Detection of PVC in ECG and S1 & S2 Sounds in PCG using ECG & PPG

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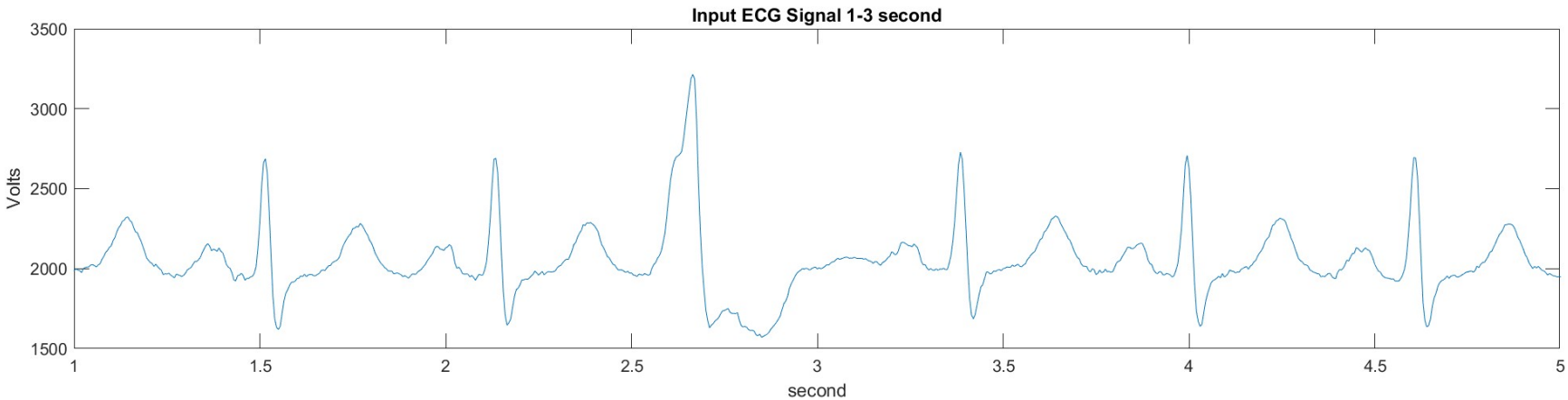
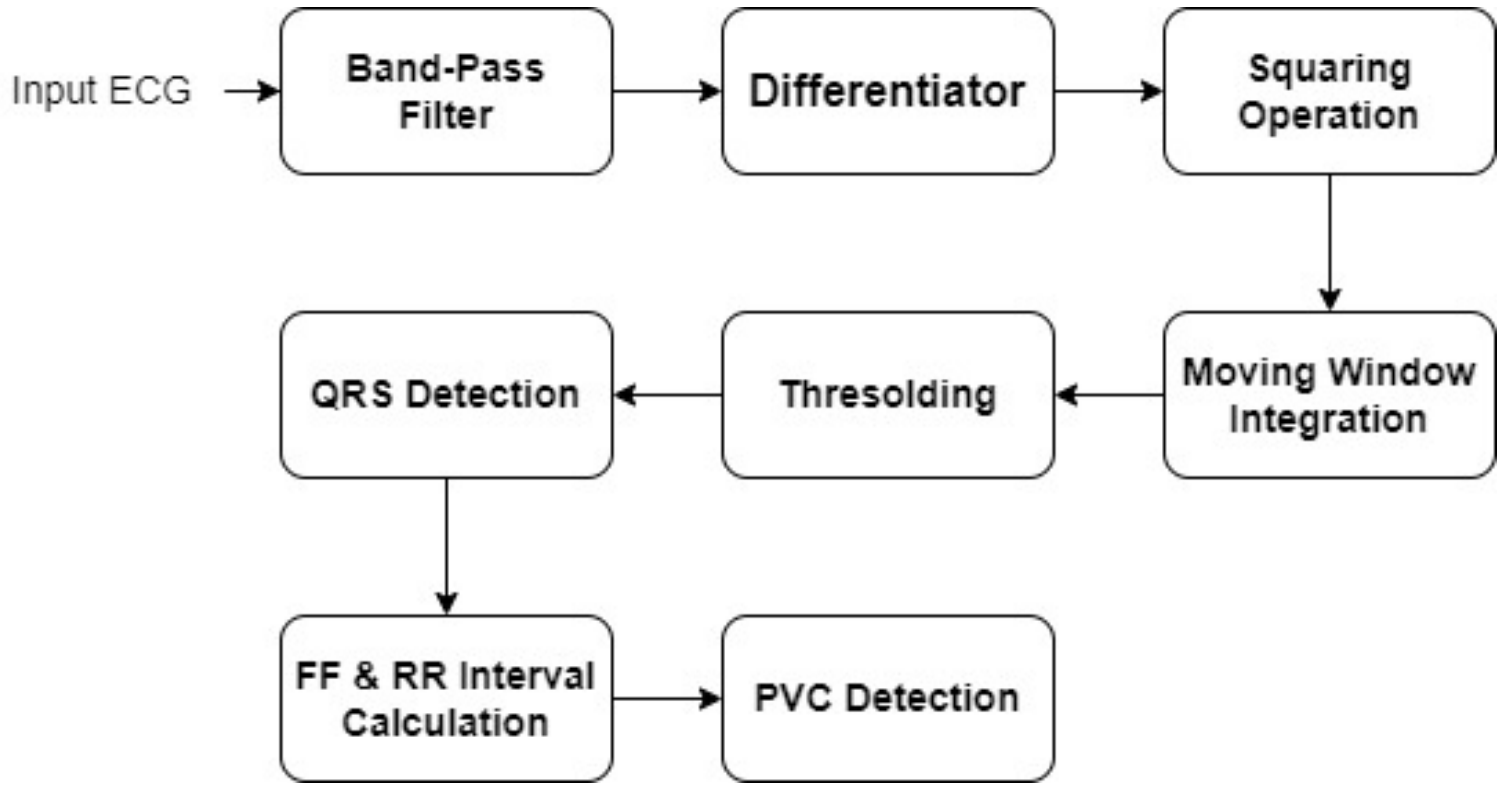
Detection of Premature Ventricular Contraction

What is Premature Ventricular Contraction (PVC)?

- These are **premature heartbeats** originating in one of the ventricles.
- This happens when the **ventricles are activated prematurely by an "abnormal firing site"** called **"ECTOPIC SITE"**, located in one of the ventricles, instead of P-wave from atrium.
  So **PVC complexes are not preceded by P-waves**.
- Unlike the normal conduction carried out through specialized cells of conduction pathway, the signal in PVC is conducted through myosites of the heart muscles, and so **PVC produce "Broader QRS" complex**



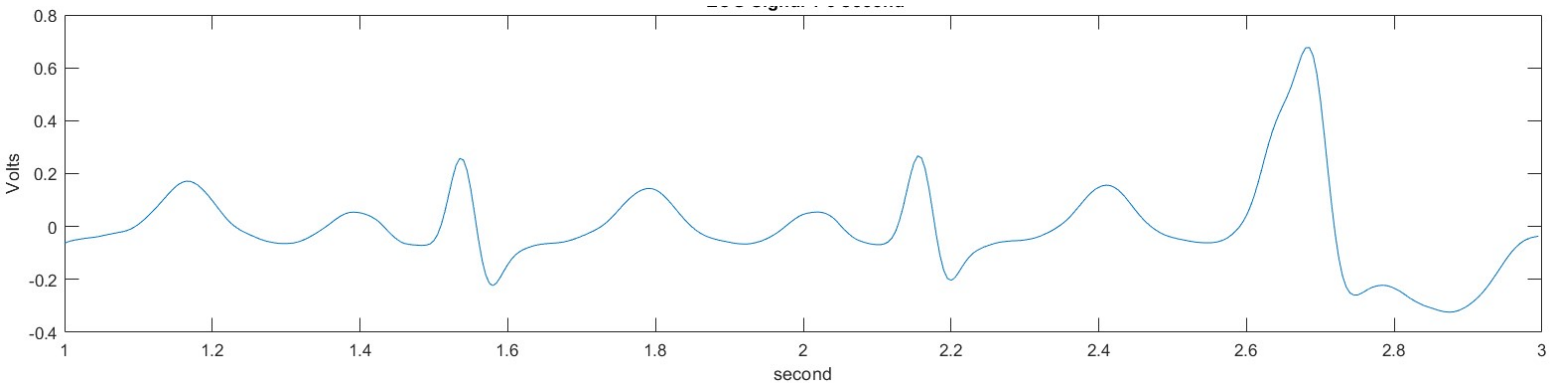
QRS Complex Detection Algorithm



We are going to use the Pan Tompkins technique to locate the peaks of the ECG.

