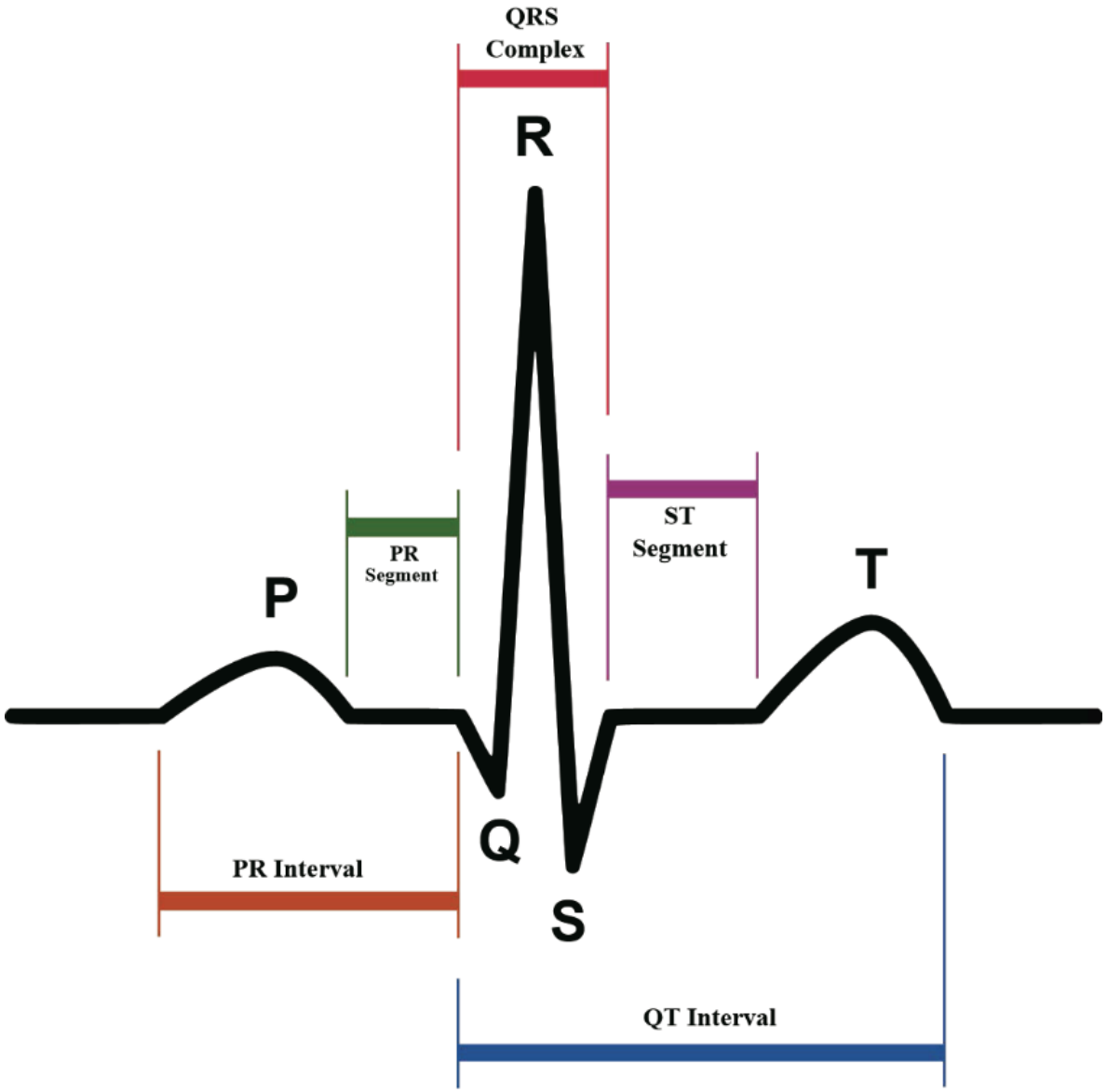
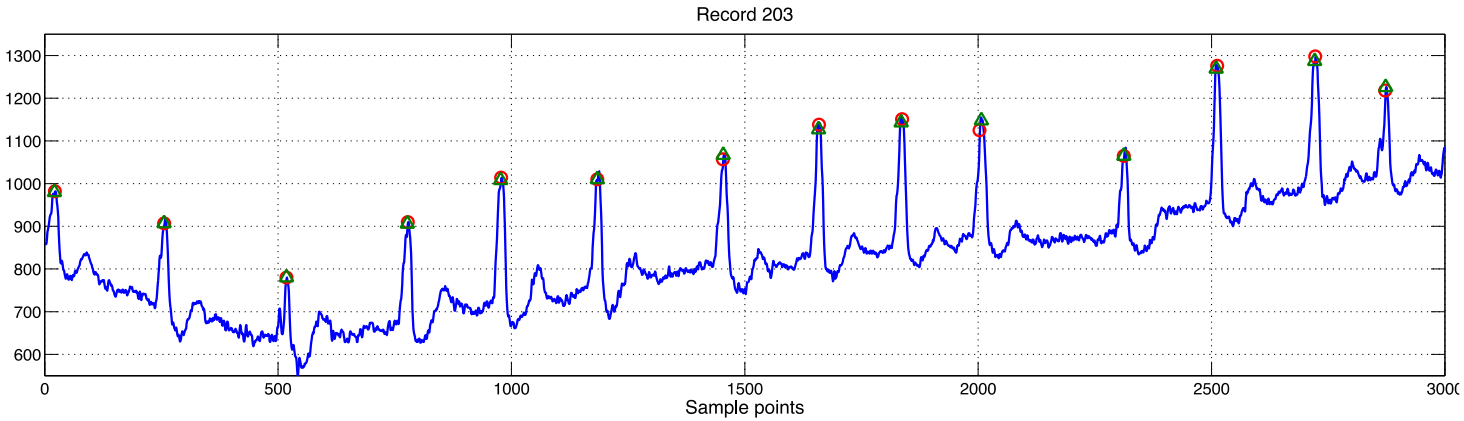
# 數位訊號處理實驗
# Digital Signal Processing Laboratory
# Lab 3
# Pre-Processing of ECG Signals

