</b>	0.14	
94.39	159.53	65.14	t Crit.o	2.01	
84.64	170.69	86.04	Ptwo-t	0.29	
81.27	90.09	8.82	T Crit.t	2.57	
92.11	114.6367	22.51			

The results of t-test for the non- smokers and smokers show that there is no significant difference between two data sets. Because, the p value is 0.29 which is greater than 0.05. Therefore, these results were not enough to make any

conclusion about the effect of smoking on the heart rate.

There are many articles in literature that were written about heart rate variability due to the smoking habit. In many of these articles, it has been observed that parameters are the most important fact that effect to the experimental results. For instance, the results could be different when the data were taken in daytime and in nighttime [18]. Moreover, it has been proved that body mass index and physical activity are very effective to the results of the heart rate experiments [19]. In addition to them, refrain time from smoking before the experiments could be also an essential issue for the results [20].

In this study, the experiments were conducted with 12 male (6 non-smokers + 6 smokers) age ranged from 21-27. The results could be different if more parameters would be included to the experiments.

#### 4. CONCLUSION

In this study, ECG was measured from the human body and the ECG signals were acquired using NI myDAQ. By running the program that is developed in LabVIEW, the signals could be read clearly in real-time. With the help of biomedical signal processing toolkit, the ECG signal was filtered and using wavelet transform methods noises of the signal was eliminated. Additionally, by using Teager Energy method the heart rate was calculated in real time.

After completing the program, several experiments have been conducted with 12 male subject (6 smokers+6 non-smokers) and their heart rate values were recorded for 2 minutes in both relaxing and after run condition. Later on, the results were loaded into MATLAB and Excel for the graphical and statistical analysis. The statistical analysis show that there is no significant difference between heart rate values of non-smokers and smokers in relaxing and after run condition.

Future studies should be focused on including more parameters to the experiments and increasing number of subjects to make the results more efficient. It is also essential for the further studies that more peaks and intervals from the ECG tracing should be detected. Therefore, different diagnostic information could be obtained from the ECG. Moreover, not only the ECG signals, by

implementing another channels, it could be also possible to determine different type of information such as body temperature, respiratory rate, EMG at the same time.

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