ECE 105: Introduction to Electrical Engineering

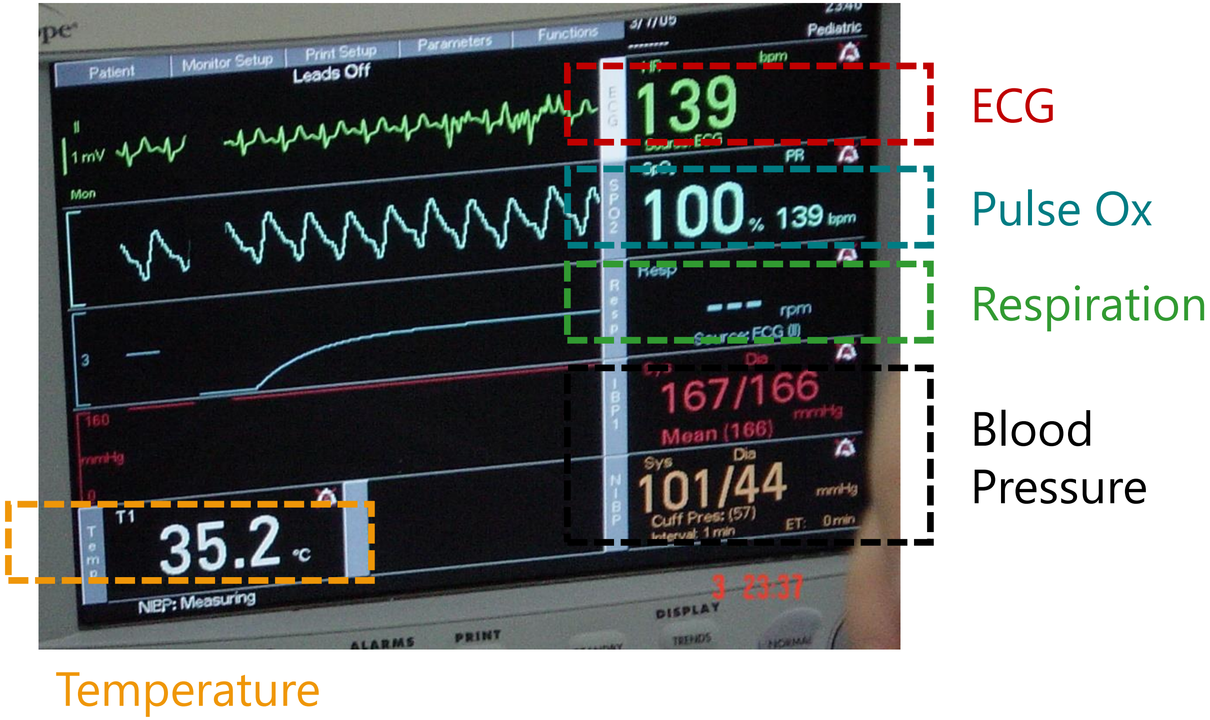
Lecture 13

Bio 3

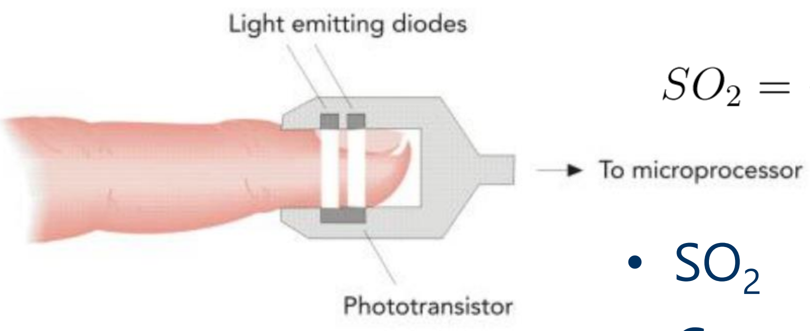
Yasser Khan

Rehan Kapadia

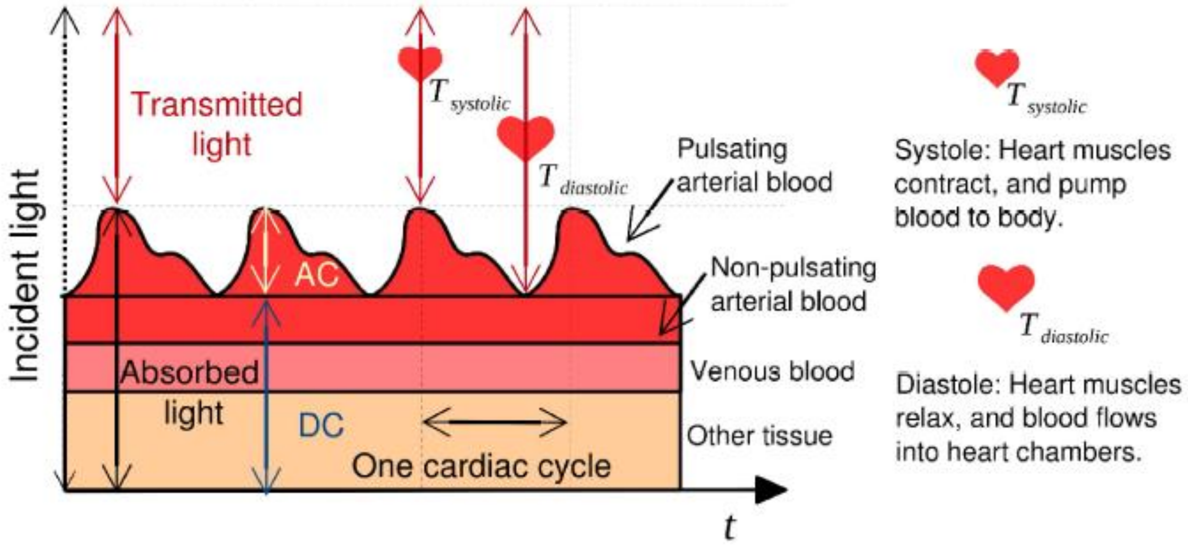
Pulse oximetry



- Pulse oximetry measures blood oxygenation. Using spectrophotometry of absorptivity of blood at two distinct wavelengths, blood oxygen saturation is quantified.
- Can detect hypoxemia, ie. lower than normal blood oxygenation.

