DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING,
FACULTY OF ECE,
Rajshahi University of Engineering & Technology, Bangladesh

EEE - 4262– Biomedical Engineering Sessional

Student Sessional Report

Submitted to

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Heaven's light is our guide.

Rajshahi University of Engineering and Technology

RUET

Department of Electrical & Electronic Engineering

Course no. EEE 4262

Course title: Biomedical Engineering Sessional

Experiment no. 1

Experiment name: Body composition analysis using four electrode bio impedance measurement technique

Date of experiment: , 2023

Date of submission: , 2023

Submitted to:	Submitted by:
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RUET

Experiment No. 01

1.1 Experiment Name

Body composition analysis using four electrode bio impedance measurement technique

1.2 Objectives

- To gain knowledge about the composition of the human body in terms of its percentage of body fat, water, and muscle mass.
- To obtain practical knowledge and skills in utilizing the four-electrode bioimpedance measurement technique
- To learn to categorize health status based on the results of bioimpedance analysis and identify potential health risks associated with body composition imbalances

1.3 Theory

The four-electrode method, a well-established technique dating back to the late 19th century, measures the resistivity of materials using separate pairs of electrodes for current injection and voltage measurement. In this application, one electrode pair was strategically placed at the finger joint, while the other pair was positioned on the wrist. To ensure proper measurements, the black and red leads must be consistently paired across both locations. This configuration allows for accurate and reliable determination of resistivity through the analysis of the induced voltage drop in response to the injected current.

Human body impedance measurements offer valuable insights into health and body composition. While cadavers exhibit an average impedance of 1,000 Ω, living bodies show significantly lower values at 500 Ω. Notably, electrode-skin contact impedance decreases significantly within the 10 Hz to 1 MHz frequency range. In terms of body composition for 18–30-year-olds, the average fat range is 12-18% for males and 20-26% for females. Additionally, water content, encompassing both extracellular and intracellular water, averages 55-65% for males and 50-60% for females at that age.

The "prediction marker," defined as the ratio of impedance at 200 kHz to 5 kHz, serves as a key indicator of health status. This analysis provides valuable information about a person's overall health and well-being.

Furthermore, the phase angle measures the functionality of cell membranes, essentially assessing the "battery life" of our cells. Leakage in the cell membrane impairs its ability to hold a voltage, leading to a decrease in the phase angle. Based on this measurement, individuals can be categorized into different health groups: poor (3.5-5.4), satisfactory (5.4-6.4), good (6.4-7.9), and outstanding (7.9+).

Finally, the impedance curve, a graph depicting the relationship between resistance and reactance for the human body, provides additional insights into health. The angle between the vector and reactance is known as the phase angle. While the experiment's sample size was limited to 2-3 individuals, the obtained data offer valuable preliminary findings for further research in this area.

1.4 Apparatus

- ❖ Carbon coated electrode (4 pieces)
- ❖ Body stat device (1 piece)
- ❖ Covering tape
- ❖ Weight machine
- ❖ Subject

1.5 Data Table

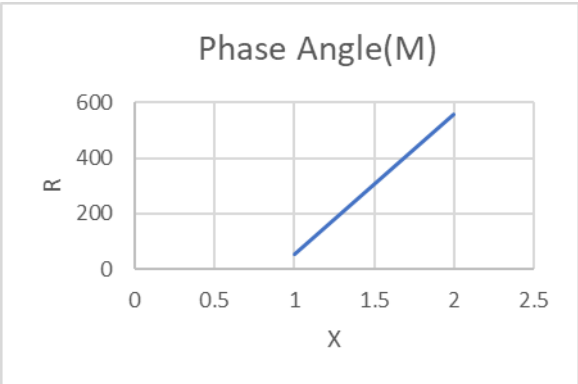
Table 1: Basic Information

Serial No.	*Name*	*Gender*	*Age*	*Weight*	*Height*
117	Modhusudan	Male	25	57	1.65
118	Efaz	Male	25	75.5	1.7
119	Noman	Male	23	74.5	1.63
120	Rakibul	Male	24	68	1.68
121	Pranto	Male	24	72.5	1.65
123	Maliha	Female	24	52	1.55
124	Mayesha	Female	24	53	1.57
126	Ifthekhar	Male	25	65	1.75
127	Saad	Male	25	79	1.73
128	Rokon	Male	24	81	1.83

