Research Article

Smart sportswear design that can detect vital parameters

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Abstract

The subject of wearable electronics is expanding quickly, and it has just lately begun to provide profitable commercial items to the consumer electronics market. It is anticipated that the use of biopotential signals in wearable systems as either biofeedback or command commands will revolutionize.There are numerous technologies, such as brain-computer interfaces, point-of-care health monitoring systems, rehabilitation tools. Since electrodes are seen to be a crucial component of such items, they have been researched for about ten years, which has led to the development of textile electrodes.In this paper , wearable devices for sport is studied with detecting vital parameters. There are a few sensors such as ECG and IMU based acceleration. Smart textile products are used for testing and taking data purpose.[1]

Keywords: ECG, Smart Textile, IMU based acceleration , Bluetooth low energy

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1. Introduction

Wearable electronics, often known as wearable computing, is a new trend in electronics that involves the shrinking and integration of devices into wearable formats such smart watches, clothing, and eyewear [1].

From 2016 to 2022, the market for wearable electronics is predicted to expand by 15.5% yearly [2].

Smart wearable devices are commonly used nowadays. In the past , there were lots of usage as a starter of the smart textile products.

Electronic textile (e-textile), also known as "smart textile," is a rapidly developing technological field in the area of wearable electronics that studies the integration of functional materials with everyday clothing to realize devices such as sensors, energy harvesters, antennas, advanced textiles for self-heating and cooling[3], and even fashion applications [4]. To quickly and easily assess heart problems, Devin D. Mehta made an reseach for portable ECG devices and result is that non-interpretable rhythm strips were added, there was less than 50% concordance between portable ECG device rhythm strips and the hospital cardiac monitor[5]. Fangmin Sun researched that It is suggested and put into practice to create a modified sports H-shirt with lactate threshold heart rate computing. High flexibility of the H-shirt prevents measuring pain while also ensuring a stable skin-electrode contact and The data communication protocol between the H-shirt and the smartphone is Bluetooth low energy (BLE). A mobile phone-based platform for ECG analysis and workout evaluation has been created[6]. As part of his research, Przemyslaw Guzik examined mobile ECG technology. A mobile device (such as a smartphone), an electrocardiographic equipment or accessory, and a mobile application make up mobile electrocardiographs. Mobile platforms are compact computers with adequate processing power, a good display, adequate data storage, and a variety of data transfer options and the result The use of mobile ECG equipment does not yet meet accepted clinical recommendations or recognized criteria. Large-scale clinical studies demonstrating the genuine value of new mobile ECG technologies should be available soon. [7] Jaehyo Jung investigated about ubiquitous healthcare and provide a software technique and protocol for AMI diagnostics that can facilitate real-time interaction between the patient and medical workers. A protocol based on ISO/IEEE 11073 was used in the development of our monitoring and diagnostic system. The medical staff consults the patient's biosensor data when data is transferred from the patient's smartphone to a server at the hospital to determine the condition of the relevant ailment and deliver the necessary medical services[8]. Hamid Gholamhosseini reviewed that evaluating adult wearable ECG monitoring systems that use wireless, mobile, and remote technology and

A examination of more than 120 ECG monitoring systems resulted in the classification of these devices into smart wearable, wireless, mobile, and associated signal processing algorithms. .[9] G. Karthikeyni researched by utilizing mobile communication and wireless communication technologies like Bluetooth Low Energy (BLE), these devices can send their results to distant terminals like smartphones , They have suggested a wireless, wearable ECG monitoring system integrated into an IOT platform that integrates many nodes and applications, has a long battery life, and produces an excellent ECG signal.[10] Haydar Ozkan , study presents a revolutionary architecture for a flexible singlet modified with textile electrodes (TEs), textile threads, snap closures, Velcro, sponges, and an ECG circuit. The system also includes a wearable Tele-ECG and heart rate (HR) monitoring system. A smartphone, a server, a web page, and a Bluetooth low energy (BLE) device have also been added to the system for remote monitoring[11]. Duarte Dias investigated about wearable health device, The state-of-the-art wearable vital signs sensing technologies, along with their system topologies and specifications.A discussion of the most crucial vital signs for health assessment using wearable health devices is first presented, followed by a description of each vital sign's origin, impact on health, monitoring, and most recent scientific advancements in the field (electrocardiogram, heart rate, blood pressure, respiration rate, blood oxygen saturation, blood glucose, skin perspiration, capnography). [12]