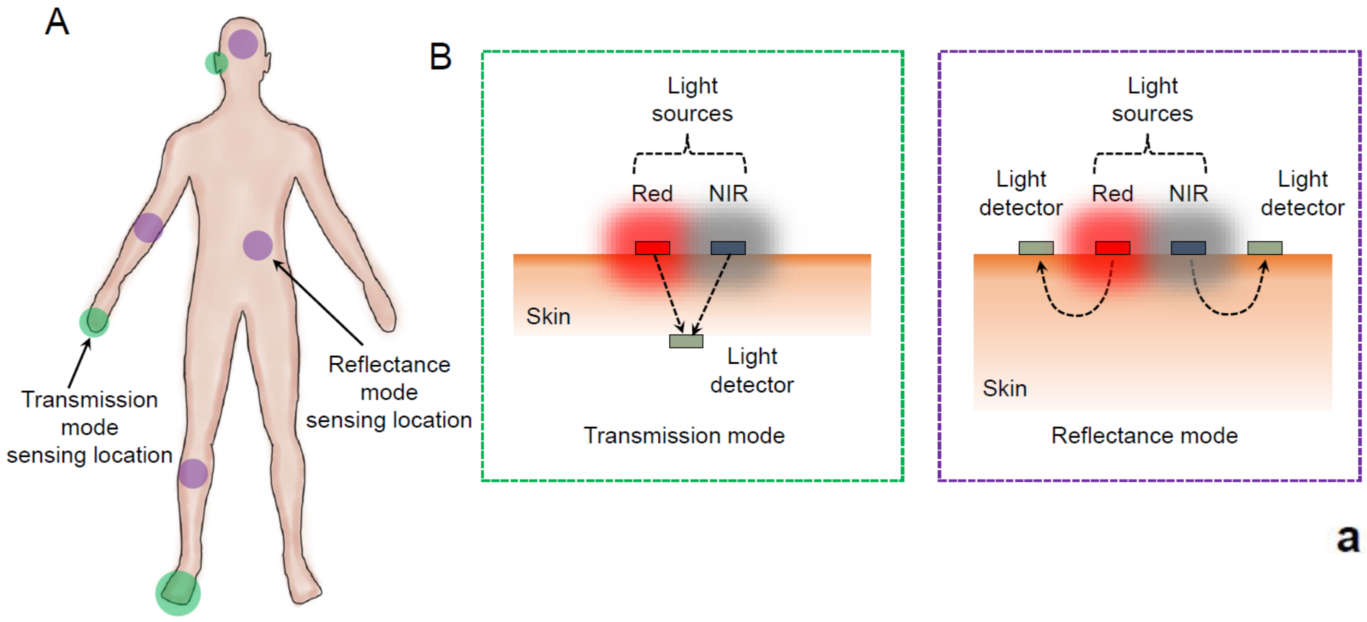


$$SO_2 = \frac{C_{HbO_2}}{C_{HbO_2} + C_{Hb}}$$



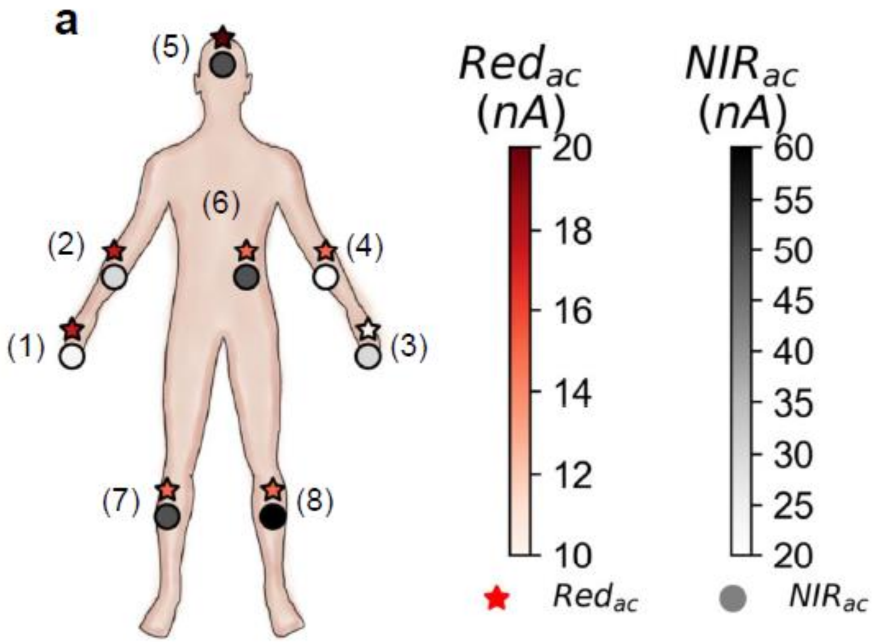
- SO_2 The saturation of oxygen in blood,
- C_{HbO_2} Concentration of oxygenated hemoglobin (HbO_2),
- C_{Hb} Concentration of deoxygenated hemoglobin (Hb).

Transmission vs. reflectance oximetry

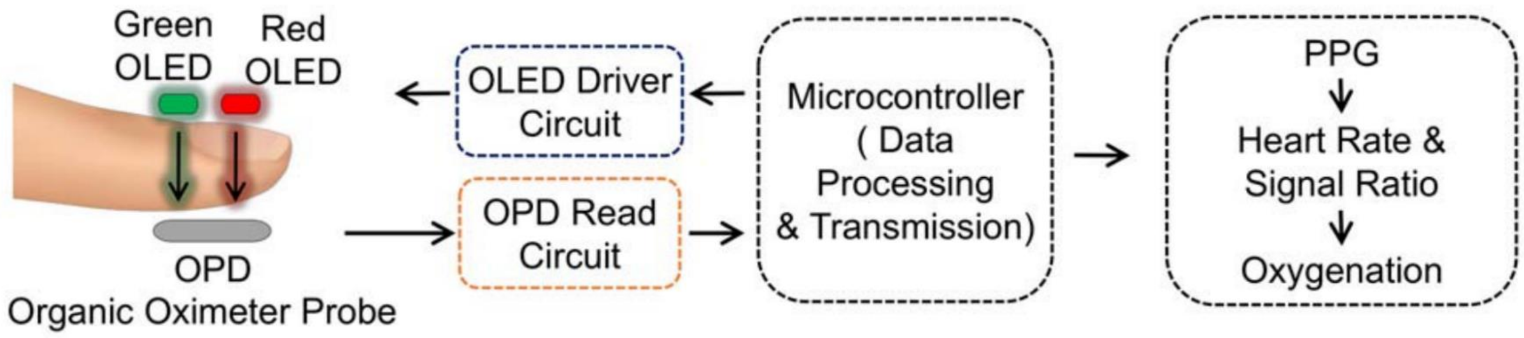


- Transmission-mode pulse oximetry is limited only to tissues that can be transilluminated, such as the earlobes and the fingers.
- If reflected light is used as the signal, the sensor can be used beyond the conventional sensing locations.

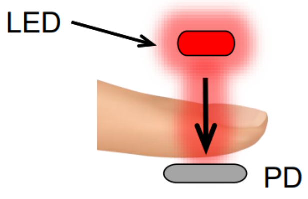
- AC signal is the highest at the forehead for both Red and NIR channels.
- Arms provide mid-range AC amplitude, while signal strength is low in the legs and chest area.
- Forehead is the best location for reflectance pulse oximetry.



