Heaven's Light is Our Guide

Rajshahi University of Engineering and Technology

Course Code

ECE 4144

Course Title

Biomedical Engineering Sessional

Lab Reports

Submitted to	Submitted by
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ECE 4144

Course Title

Biomedical Engineering Sessional

Experiment Date: July 16, 2025,

Submission Date: July 30, 2025

Lab Report 1:

Study of ECG Signal Using Digital Electrocardiogram Device

Submitted to	**Submitted by**
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Experiment 1

Study of ECG Signal Using Digital Electrocardiogram Device

Objectives

- Acquire and examine human ECG signals utilizing a digital electrocardiograph with 10 leads.
- Detect and distinguish ECG waveform features, including the P wave, QRS complex, and T wave.
- Comprehend the positioning and importance of limb and chest leads for interpreting ECG results.

Theory

An electrocardiogram (ECG) records the heart's electrical signals using electrodes placed on the skin. In clinical practice, a typical ECG setup employs 10 electrodes—4 on the limbs and 6 on the chest—to generate 12 distinct leads. These include 3 standard limb leads (I, II, III), 3 augmented limb leads (aVR, aVL, aVF), and 6 precordial (chest) leads (V1–V6). Each lead offers a different perspective on the heart's electrical activity, aiding in comprehensive cardiac assessment. By analyzing changes in the P wave, QRS complex, and T wave across these leads, clinicians can detect irregularities such as arrhythmias, heart attacks, and other cardiac disorders.

ECG Lead Types and Electrode Placement

- **Lead I** (Limb; Right Arm): LA - RA
- **Lead II** (Limb; Left Arm): LL - RA
- **Lead III** (Limb; Left Leg): LL - LA
- **Lead IV** (Limb; Right Leg): Ground
- **aVR** (Augmented): RA - (LA + LL)/2
- **aVL** (Augmented): LA - (RA + LL)/2
- **aVF** (Augmented): LL - (RA + LA)/2
- **V1** (Chest): 4th intercostal space, right sternal border
- **V2** (Chest): 4th intercostal space, left sternal border

- **V3** (Chest): Between V2 and V4
- **V4** (Chest): 5th intercostal space, midclavicular line
- **V5** (Chest): Same level as V4, anterior axillary line
- **V6** (Chest): Same level as V4, midaxillary line

Required Equipment

- 10-lead Digital Electrocardiograph (HP-1300plus)
- ECG lead wires and disposable electrodes
- Volunteer human subject
- ECG paper or digital display for signal observation

Experimental Observation

- The volunteer was asked to relax and remain still in a supine position to minimize motion artifacts.
- Standard electrode placement was followed: four electrodes were attached to the limbs and six to the chest at designated anatomical locations.
- The digital ECG system successfully recorded signals from all twelve leads, providing clear and consistent waveforms.
- Lead II produced the most prominent and stable trace, which was used to determine the subject's heart rate.
- The characteristic ECG features—P wave, QRS complex, and T wave—were easily identified in the recordings.
- The subject's ECG showed normal sinus rhythm, with no evidence of arrhythmias or abnormal patterns.

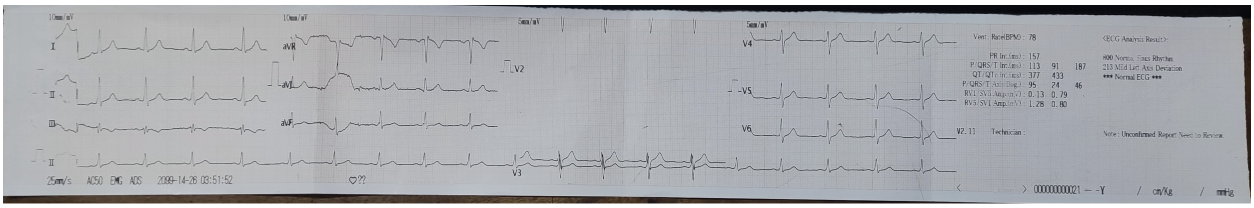

Figure 1: ECG

Discussion

Using the HP-1300plus digital ECG device, twelve standard leads were recorded with reliable signal quality. The device's IEC60601-1 safety compliance ensured safe use. Proper electrode placement was crucial for accurate waveforms, with Lead II providing the clearest signal for heart rate measurement. This experiment enhanced understanding of cardiac conduction and the clinical value of different ECG leads.

