Portable ECG Monitoring Device Design Based on ARDUINO

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***Abstract*—Biomedical signals are the primary data source for diagnosis of diseases and monitoring of patients. These kinds of operations are carried out in hospital environment with huge devices. Today, due to rapid development of embedded systems, sizes of these devices have been reduced to small dimensions. In this way, while the patients continue their daily lives, the small sized devices make it easier to record biomedical signs related to their diseases. In this study, the electrocardiogram (ECG) sign, one of the most basic signs for heart diseases, is detected and displayed on the graphic display. To determined for this goal, ECG sensor card, wireless communication module, ARDUINO nano and TFT LCD screen are used. The idea is designed independently in two circuits and all circuits are supplied with small batteries for compact size. In this way, the circuits are realized in small sizes. According to the results, the system proposed can detect heart signals and heart beats and the system can show results to users.**

***Keywords*—AD8232; ECG; TFT LCD; Portable; Wireless**

I. Introduction

The heart is vital role for human life. It is one of the most important organs that ensures the circulation of blood in human life and ensures a healthy life for human. The heart contracts and relaxes, making the blood enriched in oxygen. Heart disease ranks first among the causes of death worldwide [1]. Diseases such as heart attacks, heart arrhythmias, vascular occlusion, and heart valve problems are among the most common heart diseases. Heart signals should be monitored for early diagnosis and treatment of these diseases. The electrocardiogram (ECG) signals are recorded with the electrodes placed on the heart of skin. 3 electrodes are used for this process. The two electrodes are placed to the right and left of on the heart. The last one is placed as a reference point on the right foot or on the right side of the stomach.

Fig 1 shows the structure of the ECG signal obtained from a normal person. The amplitude value of this signal is around 1mV. The frequency range is between 0.1Hz and 150Hz. The heart beats between 60 and 90 per minute in a normal person. In addition, the ECG signals consist of waves, P wave, QRS complex and T wave. Using these waves, specialist doctors decide for definition and treatment of diseases for any patient. For instance, ST segment depicts the early diagnosis of acute myocardial infarction [2].

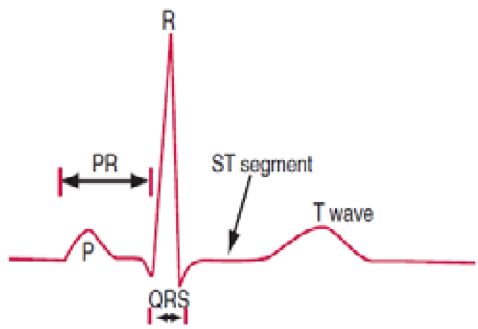

Fig. 1. ECG Signal Waveform [2]

Another important parameter about the heart is the beats per minute (BPM). The BPM parameter in a healthy person ranges from 60 to 100. This parameter changes according to the daily behavior of the person. For example, it will be increase when exercising. On the other hand, on the sleeping or resting condition, it will be decrease. Any patient's bpm value changes for no reason gives us information about heart arrhythmia disease.

In this paragraph, a short literature review is mentioned about this issue. These studies are summarized by making short quotations. Uysal et al. [3], used pulse-oximeter for receving heart rate sign from patients, and sent the the signs to PC with Bluetooth communication. Sadhukhan et al. [4], designed a system which have early detection of myocardial infarction based on ECG analysis. To detect the myocardial infarction, the system was followed the morphological and temporal changes of the ECG waveform. Wu et al. [5], in this paper, it was developed a low-cost ECG measurement system between mobile device. The collected ECG signals were sent to LabVIEW platform and analysed with Wavelet transform. Natumploy et al. [6], a system was implemented for portable ECG signal. The system has constructed by using ARDUINO Mega 2560 platform and Duinopeak ECG shield. Lee et al. [7], a system was developed for measuring ECG signals without electrode pads. For this goal, it was used signal belt. Finally, results was sent to PC by using Zigbee protocol. Taştan [8], in his paper, a system was created that can monitor

