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Al Azhar University – Gaza

**FACULTY OF ENGINEERING**
**AND INFORMATION TECHNOLOGY**

**DEPARTMENT OF ENGINEERING**


# Graduation Project 2
# Bio-signal Monitoring


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I would like to express my everlasting gratitude to my supervisor Dr. Abedallah Al-Sayed for him valuable encouragement, we are mainly we would like to thank our families and our friends and colleagues for their supports and everyone who prayed for us.

# ABSTRACT

When we think of human electrical monitoring, the first thing that comes to our mind is bio-signal devices. It is known that bio-signal devices monitor the activity and electrical function of the body's organs. Bio-signal devices are, in fact, a continuous attempt by biomedical engineers to facilitate the work of doctors in their field and to become able to perform tasks with high accuracy in diagnosing and monitoring the human condition. Our graduation project consists of human activity and electrical monitoring devices, which are ECG and EMG in one device that is easy for doctors to use wherever they want and saves them from many devices in one place, and we plan to make this cheap device with a kind of artificial intelligence in order to reduce the total cost compared to at prices than commercial ones which are hard to find in our local markets. The first step of the project is to study, analyze, and design electrogram devices, and a prototype will be developed in the second step. This project covers a wide range of topics starting from electrical design using Proteus, signal monitoring using Oscilloscope or MATLAB, continuing to work on equations for designing electrical circuits, solving and simulating them using Proteus, and finally modeling a user interface suitable for device control users.

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# Chapter1: Introduction

## 1.1 Theoretical Background

What is an electrocardiogram (ECG)? what does it actually measure, and what does the ECG curve show us? Our nerve and muscle cells communicate with each other using electrical and chemical signals. Regular electrical signals also control our heartbeat. These signals are sent by a group of cells in the right atrium of the heart known as the sinoatrial node (SA node), and they spread through the heart muscle tissue as tiny electrical impulses. This causes first the atria and then the ventricles of the heart to contract. The way that these signals spread through the heart can also be measured on the surface of our skin. An ECG measures these changes in electrical signals (or, in fact, voltage) on different areas of skin and plots them as a graph. The resulting ECG graph is called an electrocardiogram.

Figure1 (monitor ECG)

And What EMG? Electromyograph (EMG) measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. The test is used to help detect neuromuscular abnormalities. During the test, the electrical activity picked up by the electrodes is then displayed on an oscilloscope (a monitor that displays electrical activity in the form of waves). An amplifier is used so the activity can be detected.

Figure2 (monitor EMG)

Some doctors face difficulty in diagnosing the condition of the heart and muscles as a traditional method, which is auscultation. These methods have been replaced and ideas have developed into modern devices that monitor the electrical signals of the heart and other devices that monitor the electrical signals of the muscles. In some cases, we may need the availability of these two devices in one place, but space The place or the clinic does not allow the availability of several devices in the same place, and also when you want to get each device separately, you will be charged an additional price and costs, and we will learn about a solution to this problem in the coming pages.

## 1.2 Problem Statement

Most hospitals and health care facilities have multiple ECG and EMG devices. It has been noted that nerve departments sometimes require an ECG signal to monitor the patient's condition. Then, for example, the specialist should check and monitor the muscle signal. Each device occupies space in the place, and also you need the price of two devices and you do not need to pay these amounts, so we resorted to the idea of merging the two devices into one device and switching between them with a key to switch between each device separately.

The subtle problem in some projects and other devices is that the design requires the availability of many components in several devices, so we solved and addressed this problem, two devices in one device with the lowest electronic components and the least cost to the consumer.

## 1.3 Scope

**Theoretical scope**

According to the research study that we have done so far by reviewing the literature from various sources such as articles, journals, etc. related to interventions performed on neurological or rehabilitation departments, we must narrow down and deal with ECG and EMG monitoring and diagnosis.

**Technical range**

Designed a low-cost ECG and EMG device prototype and data acquisition device.

## 1.4 Project Objectives

**1.** Designing an electrocardiogram and electromyography monitoring device in one device.
**2.** Connecting two devices to one circuit and monitoring vital signs together or when needed by controlling it with a switch
**3.** Trying this device practically, can I operate it!
**4.** The use of simple electronic components that work to provide these devices with perfection**.**

# Chapter2:
# LITERETURE REVIEW

## 2.1 Introduction

This chapter gives a review of what other academicians, scholars and researchers have written about the monitoring and diagnosis of ECG and ECG, so that we are able to learn from what they have done. This will enable us to get an overview on how we shall come up with a prototype of a portable low-cost ECG & EMG monitoring device.

And in this project, two ECG and EMG devices are used in one device by using a switch. Switching between the two devices is done by changing the resistors, not changing the components of the device as a whole, because here the resistors control the GAIN values of the amplifier, and there are resistors that control the cut values off frequency. In this device, we are working on designing these two devices with simple components and fewer components than the components of other devices, but the same performance and the same measurements, and this helps to save the space of the device, and also the cost of the price is lower for the manufacturer and the user.

## 2.2 Previous Attempts

Bio-signal monitoring value chain encompasses a set of common processes, including data acquisition, preprocessing, feature extraction, processing, analysis, and visualization. Studying and analyzing the value chain of ECG, EMG and EEG monitoring systems helped in understanding the value and contribution of each process within the system, the best practices that can be adopted within each process, and the ultimate goal of the overall system in guaranteeing higher quality disease diagnosis and increased resource utilization efficiency in terms of energy and cost. Most of the existing researches agreed on the main bio-signal monitoring processes mentioned above. However, depending on the nature of the monitoring application, some research work has defined additional distinct or overlapping processes, such as data cleansing, encryption, and compression, but could be incorporated or merged as part of existing primary processes, or isolated as supporting processes.

In this paper (An Innovative Design Approach of Butterworth Filter for Noise Reduction in ECG Signal Processing based Applications) performance analysis has been carried with the help of Butterworth filter.

### ⇨ Butterworth Filter application

The first step in ECG signal analysis is recording the electrical activity of the heart. This can be done noninvasively with the help of electrodes mounted on the surface of the body. The filters designed here are with the help of MATLAB FDA Tool by specifying the filter order, cutoff frequency and sampling frequency.

# Proposed Block Diagram of Butterworth Filter

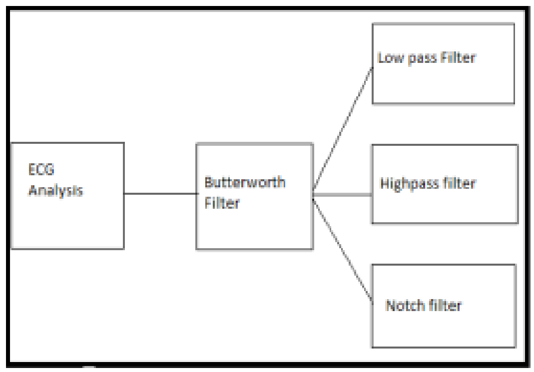



Figure3 (Butterworth filter application)

In the present scenario, the design consideration of low pass filter, high pass filter is elaborated separately for removal of noise signal from ECG using Butterworth filter. The proposed block diagram of Butterworth filter is shown in figure3.

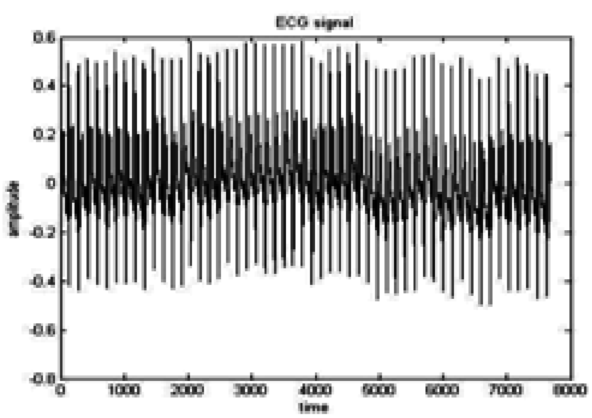



Figure4 (removal noise by using Butterworth filter)

⇨ **Design of Butterworth Low pass filter: (**Removal of High frequency noise)

the information is present in frequency range of 0.5Hz to 100 Hz is very useful. All the signals above 100 Hz are treated as noise. The section deals with design and implementation of low pass filter were designed for sampling frequency 4800 Hz and filter order 15 for the removal of high frequency noise in ECG signal. The filtration is done after this and the response is shown in figure 5.

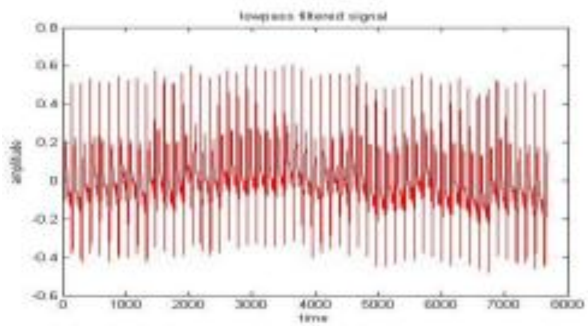



Figure5 (low pass filter)

⇨ **Design of Butterworth High Pass Filter:** (Removal of Low Frequency Noise)

In the present design of high pass filter, the order of the filter is considered is 3. Though the order of filter is less it gives satisfactory results. Baseline wander is minimized by design of high pass filter is focused in this section. Butterworth high pass filter was designed with filter order 3 and sampling frequency 4800 Hz. The filtration is done after this and the response is shown in figure 6.