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Experiment Date: July 30, 2025,
Submission Date: August 06, 2025

Lab Report 2:
Analysis of an Electroencephalogram (EEG) Signal

Submitted to
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Experiment 2

Analysis of an Electroencephalogram (EEG) Signal

Objectives

- Analyze EEG signal characteristics and identify key waveforms.
- Understand standard electrode placement for EEG recording.

Theory

Electroencephalography (EEG) records brain electrical activity using scalp electrodes. Signals originate from synchronized cortical neurons and are grouped into delta, theta, alpha, beta, and gamma bands, each reflecting different brain states. Amplitudes typically range from 10 to 100 microvolts. Proper electrode placement is essential for reliable data. EEG aids in assessing brain function and diagnosing conditions like epilepsy and sleep disorders [?].

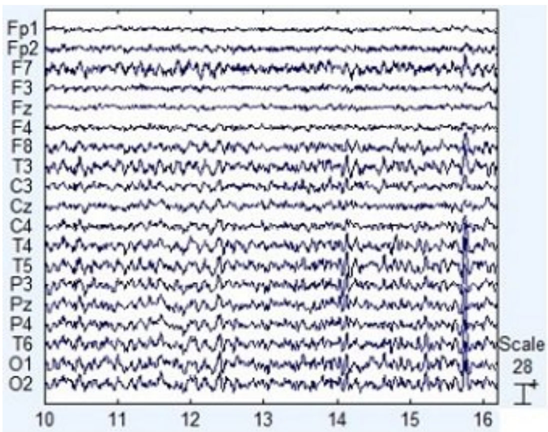

Figure 1: Sample EEG Signal[?]

EEG Electrode Placement

Basic EEG recording requires at least two electrodes: one active and one reference. For clinical assessments, 8 to 16 electrodes are typically used to ensure reliable data. The standard 10-20 system employs 21 electrodes placed at specific scalp locations. Advanced EEG setups may use up to 256 electrodes to achieve high spatial resolution.

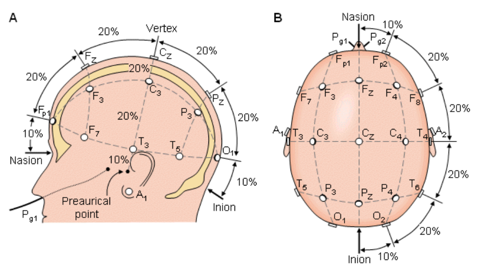

Figure 2: EEG 10-20 Electrode Placement[?]

EEG Signal Characteristic

EEG signals vary by individual and brain state but are classified into frequency bands linked to specific activities:

Band	Frequency (Hz)	Activity
Delta	0.5–4	Deep sleep
Theta	4–8	Drowsiness, meditation
Alpha	8–13	Relaxed, awake (eyes closed)
Beta	13–30	Alertness, concentration
Gamma	30–100	High-level cognition

Table 1: EEG Frequency Bands and Activities[?]

EEG Frequency Bands and Clinical Significance

EEG frequency bands reflect brain states: delta/theta (sleep, drowsiness), alpha (relaxation), beta (alertness), gamma (cognition). Abnormal patterns—such as excess slow waves or altered alpha/beta rhythms—may indicate disorders like epilepsy, sleep issues, or brain injury [?].

EEG in Diagnosis

EEG supports diagnosis of epilepsy, sleep disorders, encephalopathies, and brain death. It helps localize lesions, monitor anesthesia, and assess brain function [?].

EEG Signal Formation

EEG signals originate from synchronized postsynaptic potentials in cortical neurons, mainly pyramidal cells. Quality depends on electrode placement, tissue conductivity, and noise reduction.

Discussion

EEG signals were analyzed theoretically due to lack of lab equipment. The focus was on signal origin, electrode placement, and frequency bands. Practical data collection was not performed.

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Experiment Date: August 06, 2025,

Submission Date: August 13, 2025

Lab Report 3:

Experimental Observation of Various Features of an ECG Signal Collected from PhysioNet Public Dataset

Submitted to	Submitted by
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Experiment 3

Experimental Observation of Various Features of an ECG Signal Collected from PhysioNet Public Dataset

Objectives

- Measure key ECG features (RR, PP, PR intervals) using a PhysioNet dataset.
- Relate these intervals to heart rate and cardiac function.

Theory

An electrocardiogram (ECG) records the heart's electrical activity [1]. Key features include the P wave, QRS complex, and T wave.

Important intervals:

- **RR Interval**: Time between R-wave peaks; used to calculate heart rate.
- **PP Interval**: Time between P-wave peaks; reflects atrial rhythm.
- **PR Interval**: From P-wave onset to QRS start; indicates atrioventricular conduction.