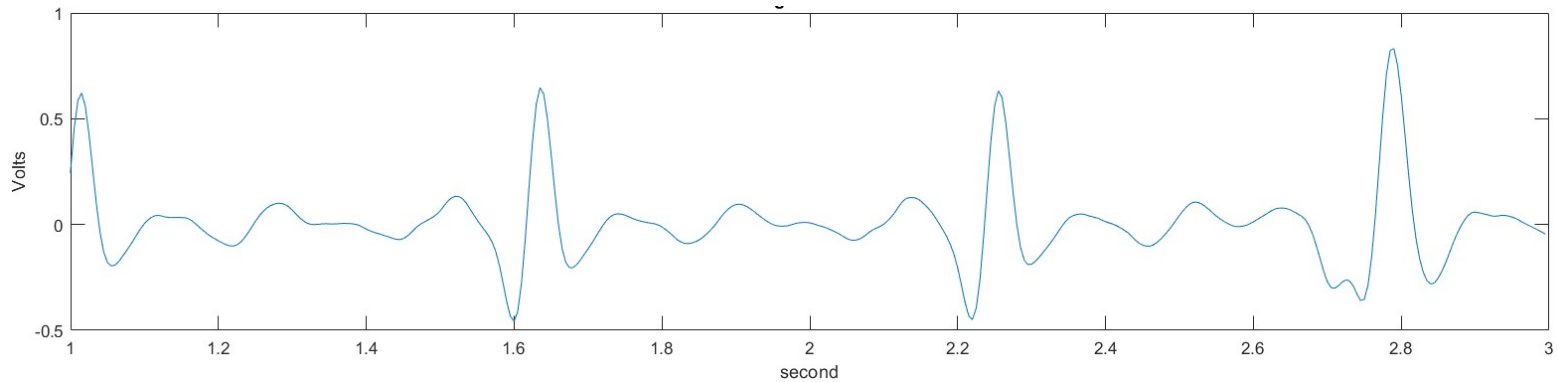
- First divide the ECG by by its maximum value to normalise the ECG within 0 and 1.
- **Band Pass Filtering:**

  High Pass Filter - Removes low frequency Baseline Wandering
  Low Pass Filter - Removes high frequency noise and power frequency artifacts



- **Derivative Filter:**

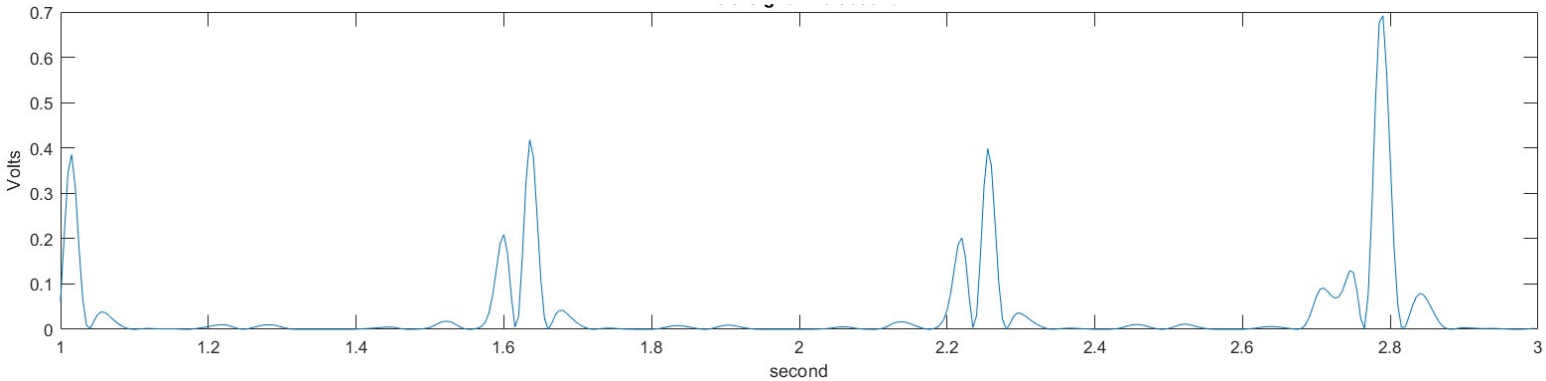
  Accentuates QRS complex (high frequency component of ECG).
  QRS now is more prominent.
  During the derivative process, the low-frequency P- and T-waves were cancelled out in order to concentrate on the high-frequency signals that were present in the steeper portions of the QRS complex.



But now we have to use double threshold on positive and negative side of QRS to identify them, so to avoid that we will do Squaring operation.

- **Squaring Operation:**

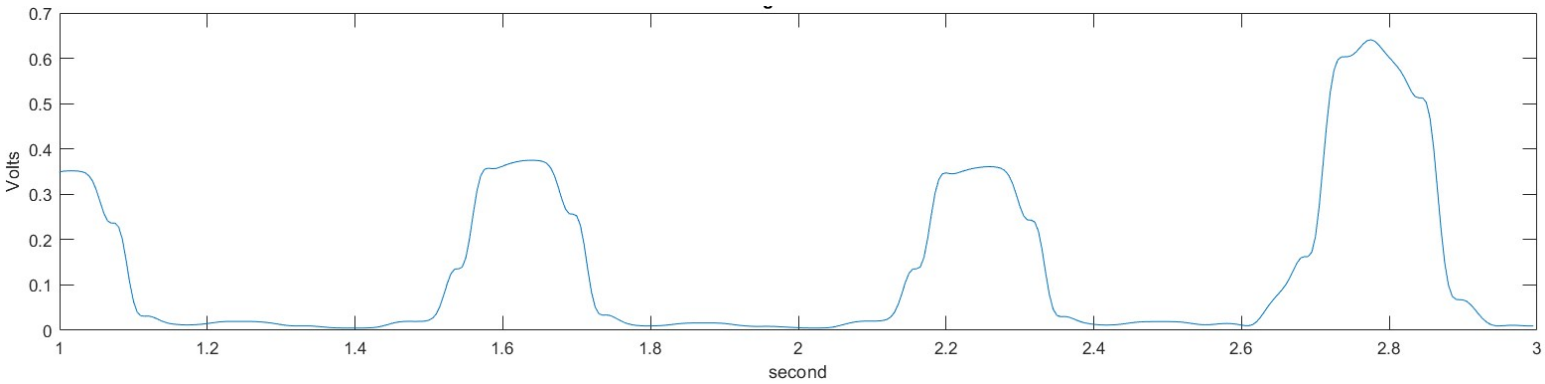
As shown in Figure, signal was squared after the derivative process so that all of its parts had a positive value. The stronger parts of the signal that were related to the QRS complex were made even stronger. The squaring function helps get rid of the higher T-wave amplitudes that can lead into false detection.
This process makes it clear that the QRS complexes are very different from other i.e **difference between high and low peaks increases**.



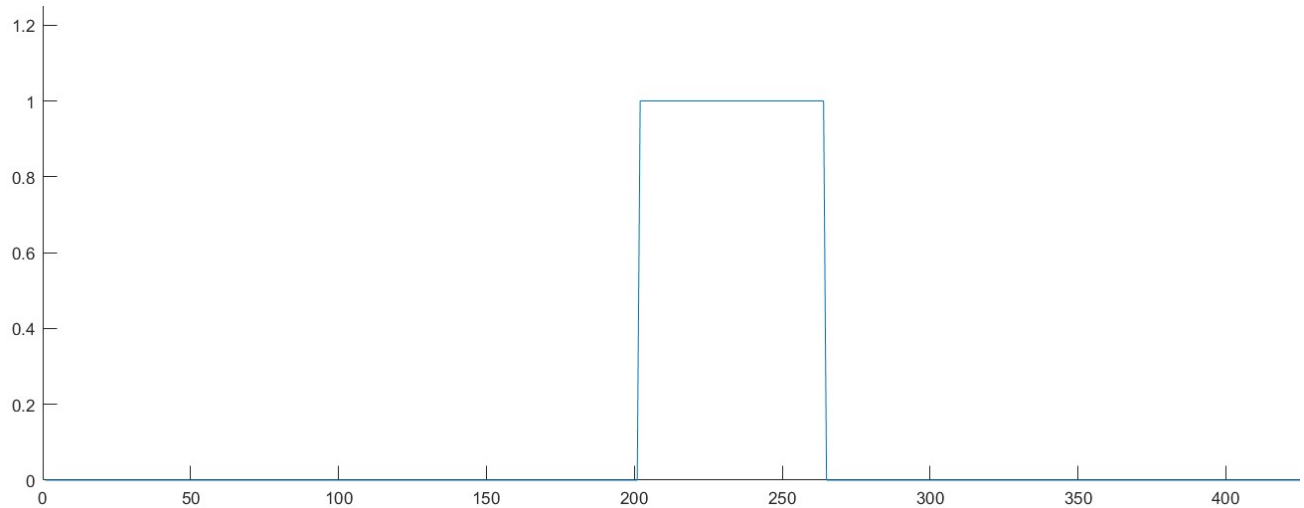
But now it has multiple peaks, so merge with MA Filter.

