5.4 Real Time Signal Processing

Introduction

Real-time acquisition of physiological signals involves continuously measuring biological parameters from the human body and processing them instantly. These signals are essential in:

- Clinical diagnosis
- Patient monitoring
- Biomedical research
- Wearable health devices

Common Physiological Signals

- Electrocardiogram (ECG)
- Photoplethysmography (PPG)
- Respiration signals

Basic Concept of Signal Acquisition

Signal acquisition consists of converting a biological signal into an electrical signal and processing it.

Steps in Signal Acquisition

1. Sensing (Transducer)
2. Signal Conditioning
3. Analog-to-Digital Conversion (ADC)

4. Processing & Display

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Components of Data Acquisition System (DAQ)

1. Sensors / Transducers

- Convert physiological activity into electrical signals
- Example: Electrodes, Optical sensors

2. Signal Conditioning Unit

- Amplification
- Filtering (Noise removal)
- Isolation

3. Analog to Digital Converter (ADC)

- Converts analog signal to digital form

4. Microcontroller / Processor

- Processes signals
- Examples: Arduino, Raspberry Pi

5. Display / Storage

- Monitor, mobile app, cloud storage

ECG (Electrocardiogram)

Introduction to ECG

ECG records the electrical activity of the heart over time.

Importance

- Detect heart diseases

- Monitor heart rate

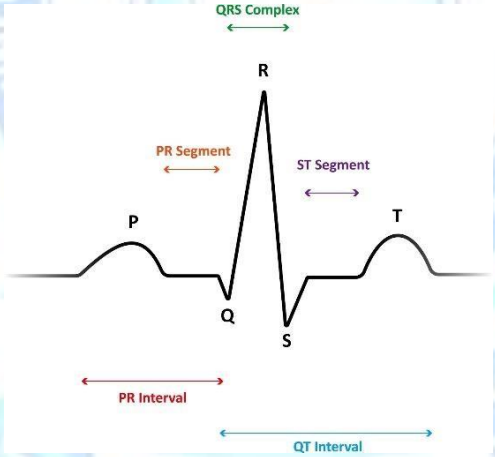
- Diagnose arrhythmias

ECG Signal Characteristics

- Amplitude: 0.5 mV to 5 mV
- Frequency range: 0.05 Hz to 100 Hz

ECG Wave Components

- P wave → Atrial depolarization
- QRS complex → Ventricular depolarization
- T wave → Ventricular repolarization



ECG Acquisition System

Block Diagram

- Electrodes → Amplifier → Filter → ADC → Processor

Electrode Placement

- Limb leads (RA, LA, RL, LL)

- Chest leads

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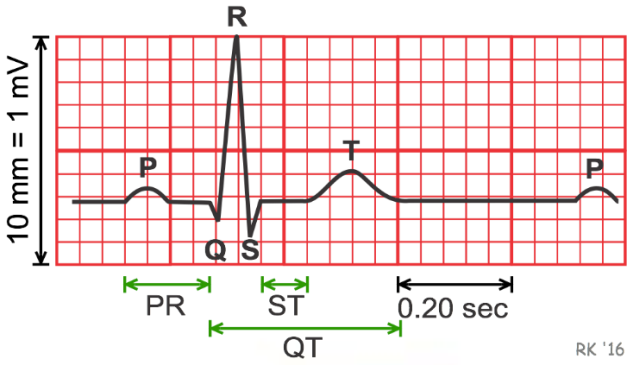

- P wave → Atrial depolarization
- QRS complex → Ventricular depolarization
- T wave → Ventricular repolarization
- PR interval → Conduction from atria to ventricles
- QT interval → Total ventricular activity

ECG Signal Conditioning

Amplification

- Instrumentation amplifier (e.g., AD620)

Filtering

- Low-pass filter → Remove high-frequency noise
- High-pass filter → Remove baseline drift
- Notch filter → Remove 50/60 Hz interference

Noise in ECG

- Power line interference

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- Motion artifacts
- Muscle noise

Real-Time ECG Monitoring

- Continuous monitoring using microcontrollers
- Data displayed on:
  - LCD
  - Computer
  - Mobile apps

Applications of ECG

- ICU monitoring
- Wearable health devices
- Fitness trackers

PPG (Photoplethysmography)

Introduction to PPG

PPG measures blood volume changes using light.