# ECG Signal and Interferences (1/2)

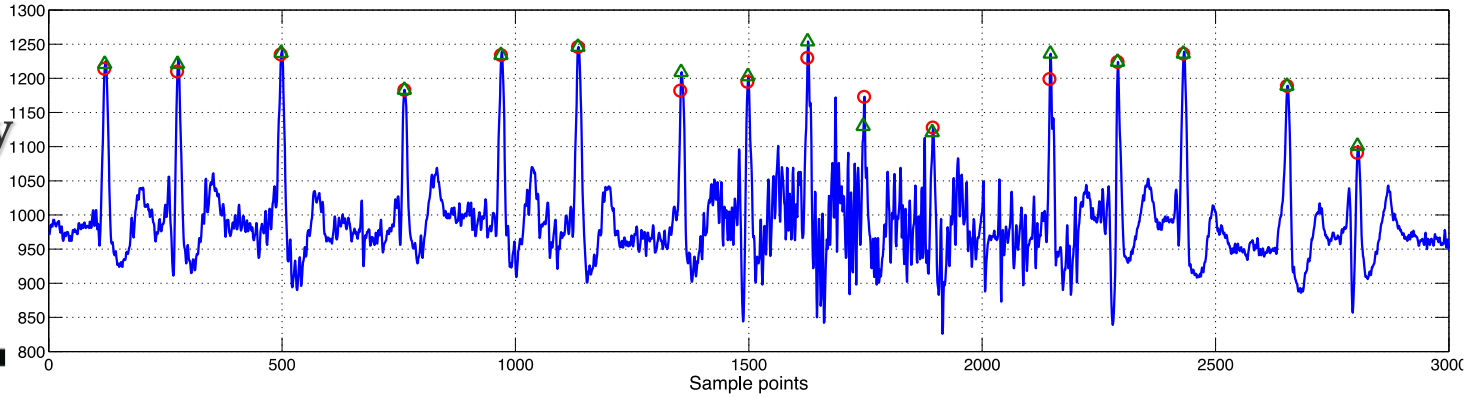


# ECG Signal and Interferences (2/2)

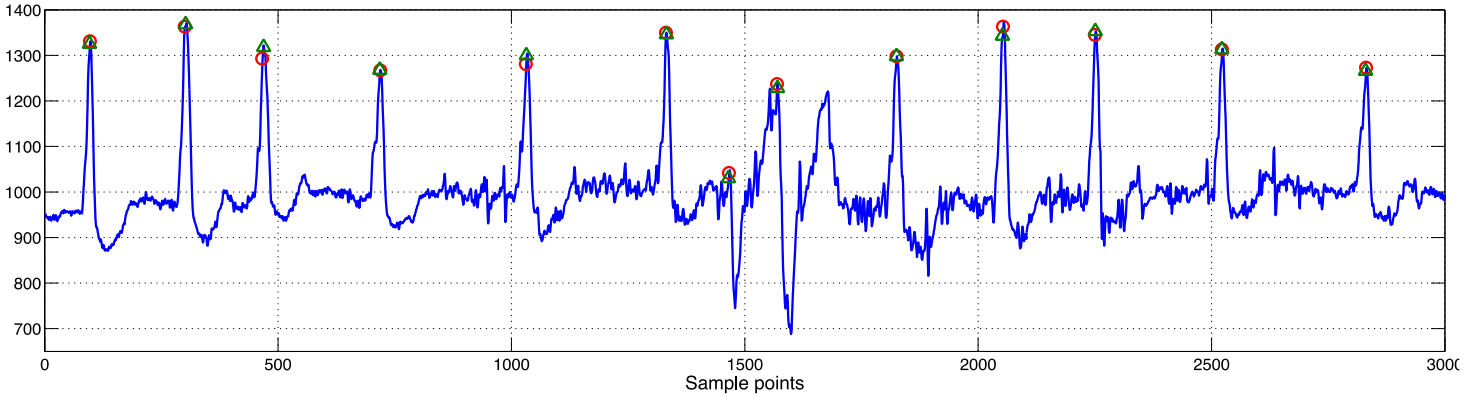
