**Department of Biomedical Engineering**

**VI Semester**

**CBM 370 - Wearable Devices**

Unit- 2 Signal Processing and Energy Harvesting for Wearable Devices

## 2.5 Rejection of irrelevant information

In the context of wearable devices, rejecting irrelevant information is crucial for enhancing data quality and ensuring efficient processing. This process involves several strategies and techniques aimed at filtering out noise and non-essential data, thus improving the accuracy and reliability of the information collected.

Wearable devices collect vast amounts of data from multiple sensors, but **filtering out irrelevant information** is crucial to enhance accuracy, reduce power consumption, and improve user experience. Below are key techniques used for this purpose:

### 1. Signal Processing Techniques

Filtering raw sensor data helps remove unwanted noise and irrelevant signals.

❒ **Low-Pass & High-Pass Filters**

- **Low-pass filter**: Removes high-frequency noise (e.g., muscle artifacts in ECG).
- **High-pass filter**: Eliminates slow-changing drift (e.g., movement artifacts in PPG).

❒ **Band-Pass & Notch Filters**

- **Band-pass filter**: Isolates specific frequencies (e.g., EEG signals).
- **Notch filter**: Removes specific interference (e.g., 50/60 Hz power line noise).

**2. Adaptive & Context-Aware Sampling**

Reducing data collection when it's unnecessary can improve battery life.

❒ **Motion-Triggered Sampling**

- Use a **low-power accelerometer** to activate high-power sensors (ECG, gyroscope) only during movement.

❒ **Activity Recognition-Based Filtering**

- Reduce heart rate sampling during rest and increase during workouts.
- Ignore irrelevant motion patterns (e.g., minor hand tremors in gesture tracking).

❒ **Event-Driven Data Collection**

- **Sleep tracking**: Lower sampling rate during deep sleep.
- **Fall detection**: Store only high-impact acceleration changes.

**3. Data Fusion & Machine Learning**

Combining sensor data can enhance relevance while rejecting useless information.

❒ **Sensor Fusion**

- Merge accelerometer, gyroscope, and magnetometer data to improve motion accuracy.
- Combine heart rate (PPG) and motion data to eliminate motion artifacts.

❒ **AI & Machine Learning Filters**

- Train models to **ignore false positives** in step counting, fall detection, and ECG anomalies.

- Use deep learning to distinguish **real voice commands from background noise**.

**4. <u>Edge Processing & Data Compression</u>**

Processing data locally can prevent sending irrelevant data to the cloud.

❒ **Feature Extraction on Device**

- Only transmit key metrics (e.g., **average heart rate**, not raw PPG signals).

❒ **Compressed Data Storage**

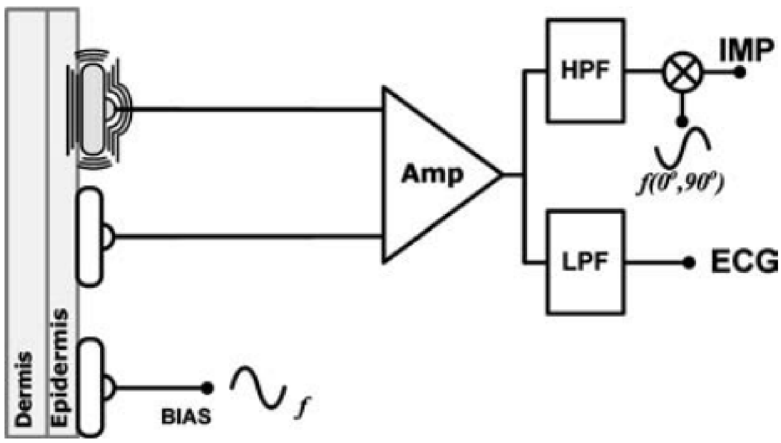
- Store only significant deviations from normal trends.

**5. <u>User-Customized Data Filtering</u>**

Let users **define thresholds** for relevant information:

❖ Adjust **step count sensitivity** to ignore minor movements.
❖ Filter out **non-essential notifications** based on activity context.
❖ Enable **priority-based alerts** for health anomalies.