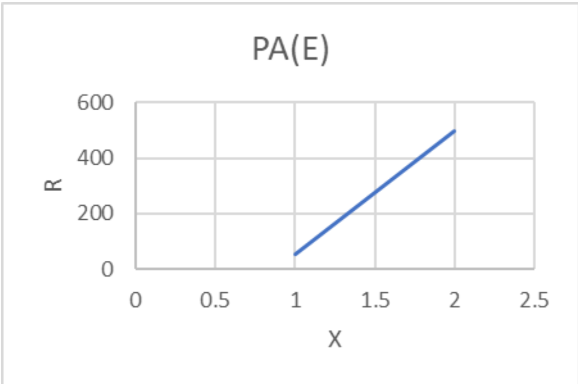
Table 2: Analytical Data

Serial. No.	*Fat(%)*	*TBW(%)*	*Lean(%)*	*Z at 50Khz*	*PA*	*Status*	*BMI*	*Status*
117	13.5	61.6	86.5	557.4	5.62	Satisfactory	19.2	Underwieght
118	22.1	47.7	77.9	498.4	6.32	Satisfactory	28.5	Overweight
119	14.6	74.8	85.4	402.2	8.25	Outstanding	28	Overweight
120	21	46.1	79	562.9	5.58	Satisfactory	26	Overweight
121	22.5	61.1	77.5	500.4	7.3	Good	29	Overweight
123	19.4	47.6	80.6	546.4	7.05	Good	20.8	Healthy
124	30.5	42.9	69.5	653.2	4.36	Poor	23.8	Healthy
126	14.7	53.5	85.3	582.4	5.44	Satisfactory	21	Healthy
127	20.6	49.5	79.4	473.5	6.2	Satisfactory	28.3	Overweight
128	18.1	52.2	81.9	526.5	7.2	Good	25.1	Overweight

