EXERCISES – BIOLOGICAL SIGNALS

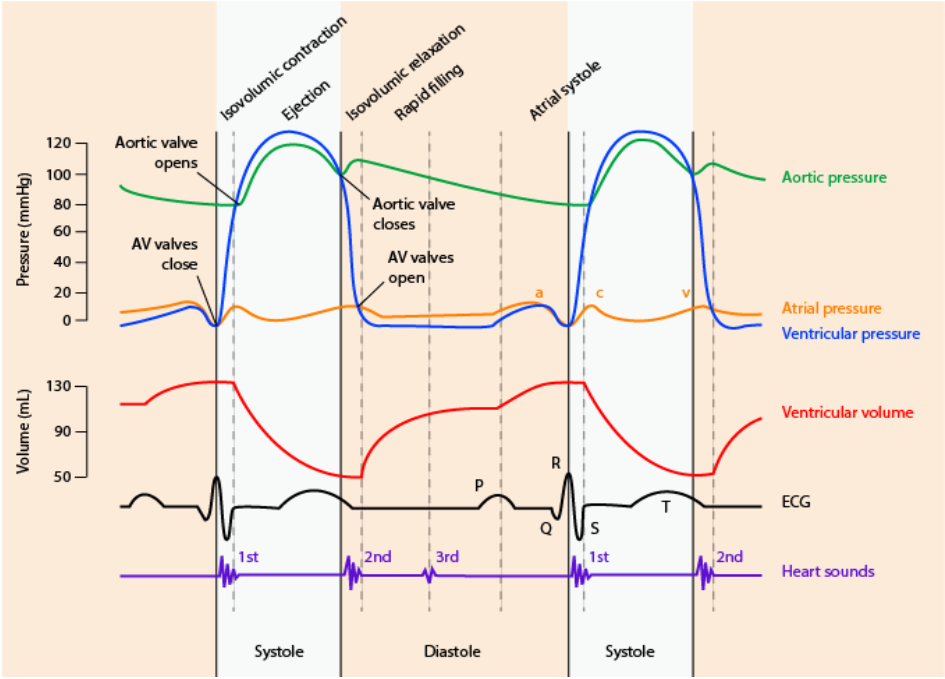
Exercise 4 - SS 2014 – Michel Kana

What will we do today?

1. **The physiology behind PPG**
2. **Structure of the PPG Signal**
3. **PPG measurement with BIOPAC**
4. **Summary**

The physiology behind PPG

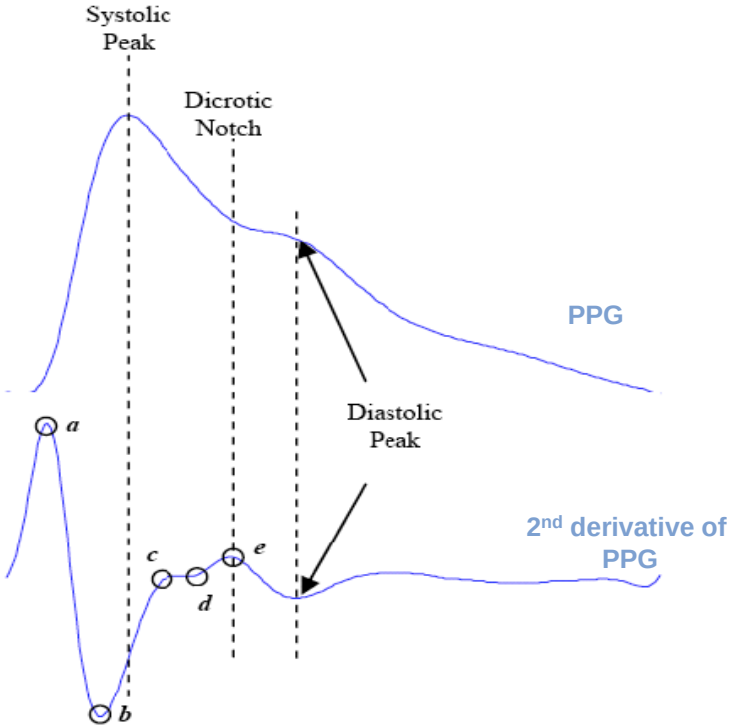
- Photoplethysmography (PPG) is an optical measurement technique that can be used to detect blood volume changes in the microvascular bed of tissue
- A photodetector can be placed on a tissue's surface alongside the light-emitting diode and record the light that returns back
- Light intensity is attenuated by oxygenated and deoxygenated hemoglobin (in blood cells), myoglobin (in muscle), and cytochromes, as well as melatonin (in skin)
- Reductions in light intensity indicate relative increases in blood volume and *vice versa*