Working Principle

- Light emitted into skin
- Reflected light varies with blood flow

Types of PPG

1. Transmission mode

2. Reflection mode

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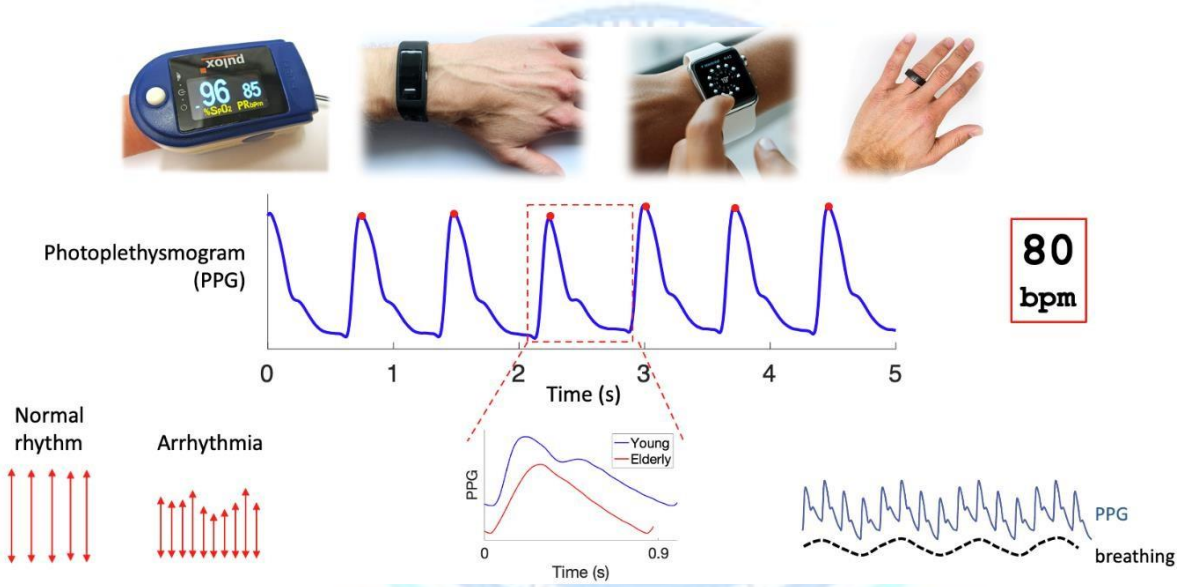
PPG Signal Characteristics

- Frequency: 0.5 Hz to 4 Hz
- Contains pulsatile component



PPG Acquisition System

Components

- LED (Light source)
- Photodiode (Detector)
- Amplifier
- Filter

Signal Processing

- Remove noise
- Extract heart rate
- Measure oxygen saturation (SpO_2)

Noise in PPG

- Motion artifacts
- Ambient light interference
- Poor sensor contact

Applications of PPG

- Pulse oximeter
- Smartwatches
- Fitness monitoring

Respiration Signal Acquisition

Introduction

Respiration signals measure breathing rate and pattern.

Methods of Measurement

1. Chest Movement

- Strain gauges

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- Piezoelectric sensors

2. Airflow Measurement

- Thermistors
- Spirometers

3. Impedance Pneumography

- Measures electrical impedance change

Signal Characteristics

- Frequency: 0.1 Hz to 0.5 Hz
- Slow varying signal

Respiration Acquisition System

Block Diagram

Sensor → Amplifier → Filter → ADC → Processor

Noise in Respiration Signals

- Motion artifacts
- Environmental disturbances