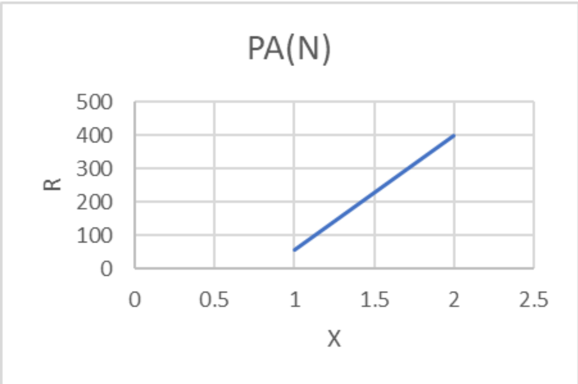
Impedances Curves



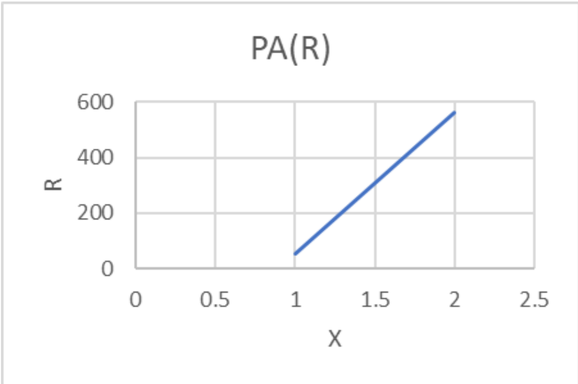
Fig(a) Phase Angle of SN 117



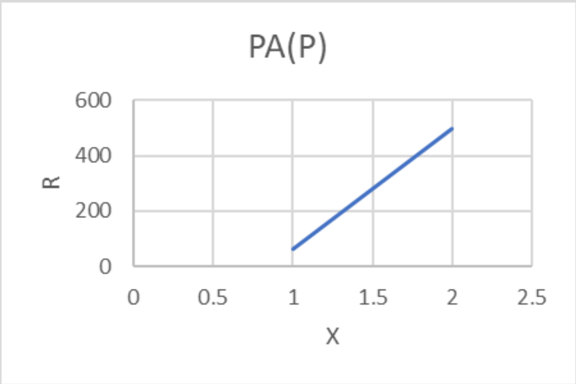
Fig(b) Phase Angle of SN 118



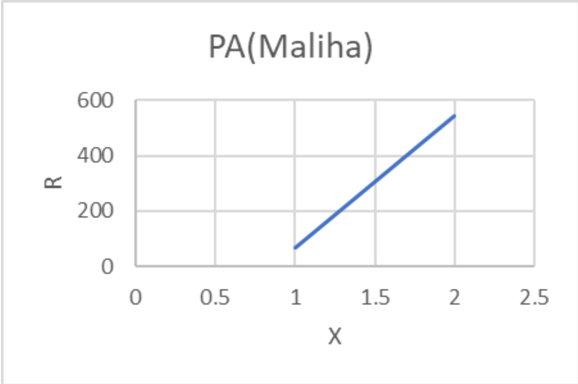
Fig(c) Phase Angle of SN 119



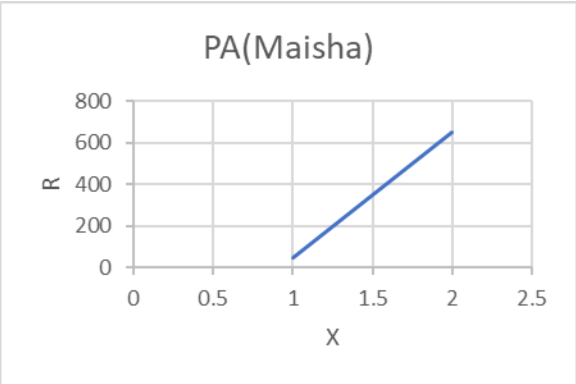
Fig(d) Phase Angle of SN 120



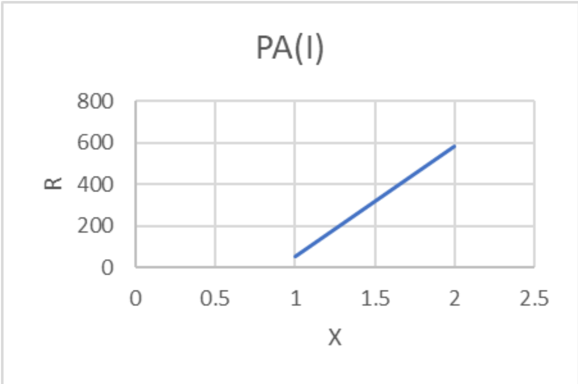
Fig(e) Phase Angle of SN 121



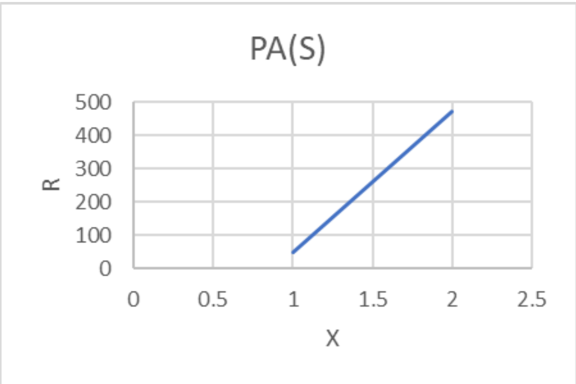
Fig(f) Phase Angle of SN 123



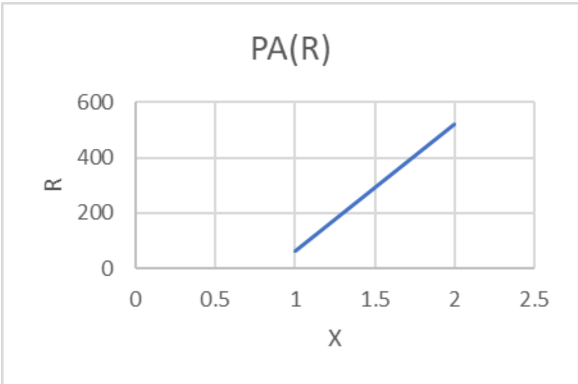
Fig(g) Phase Angle of SN 124



Fig(h) Phase Angle of SN 126



Fig(i) Phase Angle of SN 127



Fig(j) Phase Angle of SN 128

1.6 Discussion & Conclusion

This experiment successfully employed electrode bioimpedance analysis to assess body composition. Prior to the analysis, thorough background knowledge was acquired, and necessary precautions were implemented. Data was meticulously collected and analyzed using computer software. Standard charts facilitated the interpretation of the results and provided insights into the health status of the participant. An impedance diagram was also generated for further analysis. While limitations such as electrode-related errors and tape repetition time may have been present, all objectives were ultimately achieved, solidifying the experiment's successful execution.

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Course no. EEE 4262

Course title: Biomedical Engineering Sessional

Experiment no. 2

Experiment name: Observation of cardiac states before (at rest state) and after physical activity

Date of experiment: , 2023

Date of submission: , 2023

Submitted to:	Submitted by:
Kusum Tara **Assistant Professor** Dept. of Electrical & Electronic Engineering, Rajshahi University of Engineering and Technology.	**Ashraf Al- Khalique** **Roll:** 1801171 **Session:** 2018-2019 Dept. of Electrical & Electronic Engineering, Rajshahi University of Engineering and Technology.