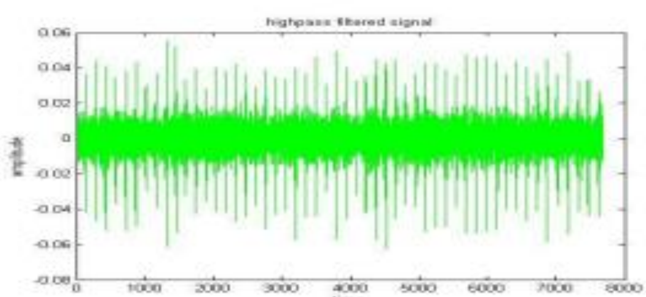



Figure6 (high pass filter)

➩ **Design of Butterworth Notch Filter:** (Removal of Power Line Interference)

Notch filter is implemented to avoid the problem of PLI in the ECG signal.

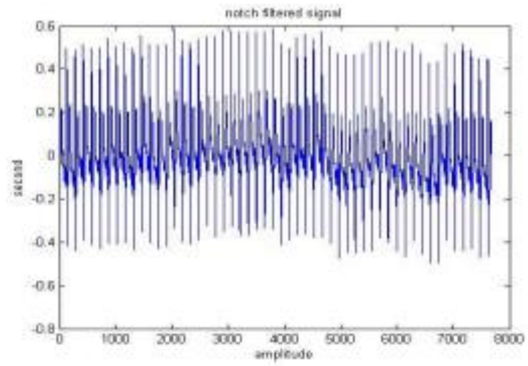



Figure7 (notch filter)

In the present section the Butterworth notch filter has been designed for order 8 and sampling frequency 4800 Hz and implemented on the ECG signal containing power line interference. The filtration is done after this and the response is shown in figure7.

➩ **RESULTS ANALYSIS & FUTURE SCOPE OF WORK**

Cascading of Butterworth Filters Finally the cascading of filters is done and after that filtration technique is applied to it. Individual performance as well as performance of cascade combination of filters has been compared. Figure 8 shows result of cascading of Butterworth filter.

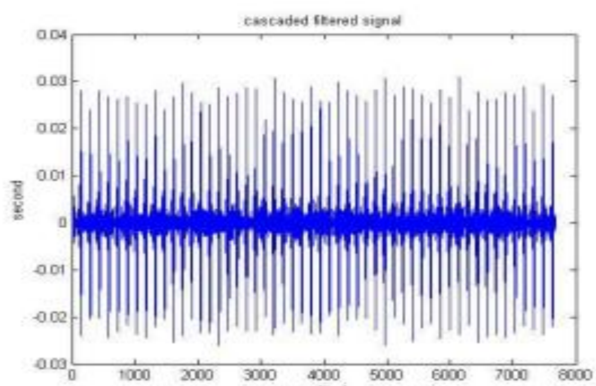



Figure8 (RESULTS ANALYSIS & FUTURE SCOPE OF WORK)

Earlier cascading of Chebyshev type-II filter has been done and shown that it suppresses the maximum of baseline wander [6]. But, the result of cascading Butterworth filter is not so impressive and individual performances of the Butterworth filter gives the better result. Yet a new path has been opened and only future will be able to judge if this method of cascading will be successfully applied.

**# In Applications Instrumentation Amplifier (AD620)**

⇨ **COMMON-MODE REJECTION**

Instrumentation amplifiers like the AD620 offer high CMR, which is a measure of the change in output voltage when both inputs are changed by equal amounts. These specifications are usually given for a full-range input voltage change and a specified source imbalance. For optimal CMR the reference terminal should be tied to a low impedance point, and differences in capacitance and resistance should be kept to a minimum between the two inputs. In many applications shielded cables are used to minimize noise, and for best CMR over frequency the shield should be properly driven. Figures 9 and 10 show active data guards that are configured to improve ac common-mode rejections by “bootstrapping” the capacitances of input cable shields, thus minimizing the capacitance mismatch between the inputs.

# Differential Shield Driver

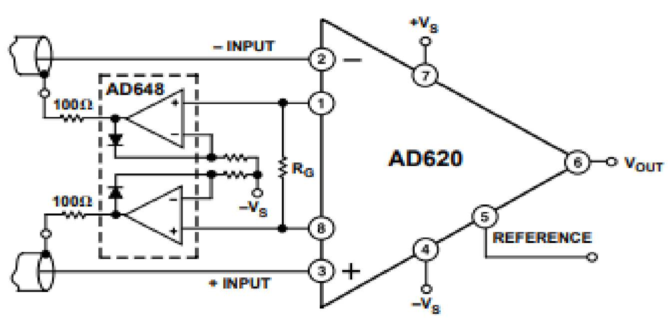



Figure9 (Differential Shield Driver)

# Common-Mode Shield Driver

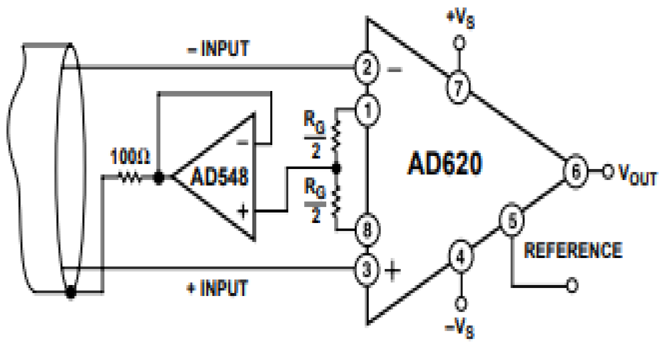



Figure10 (Common-Mode Shield Driver)

## 2.3 Research's gap

We intend to identify research gaps in defining the complete lifecycle of bio-signal monitoring systems and highlight the existing models, which include processes that overlap, or processes that are merged. Our main objective is to highlight the added value these processes provide to the monitoring system's lifecycle, as well as possibilities for optimization and improvement. One of the most important processes is data acquisition; it involves measuring and recording the heart's activity using different sensors. The massive data generated by the ECG and EMG acquisition process requires preprocessing to prepare the data for the next stages, which are feature extraction and processing. The accuracy of preprocessing indirectly affects the subsequent stage of the value chain. Such preprocessing activities include cleansing the ECG & EMG data without losing its main components and features. This is why most of the research work devotes huge efforts to the preprocessing stage. Having huge volumes of ECG &EMG signals necessitates the feature extraction process to reduce the amount of processing and save resources prior to the processing and analysis stage. Features extraction is a very critical stage, as it has a significant effect on the subsequent stages of the lifecycle. The processing and analysis stage requires the application of various optimization techniques to achieve higher accuracy, precision and quality results. This is the most important stage in the monitoring system's lifecycle as it affects the accuracy of signal interpretation and diagnostics.

Finally, the different visualization tools enable end-users to clearly and efficiently visualize the results of the monitoring systems. This stage is also significant as it allows accessibility, usability, and understandability of complex data Since the previous research and projects were working on the availability of several devices in one device, but not in one circuit, but each circuit for each device separately, in our project we will make a device that monitors the electrical heart and electrical muscles in one circuit and with fewer components that save the consumer this product and provide space In the place where these devices are used, not like the previous projects, you need to provide places to put these devices in the same place, and also the availability of components leads to saving the price for the consumer.

# Chapter3:
# DESIGN AND SIMULATION

## 3.1 introduction

Designing the system before starting to build it is one of the most important stages of the manufacturing process and the system or product, as this stage can play a good role in building the rest of the project with less problems and more ease if this stage is done properly and takes its time.

## 3.2 Solutions

After researching about the project in the previous works, we reached a suitable solution and a good shape and idea for the project by making two ECG and EMG devices, where we developed the idea of designing the two devices in one device with the least components, simple costs, and little space that helps rehabilitation or neurological departments in hospitals and private clinics to provide these two devices In one place in one device via a switch, we switch between the two devices and we will design the project according to the following block diagram:

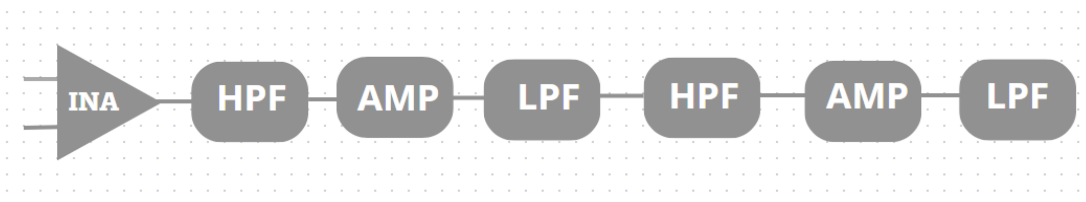



Figure11 (block bigram of project)

⇨ **Instrumentation amplifier (INA)**

An instrumentation amplifier (INA) is used to provide a large amount of gain for very low-level signals, often in the presence of high noise levels. The major properties of INAs are high gain, large common-mode rejection ratio (CMRR), and very high input impedance.