Baseline Noise



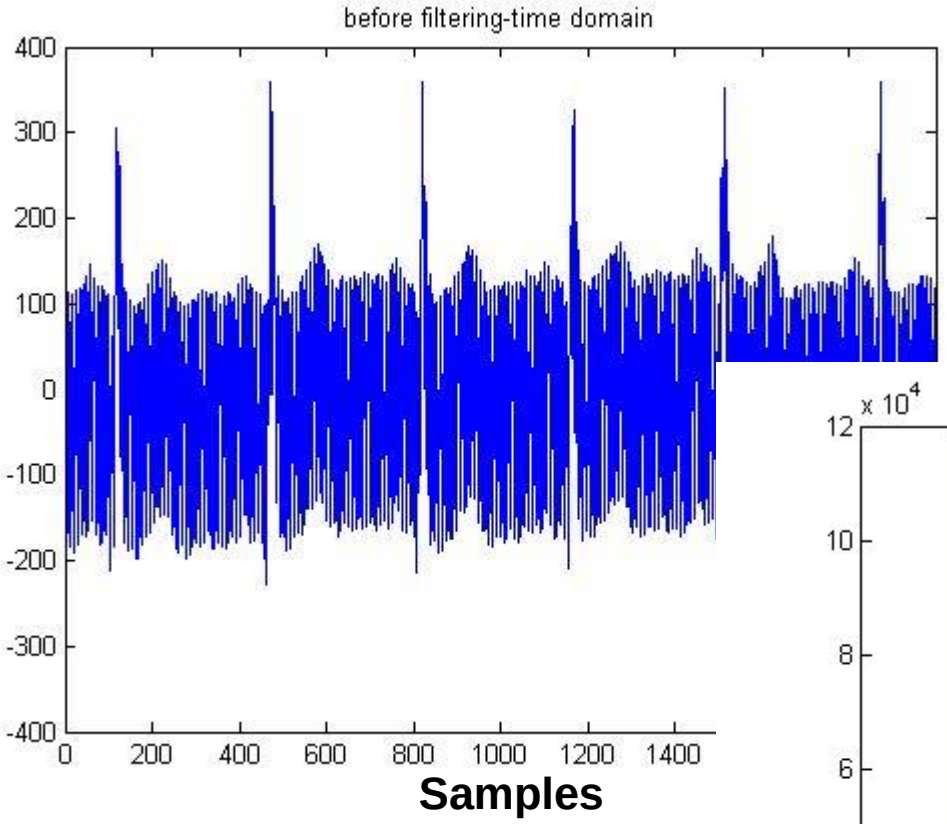

Electromyography (EMG) Noise

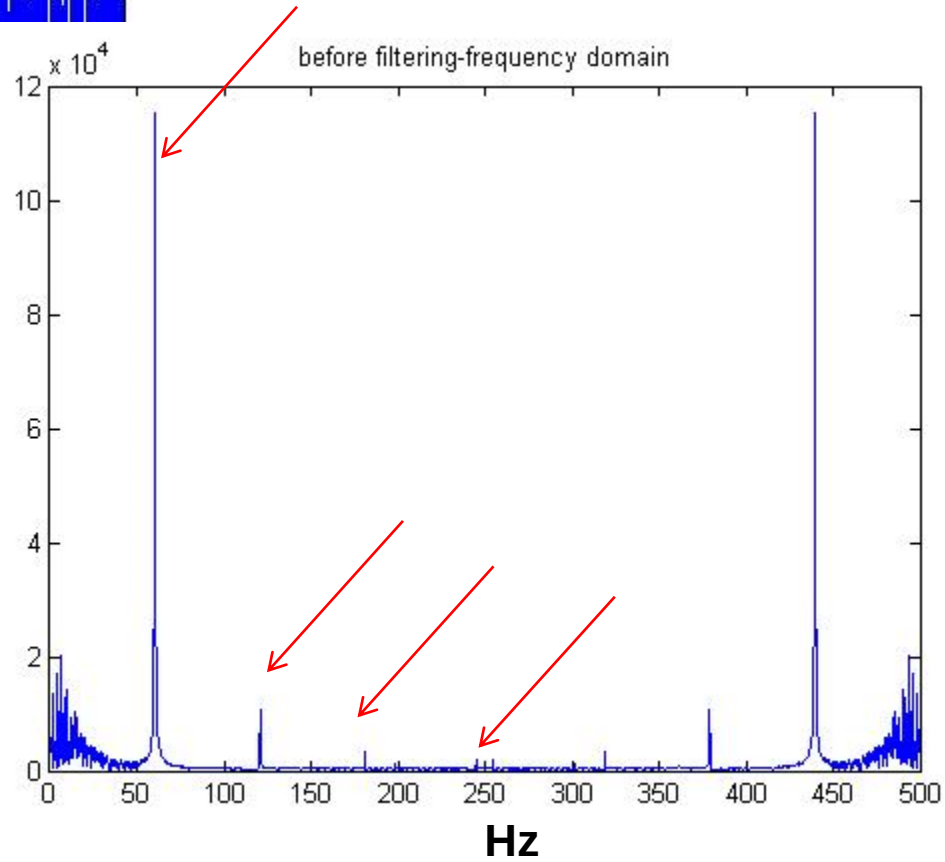



Motion Artifact