- **Moving Window Integration :**

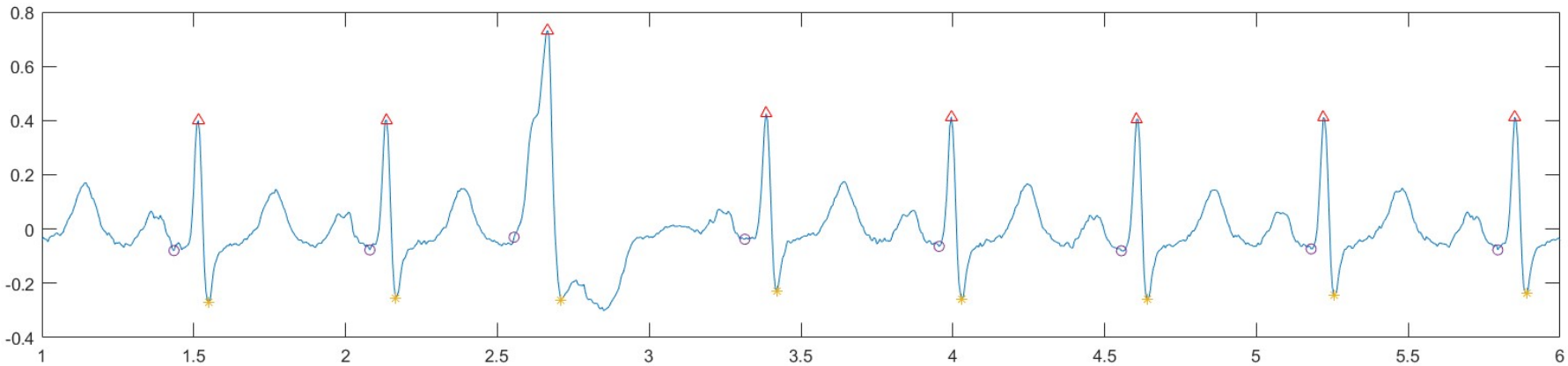
  First pad the signal with zeros.
  Pad 30 zeros at start and end of the ECG.
  Then **take integration with window of width 30**.



- **Thresholding:**
  - Take mean of ECG as Thresholding.
  - Make an array which contains '1' at only those locations where the ECG value is more than the threshold.
  - Now identify the location on this array where the values are becoming (0 to 1) and (1 to 0).
  - Store in **X** and **Y** (represents **points inside which QRS lies**).



- **Final QRS Detection:**
  - **R**-peak - Maximum value within X and Y is R- peak.
  - **Q**-peak - Minimum value between X and R-peak.
  - **S**-peak - Minimum value between R-peaks and Y.



PVC Detection in ECG

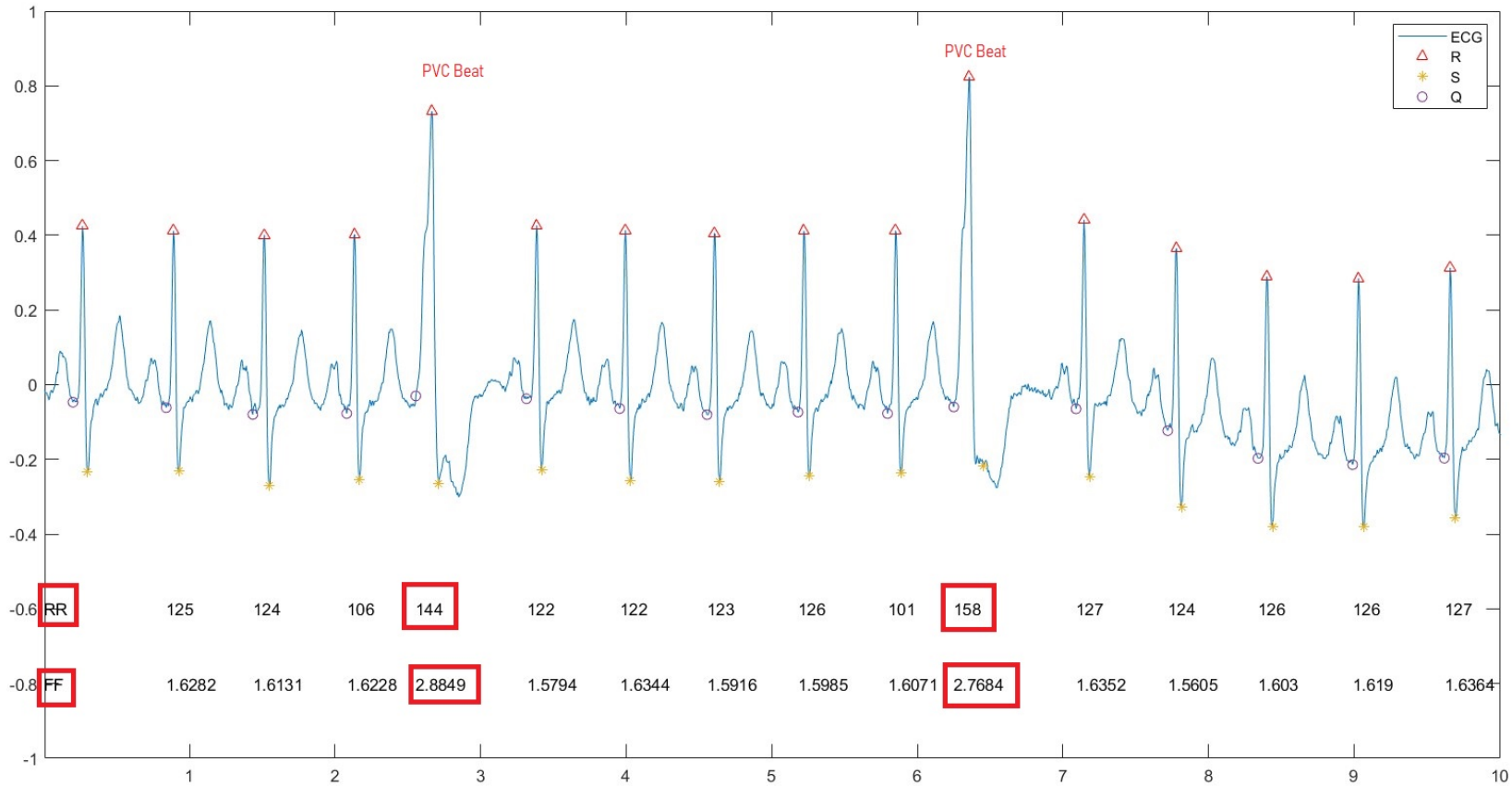
- **Form Factor Calculation:**
  - We can **detect the PVC beats** on the basis of **Form Factor** or **R-R interval**. So in first case we find the Form Factor.
  - Form Factor(FF) is ratio of Mobility of First Derivative ($M_{X'}$) of the signal to the Mobility of Signal (M_X) itself.

$$\boxed{M_X = \frac{\sigma_{X'}}{\sigma_X}} \quad \boxed{FF = \frac{M_{X'}}{M_X} = \frac{\sigma_{X''}\sigma_X}{\sigma^2_{X'}}}$$

- We found that **PVC beats has Larger FF & RR-Interval**.