In fact, Shyamal Patel, Hyung Park, monitoring physiological parameters is helpful for determining physiological status, as well as the activities and levels of weariness of workers (such as muscle-skeletal and cardiovascular problems), for improving their health, well-being, and safety and thus complying with ergonomics requirements. Technologies with an emphasis on safety, home rehabilitation, treatment efficacy evaluation, and early disorder detection are among those covered in this review study[13]. Kim van Loon, Bas van Zaane , To find out if continuous non-invasive respiratory monitoring enhances early detection of patient deterioration and lowers critical events on hospital wards, we conducted this systematic study and as of right now, it is not recommended to establish routine continuous noninvasive respiratory monitoring on general hospital wards because the studies' methodological quality needs to be improved and the results are not definitive[14].Since they are directly related to various physiological and pathological situations of the patients/workers (e.g., early detection of crucial events) and various environmental stresses, respiratory rate (RR) and heart rate (HR) have attracted a lot of attention in these circumstances[15,16].Beck, Simon , Laufer, Bernhard researched and resulting The most advanced wearable devices for RR monitoring use methods based on the rib cage's cyclic expansion and contraction during breathing activity.Most of these systems use electrical components (such as resistive and piezoresistive sensors, capacitive sensors, and inductive sensors) and fiber optic sensors to directly measure the expansion of the rib cage[17].Waqas Qureshi, Li Guo investigated that the breathing rate can be properly analyzed via an IMU-belt. The belt may be used to monitor heart and respiratory rates in conjunction with ECG measures, and it may offer a method for the surveillance of key critical indicators in clinical settings or home care. The success of our work is that we are now certain that textile knitted sensors may be used to monitor patients' breathing in their daily lives without interfering with their normal activities[18].

In this work we present a T-Shirt as a wearable device that is capable of monitoring acceleration and ECG signals . Data is acquired and transmitted via Bluetooth via a microcontroller operated by battery and mounted on the same circuit board with the IMU sensor and the ECG. The main aim in this study is to evaluate the effectivity of training by simultaneous monitoring the ECG and activity of the athlete. The following chapter introduces the methodology used during this study which is followed by a chapter introducing our results. The last chapter concludes our results and introduces our future studies.

2. Materials and Methods

In this work an ECG sensor and an IMU sensor are placed on a tiny circuit board which also includes a microcontroller with Bluetooth communication capability. The board is placed on a T-Shirt with a battery and electrodes of the ECG sensor to monitor the activity and ECG of a training athlete.We used AD8232 from Analog Devices as the ECG sensor which requires three electrodes[19] which are placed as presented in Fig. 3. The ECG sensor is connected to the analog input of the microcontroller. The IMU sensor preferred is MPU6050 from InvenSense, which is a 9-axis motion sensor with three gyroscopes and three accelerometers and also capable of communicating via I2C interface[20]. The microcontroller preferred is Rsl10 by Onsemi which uses the Bluetooth Low Energy protocol to deliver data acquired from the sensors. Block diagram of the system is presented in Fig. 1.

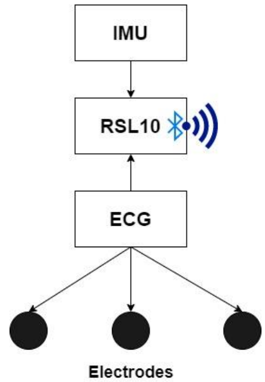

Figure-1: Block diagram of the system

2.1. Electrocardiogram Measurement

The Electrocardiogram (ECG) sensor is a device that is frequently used in the medical industry to monitor the contractions of the heart's muscle tissues during heartbeats by placing electrodes on the skin. This acquisition produces a signal or waveform. Depending on where the cardiac activity is monitored, different waves can be displayed. Each lead variation can be viewed as a portrayal of the same phenomenon from many perspectives. Professional ECG sensors use 10-12 electrodes, while it is possible to acquire the ECG signal with at least 3 electrodes.
At each beat of the heart, the depolarization of the heart occurs, causing it to contract.This electrical activity can be deteceted over the skin. This signal is presented in Fig.2 .The process of depolarization results in P waves. The first negative deflection is called as Q while the highest wave, known as the R wave, is frequently used to estimate the average heart rate which is followed by the S section. The T wave represents ventricular repolarization. T waves can be biphasic, positive, or negative.