# 60-Hz Power-Line Interference



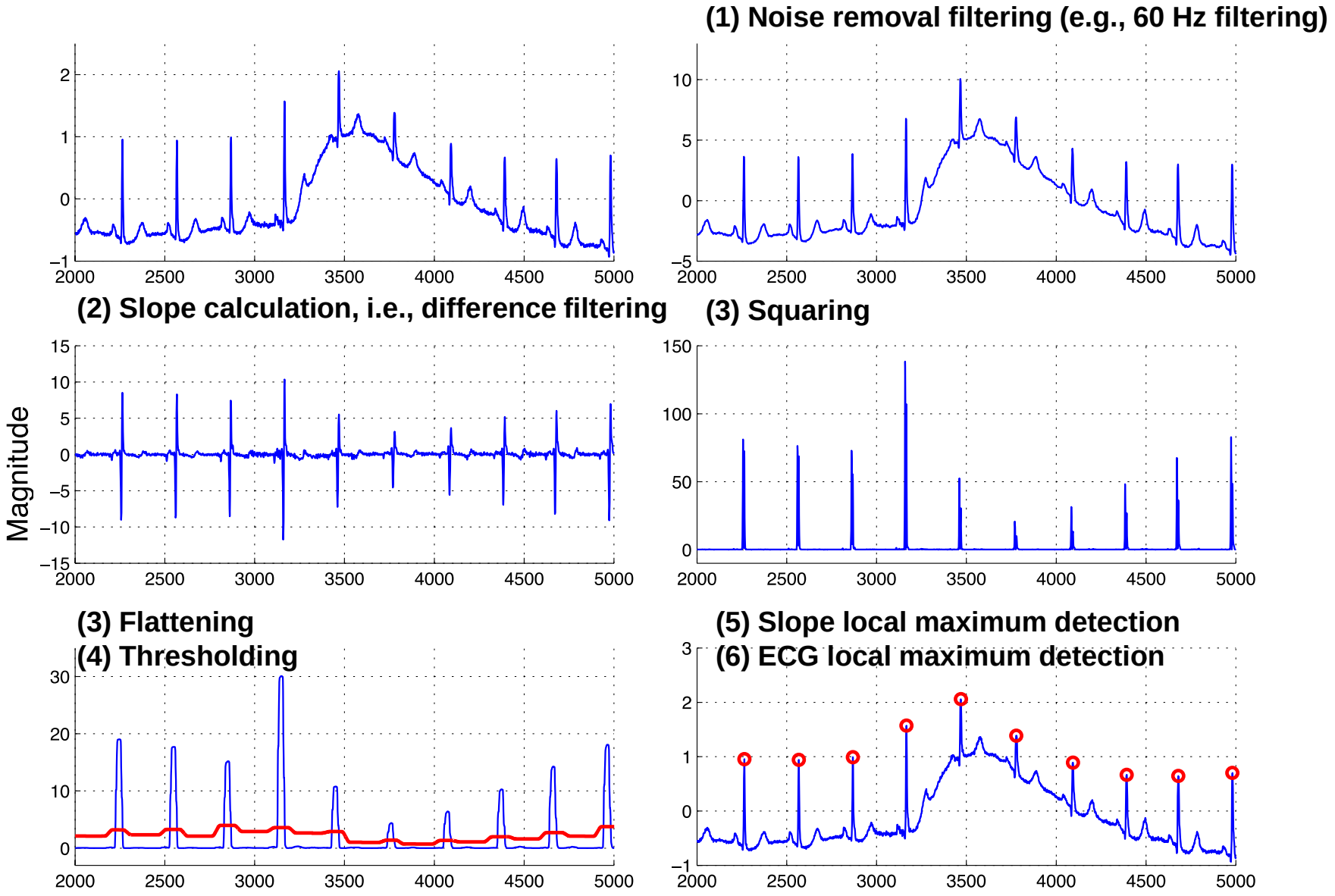



# ECG Noise Reduction

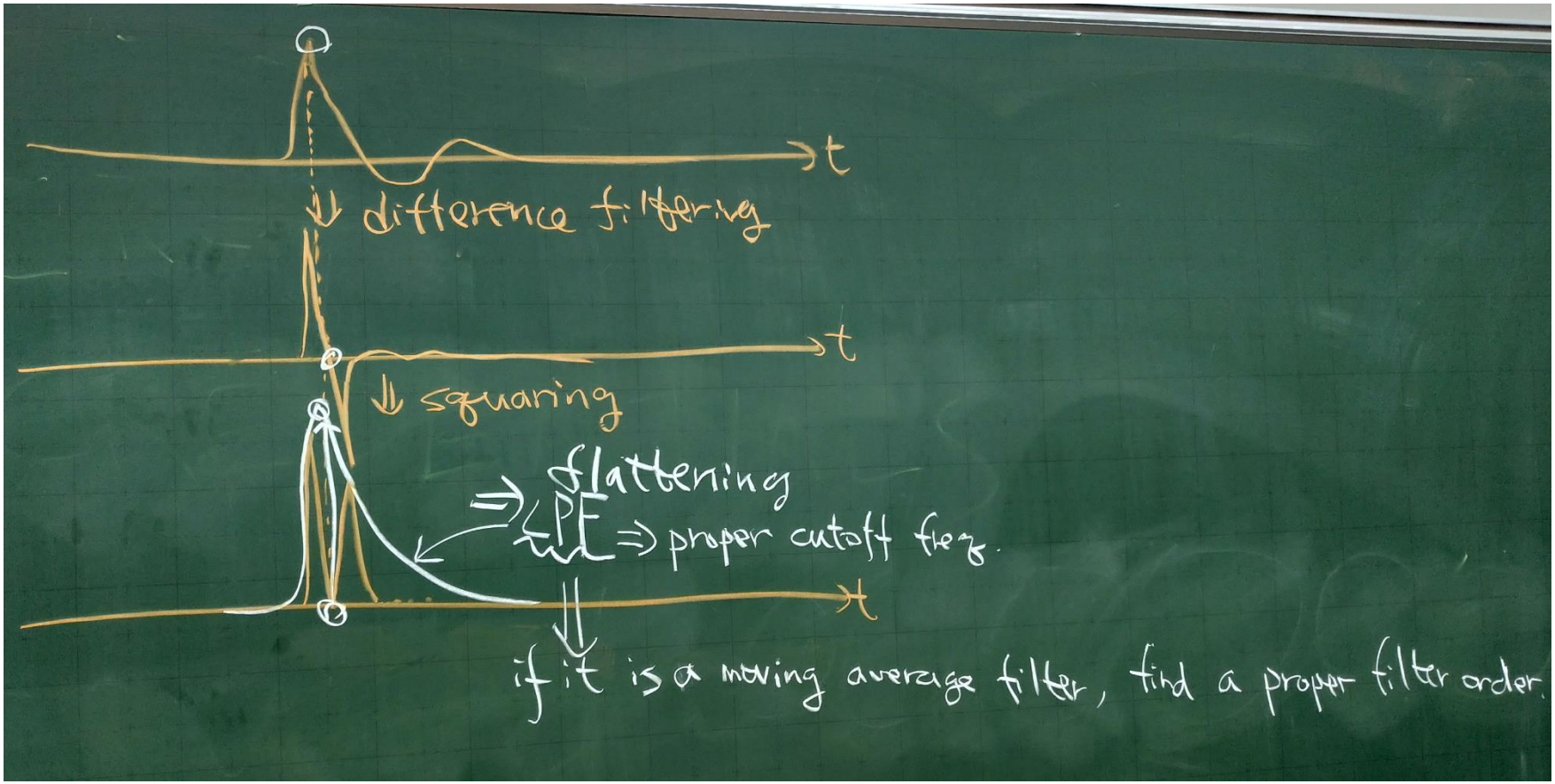
- **Noise types:**
  - **Baseline wander (BW) (below 1Hz)**
  - **50 or 60 Hz power-line interference (PLI)**
  - **Electromyogram (EMG)**
  - **Motion artifact (MA)**

