Assignment 4 – Pan-Tompkins Algorithm for QRS Detection

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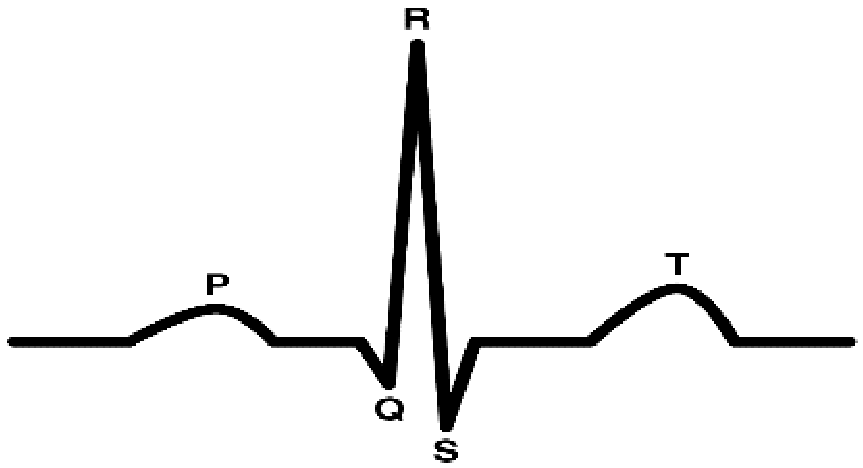
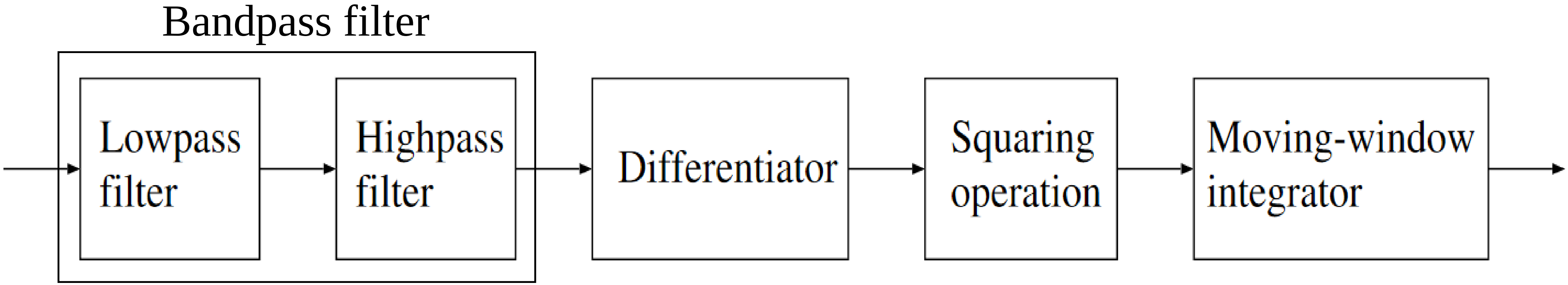
Aim