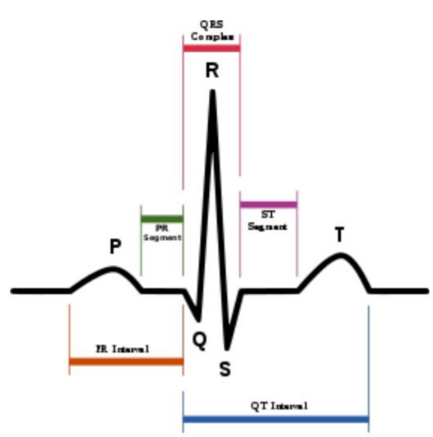

Figure 2: Electrocardiogram Waveform

Gel-free, "dry" electrodes can make excellent candidates for wearable, long-term, point-of-care personal health monitoring applications and many other comparable systems, even though wet electrodes are the norm in clinical settings. Therefore, we will be preferring the dry electrodes in our system.

To achieve the optimum results, position electrodes on the chest wall are equally spaced from the heart (instead of the targeted limbs). RSL10 microprocessor by Onsemi is used to acquire data from AD8232 ecg sensor as presented in Fig 3. Since the voltage voltage acquired from the ECG is in the level of mV Kalman filter is implemented in the RSL10 to denoise the signal

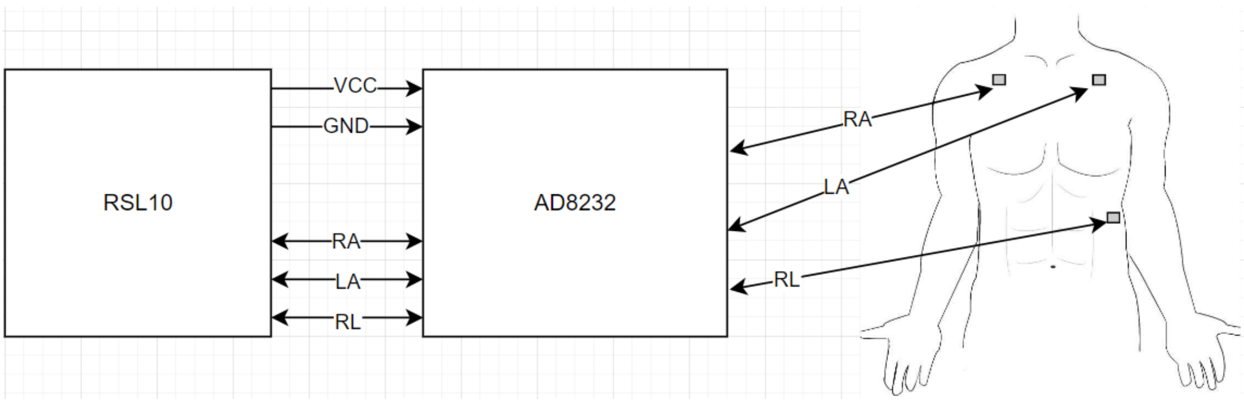

Figure 3: Heart rate measurement setup

2.2. Inertial Measurement Unit Sensor

The purpose of Inertial Measurement Unit (IMU) sensor is used for evaluation of activity of the athlete. It is capable of gathering the acceleration value of the three axes or gyro value,which is converted to a digital output. In this paper, MPU-6050 IMU sensor is used to determine movement of the sportsmen and detecting its acceleration by using measurement data and calculation. The data which can be obtained from IMU sensor is acceleration , direction ,displacement and velocity. During this paper , direction and acceleration is analysed by taking measurement. Direction and acceleration are determined.

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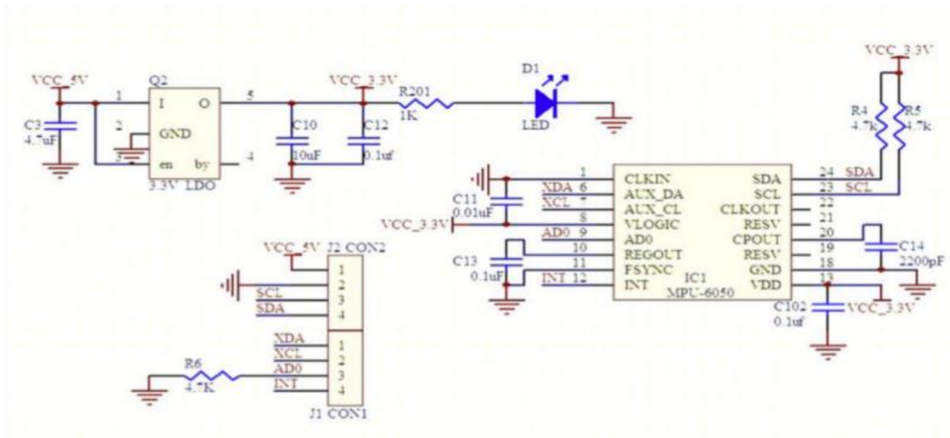