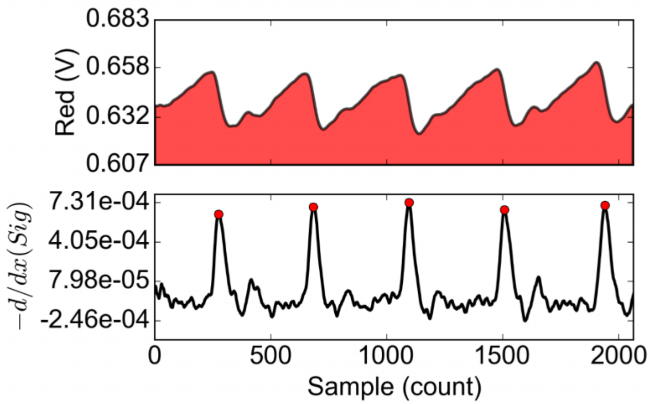
Oximeter readout circuit

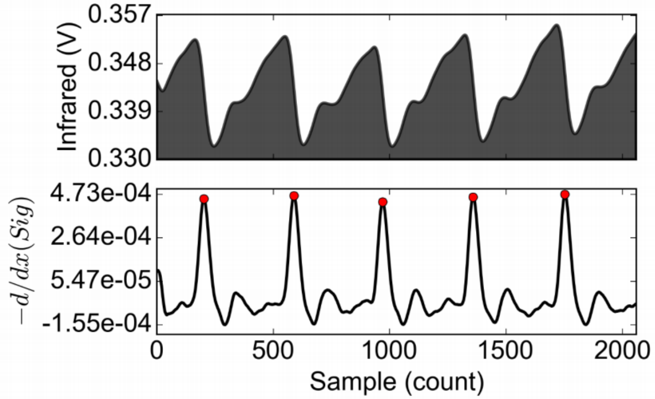


Calculating oxygen saturation



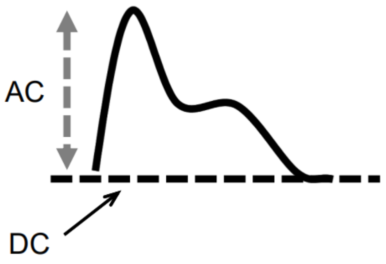
Measuring Transmission Mode PD Current

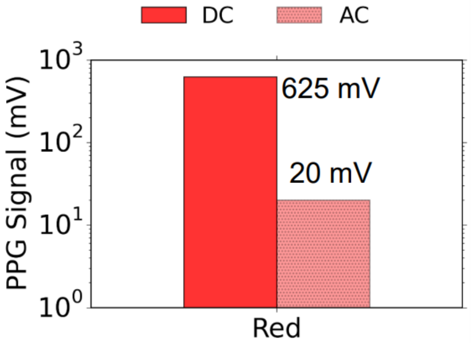


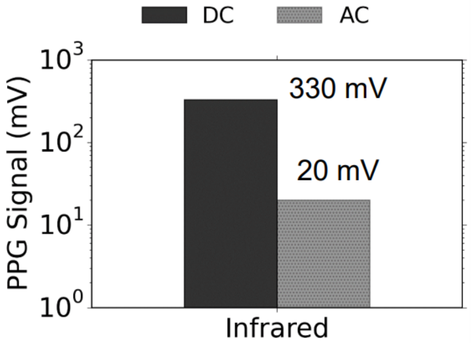


$$R = \frac{AC_{rd}/DC_{rd}}{AC_{ir}/DC_{ir}}$$

$$R = \frac{20mV/625mV}{20mV/330mV} = .528$$







Pulse oximeter basics

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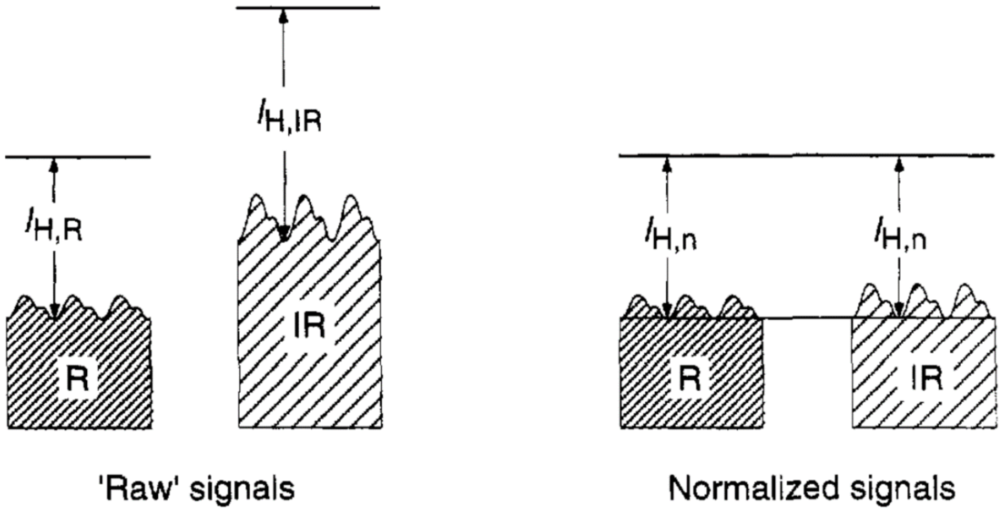