Experiment No. 02

2.1 Experiment Name

Observation of cardiac states before (at rest state) and after physical activity

2.2 Objectives

- To observe and analyze variations in cardiac parameters, including heart rate and blood pressure, during a state of rest and after physical activity
- To understand the correlation between physical activity and cardiac responses
- To observe the R wave duration of lead-2

2.3 Theory

Each heartbeat, a single cardiac cycle, is marked by a complex dance of electrical activity within the heart. It begins with the firing of the SA node, generating the P wave on an electrocardiogram as the atrial muscles depolarize. The signal then travels silently through the AV node before igniting the Purkinje fibers, initiating ventricular depolarization.

This rapid activity creates the downward and upward deflections of the QRS complex, followed by minimal deflection during basal ventricular depolarization. A straight line, the ST segment, signifies complete ventricular depolarization. After a brief pause, repolarization starts, marking the cycle's completion.

This intricate process, normally occurring 60-80 times per minute, can accelerate beyond 80 beats per minute after exercise, ensuring efficient blood flow throughout the body.

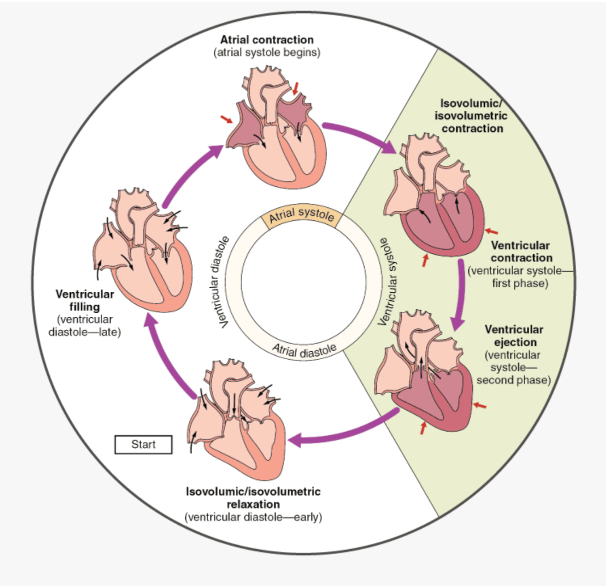

Figure 2.1: Different phases of the cardiac cycle

The atrial and ventricular rates are the same and are measured by the following equation:

Atrial rate = 1500 / t(P-P) bpm	**Ventricular rate = 1500 / t(R-R) bpm**

2.4 Apparatus

- ❖ Carbon coated electrode (4 Nos.)
- ❖ ECG machine
- ❖ Silver Fluoride gel

2.5 Data Table

Subject No.	Heart rate at rest (bpm)	Heart rate after exercise (bpm)
1.	62.5	136.36
2.	83.33	150
3.	79	150
4.	60	166.67
5.	57.7	150