Wiggers diagram

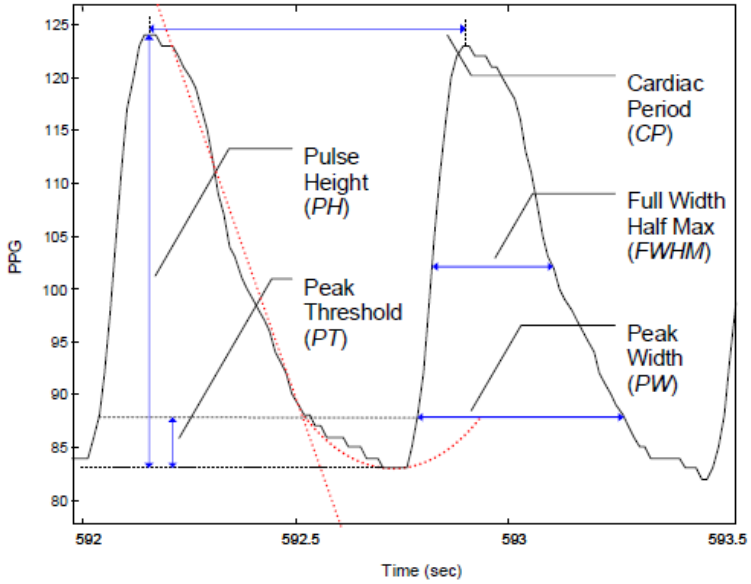
Structure of the PPG Signal

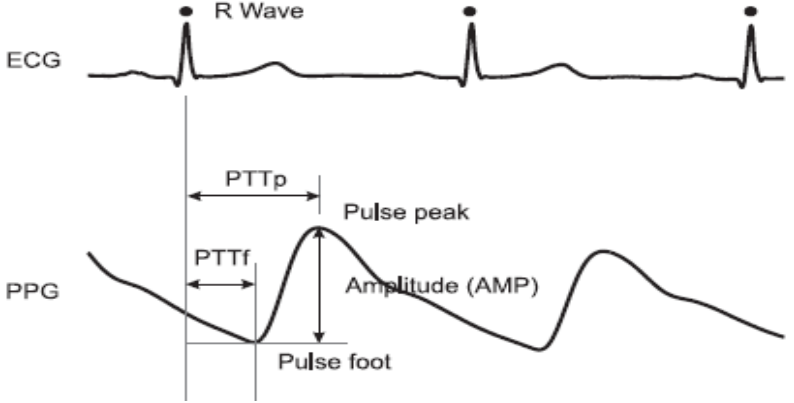
- **Waves in the PPG**
  - The photoplethysmogram waveform consists of one systolic wave and one diastolic wave.
  - The second derivative photoplethysmogram waveform consists of four systolic waves (a, b, c, and d waves) and one diastolic wave (e wave).



Ref.: M. Elgendi "Standard Terminologies for Photoplethysmogram Signals"

Structure of the PPG Signal

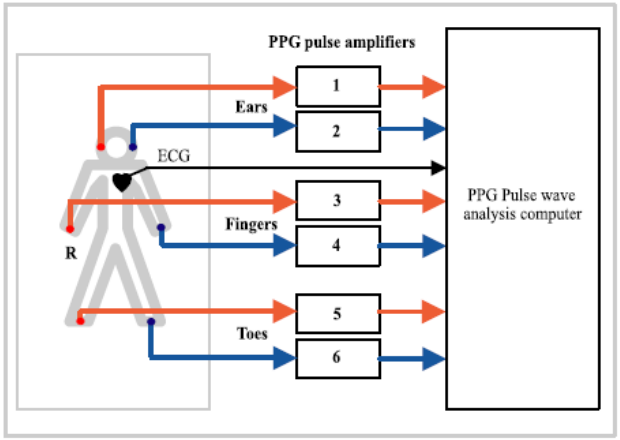


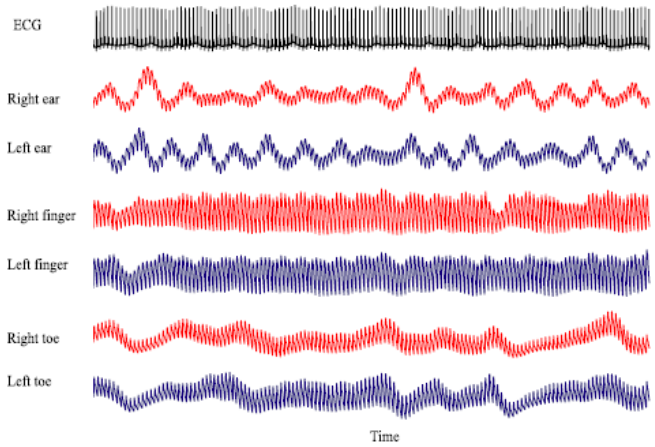


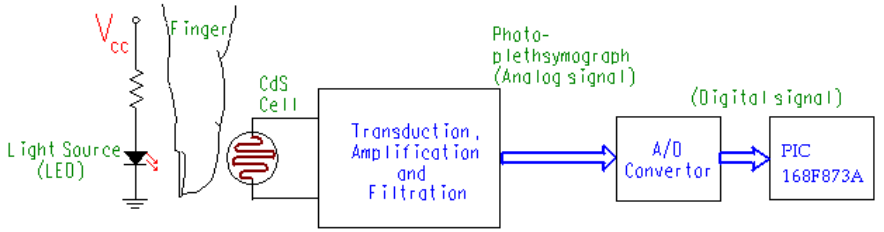
- **Parameters in the PPG signal**
  - **PH:** pulse height or pulse amplitude
  - **CP:** cardiac period
  - **FWHM:** full width half max
  - **PW:** peak width
  - **PT:** peak threshold
  - **PPT:** pulse travelling time