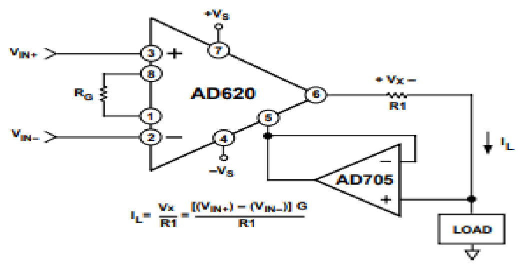



Figure12 (AD620)

## ⇨ High pass & Low pass Filter

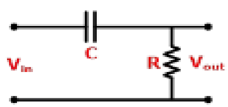
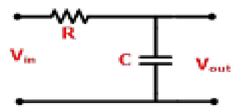
| | High Pass Filter (HPF) | Low Pass Filter (LPF) |
|---|---|---|
| Definition | HPF is an electric filter that allows signals with higher frequency than the cut-off frequency. It is known as the low-cut filter. | LPF is an electric filter that allows signals with a lower frequency than the cut-off frequency. It is known as the high-cut filter. |
| Circuit Diagram | In HPF, the capacitor followed by the resister. | In LPF, the resister followed by the capacitor. |
| RC Filter |  |  |
| Operating frequency | Higher than the cut-off frequency | Lower than the cut-off frequency. |
| Importance | It is important to cancel the low-frequency noise from the input signal. | It is important to cancel the aliasing effect. |
| Applications | It is used in amplifiers like an audio amplifier, low-noise amplifier. | It used in communication circuits as an anti-aliasing filter. |

Table (1)

### ⇨ Band Pass Filter

The main function of such a filter in a transmitter is to limit the bandwidth of the output signal to the band allocated for the transmission.

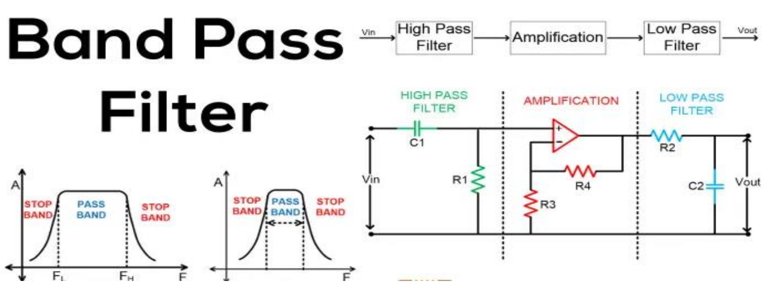



Figure13 (band pass filter)

#Use Butterworth 4$^{th}$ order so that the percentage of error in the use of filters is close to zero.

## 3.3 First design

Designing an ECG device initially and simulating it on the proteus device and displaying the signal coming out of this initial design according to the frequency values and the values of the special filters. A suitable design for the amplifier with suitable resistors with a suitable GAIN is commensurate with the overall design of the project, whose value is approximately 1000.

And according to the following design of this circuit, according to the values in the figure, according to the calculations used in the design of the circuits for the bio-signal devices, and the ECG circuit was designed according to the previous block diagram method as a preliminary design to simulate the initial project idea.

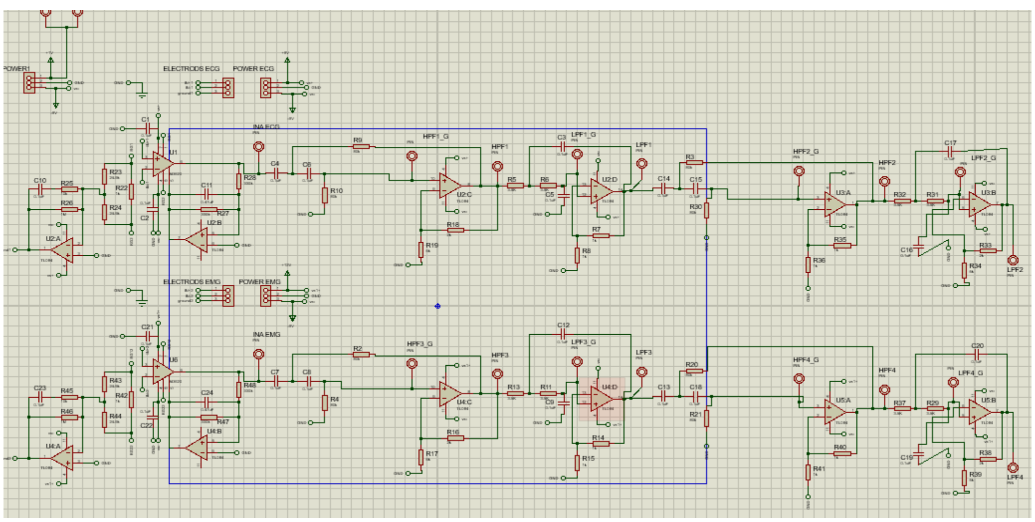


Figure14 (design circuit by proteus)

# The following picture shows Initial diagram of the design of the ECG circuit using the Proteus program .

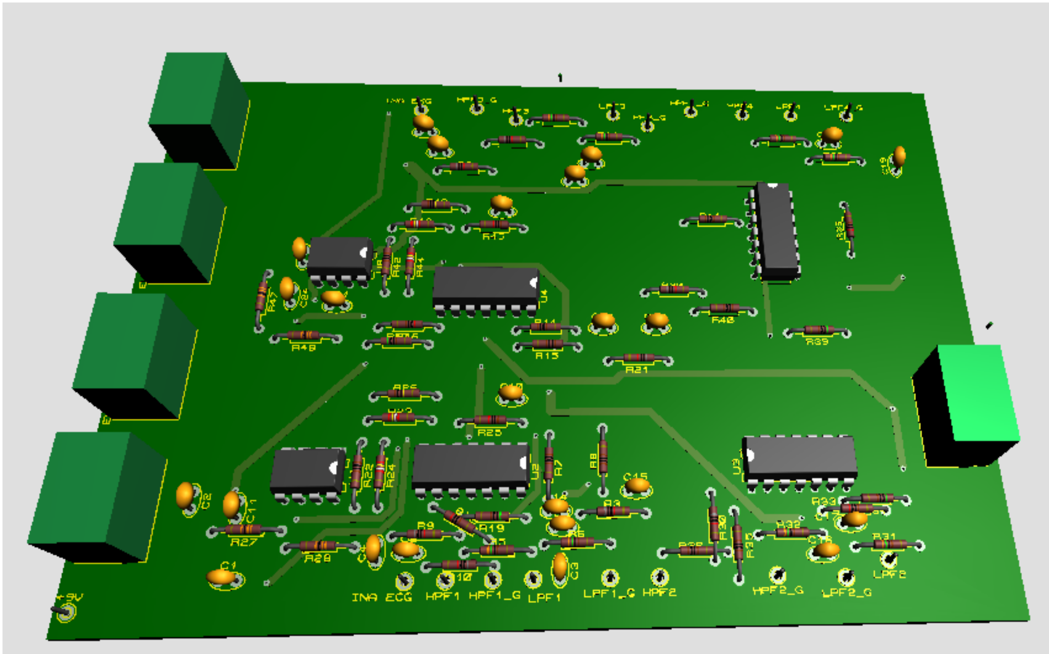


Figure15 (design circuit 3D)

# Design PCB Circuit by using proteus program

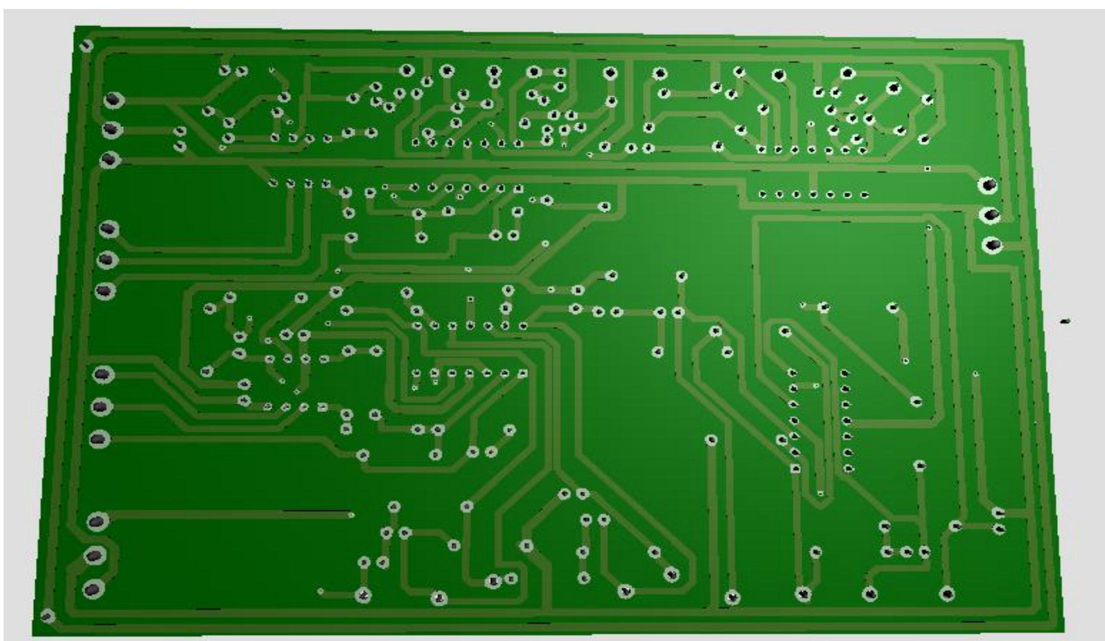


Figure16 (PCB circuit)

In Figure 17, it shows the shape of the prison after passing through the INA and the filters, and in each prison it has a specific place after each specific area, and this is after the initial design of the ECG circuit, which is the basis of our work.