Figure 4.6 The normalization of the signals. The transmitted light from the red LED (R) and from the infrared LED (IR) is divided by its individual DC component. Thus, both normalized light intensities have the same magnitude during diastole. The normalized signals determine the basis for the calculation of the arterial oxygen saturation.

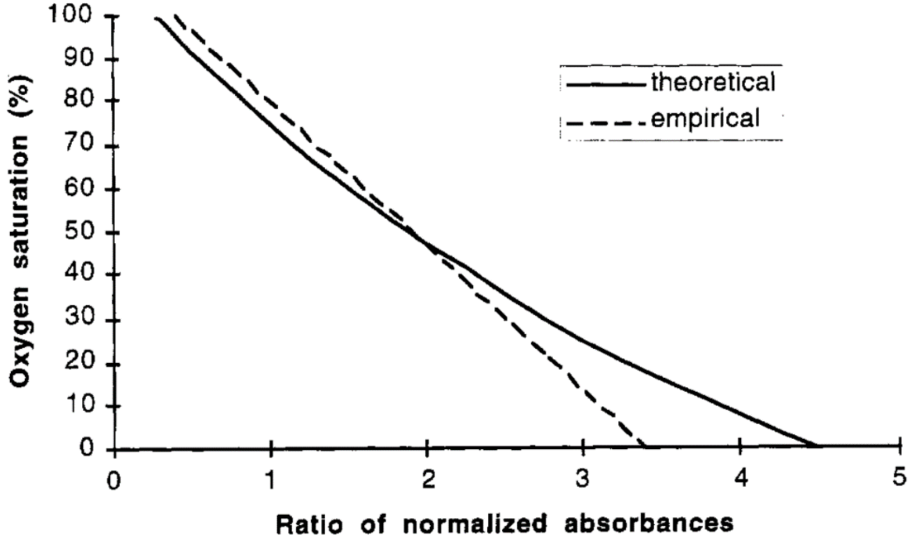

Figure 4.7 Calibration curves for pulse oximeters: the solid line is the theoretical curve by Beer's law and the dashed line is the empirical curve. The difference between these curves is due mainly to light scattering effects. This empirical calibration curve is derived by a second order polynomial.

AFE – MAX30102

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Click here for production status of specific part numbers.

MAX30102 — **High-Sensitivity Pulse Oximeter and Heart-Rate Sensor for Wearable Health**

General Description

The MAX30102 is an integrated pulse oximetry and heart-rate monitor module. It includes internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. The MAX30102 provides a complete system solution to ease the design-in process for mobile and wearable devices.

The MAX30102 operates on a single 1.8V power supply and a separate 3.3V power supply for the internal LEDs. Communication is through a standard I^2C-compatible interface. The module can be shut down through software with zero standby current, allowing the power rails to remain powered at all times.

Applications

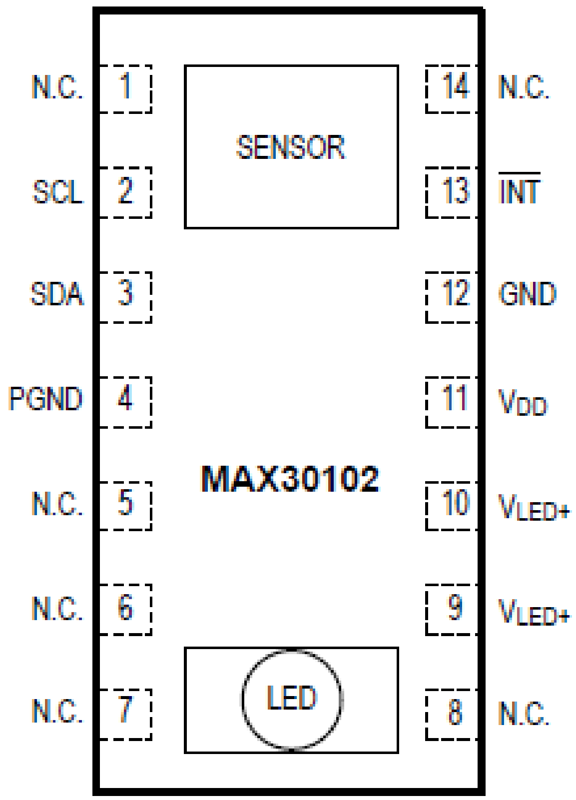
- Wearable Devices
- Fitness Assistant Devices
- Smartphones
- Tablets