| Method | Noise Type |
|---|---|
| Adaptive Filter | BW, PLI, MA |
| Wavelet Transform | BW, EMG, MA |
| Empirical Mode Decomposition | BW, EMG, MA |
| Independent Component Analysis | MA |
| Moving Average | BW, (PLI), MA |

# Pre-Processing of ECG Signals to Locate R peaks (1/4)



# Pre-Processing of ECG Signals (2/4): Why Squaring and Flattening



# Pre-Processing of ECG Signals (3/4)

- **(1) 60 Hz filtering:**

$$x[i] = \frac{1}{M} \sum_{K=i-M/2}^{i+M/2-1} r[k].$$

**(Low pass filtering: moving average filtering, FIR, How about IIR?)**

- **(2) Slope calculation:**

http://oregonstate.edu/instruct/ch490/lessons/lesson11.htm

$$X_d[i] = 2x[i] + x[i-n] - x[i-2n] - 2x[i-3n].$$

**(High pass filtering: difference filtering, FIR, How about IIR?)**

- **(3) Squaring and flattening:**

$$\hat{X}_d[i] = X_d^2[i], \qquad \hat{X}_{df}[i] = \frac{1}{N} \sum_{k=i-N/2}^{i+N/2-1} \hat{X}_d[k].$$

- **(4) Adaptive threshold calculation:**

**(Low pass filtering: moving average filtering, FIR, How about IIR?)**

$$TH = \frac{1}{S/2} \sum_{n-S/4}^{n+S/4} \hat{X}_{df}[i].$$