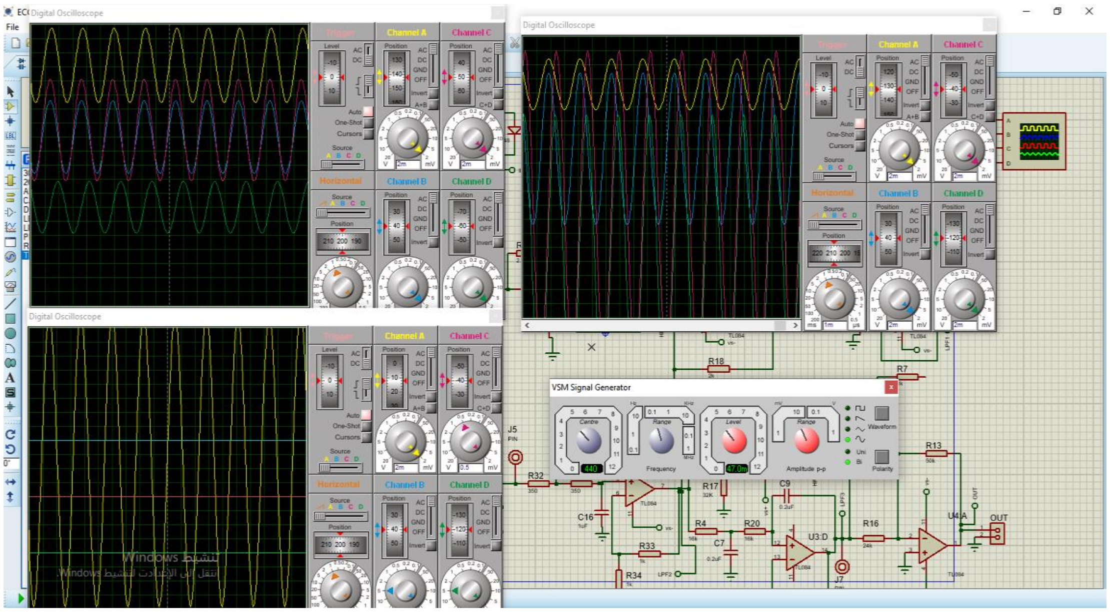


Figure17 (results simulation)

# Chapter4:
# EXPERIMENTS AND RESULTS

## 4.1 Introduction

This chapter delves into the heart of our project, the experiments, findings, and insights gained through the design and implementation of an integrated circuit capable of recording Electrocardiogram (ECG) and Electromyogram (EMG) signals. Our endeavor explores the intersection of electronics and medicine, providing a window into the complex electrical activities of the human body.
With a foundation built upon meticulous circuit design, our project seeks to uncover patterns and responses in both cardiac and muscular electrical signals. This chapter chronicles our journey of experimentation, presenting not only the methods employed but also the fascinating results that have emerged.

## 4.2 Circuit Design and Implementation

In this section, we delve into the intricate world of circuit design for the dual purpose of recording ECG and EMG signals. Our circuit integrates the precise capture of cardiac and muscle electrical activities, paving the way for a comprehensive understanding of the body's responses, show to Figure18 explain circuit of project.

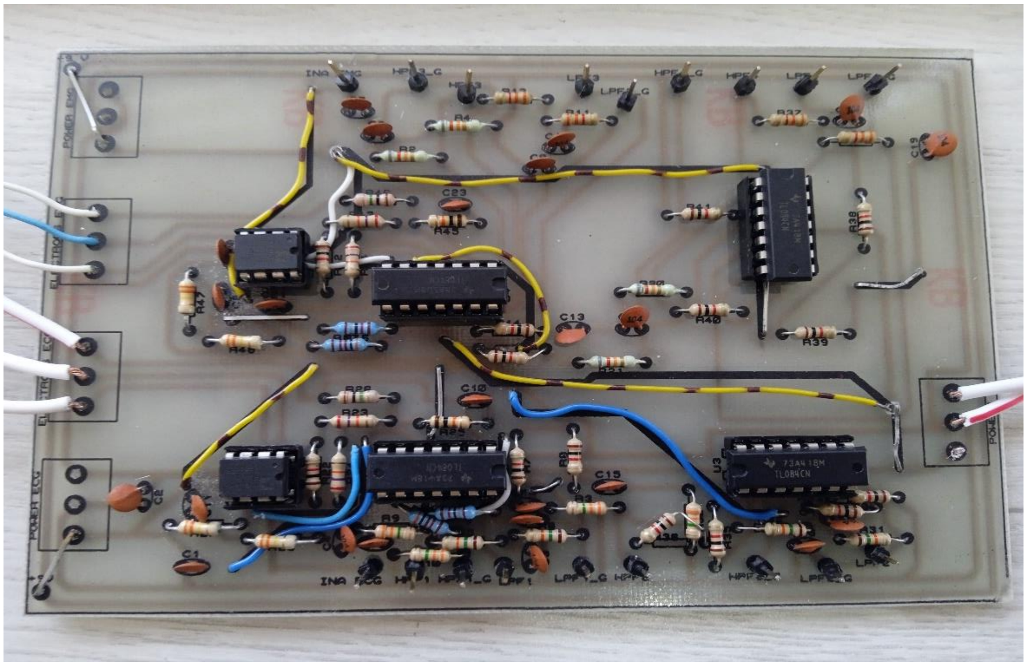


Figure18 (circuit of project)

### 4.2.1 Components Selection

The design process commenced with the careful selection of components tailored to our project's requirements. Integrated amplifiers, filters, and signal processing units were meticulously chosen to ensure accurate signal capture.

**1- INA (AD620).**

# **FEATURES:**

EASY TO USE

- Gain Set with One External Resistor (Gain Range 1 to 1000)
- Wide Power Supply Range (62.3 V to 618 V)
- Higher Performance than Three Op Amp IA Designs
- Available in 8-Lead DIP and SOIC Packaging
- Low Power, 1.3 mA max Supply Current

EXCELLENT DC PERFORMANCE (“B GRADE”)

- 50 mV max, Input Offset Voltage
- 0.6 mV/8C max, Input Offset Drift
- 1.0 nA max, Input Bias Current
- 100 dB min Common-Mode Rejection Ratio (G = 10)

LOW NOISE

- 9 nV/√Hz, @ 1 kHz, Input Voltage Noise
- 0.28 mV p-p Noise (0.1 Hz to 10 Hz)

EXCELLENT AC SPECIFICATIONS

- 120 kHz Bandwidth (G = 100)
- 15ms Settling Time to 0.01%

APPLICATIONS

- Weigh Scales
- ECG and Medical Instrumentation
- Transducer Interface
- Data Acquisition Systems
- Industrial Process Controls
- Battery Powered and Portable Equipment

For example, use AD620 with a Medical ECG Monitor Circuit. The low current noise of the AD620 allows its use in ECG monitors (Figure 15) where high source resistances of 1 MΩ or higher are not uncommon. The AD620's low power, low supply voltage requirements, and space-saving 8-lead mini-DIP and SOIC package offerings make it an excellent choice for battery powered data recorders. Furthermore, the low bias currents and low current noise coupled with the low voltage noise of the AD620 improve the dynamic range for better performance. The value of capacitor C1 is chosen to maintain stability of the right leg drive loop. Proper safeguards, such as isolation, must be added to this circuit to protect the patient from possible harm.