PVC Detection in ECG

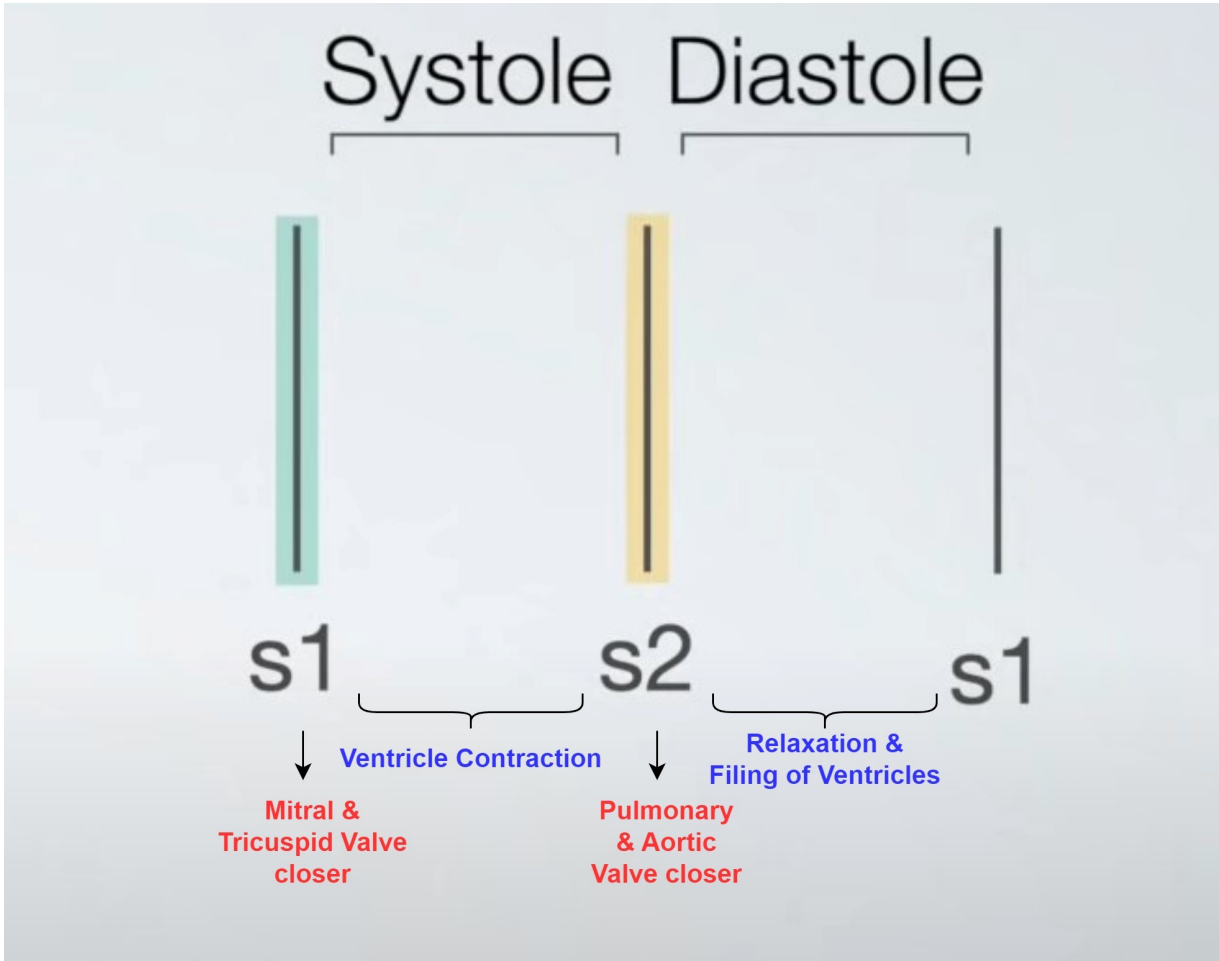
- **PVC beats has Larger FF & RR-Interval**



Detection of S1 & S2 Sound Locations in PCG by using ECG & PPG

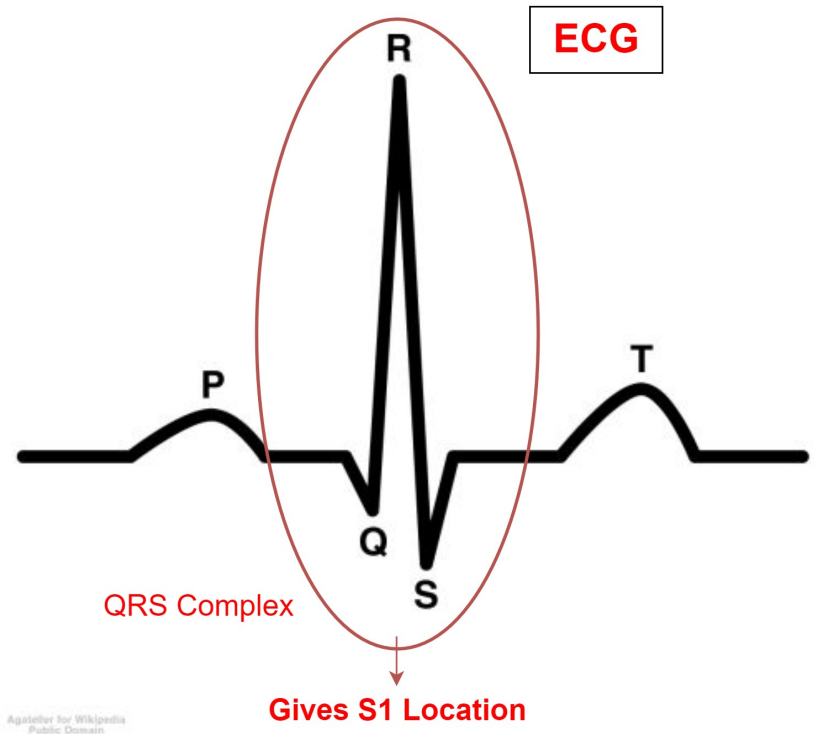
What are S1 & S2 Sounds in PCG?

- These are sounds of valve closure of the heart.



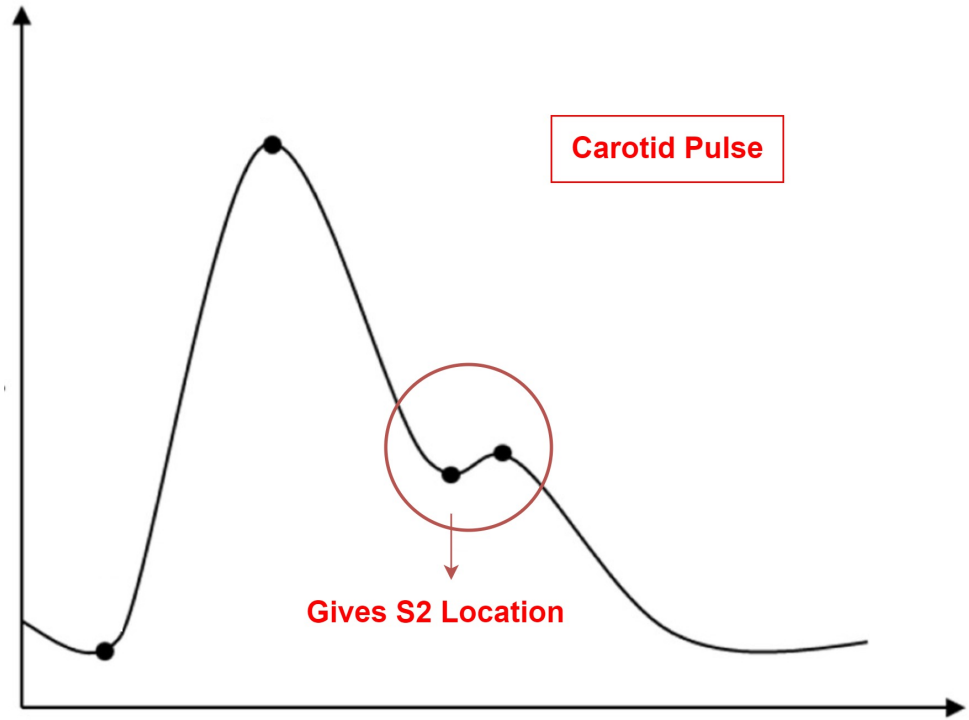
Determining S1 & S2 locations in PCG by using ECG & PPG

- These are sounds of valve closure of the heart.
- **From ECG we can find location of S1**.
- When QRS comes, ventricle starts getting compressed and just at that time Mitral and Tricuspid valves closes and produces sound S1.