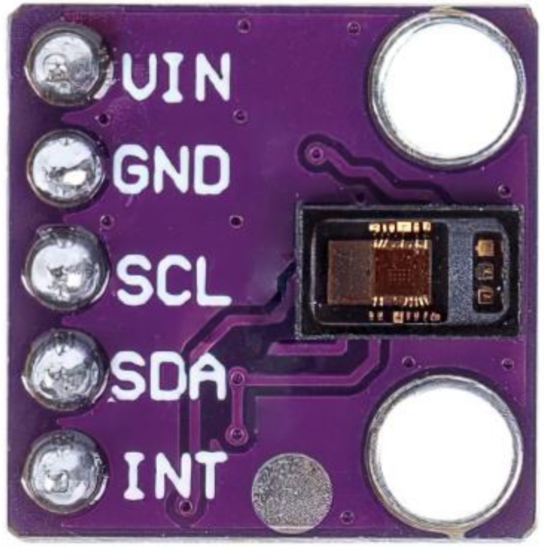
Benefits and Features

- Heart-Rate Monitor and Pulse Oximeter Sensor in LED Reflective Solution
- Tiny 5.6mm x 3.3mm x 1.55mm 14-Pin Optical Module
  - Integrated Cover Glass for Optimal, Robust Performance
- Ultra-Low Power Operation for Mobile Devices
  - Programmable Sample Rate and LED Current for Power Savings
  - Low-Power Heart-Rate Monitor (< 1mW)
  - Ultra-Low Shutdown Current (0.7µA, typ)
- Fast Data Output Capability
  - High Sample Rates
- Robust Motion Artifact Resilience
  - High SNR
- -40°C to +85°C Operating Temperature Range

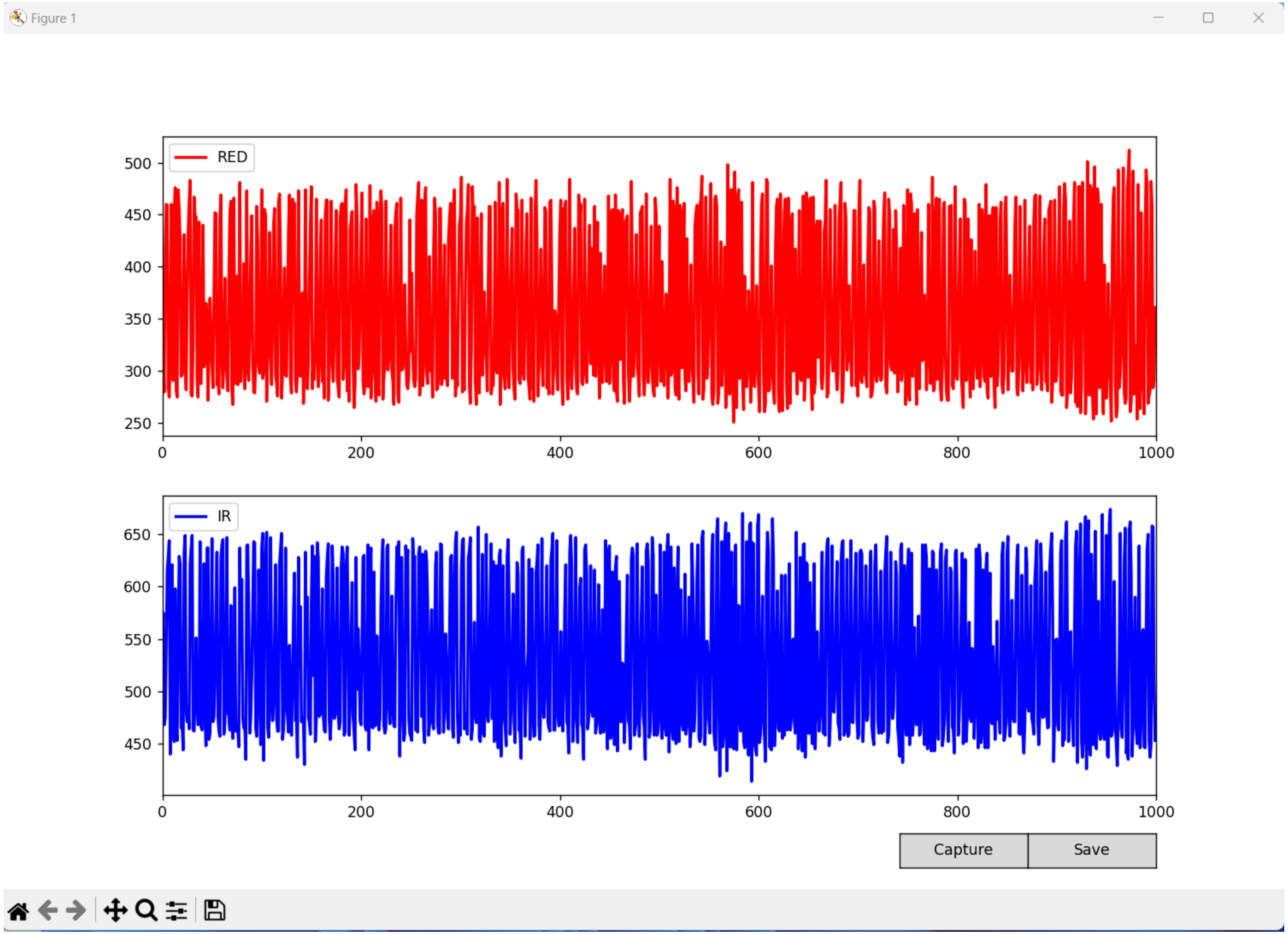
Ordering Information appears at end of data sheet.