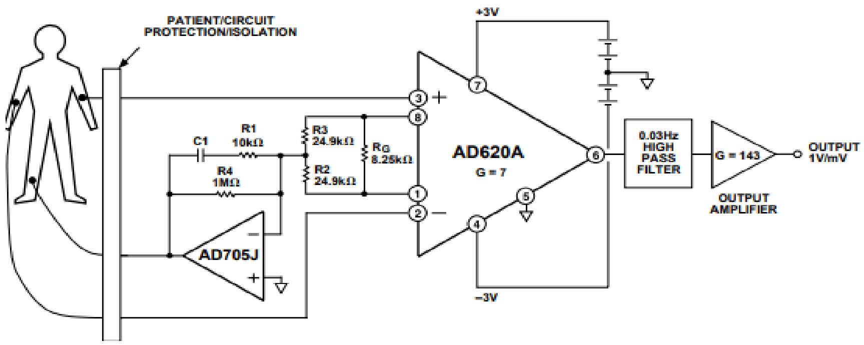



Figure19 (example use AD620 in medical)

## 2- Amplifier (TL084)

The TL084 are high speed J–FET input quad operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

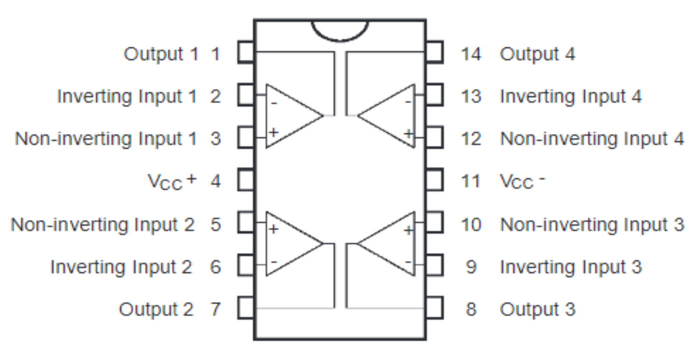



Figure20 (TL084)

**3- Resistors.**

are electronic components which have a specific, never-changing electrical resistance. The resistor's resistance limits the flow of electrons through a circuit. They are passive components, meaning they only consume power (and can't generate it).

Figure21 (Resistors)

**4- Capacitor**

is a two-terminal electrical device that can store energy in the form of an electric charge. It consists of two electrical conductors that are separated by a distance. The space between the conductors may be filled by vacuum or with an insulating material known as a dielectric.

a capacitor is a circuit component that temporarily stores electrical energy through distributing charged particles on (generally two) plates to create a potential difference. A capacitor can take a shorter time than a battery to charge up and it can release all the energy very quickly.


Figure22 (capacitor)

**5- Voltage Power Supply**

Power Supply Range (2.3 V to 18 V)


Figure23 (power supply)

### 6- Electrodes

Why there are minimum three electrodes used in ECG, EMG measurements?

In this configuration, two electrodes are used to measure a body surface's potential difference, and a third electrode provides a low-impedance return path for noise reduction. It is desirable to have few electrodes, in order to reduce the costs of the ECG acquisition system and increase patient comfort.

Figure24 (Electrodes)

# Three Multiplexers connected to Instrumentation Amplifier

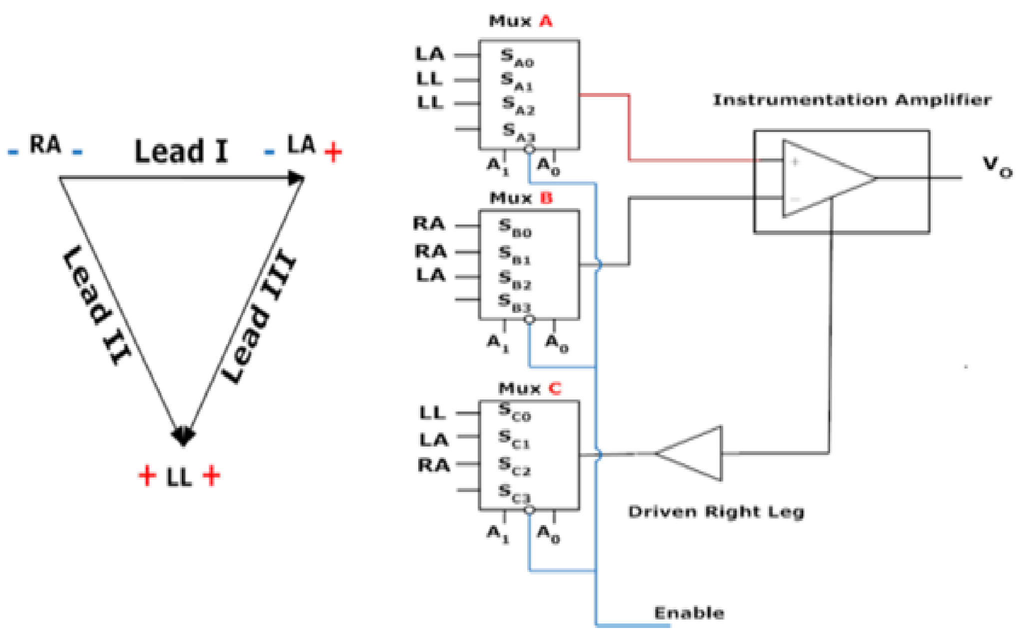



Figure25 (connected electrodes)

The following table shows the values of the resistors used in the design of the ECG device only, which monitor the electrical heart, according to the calculations used in the design.

| Quantity | References | Value |
|---|---|---|
| **24 Capacitors** | | |
| Quantity | References | Value |
| 22 | C1-C10,C12-C23 | 0.1uF |
| 2 | C11,C24 | 0.47uF |
| Sub-totals: | | |
| **46 Resistors** | | |
| Quantity | References | Value |
| 4 | R2,R4,R20-R21 | 80k |
| 4 | R3,R9-R10,R30 | 3.3M |
| 4 | R5-R6,R31-R32 | 15K |
| 14 | R7-R8,R14-R15,R22,R33-R36,R38-R42 | 1k |
| 4 | R11,R13,R29,R37 | 3.5K |
| 2 | R16,R18 | 30k |
| 2 | R17,R19 | 18k |
| 4 | R23-R24,R43-R44 | 24.9k |
| 2 | R25,R45 | 10k |
| 2 | R26,R46 | 1M |
| 4 | R27-R28,R47-R48 | 330k |
| Sub-totals: | | |
| **6 Integrated Circuits** | | |
| Quantity | References | Value |
| 2 | U1,U6 | AD620 |
| 4 | U2-U5 | TL084 |

Table2 (Component)

### 4.2.2 Signal Conditioning

The acquired ECG and EMG signals are often weak and susceptible to noise. Signal conditioning played a pivotal role, involving noise reduction techniques, amplification, and filtration to enhance the quality of captured data.

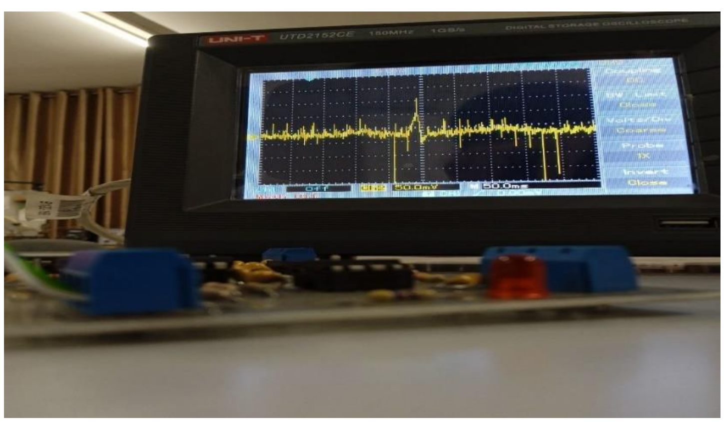


Figure26 (signal)

## 4.3 Equipment Used

The following equipment was utilized in these experiments:

- High-quality recording devices for both heart (ECG) and muscle (EMG).


Figure27 (simulation device)

- Electrode stickers for connecting leads to the skin's surface.


Figure28 (electrodes stickers)

- High-performance connecting cables.

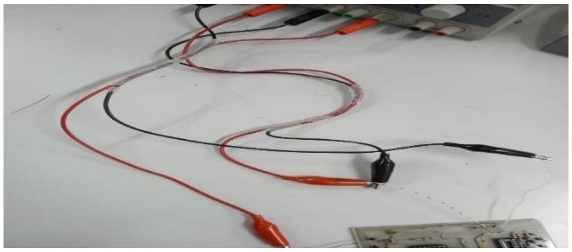


Figure29 (cables)

- oscilloscope device for control, recording, and analysis.

Figure30 (oscilloscope device)

- Voltage power supply


Figure31 (voltage power supply)

- Function generator device


Figure32 (function generator)

## 4.4 Experimental Procedure

This section covers the procedures undertaken during the experiments, including participant preparation and equipment arrangement.