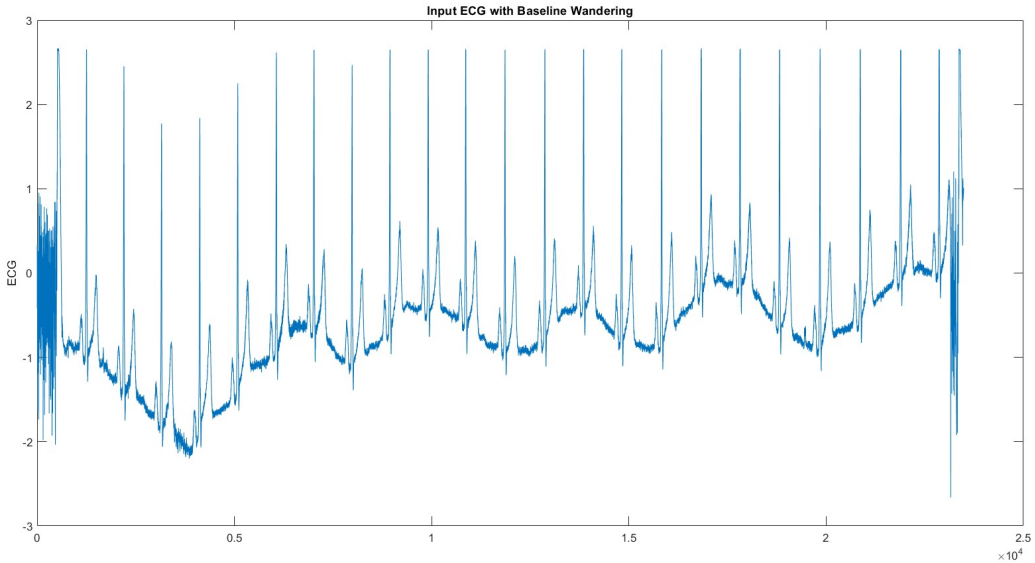
Determining S1 & S2 locations in PCG by using ECG & PPG

- **From PPG we can find location of S2**.
- At end of compression of ventricle then it starts to relax. Then to hold the pressure, Aortic and Pulmonary valves closes and that gives rise to a small dip in the carotid pulse signal (pressure at carotid pulse) and valve closure produces S2 sound.

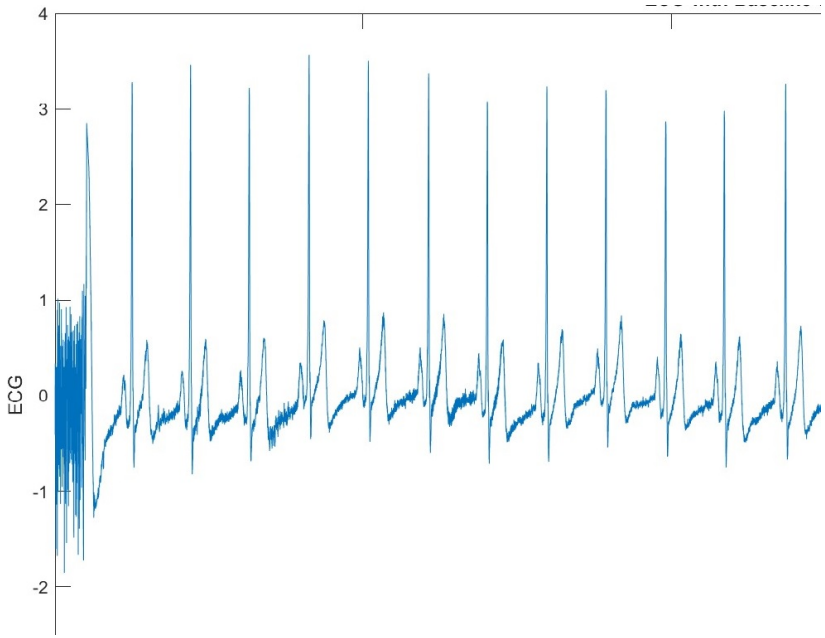


QRS location Detection

- Locate QRS complex locations using Pan Tomkins method.