Connection

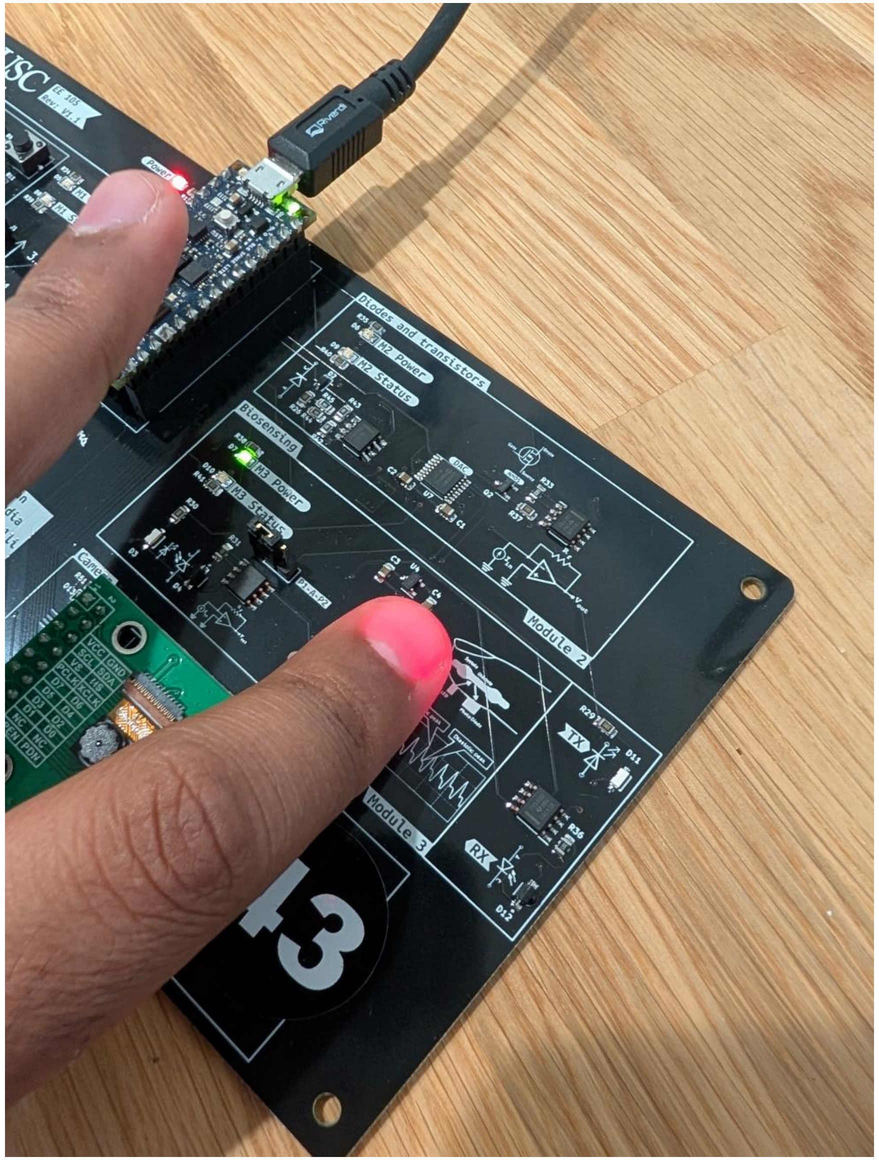

N.C. 1
SCL 2
SDA 3
PGND 4
N.C. 5
N.C. 6
N.C. 7
SENSOR
MAX30102
LED
14 N.C.