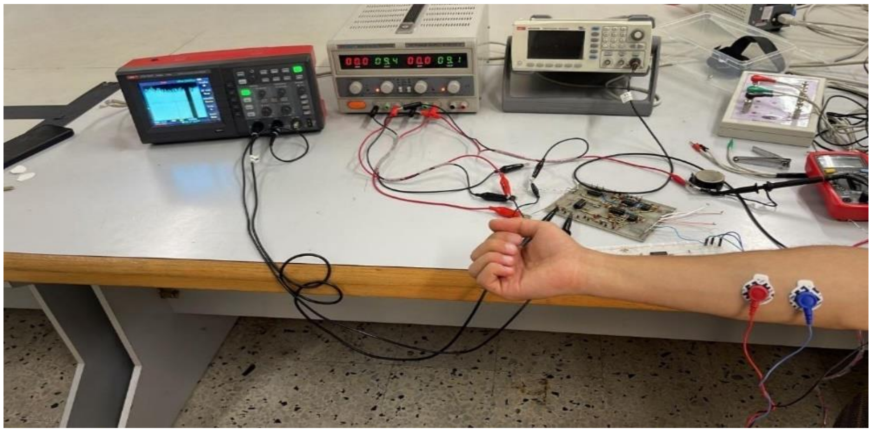


Figure33 (connecting electrodes)

### 4.4.1 ECG Circuit Design Using 4th-Order Butterworth Filter

**Experimental Design:**

1. **Circuit Setup:**
   The ECG circuit was constructed using standard ECG electrodes to capture electrical signals from the subject's body or simulation. (Range cut off frequency 0.5Hz to 100Hz)

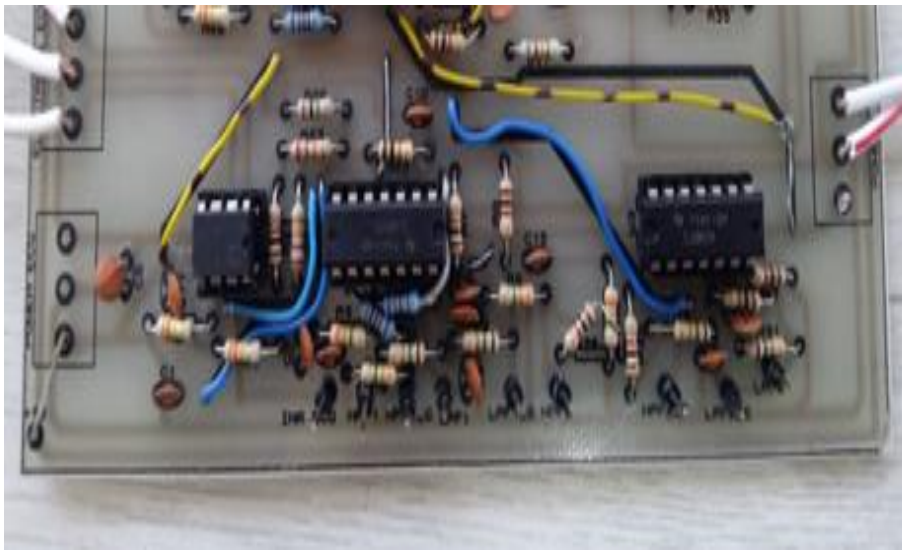


Figure34 (ECG circuit)

2. **Signal Amplification:**
   The raw ECG signals were initially amplified using operational amplifiers to ensure an adequate signal level for further processing.

**1- Experience by function generator**

- When set frequency 100mHz by function generator

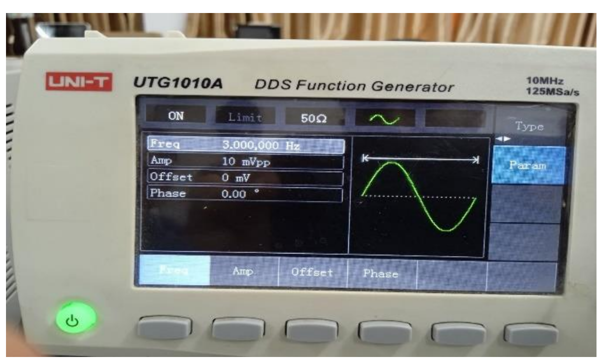



Figure35 (frequency 100mHz)

When apply filters of circuit on frequency 100mHz the signal will disappear because range frequency from 0.5Hz to 100Hz design in project

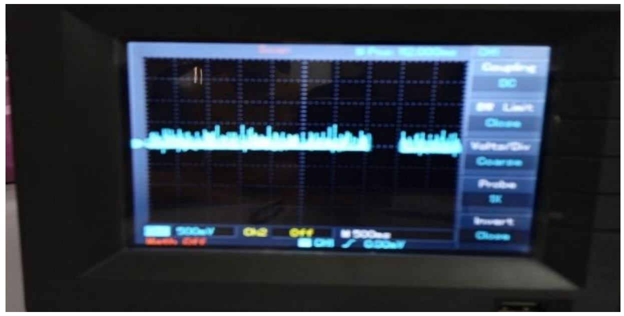


Figure36 (signal with 100mHz)

- When set frequency 3Hz by function generator

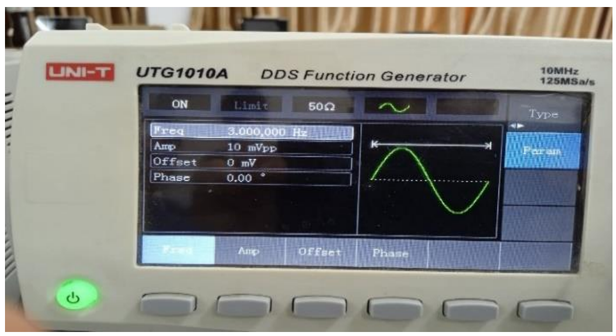



Figure37 (frequency 3Hz)

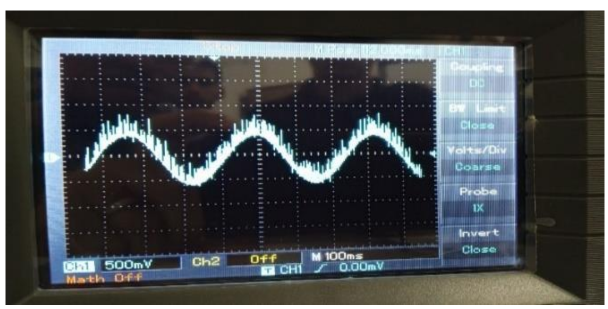



Figure38 (signal with 3Hz)

The signals will come out like this because of the cut off frequency designed in the special circuit of the ECG

**2- Experience by simulator device**

- Pulse mode

The "Pulse Mode" signal is a pulsatile waveform commonly used to test and evaluate the performance of measurement devices and electronic equipment. For instance, in the context of the simulator device mentioned earlier in the ECG circuit design project, the Pulse Mode signal is employed to generate recurring electrical pulses that represent heartbeats. This signal typically consists of pulses that repeat at a specific frequency. The signal's value is high during a defined pulse period and then returns to its baseline value during the resting phase, repeating this pattern periodically. Using the Pulse Mode signal on a simulator device allows engineers and technicians to test how the device responds to recurring signals and understand its behavior over time. This signal can be used for calibrating equipment or testing its resilience and stability when subjected to pulsatile signals. In the context of an ECG circuit design project, utilizing the Pulse Mode signal can help assess the circuit's efficiency in handling cardiac pulse signals and its ability to accurately extract and filter the desired signal while minimizing noise and interference.

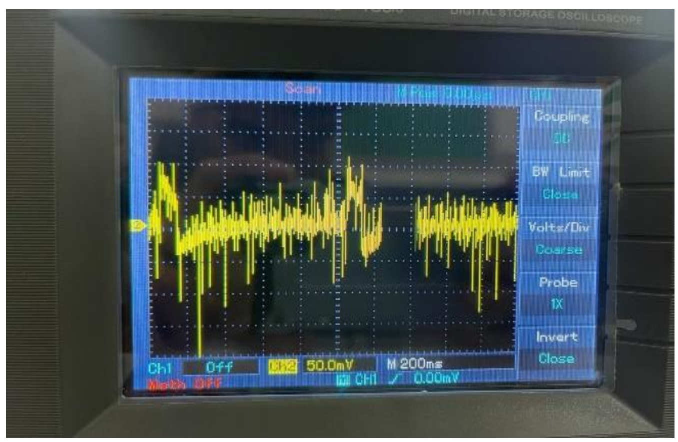



Figure39 (signal pulse mode)

The following image shows the shape of the signal after applying Butterworth in the case of pulse mode, which shows that the filter has reduced the amount of distortion with low and high frequencies, which is located in the cut off range designed in the project, which is from 0.5 Hz to 100 Hz(while CH1 :Initial signal , CH2: after Butterworth filter signal)

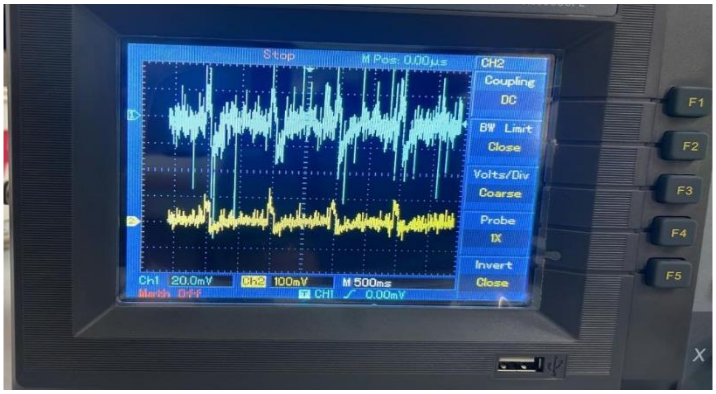



Figure40 (signal pulse mode after applying Butterworth filter)

- 60 beak per minute mode

In this mode, the simulator device produces a signal that emulates the electrical activity of the heart, generating a sequence of pulses that correspond to the rhythmic contraction and relaxation of the heart's chambers. The 60 beats per minute setting is commonly used for testing and calibrating medical equipment, such as electrocardiogram (ECG) machines, where the simulation of a normal heart rate is required.