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ECG parameters and body temperatures by using Internet of Things (IOT) technology. Puente et al. [9], implemented for acquisition of EMG and ECG signals. The system was connected with ARDUINO Uno and e-health shield. Deshpande and Kulkarni [10], designed a system for gathering ECG data from patients and, transmitted these signals to the IOT cloud environment using Wi-Fi. Baig and Gholamhosseini [11], in review article, reviewed and discussed similarities and advantages of wearable, remote and mobile health monitoring systems. Rahman et al. [12], a smart ECG monitoring system was designed based on ARDUINO and cell phone. The results from data acquisition process was depicted on cell phone screen and this information was send to medical expert. Nemati et al. [13], developed a new system, which used capacitive ECG sensor. In this way, they managed to collect the signals without touching the skin surface. Then, they transmitted the signals to PC environment. Chou et al. [14], proposed a new wearable ECG monitoring systems with compact and power efficiency. Led et al. [15], a new wearable device was created based on ADuC831 Micro-Converter. It was sending result using Bluetooth technology. Jeon et al. [16], implemented a wearable ECG system with t-shirt based on Android OS platform.

II. MATERIAL AND METHODS

The purpose of this study is to design electronic circuits for the measurement of the ECG signal and the calculation of the BPM value on screen. This process is provided by two electronic circuits that do not occupy much space. Thanks to the two circuits being separated, unnecessary cable connections are avoided. In addition, supplying circuits is provided with small 12V batteries. The block diagram of the designed systems can be seen in Fig 2.

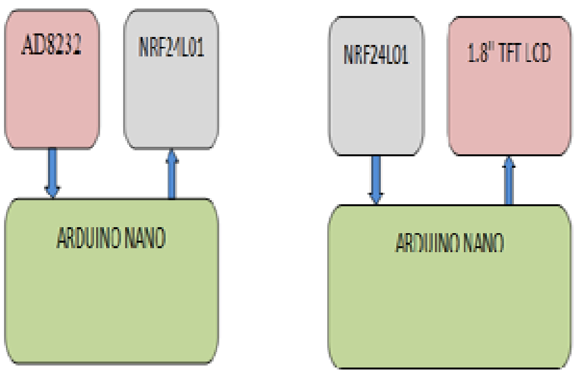

Fig. 2. Block Diagram of Designed System

As seen in Fig 2, in the circuit on the left, ECG signal was captured and transmitted using wireless modules. AD8232 sensor was used as ECG measurement sensor. In the circuit on the right, ECG signals are received and plotted on the TFT_LCD screen. In addition, the BPM value of the incoming signal is calculated and printed on the screen. In the next sections, the electronic materials and software part used are briefly mentioned.

A. AD8232

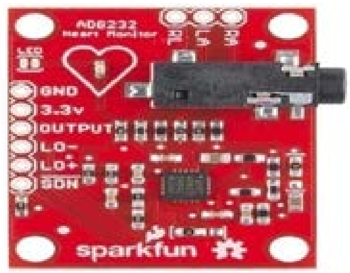

Fig. 3. AD8232 ECG Measurement Sensor [17]

This sensor has 6 connecting pins. The supply voltage of this sensor is 3.3V. 3 ECG electrode pads are needed for the sensor to take measurements in the human body. These pads are connected to the sensor via the sterao jack. In addition, it contains one led so that the led will blink at the time of heart beat. Since the amplitude levels of biomedical signals are at uV levels, amplification is required. Therefore, another advantage of this sensor is that it contains the amplifier and filter circuit. In the output output, it sends the ECG signal to the ARDUINO platform as analogue form [17].

NRF24L01 modules produced by NORDIC company are used for wireless communication. 2Mbit communication speed on air and simplex communication are preferred. SPI communication protocol is provided between this module and ARDUINO for data transmission.

B. 1.8" TFT LCD

Fig. 4. TFT LCD Screen [18]

The screen in Fig 4 is preferred to draw the shape of the ECG wave. The screen width of this screen is 1.8 inches. The supply voltage is 3.3V. The screen resolution is 128x160 points and RGB.

First experiments are done on breadboard, then soldering is started. In addition, 10nF, 100nF, 10uF capacitors are filtered for noise reduction in each circuit. The final version of the proposed system is illustrated in Fig 5.