**6. <u>Example-1</u>:**




Schematic of a **bioimpedance measurement system** combined with an ECG (electrocardiogram) sensor.

- **BIAS signal:** A sinusoidal current at frequency fff is injected into the skin (dermis/epidermis), likely to measure bioimpedance (IMP).
- **Amp (Amplifier):** The signals are amplified before filtering.
- **HPF (High-Pass Filter):** Extracts high-frequency components, which are used for impedance (IMP) measurement.
- **LPF (Low-Pass Filter):** Extracts low-frequency components, which correspond to the ECG signal.
- **IMP Measurement:** There's a mixer or demodulator (shown with f($0^0$ ,$90^0$) for extracting impedance-related information from the high-frequency signal.

**Rejection of Irrelevant Information:**

- **HPF and LPF are classic filters** used to separate signals of interest (ECG vs. IMP) and reject irrelevant information.
- The **demodulation step** (mixing with reference signals) helps isolate the desired impedance measurement from other noise.

**Working**

- **ECG Acquisition:** Low-frequency components are passed through the LPF to capture the heart's electrical signals.
- **Impedance Measurement:** The high-frequency current injected into the body creates a modulated signal detected through impedance changes (e.g., due to blood flow). The HPF and mixer demodulate this to provide the IMP signal.

**7. <u>Example- 2: Sources of Irrelevant Information in EMG Signals</u>**

- ❒ **Motion Artifacts:** Caused by electrode movement, skin stretching, and external forces.
- ❒ **Power Line Interference:** 50/60 Hz noise from electrical sources.
- ❒ **Cross-Talk from Other Muscles:** Overlapping signals from nearby muscle groups.
- ❒ **Baseline Wandering:** Slow changes in signal due to sweat, skin-electrode impedance shifts.
- ❒ **Electrode Noise:** Poor contact with the skin leads to high impedance and unstable signals.

## 7.1 Filtering Techniques

❒ **High-Pass Filtering (HPF):**

- Removes low-frequency motion artifacts and baseline drift.
- Cutoff frequency: **10–20 Hz**.

❒ **Notch Filtering:**

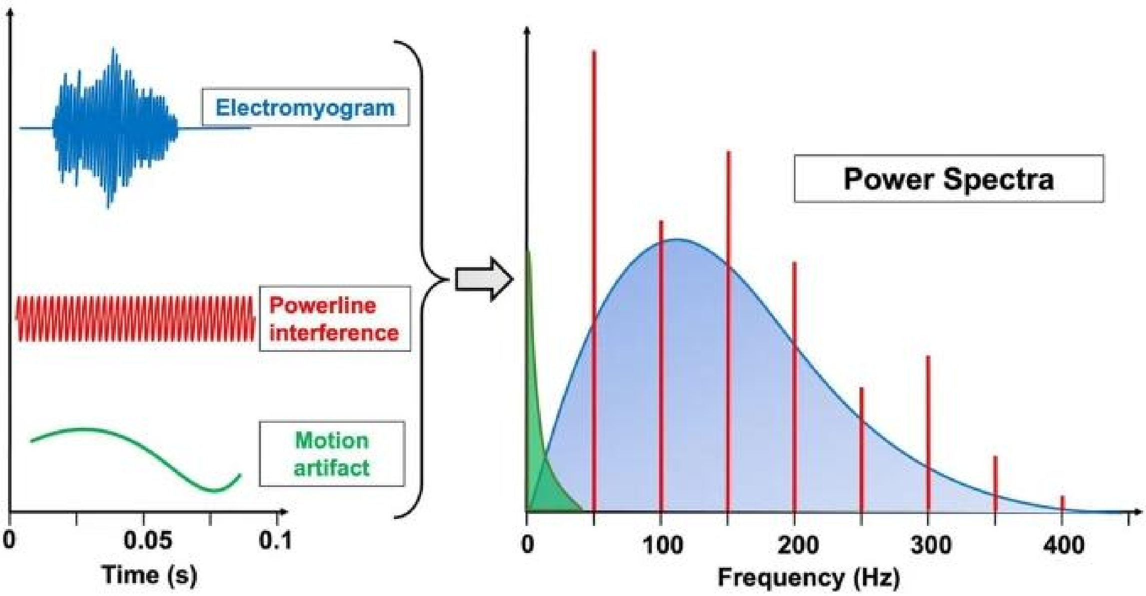
- Eliminates power line interference (50/60 Hz).