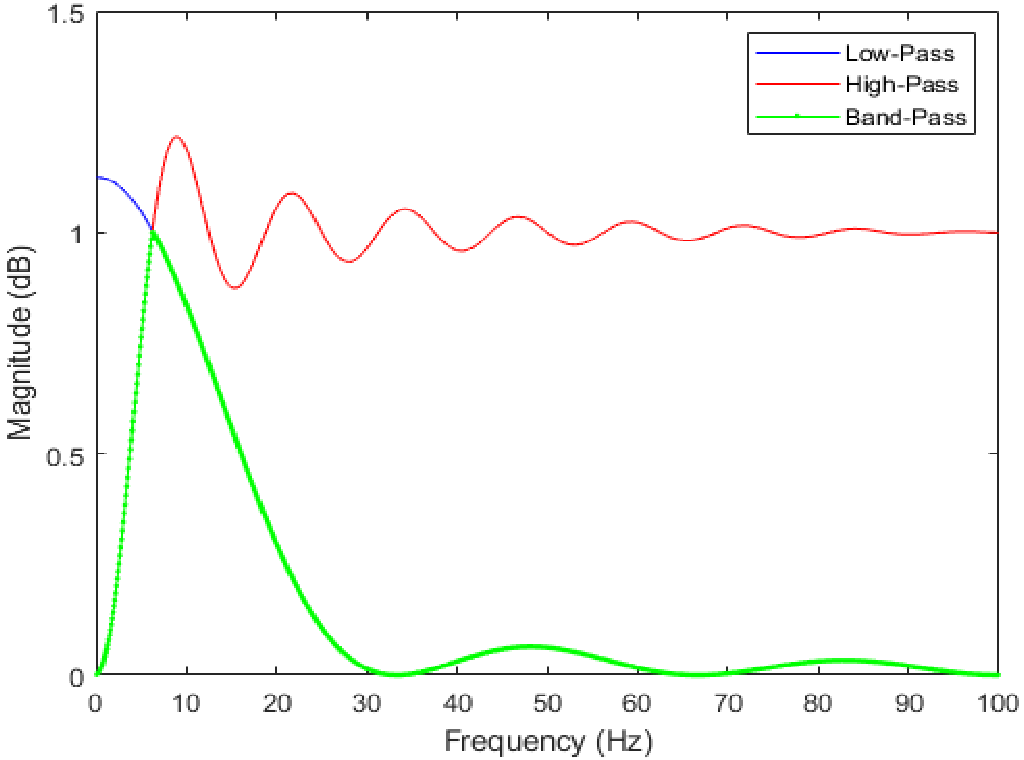
- Implement the Pan-Tompkins algorithm to identify the QRS complexes.

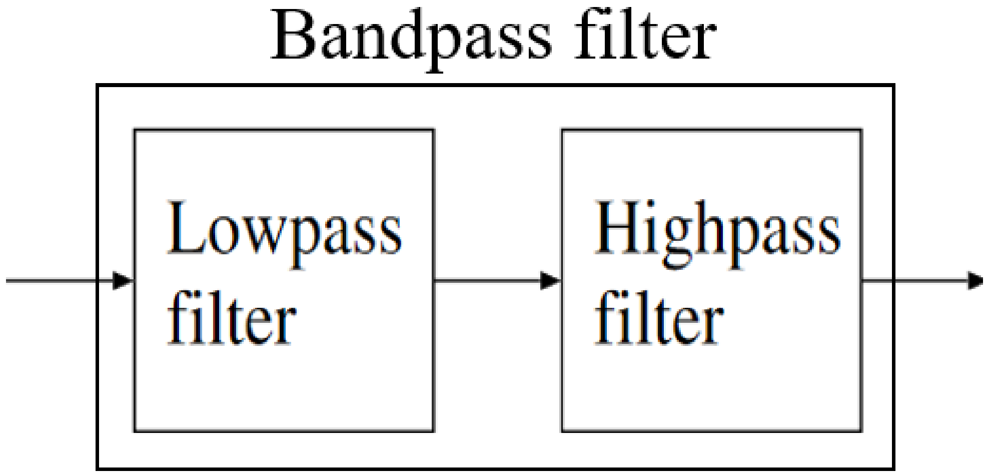




1- Bandpass Filter

– The bandpass filter, formed using lowpass and highpass filters, reduces noise (such as muscle noise, 60 Hz interference and baseline drift) in the ECG signal.





Lowpass and Highpass Filters

– LPF → Section 4.3.2: equation 4.7

– HPF → Section 4.3.2: equation 4.11

– Example of a Lowpass filter is explained in the second lab notes.