Figure 4: IMU sensor circuit

3. Results

Measurement results for approximately 2 minutes are presented in Fig. 5 for ECG signal. A close up of this figure is presented in Fig. 6

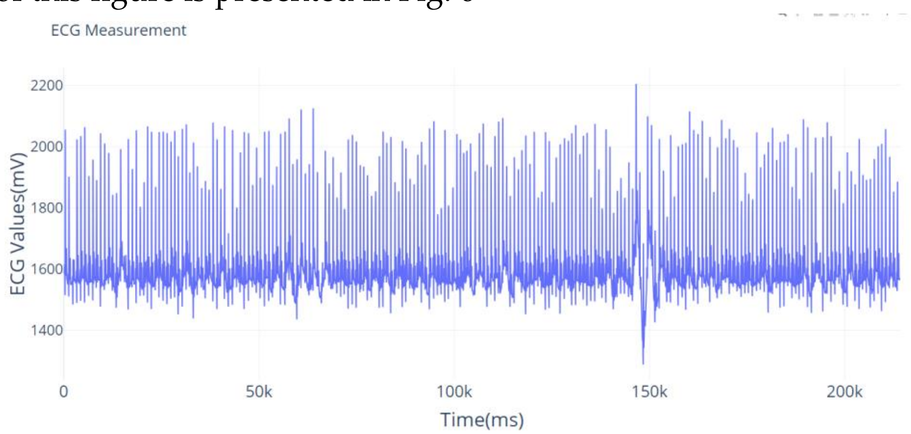

Figure 5: ECG measurement

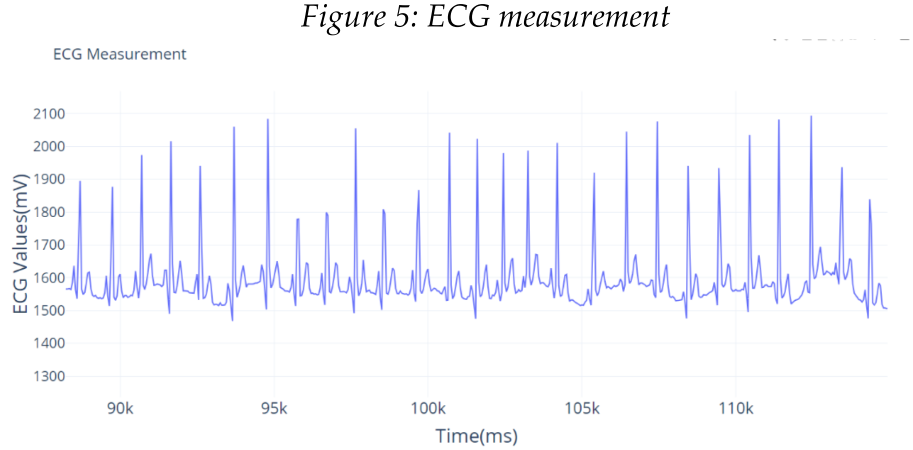

Figure 6: ECG measurement(zoom)

As can be observed in Fig. 4, the electronic circuitry including the IMU sensor is placed on the back of the neck so that the activity of the player can be measured. Acceleration changes depending on movement can be extracted from measured data.

Figure 7: IMU sensor position

The acquired acceleration values are presented in the figures 7,8,9. As shown figure 5 ,Z-axis is the direction of movement of the athlete, hence acceleration values for z-axis will change in accordance with forward movement of the athlete.