- **Information in the PPG**
  - **Heart rate:** $\frac{60}{CP}$ in beats per minute
  - **Blood pressure:**
    - $p_1 - p_2 \cdot PTT$ (e.g. p_1 = 246, p_2 = 0.4, PTT=315ms)
    - $p_1 \cdot e^{p_2 \cdot PH} + p_3 \cdot e^{p_4 \cdot PH}$ (e.g. $p_1 = 105, p_2 = -4, p_3 = 0.2, p_4 = 18$)
  - **Respiration:** using low frequency respiratory induced intensity variations and PPT
  - **Arterial stiffness:** $\frac{c}{a}$
  - **Vascular aging:** $\frac{b-c-d-e}{a}$

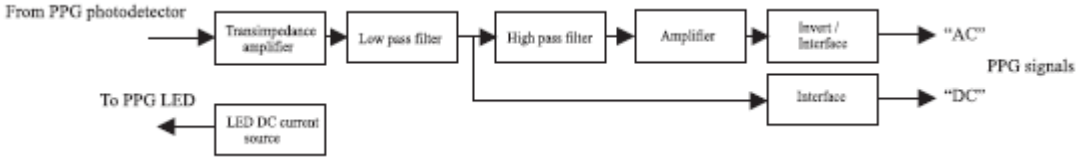
PPG Measurement







Ref.: http://www.engin.swarthmore.edu/~dluong1/E72/FinalProject/heart.htm



- **Operational configuration**
  - Side-by-side mode
  - Transmission mode
- **Noise sources**
  - Movement artefacts
  - Ambient light interference
  - Variation in temperature
  - power line interference

Exercice 1: PPG measurement with BIOPAC

- **Biopac MP35 measurement system**
  - PPG is recorded using Biopac SS4LA plethysmograph transducer plugged in the first channel.
  - Tranducer should be attached to the left hand, index finger.
- **Biopac Student Lab PRO software**
  - The acquisition is set up for *Recording* and *Append into Memory* at a sampling rate of *200 Hz*. The total acquisition length can be set to 1 hour.
  - In the *Setup Channels* menu, the check boxes *Acquire Data, Plot on Screen, Enable Value Display* are enabled for the first channel.
  - Analog Channel CH1 should have the following settings
    - AC coupling 0.5 Hz High Pass, 1K Low Pass
    - Hardware-based filter 60 Hz Low Pass
    - Total gain 5000
  - Calculation Channel C1 should calculate the Difference of the channel CH1 in order to estimate the first derivative of the PPG waveform. Channel C1 should not be visible.
  - Calculation Channel C2 should calculate the Difference of the channel C1 in order to estimate the second derivative of the PPG waveform
- **PPG parameters calculation**
  - Select two consecutive cardiac cycles
  - Read the values for PH, CP, FWHM, PW, PT
  - Estimate the heart rate
  - Estimate arterial stiffness and vascular aging

Exercice 2: ECG & PPG measurement with BIOPAC

- **Biopac MP35 measurement system**
  - PPG is recorded using Biopac SS4LA plethysmograph transducer plugged in the first channel.
  - 3 leads ECG is recorded using Biopac SS2L connecting wires plugged in the 2nd channel.
- **Biopac Student Lab PRO software**
  - Analog Channel CH2 should have the following settings
    - AC coupling 0.5 Hz High Pass, 1K Low Pass
    - Hardware-based filter 35 Hz Low Pass
    - Total gain 2000
  - Calculation Channel C3 should calculate the heart rate from the PPG signal
  - Calculation Channel C4 should calculate the heart rate from the ECG signal
  - Calculation Channel C5 should estimate the mean arterial pressure from the pulse amplitude in the PPG signal
- **Pulse travel time calculation**
  - Select one cardiac cycle
  - Use the measurement window and calculate the PPT
  - Estimate the mean arterial blood pressure using the PPT and the pulse amplitude
  - Suggest a method for calculating and displaying the PPT during realtime measurement
- **Heart rate comparison**
  - Select a sufficiently long time period
  - Calculate and compare the mean, min and max heart rates obtained from ECG and PPG

Exercise 3: active standing test

- **Active Change of Posture Test**
  - Subject is instrumented for PPG measurement with Biopac by the examiner.
  - The examiner records the PPG signal for 120 seconds.
  - The examiner gives a vocal signal to the subject to stand.
  - Subject stands up.
  - The examiner records the PPG signal for 120 seconds.
- **Evaluation**
  - Identify significant phases in the heart rate and blood pressure waves
  - Compare the mean values between phases

Summary

[What did we learn today]

Physiology behind the photoplethysmogram.
Structure of the PPG signals.
Measurements and signal analysis.

[Plan for the next week]

Respiration measurement & analysis