Heart rate (HR) is calculated from the RR interval [1]:

$$\text{Heart Rate (bpm)} = \frac{\text{Number of R-peaks}}{\text{Time (s)}} \times 60$$

Dataset Description

This experiment uses the MIT-BIH Arrhythmia Database from PhysioNet, which contains 48 half-hour, two-channel ECG recordings from 47 subjects [2].

Key details:

- **Sampling Frequency:** 360 Hz
- **Annotations:** ~110,000
- **Subjects:** 60% inpatients, 40% outpatients

Record 100 was analyzed, including files: `100.atr` (annotations), `100.dat` (ECG data), `100.hea` (metadata), and `100.xws` (extra waveform data).

Tools Used

- **MATLAB**: For ECG signal processing and analysis.
- **WFDB Toolbox**: To access and handle PhysioNet data in MATLAB.

ECG Signal Analysis: MATLAB Implementation

The MATLAB code below reads ECG data from the MIT-BIH Arrhythmia Database, plots a segment, and calculates heart rate and key intervals:

```
[sig, Fs, tm] = rdsamp('mit bih/100', 1);
plot(sig(1:3600, 1));
duration_sec = 10; % seconds
num_r_peaks = 13;
heart_rate_bpm = (num_r_peaks / duration_sec) * 60;
fprintf('Heart Rate (bpm): %.2f\n', heart_rate_bpm);
r_peak_indices = [78 371 664 948 1232];
rr_intervals = diff(r_peak_indices);
mean_rr_samples = mean(rr_intervals);
fprintf('Mean R-R Interval (samples): %.2f\n', mean_rr_samples);
mean_rr_seconds = mean_rr_samples / 360;
fprintf('Mean R-R Interval (seconds): %.4f\n', mean_rr_seconds);
p_peak_indices = [311 605 885 1164 1467];
pp_intervals = diff(p_peak_indices);
mean_pp_samples = mean(pp_intervals);
fprintf('Mean P-P Interval (samples): %.2f\n', mean_pp_samples);
mean_pp_seconds = mean_pp_samples / 360;
fprintf('Mean P-P Interval (seconds): %.4f\n', mean_pp_seconds);
```

Output

```
Heart Rate (bpm): 78.00
Mean R-R Interval (samples): 288.50
Mean R-R Interval (seconds): 0.8014
Mean P-P Interval (samples): 289.00
Mean P-P Interval (seconds): 0.8028
```

Annotated ECG Segment

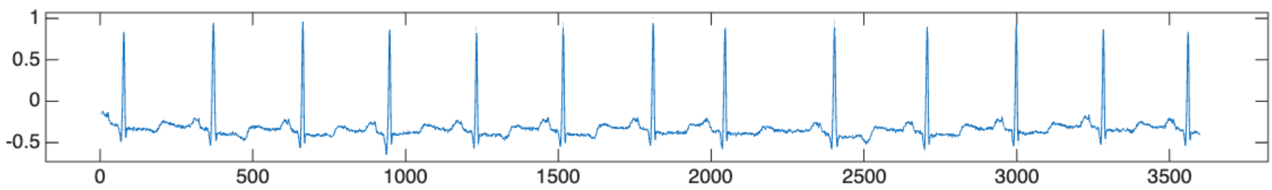

Figure 1: ECG segment with R- and P-peaks.

Result & Discussion

The analysis yielded:

- **Heart Rate:** 78 bpm
- **Mean R-R Interval:** 288.5 samples (0.80 s)
- **Mean P-P Interval:** 289.0 samples (0.80 s)

These results, obtained using MATLAB and WFDB Toolbox, confirm accurate peak detection and fall within normal adult ranges. The close agreement between RR and PP intervals indicates a regular sinus rhythm in the analyzed ECG segment.

References

[1] J. R. Hampton, *The ECG Made Easy*, 9th ed. Elsevier, 2019.

[2] G. B. Moody and R. G. Mark, "Mit-bih arrhythmia database," https://physionet.org/content/mitdb/1.0.0/, 1992, physioNet. [Online]. Available: https://physionet.org/content/mitdb/1.0.0/

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Experiment Date: August 13, 2025,

Submission Date: September 17, 2025

Lab Report 4:
Observation of Various Features of an EEG Signal Collected from Kaggle MNE Database

Submitted to	**Submitted by**
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Experiment 4
Observation of Various Features of an EEG Signal Collected from Kaggle MNE Dataset

Objectives

- To analyze and observe key features of EEG signals from the Kaggle MNE database.
- To identify and visualize major EEG frequency bands.