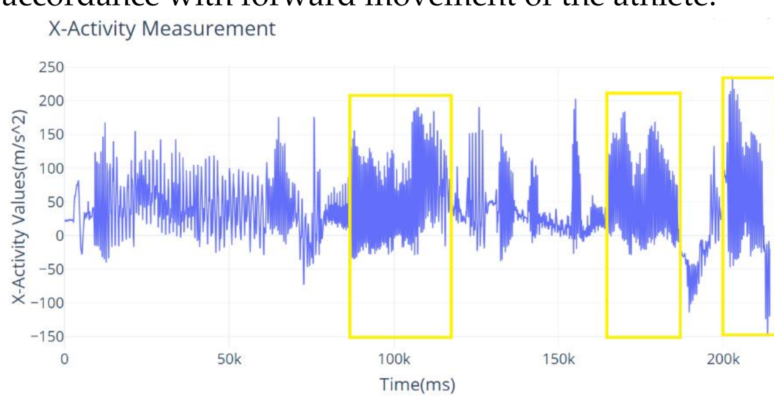

Figure 8: X-activity measurement

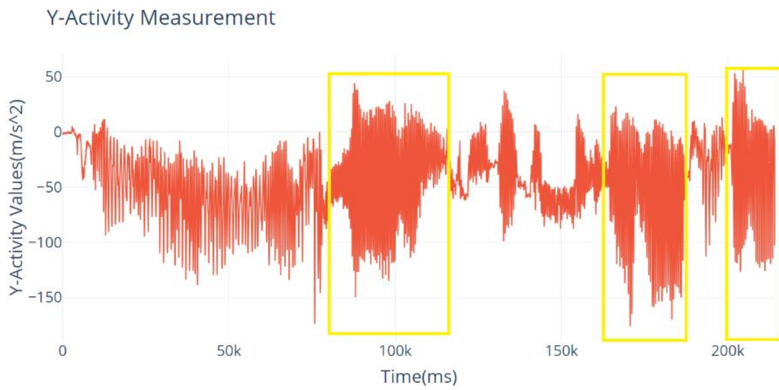

Figure 9: Y-activity measurement

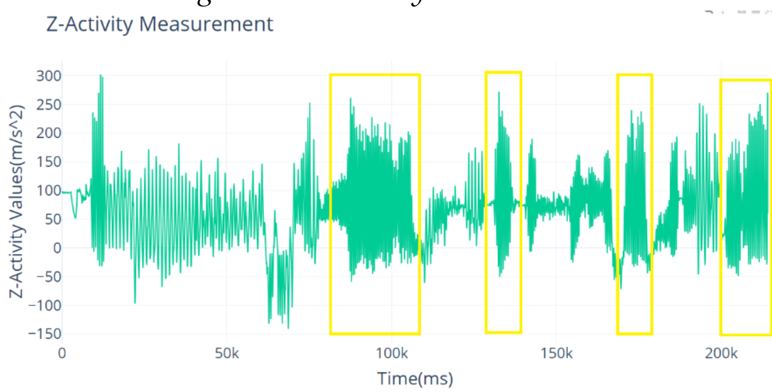

Figure 10: Z-activity measurement

The relationship between movement and heart rate can be demonstrated using the ECG measurement and acceleration measurement. There is a correlation between acceleration and the ECG, as illustrated in the image below. The heart rate of a person moving along the z axis increases as they move. If he stays still, his heart rate will remain normal and his pulse won't rise.(The measurement result is scaled by 100)

The repeating pattern on the ECG is often tallest at the QRS complex. As a result, the interval between two successive QRS complexes determines the heart rate, which is expressed in beats per minute.

Heart rate = 60000 (milliseconds) / QRS peak time difference in milliseconds

As shown figure 10 , Time measurement between QRS complex can be used in here.

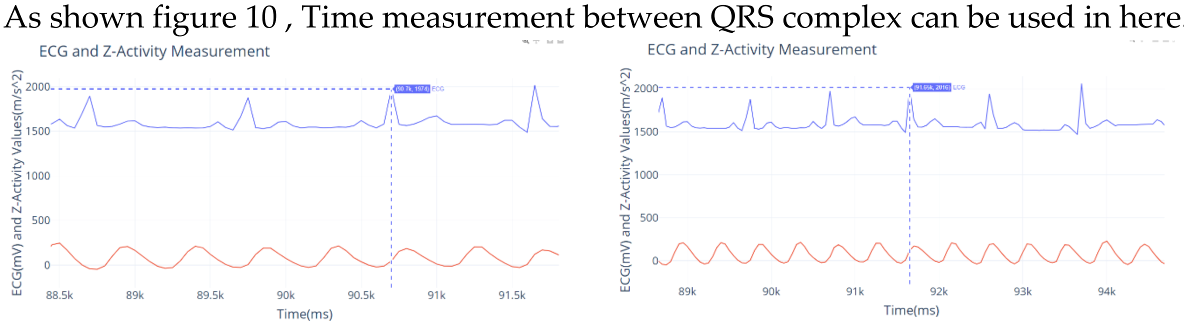

Figure 11: Time measurement QRS complex

The time difference between QRS peak is 950ms and heart rate is 63 bpm roughly. This calculation is for walking of the athlete scenario.