In summary, the "60 beats per minute mode" simulates a heart rate of 60 beats per minute and is utilized to create a standard reference signal for evaluating the performance of medical and physiological monitoring equipment.

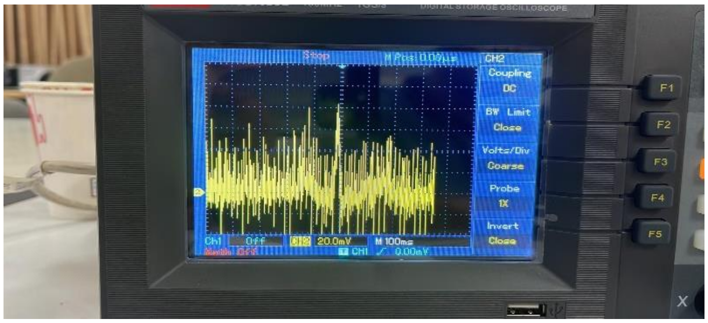



Figure41 (signal 60bpm mode)

⇨ When applying HPF1 as in the block diagram

✓ without gain (without amplifier)

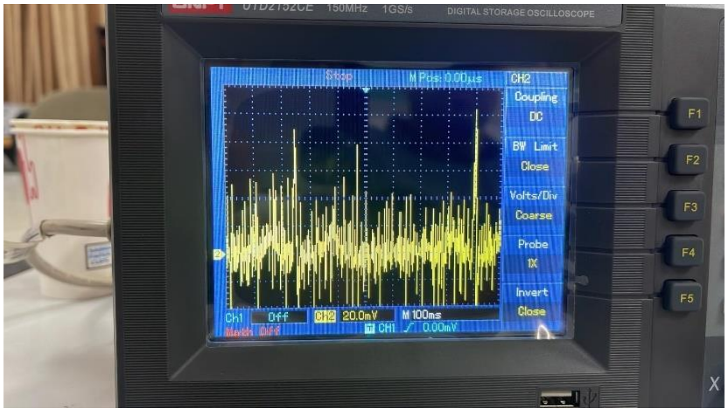



Figure42 (HPF1 without gain)

We notice when applying a high pass filter to this signal with a cut off frequency of 0.5Hz, it works to reduce the small amount of noise in this signal, and reduces the amount of ripple in it

✓ with gain equal = 2 (with amplifier)

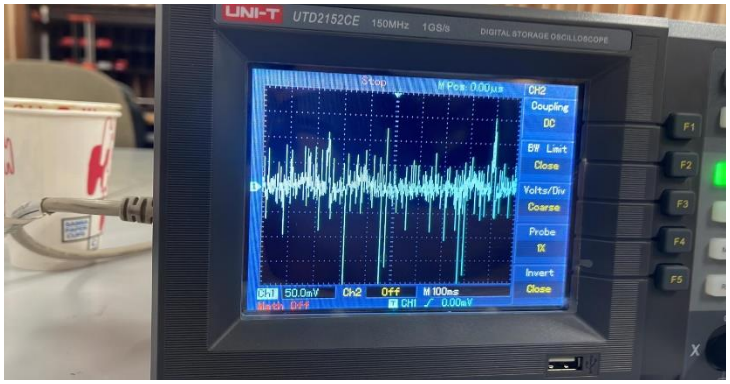



Figure43 (HPF1 with gain)

We notice when placing an amplifier with a value equal to 2, we find the extent of the improvement of the signal from the one before it, but we must take into account that it does not always magnify helps to understand the signal, sometimes the excessive increase in the magnification leads to distortion of the shape of the ECG signal, making it difficult to understand.

And when we continue to apply filters to the signal according to the previous block diagram of the project, we find that the extent of this signal improves until it reaches the final output of the project, so we find that the signal comes out in the best form and the lowest error rate in the application of filters, as this error rate reaches almost 0%

- ✓ OUTPUT Signal in project ECG with amplifier when cut off frequency equal 100Hz after low pass filter2 (after band pass filter 2)

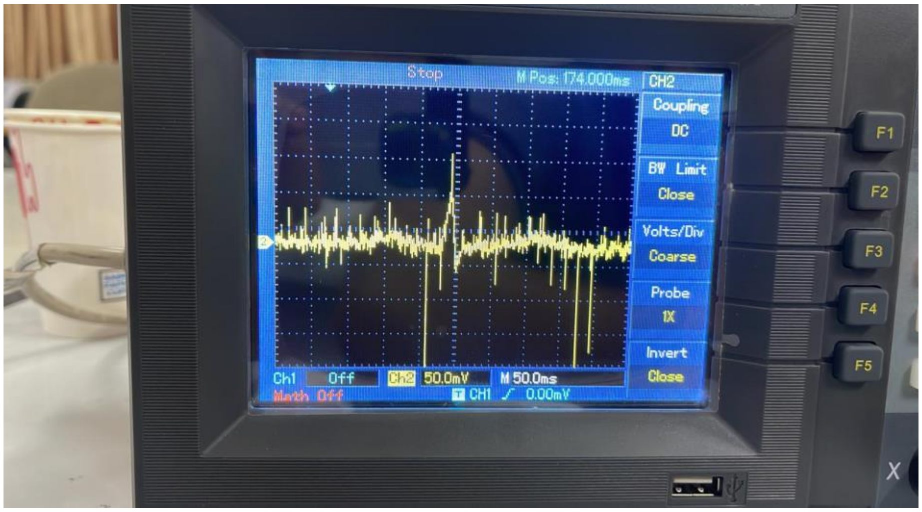



Figure44 (output signal ECG project)

**Results:**

1. **Raw ECG Signals:** The raw ECG signals exhibited baseline wander and high-frequency noise, which could potentially obscure important features of the cardiac waveform.
2. **Filtered ECG Signals:** After passing through the 4th-order Butterworth filter, the ECG signals showed significant noise reduction and improved clarity of the QRS complexes, P-waves, and T-waves.
3. **Frequency Response:** The filter effectively attenuated high-frequency noise beyond the typical range of ECG signals while preserving the relevant frequency components.

**Discussion of Results:**

The integration of the 4th-order Butterworth filter into the ECG circuit yielded promising results. The filter successfully removed unwanted high-frequency noise, enhancing the visibility of important cardiac features in the signal. This improvement can aid medical professionals in accurate ECG interpretation and diagnosis.

### 4.4.2 EMG Circuit Design Using 4th-Order Butterworth Filter

**Use of 4th-Order Butterworth Filter:**

The choice of a 4th-order Butterworth filter was motivated by its ability to effectively suppress high-frequency noise while maintaining the integrity of the underlying EMG waveform.

**Experimental Design:**

3. **Circuit Setup:** The EMG circuit was constructed using standard EMG electrodes to capture electrical signals from the subject's body or simulation.
   (Range cut off frequency 20Hz to 450Hz)

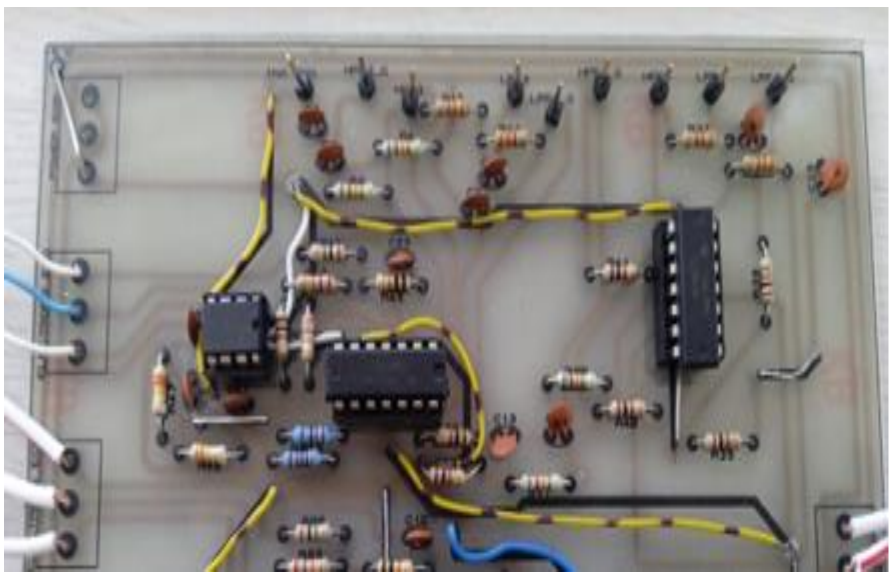


Figure45 (EMG circuit)

4. **Signal Amplification:** The raw EMG signals were initially amplified using operational amplifiers to ensure an adequate signal level for further processing.
   **1-** By function generator
   - When set frequency 10Hz by function generator


Figure46 (frequency 10Hz)

When apply filters of circuit on frequency 10Hz the signal will disappear because range frequency from 20Hz to 450Hz design in project