2.6 ECG Signal

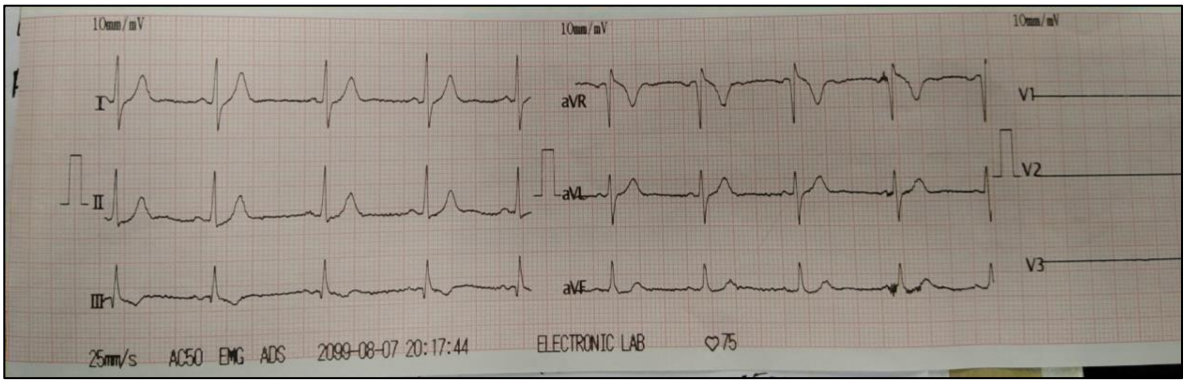

Figure 2.2: ECG signal from ECG machine

2.7 Calculation

Ventricular rate of S5 = 1500 / t(R-R) bpm

At rest, Ventricular rate of S5 = 1500 / 26 = 57.7 bpm

After physical activity, Ventricular rate of S5= 1500 / 10 = 150 bpm

2.8 Discussion & Conclusion

In this experiment, while examining lead 2 of the ECG, we observed that during rest, subject 5 (S5) exhibited longer intervals between consecutive R-peaks (R-R intervals) compared to their post-exercise measurements. This resulted in a higher frequency of R-peaks and, consequently, a lower heart rate at rest and an elevated heart rate during activity. Notably, all subjects displayed similar findings, further solidifying the link between R-R intervals and heart rate changes in response to exercise.

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Course no. EEE 4262

Course title: Biomedical Engineering Sessional

Experiment no. 3

Experiment name: Measurement and analysis of the gain in an instrumentation amplifier circuit

Date of experiment: , 2023

Date of submission: , 2023

Submitted to:	Submitted by:
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Experiment No. 03

3.1 Experiment Name

Measurement and analysis of the gain in an instrumentation amplifier circuit

3.2 Objectives

- To observe the amplification of differential input and rejection of common-mode input
- To understand the basic principles and operation of an instrumentation amplifier
- To measure the differential gain in instrumentation amplifier

3.3 Theory

Instrumentation amplifiers are a specialized type of differential amplifier boasting exceptional common-mode rejection and high differential gain. Essentially, they amplify the difference between two input signals while simultaneously rejecting any common noise present in both.

This remarkable ability is achieved through a specific internal circuit configuration where a current, I3, flows through resistors R1, R2, and R3 based solely on the difference in voltage between the two inputs, Vi1 and Vi2. As a result, the output voltage differential, Vo1-Vo2, becomes directly proportional to this voltage difference, further amplified by a factor of (1+2(R1/R3)) and multiplied by the gain of the output stage (R6/R4).

This clever design allows the instrumentation amplifier to effectively extract the desired signal while ignoring any unwanted common-mode noise, making it a valuable tool in various applications requiring precise and accurate measurements.

3.4 Apparatus

- Multimeter
- Oscilloscope
- Resistor
- Potentiometer
- Op-amp
- Project Board
- Wires
- Signal generator

3.5 Data Table (Measured value)

V_{i1}(volt) (p-p)	V_{i2}(volt) (p-p)	R_3 (Ω)	V_o (volt)	Differential gain, $A_d = V_o/(V_{i1}-V_{i2})$
4	4.5	10k	3	6
4	4.5	20k	2.8	5.6
4	4.5	40k	2.72	5.44
4	4.5	infinity	0.5	1

3.6 Calculated value

For $R_3 = 10k\Omega$; $V_{i1} = 4$ V; $V_{i2} = 4.5$ V

$V_o = (1+2(10/10))(10/10)(4-4.5) = 1.5$ V

$A_d = V_o / V_{i1}-V_{i2} = 1.5/0.5 = 3$

For $R_3 = 20k\Omega$; $V_{i1} = 4$ V; $V_{i2} = 4.5$ V

$V_o = (1+2(10/10))(10/10)(4-4.5) = 1$ V

$A_d = V_o / V_{i1} - V_{i2} = 1/ 0.5 = 2$

For $R_3 = 40k\Omega$; $V_{i1} = 4$ V; $V_{i2} = 4.5$ V

$V_o = (1+2(10 /40)) (10/10) (4-4.5) = 0.75$ V

$A_d = V_o / V_{i1} - V_{i2} = 0.75/ 0.5 = 1.5$

For $R_3 = \infty$; $V_{i1} = 4$ V; $V_{i2} = 4.5$ V

$V_o = (1+2(10 / \infty)) (10/10) (4-4.5) = 0.5$ V

$A_d = V_o / V_{i1} - V_{i2} = 0.5/ 0.5 = 1$

3.7 Discussion & Conclusion

The experiment successfully constructed the instrumentation circuit and accurately utilized a potentiometer as the gain resistor (R3). By varying the value of R3, different differential gains (Ad) were achieved, demonstrating its role in amplifying the differential input. While some discrepancies existed between the estimated and measured output, the observed decrease in Ad with increasing R3 aligned perfectly with theoretical predictions, validating the experiment's successful execution.