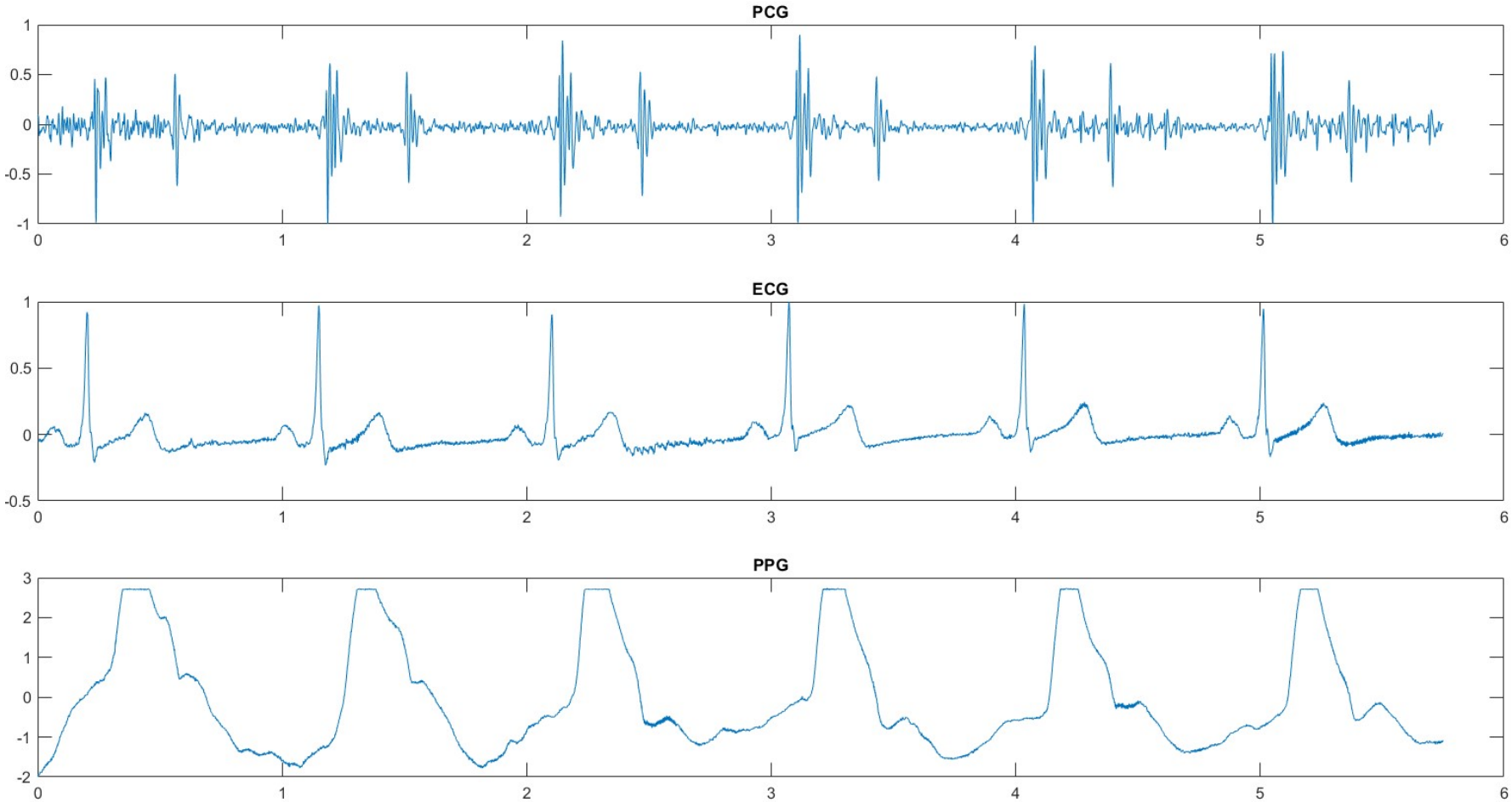


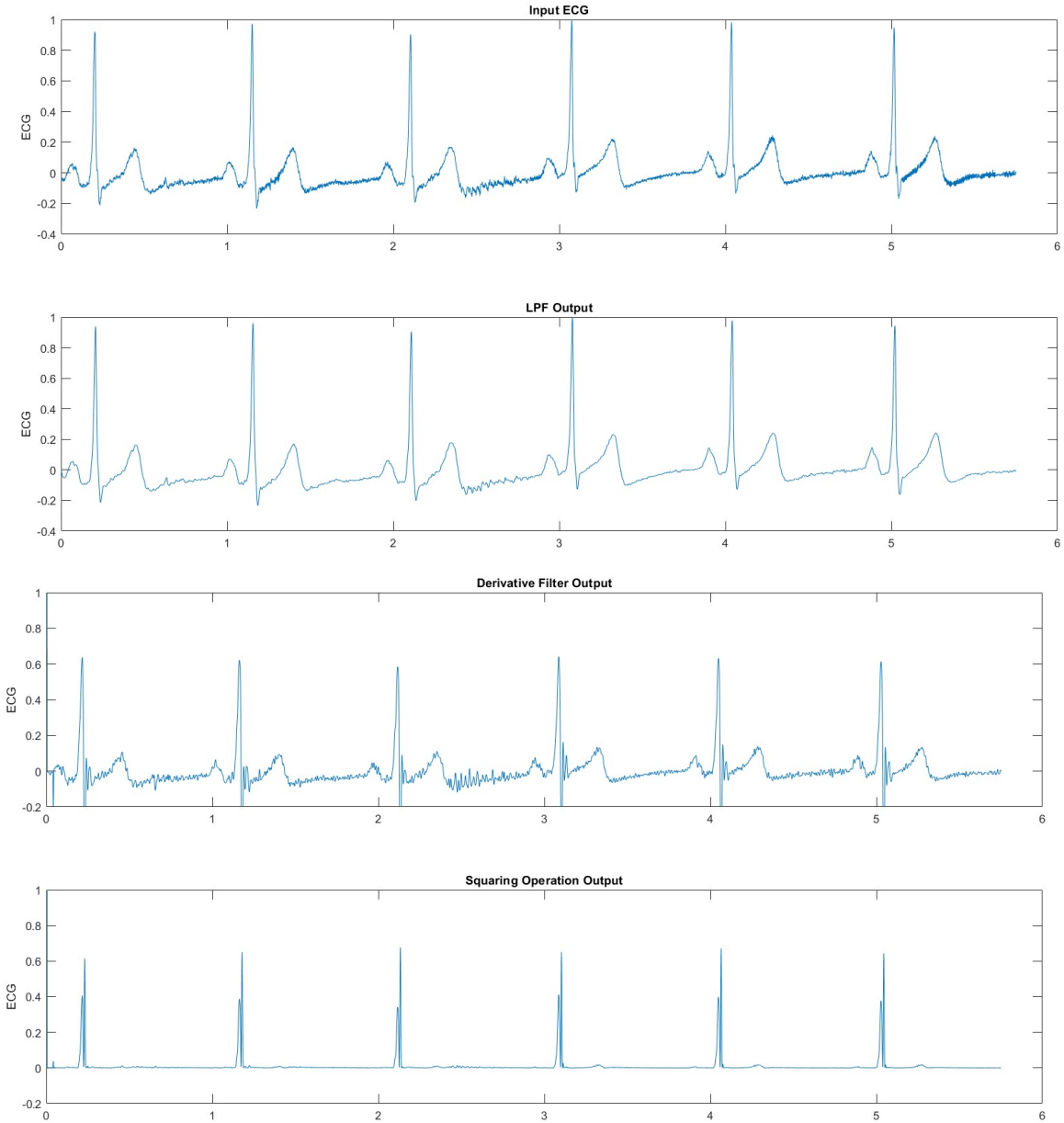
Input ECG with Baseline Wandering



Baseline Wandering Removed

- Input Data: PCG, ECG PPG.




Input ECG
ECG
LPF Output
ECG
Derivative Filter Output
ECG
Squaring Operation Output
ECG

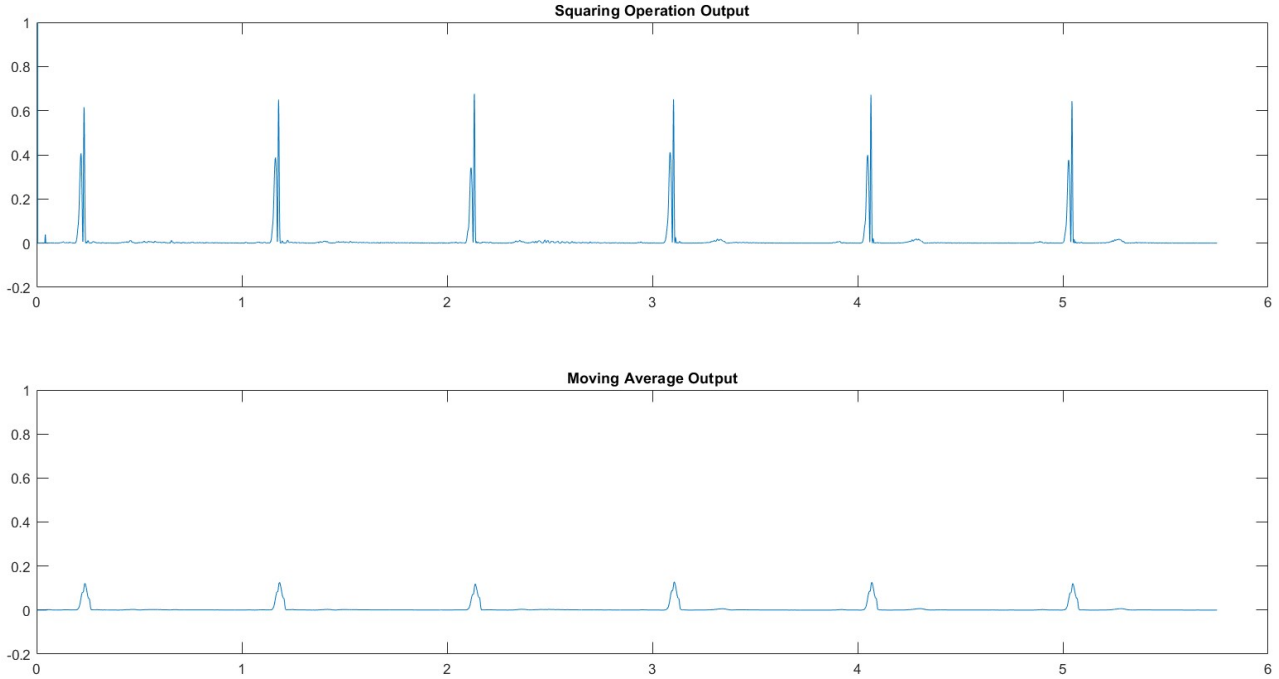


Figure 1: Squaring then Moving Average Output

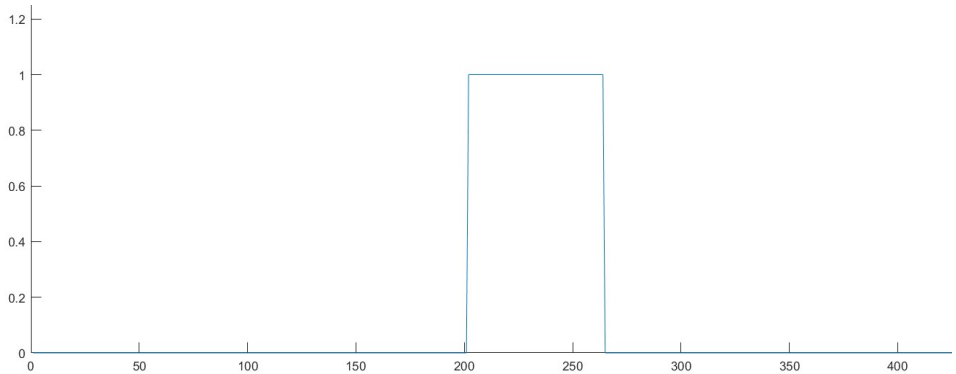
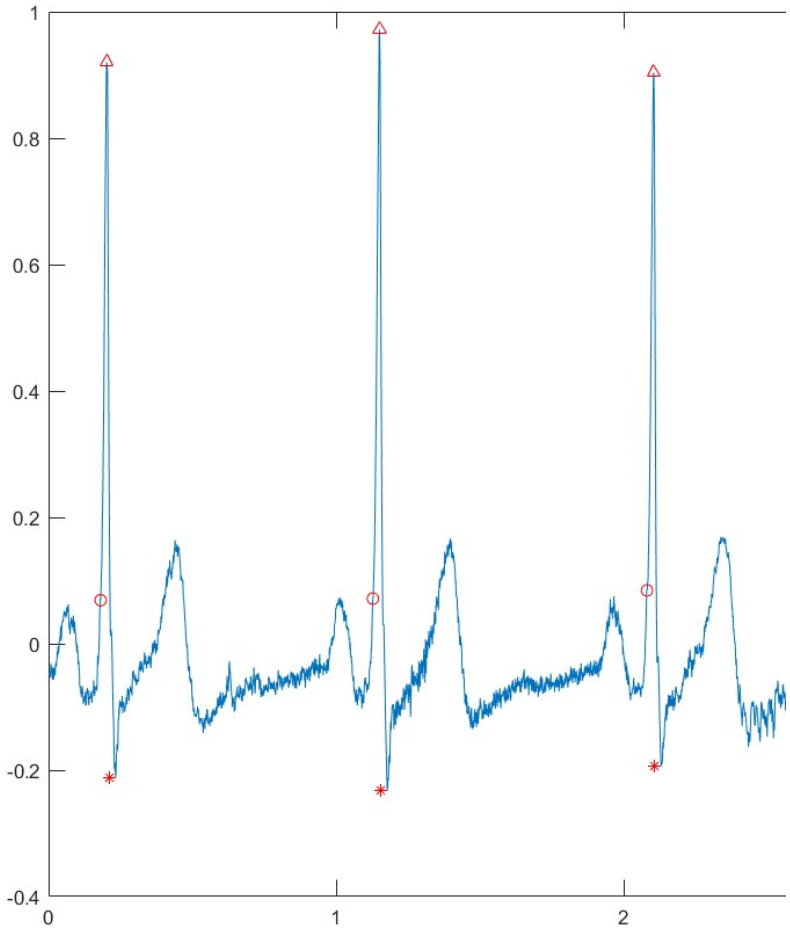