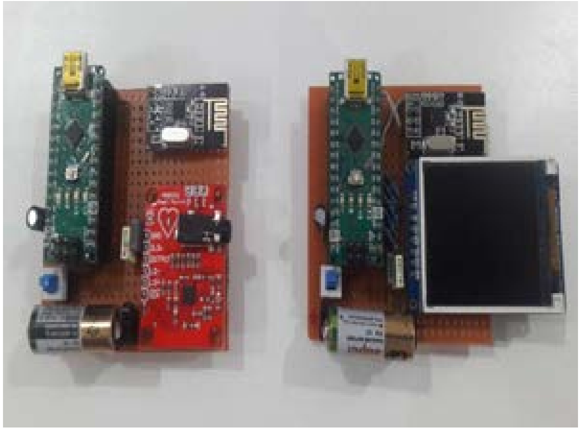

Fig. 5. Soldered Circuits

C. Software Part

In the sampling process of the ECG signal, the sampling frequency was selected as 70 Hz. The value of each sample has 10-bit resolution. This resolution value takes up 2-bytes of memory space. In this study, 8-bit is preferred for sampling. Part of the sketch structure used in the transmitter part is shown in Fig 6.

```
void loop()
{
  while(1){
   if ((digitalRead(LO_POS_PIN) != 1) && (digitalRead(LO_NEG_PIN) != 1))
     {
        useconds_sampling = micros();
        adc_deger_10_bit = analogRead(analog_pin);
        ADMUX |= (1<< ADLAR);
        data[0] = ADCH;
        radio.write(data, sizeof(data));
        while(micros() < (useconds_sampling + sampling_period_us )){
        //wait...
        }
     }
  }
}
```

Fig. 6. Transmission Sketch Part

The screen width of the TFT consists of 160 pixels. Two 160-point arrays are created in the receiver circuit (new_values, old_values). Each incoming data is sequentially recorded in these arrays. When the screen reaches the 160th pixel, not all of the screen is cleaned. Instead, a black dot is put at the point in the old _values array. Green pixel is placed in the coordinate of the new_point array. In this way, a dynamic screen refresh process is realized.

In the receiver circuit, both NRF24L01 and TFT_LCD display are provided with SPI communication protocol. However, ARDUINO nano has one SPI hardware structure. Therefore, for the second connection with SPI, the software SPI structure has been created.

There are two methods to calculate the BPM value. Former, the number of QRS complexes is counted during 60 seconds. Later, the time between two R-R complexes is measured and proportioned to 60 seconds. In this study, the second method was used. When the 160-point arrays reach the last point, it was searched for the first maximum high value and second maximum high value points in the entire array. The difference between the two points is found ($RR_{interval}$). This process is formulated in question 1 and 2.

$$Fs = 70Hz \rightarrow Ts = 14{,}29ms \rightarrow T_{RR} = Ts * RR_{interval} \quad (1)$$

$$BPM = \frac{1}{T_{RR}} * 60 \quad (2)$$

III. Experimental Results

The screenshots for 4 different sampling frequencies are shown in the between Fig 7 and 9 sequentially. These sampling frequencies are fs = 500 Hz, fs = 300Hz, fs = 150 Hz and fs = 70Hz.

Fig. 7. Sampled ECG Result for fs=500 Hz

Fig. 8. Sampled ECG Result for fs=300 Hz

Fig. 9. Sampled ECG Result for fs=150 Hz

As shown in the Fig 10, 3 heart beat waveforms are drawn. There are subtraction in the form of QRS complex. This is due to the low frequency of sampling. When fs = 300Hz was made during the tests, only one heart beat could be displayed on the screen. Therefore, fs = 70Hz is chosen. Besides, the BPM value is printed on the bottom right.

Fig. 10. Sampled ECG Result for fs=70 Hz

In addition to these measurements, the current consumption values of both the transmitter and receiver circuits were measured. The transmitter circuit consumes 30 mA and the receiver circuit consumes 20 mA.

Table 1. Current Consumption of Circuits

Transmitter	30 mA
Receiver	20 mA

IV. Conclusions

In this study, the small and portable ECG measuring device is successfully implemented. In this way, it is possible to monitor ECG signals while doing daily activities of unhealthy people. In addition, due to its small size, it works independently from other platforms (smartphone, PC, web).

In future studies, the signals obtained can be transmitted to specialist doctors with internet-based systems. In addition, if there is any heart attack situation, emergency services can be reported.

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