ECG Research Guide

1. What is ECG?

An Electrocardiogram (ECG or EKG) is a test that measures the electrical activity of the heart. It is a widely used, non-invasive diagnostic tool for evaluating heart conditions such as arrhythmias, myocardial infarction, and heart block. ECG captures this activity using electrodes placed on the body, producing a waveform that reflects each heartbeat.

2. ECG Signal Components

A typical ECG waveform consists of the following components:

- P wave: Atrial depolarization (~80 ms)
- QRS complex: Ventricular depolarization (~80-120 ms)
- T wave: Ventricular repolarization (~160 ms)
- U wave: Occasionally observed after T wave
- PR interval: Time from atrial to ventricular depolarization (~120-200 ms)
- ST segment: Time between ventricular depolarization and repolarization
- QT interval: Represents total ventricular activity

3. Electrode Placement and Types

Standard 12-lead ECG uses 10 electrodes:

- Limb leads: RA (Right Arm), LA (Left Arm), RL (Right Leg), LL (Left Leg)
- Chest leads: V1-V6 for anterior, lateral, and posterior views

Electrode types include:

- Wet electrodes (Ag/AgCl): Standard clinical use
- Dry electrodes: Used in wearables
- Textile electrodes: Emerging for continuous monitoring

4. Signal Acquisition

The process includes amplification, filtering, and analog-to-digital conversion:

- Amplifier: Boosts microvolt ECG signals
- Filters: Remove noise (high-pass, low-pass, notch at 50/60 Hz)
- ADC: Converts signals to digital (sampling rate >=500 Hz, resolution >=12 bits)

- Preprocessing: Includes noise filtering, baseline correction, and segmentation

5. ECG Signal Analysis

- Time-domain: Measure intervals (R-R, PR, QRS, QT)
- Frequency-domain: Analyze spectral content using FFT
- Nonlinear: Use entropy, fractals for complex dynamics

Analysis helps detect arrhythmias, ischemia, and other cardiac anomalies.

6. ECG Classification

Common classes:

- Normal sinus rhythm
- Arrhythmias (e.g., atrial fibrillation)
- Myocardial infarction
- Conduction blocks (e.g., AV block)

Techniques:

- ML: SVM, KNN, Random Forest
- DL: CNN, RNN/LSTM, Transformers for raw signal learning

7. Public ECG Datasets

- MIT-BIH Arrhythmia: Annotated arrhythmias
- PTB-XL: >20,000 clinical ECGs
- Chapman-Shaoxing: Labeled for disease classification
- PhysioNet Challenges: Provide new annotated ECG datasets annually

8. Applications

- Medical diagnostics
- Wearable monitoring (Apple Watch, Fitbit)
- Stress and emotion analysis
- Biometric authentication
- Telehealth and remote patient care

9. Trends in Research

- Self-supervised learning and contrastive ECG representation
- Explainable AI in clinical diagnosis
- Lightweight models for wearables (Edge AI)
- Multimodal biosignal fusion (e.g., ECG + PPG)