From difference equation to Z-transform

$$y(n) = \boxed{y(n-1) - 2y(n-2)} + x(n) - 5x(n-5)$$

$$\underbrace{\boxed{}}_{a_0}\, y(n) \underbrace{\boxed{-}}_{a_1} y(n-1) + \underbrace{\boxed{2}}_{a_2} y(n-2) = \underbrace{\boxed{}}_{b_0} x(n) \underbrace{\boxed{-5}}_{b_5} x(n-5)$$

Always = 1

Apply Z-transform:

$$Y(z)[a_0 z^0 + a_1 z^1 + a_2 z^2] = X(z)[b_0 z^0 + b_5 z^5]$$

$$Y(z) = H(z)X(z) = \frac{b_0 z^0 + b_5 z^5}{a_0 z^0 + a_1 z^1 + a_2 z^2} X(z)$$

$$H(z) = \frac{b_0 z^0 + b_5 z^5}{a_0 z^0 + a_1 z^1 + a_2 z^2} = \frac{Y(z)}{X(z)} \Rightarrow \frac{b\ coeff.}{a\ coeff.}$$

Differentiator

- A differentiator filter is used to provide a large response at the high slopes that distinguish QRS complexes from low-frequency ECG components such as the P and T waves.

- Filter equation:

$$y(n) = \frac{1}{8}\left[2x(n) + x(n-1) - x(n-3) - 2x(n-4)\right] \times$$

$$y(n) = \frac{1}{8}\left[x(n) + 2x(n-1) - 2x(n-3) - x(n-4)\right] \checkmark$$

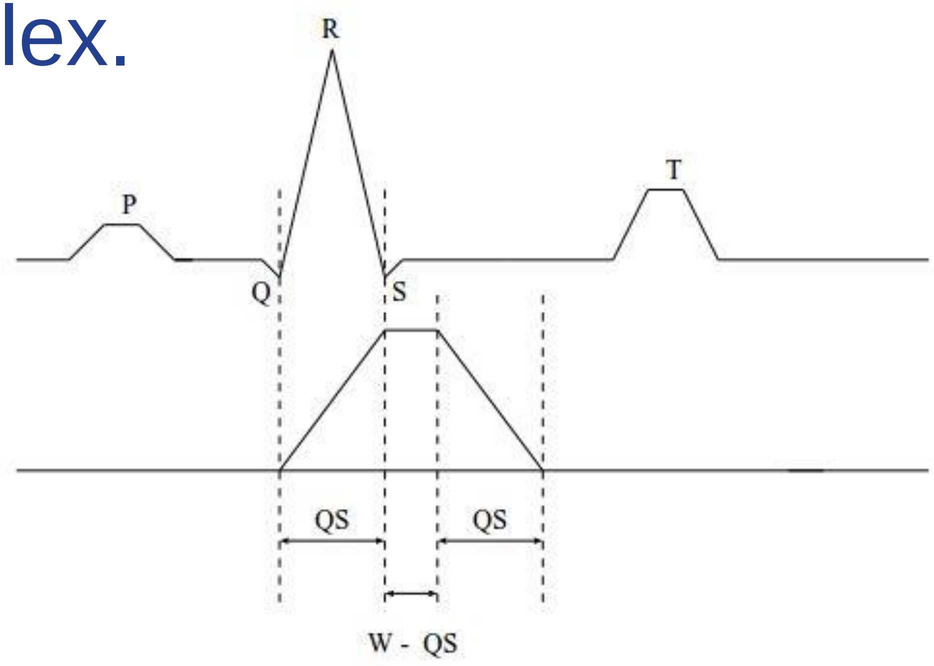
Squaring and integration

- Squaring operation makes the result positive.
- emphasizes the higher values expected within QRS complexes.
- suppresses smaller values related to the P and T waves.

Moving-Window integration

- Results in a single smooth peak related to the QRS complex for each ECG cycle.
- The output of the moving-window integrator may be used to detect QRS complexes, measure RR intervals, and determine the duration of the QRS complex.

- Section 4.3.2: equation 4.15



Notes:

- Do not forget to **read the chapter from the book**! Important information is there!
- The output of a stage is an input to another (pipeline).
- Write the equations and coefficients by hand first, then move to the coding.
- The **findQRS** function is provided to detect the important features from the output of the integrator.
- The **syntax** of the function is in the **task description**.
- The **filter delays are already in the book**!
- The **delays** are required to be calculated in [**samples**] not in [**ms**]