# Pre-Processing of ECG Signals (4/4)

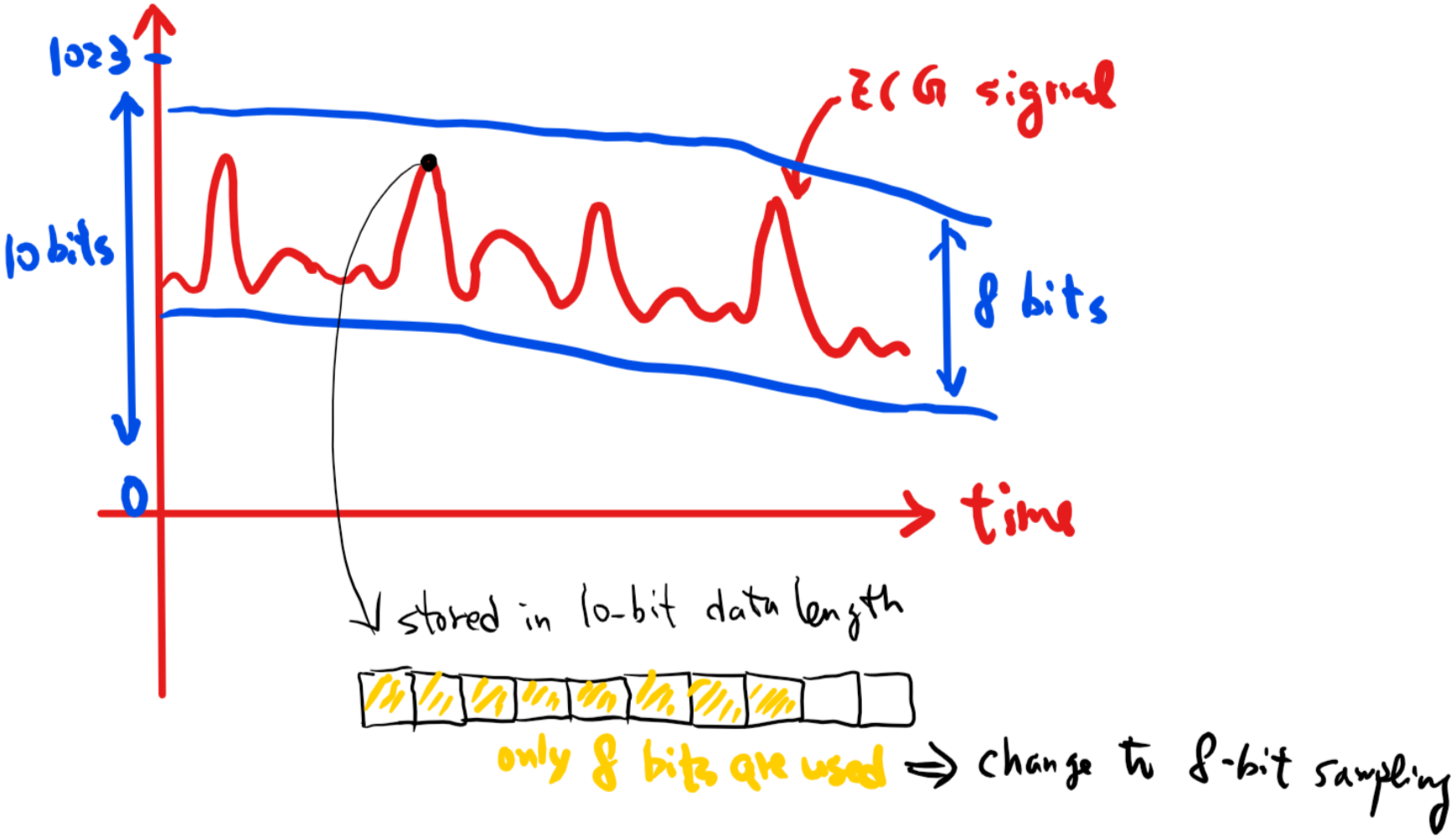
- **(4) Hard threshold:**

$$\hat{X}_{dfT}[i] = \hat{X}_{df}[i] - TH, \quad \begin{cases} \hat{X}_{dfT}[i], & \hat{X}_{df}[i] - TH > 0 \\ 0 & \hat{X}_{df}[i] - TH < 0 \end{cases}$$

- **(5) Slope local maximum detection**
  - **Find the time index *i* of the local maximum of the slope.**

- **(5) ECG local maximum detection:**
  - **Use the sample index *i* to find the local maximum of original ECG signal by applying a short searching range.**
  - **Searching region is set to be 0.1 second since normal QRS complex (5-40Hz) is about 80~100 ms duration.**

# Task 3 (in the Handout) Today

- Use 8 bits instead of 10 bits for the digitization of ECG signals. Design an algorithm and implement in Arduino to maintain the maximum dynamic range of the input ECG signal with 8-bit sampling.
  - From 10 bit to 8 bit sampling while maintaining the maximum dynamic range of the ECG signals can (1) reduce the data rate and (2) for example, utilize the full swing (full range) of a following DAC (8 bit).

# Task 3 (in the Handout) Today