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Course no. EEE 4262

Course title: Biomedical Engineering Sessional

Experiment no. 4

Experiment name: Development of a MATLAB based GUI app for processing ECG signal to determine Cardiac state

Date of experiment: , 2023

Date of submission: , 2023

Submitted to:	Submitted by:
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RUET

Experiment No. 04

4.1 Experiment Name

Development of a MATLAB based GUI app for processing ECG signal to determine Cardiac state

4.2 Objectives

- To develop a MATLAB-based GUI application that effectively processes ECG signals
- To contribute to the efficient determination of cardiac states, enabling timely diagnosis and intervention

4.3 Theory

The electrocardiogram (ECG) stands as a pivotal diagnostic tool, capturing the heart's electrical activity over time. In the realm of ECG signal processing, essential steps include filtering, noise reduction, and feature extraction. Leveraging MATLAB's capabilities in data analysis, signal processing, and visualization proves ideal for developing tools tailored to process and analyze ECG signals. The Graphical User Interface (GUI) feature within MATLAB enhances user interaction, paving the way for user-friendly applications. The integration of automated analysis within the GUI application streamlines this complex process, offering a swift and accurate means of assessing cardiac health.

4.4 Apparatus

- ❖ MATLAB

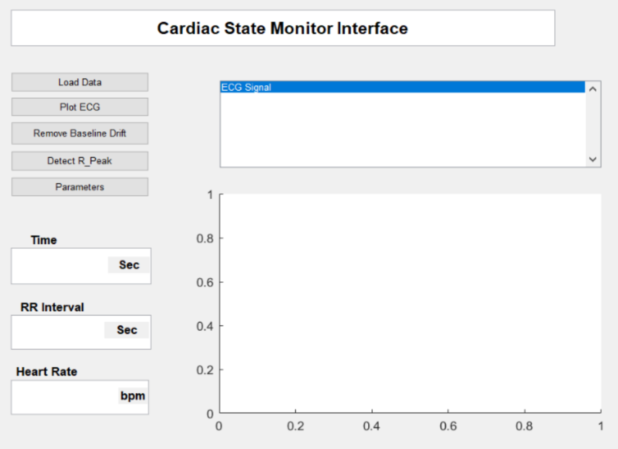
4.5 MATALAB Code

```
function varargout = ecg(varargin)
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
'gui_Singleton',  gui_Singleton, ...
'gui_OpeningFcn', @ecg_OpeningFcn, ...
'gui_OutputFcn',  @ecg_OutputFcn, ...
'gui_LayoutFcn',  [] , ...
'gui_Callback',   []);
if nargin && ischar(varargin{1})
gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
[varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
gui_mainfcn(gui_State, varargin{:});
end
function ecg_OpeningFcn(hObject, eventdata, handles, varargin)
handles.output = hObject;
guidata(hObject, handles);
function varargout = ecg_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;
function ecgsig_Callback(hObject, eventdata, handles)
fullfile = dlmread('ECG_Signal.tsv');  %Load ECG signal during walking
Fs = 250; %The data are sampled at 250Hz
ecgsig = fullfile(:,2);  %reading ecg signal
samples = 1:length(ecgsig);  %No. of samples
tx = samples./Fs;  %Getting time vector
f = 1./tx; % frequency of ecg
set(handles.listbox1,'String',ecgsig);
function listbox1_Callback(hObject, eventdata, handles)
function listbox1_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
set(hObject,'BackgroundColor','white');
```

```
end
function plot_ecg_Callback(hObject, eventdata, handles)
ecgsig = str2num(get(handles.listbox1,'String'));
Fs = 250; %The data are sampled at 250Hz
samples = 1:length(ecgsig);  %No. of samples
tx = samples./Fs;  %Getting time vector
f = 1./tx; % frequency of ecg
axes(handles.axes1);
plot(tx,ecgsig);
title('Original Lead II ECG Signal')
legend('Original ECG');
xlabel('Time (sec)')
ylabel('Voltage (volt)')
grid on
function baseline_drift_Callback(hObject, eventdata, handles)
ecgsig = str2num(get(handles.listbox1,'String'));
Fs = 250; %The data are sampled at 250Hz
samples = 1:length(ecgsig);  %No. of samples
tx = samples./Fs;  %Getting time vector
f = 1./tx; % frequency of ecg
for i = 1:1:length(ecgsig)
if i == 1
m(i) = ecgsig(i+1)-ecgsig(i);
end
if i>1
m(i) = ecgsig(i-1)-ecgsig(i);
end
end
denoised = m;
wp=20; ws=60; rp=0.5; rs=25; %Design a Butterworth filter of order 9 for smoothing noise
[N, Wn] = buttord(wp/(Fs/2), ws/(Fs/2), rp, rs);
[b, a]=butter(N, Wn);
yy=filter(b,a,denoised);
axes(handles.axes1);
plot(tx, yy);
title('Baseline noise removed ECG')
legend('Baseline noise removed ECG');
xlabel('Time (sec)')
ylabel('Voltage (volt)')
grid on
function r_peak_Callback(hObject, eventdata, handles)
ecgsig = str2num(get(handles.listbox1,'String'));
Fs = 250; %The data are sampled at 250Hz
samples = 1:length(ecgsig);  %No. of samples
tx = samples./Fs;  %Getting time vector
f = 1./tx; % frequency of ecg

for i = 1:1:length(ecgsig)
if i == 1
m(i) = ecgsig(i+1)-ecgsig(i);
end
if i>1
m(i) = ecgsig(i-1)-ecgsig(i);
end
end
base_remove_signal = m;
for i = 1:1:length(base_remove_signal)
if base_remove_signal(i)>=0.0005
n(i)=base_remove_signal(i);
end
end
r_peak=n;
plot(r_peak);
title('R Peak Detected Signal')
legend('R Peak Detected Signal');
xlabel('Time (sec)')
ylabel('Voltage (volt)')
grid on
```

```
end
end
```