Theory

Electroencephalography (EEG) is a non-invasive method for recording brain electrical activity via scalp electrodes, capturing summed neuronal post-synaptic potentials. EEG signals are categorized into frequency bands—delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–100 Hz)—each linked to specific brain states such as sleep, relaxation, or alertness [1]. While EEG offers high temporal resolution for studying dynamic brain activity, signals often require preprocessing to remove artifacts. This experiment analyzes Kaggle MNE EEG data [2] to observe and interpret these characteristic frequency features.

Dataset Description

The Kaggle MNE EEG Dataset provides multi-channel EEG recordings from healthy subjects. Each recording includes 64 scalp channels (10-20 system), sampled at 160 Hz, with metadata on channels and subjects. The dataset is widely used for EEG analysis and frequency band studies [2].

Key details:

- **Source:** Kaggle MNE EEG Dataset [2]
- **Channels:** 64 (10-20 system)
- **Sampling Rate:** 160 Hz
- **Format:** Multichannel time-series

Tools Used

- **Jupyter Notebook**
- **VS Code**
- **LaTeX**

Output

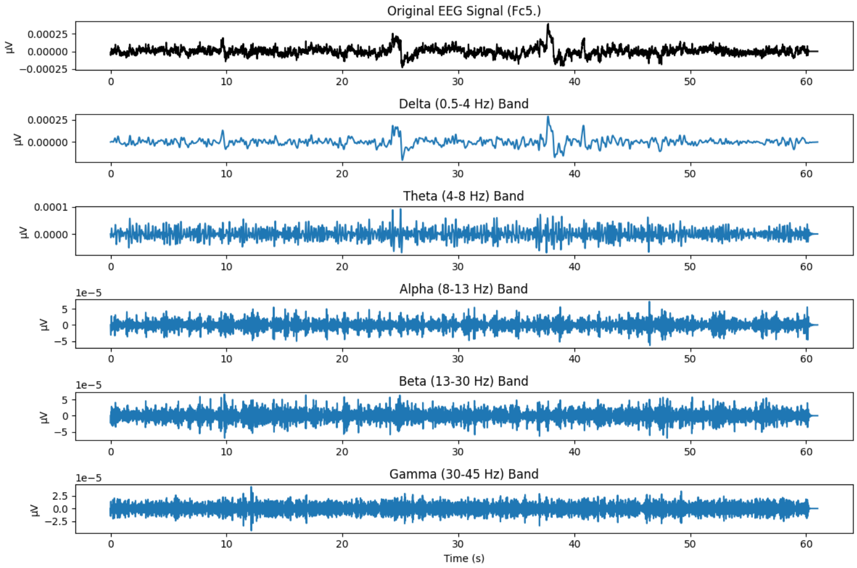

Figure 1: Observation of EEG signals

```
EEG Band Statistical Features:
                   Mean  Std Dev  Variance  Skewness  Kurtosis  RMS  Band Power
Delta (0.5-4 Hz)    0.0      0.0       0.0    0.6923    6.4781  0.0         0.0
Theta (4-8 Hz)     -0.0      0.0       0.0    0.2412    0.8139  0.0         0.0
Alpha (8-13 Hz)    -0.0      0.0       0.0    0.0061    0.7088  0.0         0.0
Beta (13-30 Hz)    -0.0      0.0       0.0    0.0018    0.9454  0.0         0.0
Gamma (30-45 Hz)   -0.0      0.0       0.0   -0.0029    0.3404  0.0         0.0
```

Analysis

The outputs include the original EEG signal and band-specific signals (Delta, Theta, Alpha, Beta, Gamma) obtained via bandpass filters. For each band, statistical features—mean, standard deviation, variance, skewness, kurtosis, RMS, and band power—were computed. These results highlight how different brain rhythms appear in EEG and demonstrate the effectiveness of signal processing for isolating and analyzing specific components.

Discussion & Conclusion

The experiment demonstrated key EEG features using the Kaggle MNE dataset. Raw EEG signals showed characteristic brainwave patterns, and bandpass filtering isolated the delta, theta, alpha, beta, and gamma bands. Statistical analysis confirmed the separation of these frequency bands. The results highlight the importance of preprocessing and spectral analysis for extracting meaningful information from EEG data.

References

[1] E. Niedermeyer and F. L. da Silva, *Electroencephalography: Basic Principles, Clinical Applications, and Related Fields*, 5th ed. Lippincott Williams & Wilkins, 2005.

[2] A. L. Goldberger *et al.*, “Eeg motor movement/imagery dataset,” 2013.