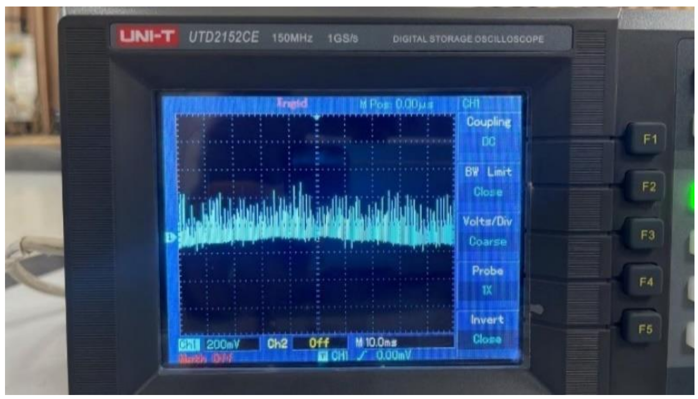



Figure47 (signal with 10Hz)

- When set frequency 80Hz by function generator

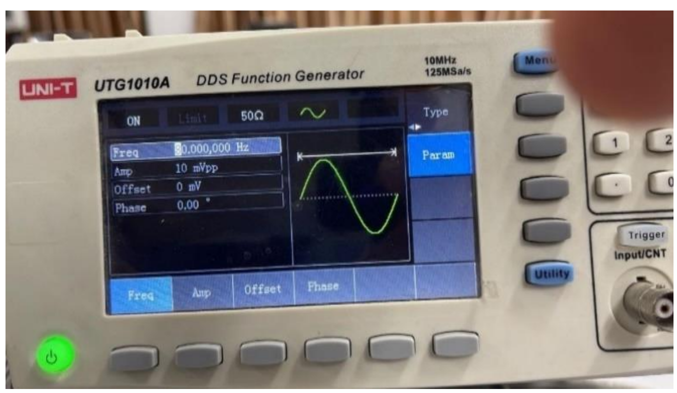



Figure48 (frequency 80Hz)

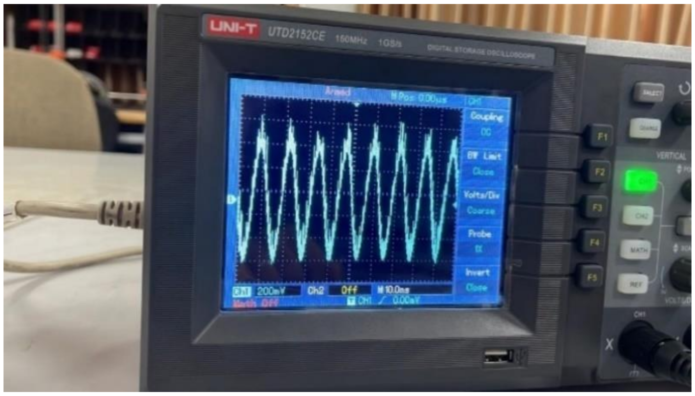



Figure49 (signal with 80Hz)

The signals will come out like this because of the cut off frequency designed in the special circuit of the EMG

**2-** By arm muscles

The following image shows the shape of the signal taken from the arm muscle chart, which is shown when HPF is applied to it, but without enlarging the signal, and the shape of the final signal that is considered the design output of the circuit, which is after LPF2. The difference between the signal when applying the filter at 20Hz frequency and the signal when applying the LPF filter at 450Hz in Muscle tension and relaxation

(while CH1: after applying LPF2 this output of circuit, and CH2: after applying HPF1 without gain to signal (not use amplifier))


Figure50 (signal HPF1 without gain & LPF2)

Here we note that with the application of LPF2 (the signal that comes out after the Bandpass filter), we see some reduction in high-frequency noise. This helps to understand the EMG signal more clearly than the HPF.

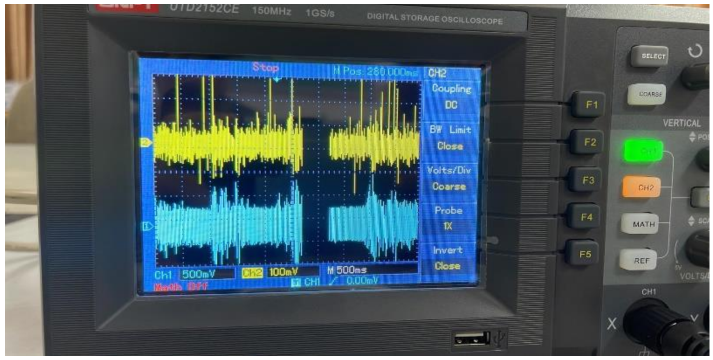



Figure51 (signal HPF1 & LPF2 with gain)

Here we note that with the application of LPF2 (the signal that comes out after the Bandpass filter), we see some reduction in high-frequency noise. This helps to understand the EMG signal more clearly than the HPF. This image shows the difference between the signal after applying HPF1 with an amplifier and the final signal after applying all filters to it, up to the last filter, which is LPF2, with an amplifier for the signal according to the special block diagram in the project

We see that there is a big difference in the two signals, as the final signal, which is the output of the special project in circuit EMG, is much clearer than the signal entered into the circuit.

**Results:**

1. **Raw EMG Signals:** The raw EMG signals exhibited noticeable interference from environmental noise, leading to difficulty in distinguishing genuine muscular activity.
2. **Filtered EMG Signals:** After passing through the 4th-order Butterworth filter, the EMG signals displayed a marked reduction in high-frequency noise and improved visibility of muscle activation patterns.
3. **Frequency Response:** The Butterworth filter effectively attenuated high-frequency noise, resulting in a cleaner and more informative EMG signal.

**Discussion of Results:**

The integration of the 4th-order Butterworth filter into the EMG circuit yielded favorable outcomes. By attenuating high-frequency noise, the filter enhanced the discernibility of genuine muscle activity patterns in the EMG signal. This improvement is particularly valuable for accurate clinical diagnoses and research applications.

### 4.5 Practical Implications

The purpose of using a Butterworth filter on EMG and ECG circuits is to achieve specific signal processing goals:

1. **Noise Filtering:** A Butterworth filter is designed to reduce interference and noise that could affect the quality of recorded signals. In the context of recording electrical signals from muscles (EMG) or the heart (ECG), it's crucial to eliminate unwanted noise for accurate readings.
2. **Frequency Band Selection:** A Butterworth filter can be configured to pass only the desired frequency range that carries relevant information. When recording cardiac or muscular electrical signals, there might be a specific frequency band containing vital information that needs to be accurately preserved.
3. **Attenuation of High/Low Frequencies:** In some cases, high or low frequencies might be undesirable. A Butterworth filter can effectively reduce the impact of these frequencies and filter the signal to achieve better coherence.
4. **Control of Time Delay:** Butterworth filters have a constant time characteristic, meaning they don't introduce time shifts to signal components. This feature is useful when maintaining precise signal timing is essential.

In general, applying a Butterworth filter to EMG or ECG signal recording circuits aims to enhance the quality of the recorded signal by reducing interference, selecting the relevant frequency band, and ultimately facilitating accurate and reliable analysis of these signals.

# Chapter5:

# Conclusion and Reference

## 5.1 Conclusion

In the crucible of experimentation and analysis, our Bio-signal monitoring circuit project has ignited a spark of knowledge. By decoding the intricate electrical symphony of the body, we have unlocked doors to possibilities that transcend medicine and science. Our journey is an ode to the synergy between electronics and biology, offering a glimpse into the wonders that lie at the intersection of technology and human understanding.

Bio-signal monitoring systems have been studied thoroughly in the literature; however, the multi-dimensional aspects of these systems make it difficult for researchers, medical practitioners, and others to select, among these systems, those that fulfill their monitoring needs, match the context of their use, and support the required disease monitoring requirements.

Current development in bio-signal monitoring systems leveraged new technologies, such as deep learning, AI, Big Data and IoT to provide efficient, cost-efficient, fully connected, and powerful monitoring system. Enabling technologies provide huge opportunities for the advancement of ECG and EMG monitoring systems. IoT brings in remote, unconstrained connectivity and services that leverage data and facilitate timely, meaningful, and critical decisions for a better lifestyle. Furthermore, Fog processing and cloud processing contribute to an increased opportunity to improve efficiency and fulfill numerous in-demand scalable application services.

patterns. Also, personalized monitoring systems should be raised to the next level in terms of being highly customized according to patients' needs and interactive to allow special configurations and adaptations to users' requirements for a better quality of life. Finally, another possible research direction is to add more intelligence to the patients' surroundings, for example, embedding more sensors in the carpet to accurately detect patients' movements in order to establish behavior patterns and detect any abnormalities.

To that end, we endorse that this work, with a detailed discussion on many relevant research work, provides a comprehensive state-of-the-art review of ECG and EMG monitoring systems. It can serve as reference for various researchers and stakeholders in the field to compare, understand, and value ECG and EMG monitoring system features. It also highlights the main challenges these systems exhibit in terms of adaptability, integration, monitoring quality and durability. Finally, it outlines a future vision of the next-generation ECG and EMG monitoring systems for healthcare.

## 5.2 Reference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[12] Paper (An Innovative Design Approach of Butterworth Filter for Noise Reduction in ECG Signal Processing based Applications) performance analysis has been carried with the help of Butterworth filter.

[13]https://www.researchgate.net/publication/322083494_An_Innovative_Design_Approach_of_Butterworth_Filter_for_Noise_Reduction_in_ECG_Signal_Processing_based_Applications