4.6 GUI Layout



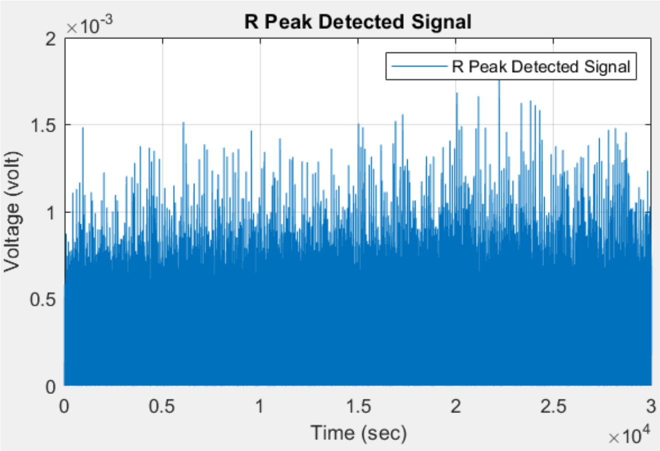


Fig.4.1: GUI of Cardiac States Monitor

Fig.4.2: R-peak Detected signal

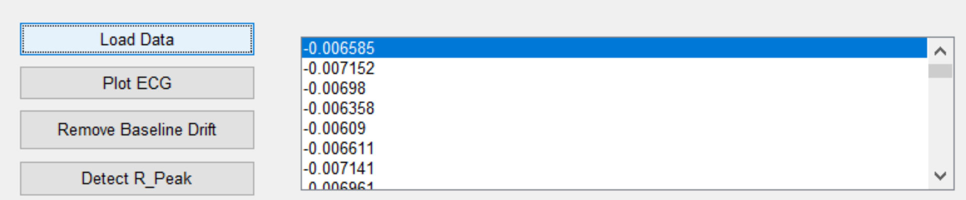
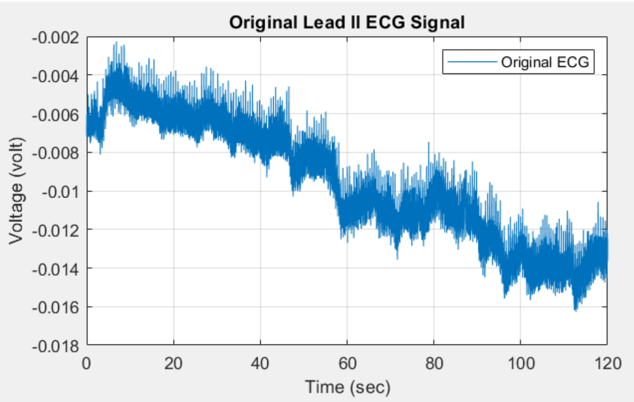