Figure 2: Thresholding

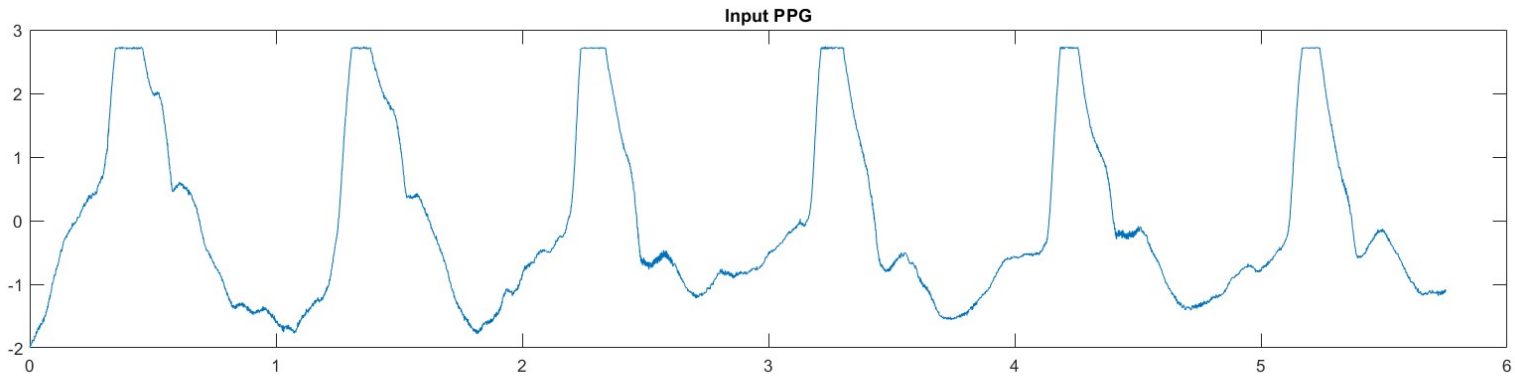
- QRS has been detected and so is S1.

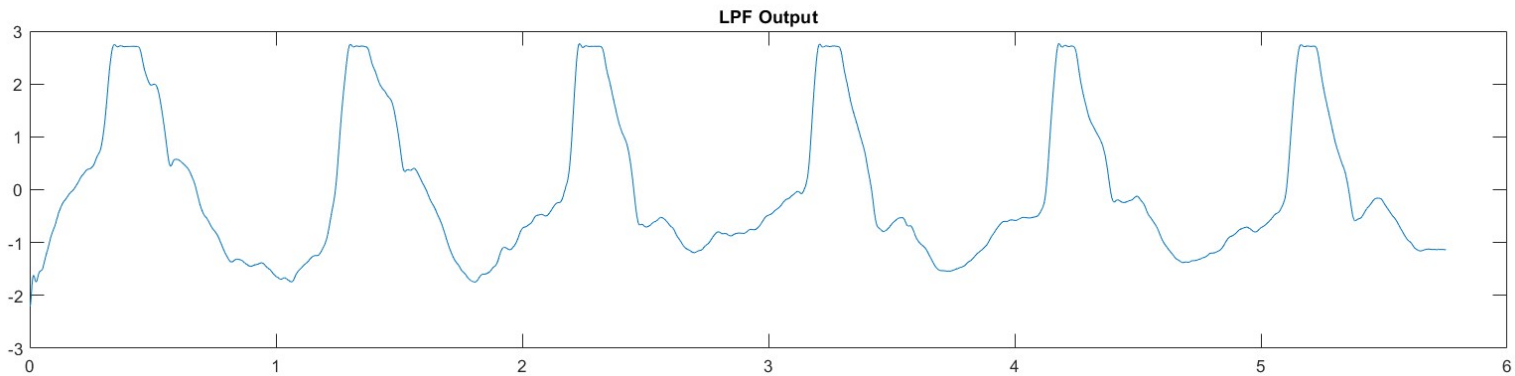


Dicrotic Notch Detection in PPG

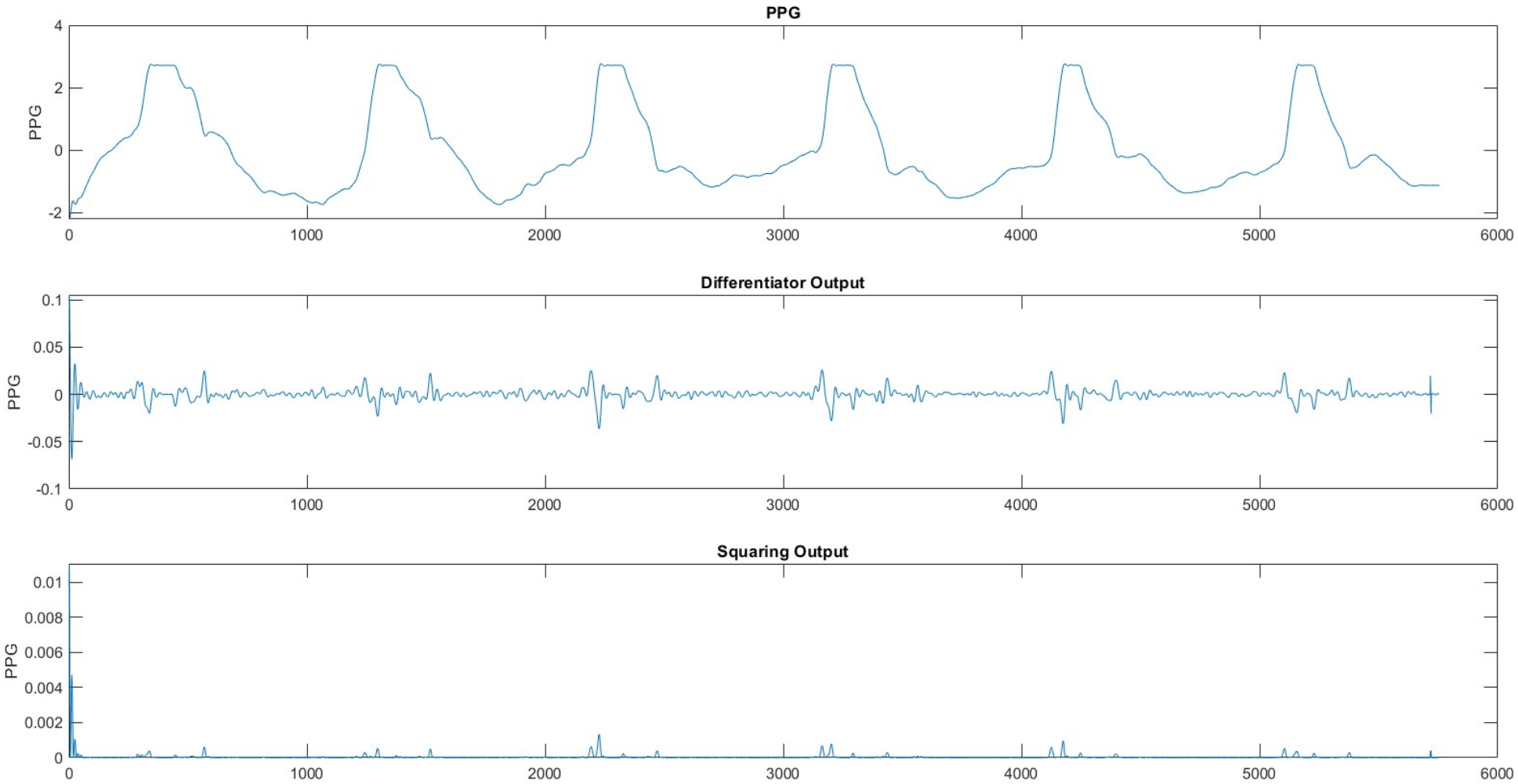
We are going to use the Lehner & Rangayyan method to locate the Dicrotic Notch of the PPG.