For the steady situation , it is calculated as 60 bpm. There is small difference between movement and steady situation ,because it is only brisk walking case.

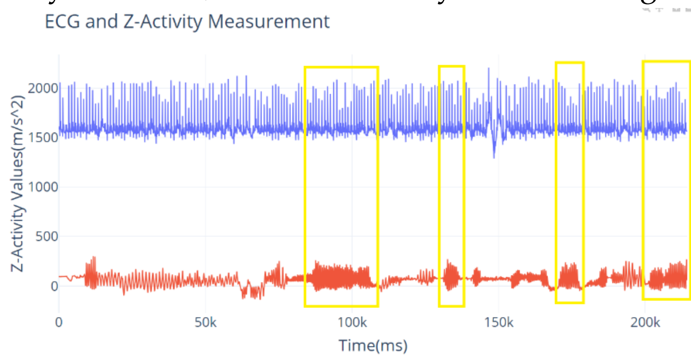

Figure 12: Ecg and Z-acceleration relation

Acceleration data can also be used to determine movement using the frequency of the signal as shown in Figure 10. This situation can be compared for a steady and rapid walking status using the z-axis acceleration data that was retrieved from the QRS complex interval. If the z-acceleration peak value counts, the frequency of that value can be utilized for estimating movement.

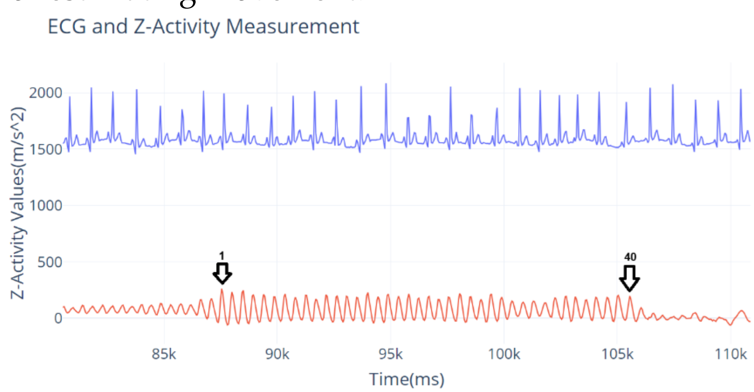

Figure 13: Z-acceleration data frequency 1

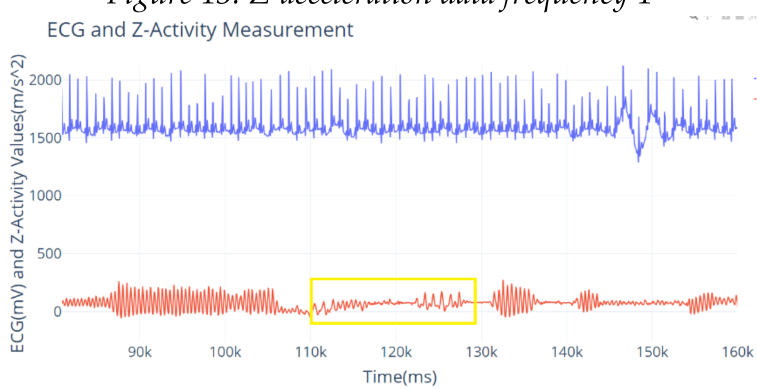

Figure 14: Z-acceleration data frequency 2

4. Discussion and Conclusion

Our observations show that the AD8232 microchip is appropriate for the AFE(analog front end) function because it produced a signal that was beneficial for a long-term single-lead ECG monitoring application. It is also possible to determine the x-axis, y-axis, and z-axis movement from the study's findings by using the inertial measurement sensor MPU6050. The x, y, and z axes serve as a representation of the motion detection prototype created by this research. Due to the amount of noise obtained and the need for great precision in the ECG since slight distortions could indicate major disorders, diagnosis is impossible, therefore, a medical professional may not be able to diagnose or accurately assess the heart's functionality with the developed product however based on the data a basic level analysis for evaluating the performance of an athlete is possible.

5. Acknowledge

In the prepared article, there is no need for ethics committee approval. There are no conflicts of interest with any individual or institution in the prepared article.

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