Fig.4.3: Load Data



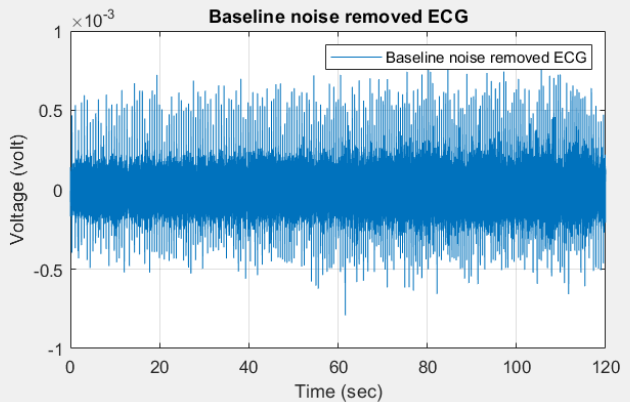


Fig.4.4: Original Lead II ECG Signal

Fig.4.5: Baseline noise removed ECG Signal

4.7 Discussion & Conclusion

The experiment successfully developed a MATLAB-based GUI application for ECG signal processing, facilitating efficient cardiac state determination. MATLAB's robust capabilities in data analysis and signal processing, combined with a user-friendly GUI, presented a valuable tool for healthcare professionals. Processed ECG signals allowed for the assessment of normal rhythms, arrhythmias, and patterns indicative of cardiac disorders. The automated analysis within the GUI demonstrated efficiency, promising accelerated decision-making in clinical settings. Further validation and testing in diverse scenarios are essential for ensuring the reliability and applicability of this innovative tool.

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Course no. EEE 4262

Course title: Biomedical Engineering Sessional

Experiment no. 5

Experiment name: Action Potential and bio electrical impedance measurement of human limbs

Date of experiment: , 2023

Date of submission: , 2023

Submitted to:	Submitted by:
Kusum Tara **Assistant Professor** Dept. of Electrical & Electronic Engineering, Rajshahi University of Engineering and Technology.	**Ashraf Al- Khalique** **Roll:** 1801171 **Session:** 2018-2019 Dept. of Electrical & Electronic Engineering, Rajshahi University of Engineering and Technology.

RUET

Experiment No. 05

5.1 Experiment Name

Action Potential and bio electrical impedance measurement of human limbs

5.2 Objectives

- To investigate the relationship between action potentials in the limbs and bioelectrical impedance
- To understand how the electrical activity associated with action potentials influences the impedance of the limb

5.3 Theory

The action potential, a critical electrical phenomenon, is observed in excitable cells like neurons and muscle cells. These rapid changes in membrane potential involve depolarization and repolarization, facilitating signal transmission along the cell's length. Bioelectrical impedance refers to the resistance living tissues present to electric current flow. In the context of human limbs, measuring bioelectrical impedance offers valuable insights into limb composition, revealing proportions of muscle, fat, and fluids.

Bioelectrical Impedance Analysis (BIA) is a method for estimating body composition, particularly body fat and muscle mass. This technique involves passing a weak electric current through the body and measuring voltage to calculate impedance (resistance and reactance). Since most body water resides in muscles, individuals with higher muscle mass typically exhibit lower impedance. BIA precisely determines electrical impedance, representing tissue resistance to electric current flow.

5.4 Apparatus

- ❖ Measuring electrodes
- ❖ Bio-electrical impedance measurement device
- ❖ Gel

5.5 Data Table (Measured value)

Ashraf (1801171)			**Efaz (1801179)**		
Position	Impedance (MOhm)	Voltage	Position	Impedance (MOhm)	Voltage
RA-RW	1.95	1.95 V	RA-RW	1.92	1.92 V
RA-LA	1.75	1.75 V	RA-LA	1.88	1.88 V
RL-LL	25	25 V	RL-LL	41	41 V
Saad (1801141)			**Sagor (1801172)**		
Position	Impedance (MOhm)	Voltage	Position	Impedance (MOhm)	Voltage
RA-RW	1.90	1.90 V	RA-RW	1.93	1.93 V
RA-LA	1.78	1.78 V	RA-LA	1.66	1.66 V
RL-LL	28	28 V	RL-LL	18	18 V

Here, injected current is 1 micro ampere.

5.6 Discussion & Conclusion

This experiment aimed to explore action potential and bioelectrical impedance across different body regions, comparing right arm to left arm, arm to leg, and leg to leg. Prior to analysis, theoretical groundwork was laid. Using a specialized device, a constant 1 microampere current was injected through the body, and impedance was measured at 15s, 30s, and 60s intervals. The report includes a theoretical framework and data table. The report combines theoretical foundations with practical insights, demonstrating a systematic approach.