- **Low-Pass Filter:**
  - (Cut off frequency 40Hz) - Remove High Frequency noise

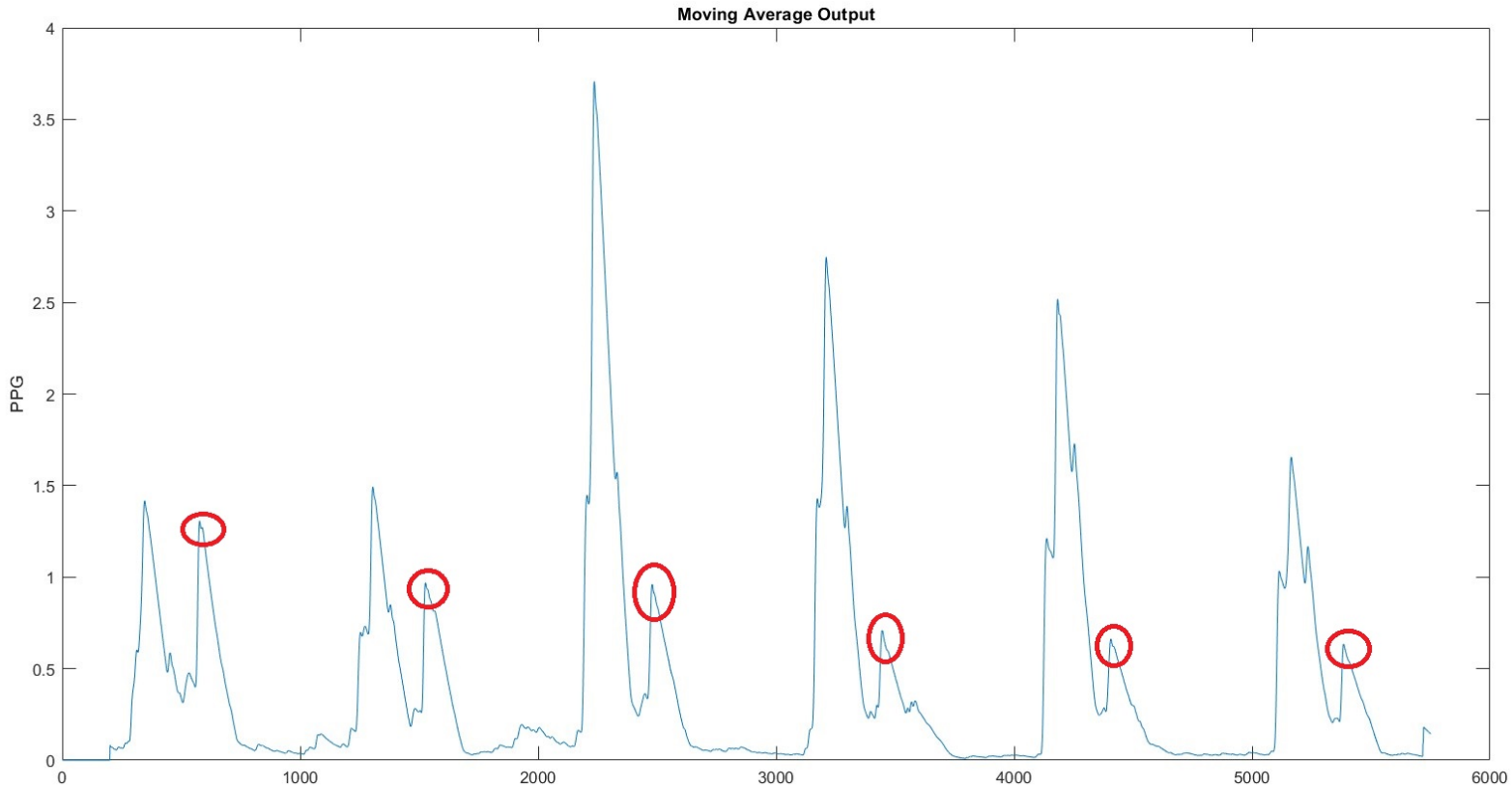




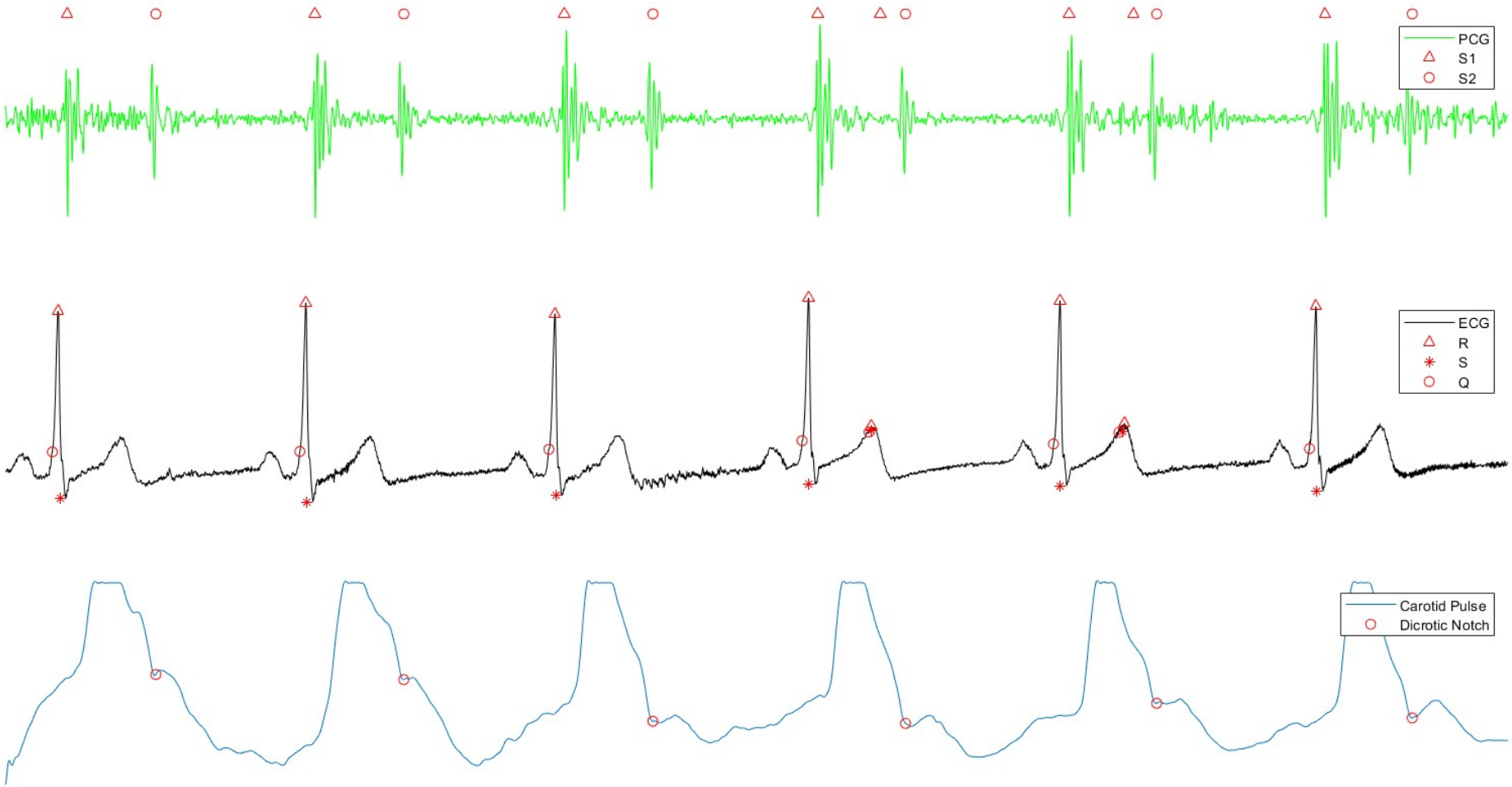
- **Derivative Filter**
- **Squaring Operation**



- **Moving Average Output:**
  - Will give two peaks in each cycle.
  - Location in PPG surrounding this moving average's output's 2nd peak will have the Dicrotic Notch.
  - Use a threshold to find this 2nd peak location.
  - **Find Dicrotic-Notch within 20ms of this 2nd peak location (Minimum value near this location in PPG)**.



Determining S1 & S2 in PCG using ECG PPG



Thank you!