❒ **Low-Pass Filtering (LPF):**

- Removes high-frequency noise and external interference.
- Cutoff frequency: **450–500 Hz** (since EMG signals typically range from 10–500 Hz).

❒ **Band-Pass Filtering (BPF):**

- Allows only the EMG signal range (e.g., **20–450 Hz**) while filtering irrelevant noise.




Qualitative sketch of sEMG signal, powerline interference and motion artifacts in time and frequency domains.

**Left Side (Time Domain Representation)**

- **Electromyogram (EMG) Signal (Blue):** Represents the desired muscle activity.
- **Powerline Interference (Red):** A high-frequency sinusoidal noise (typically at **50/60 Hz**) caused by electrical sources.
- **Motion Artifact (Green):** A low-frequency distortion due to electrode movement and skin stretching.

**Right Side (Frequency Domain - Power Spectra)**

- **EMG Power Spectrum (Blue Area):** Shows the frequency distribution of the useful EMG signal (typically **20–450 Hz**).
- **Powerline Interference (Red Lines):** Sharp peaks at **50 Hz and its harmonics** (100 Hz, 150 Hz, etc.).
- **Motion Artifact (Green Area):** Dominates the **low-frequency range (0–20 Hz)**.

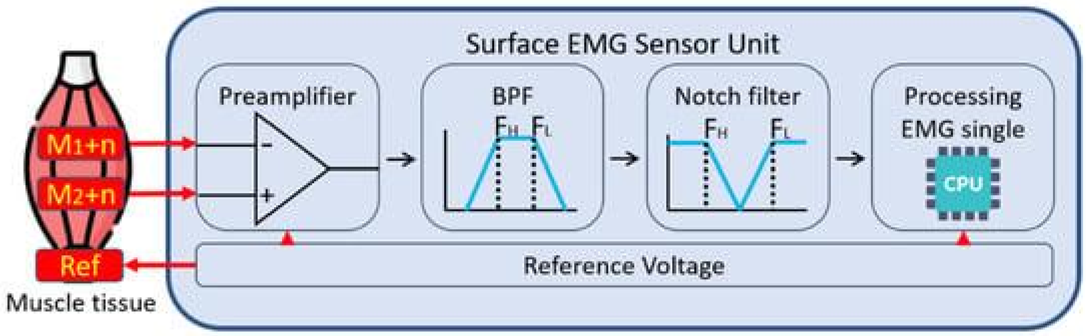
<u>**Rejection of Irrelevant Information?**</u>

❒ **Notch Filter (50/60 Hz)** – Removes powerline interference.

❒ **High-Pass Filter (Cutoff: 10–20 Hz)** – Eliminates motion artifacts.

❒ **Band-Pass Filter (20–450 Hz)** – Keeps relevant EMG signals.

❒ **Adaptive Noise Cancellation (ANC)** – Uses reference sensors (e.g., accelerometers) to remove movement-related noise.




Surface EMG measurement sensor block diagram

## 7.2 Hardware-Based Solutions for Reducing Irrelevant Information

- **Use High-Quality Electrodes:** Reduces motion artifacts and electrode noise.
- **Ensure Proper Skin Preparation:** Cleansing skin before placing electrodes minimizes impedance variations.
- **Optimize Electrode Placement:** Avoids cross-talk from unwanted muscles.
- **Shielding & Grounding:** Reduces power line interference from external devices.

*********