13 INT
12 GND
11 VDD
10 VLED+
9 VLED+
8 N.C.

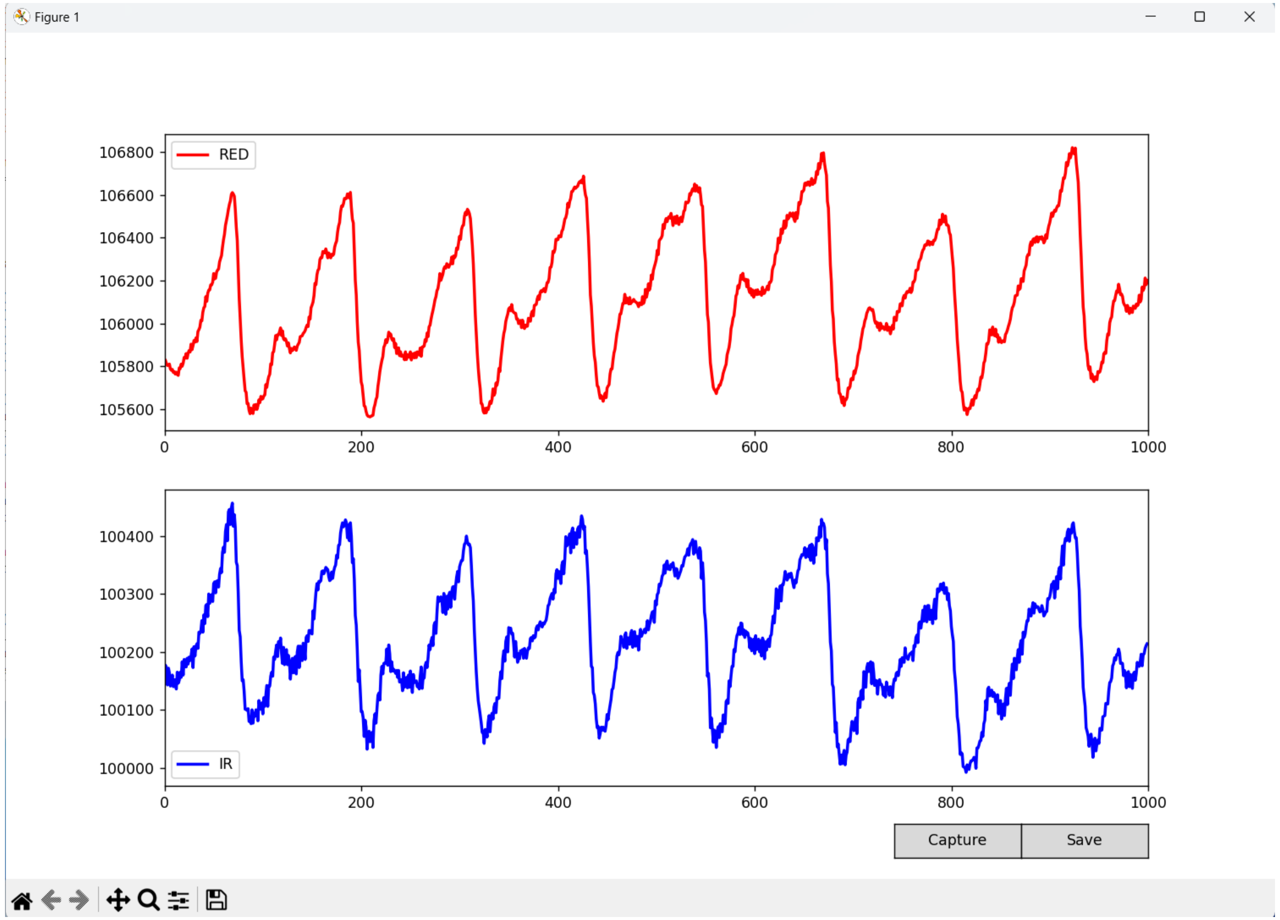

VIN
GND
SCL
SDA
INT

Press capture



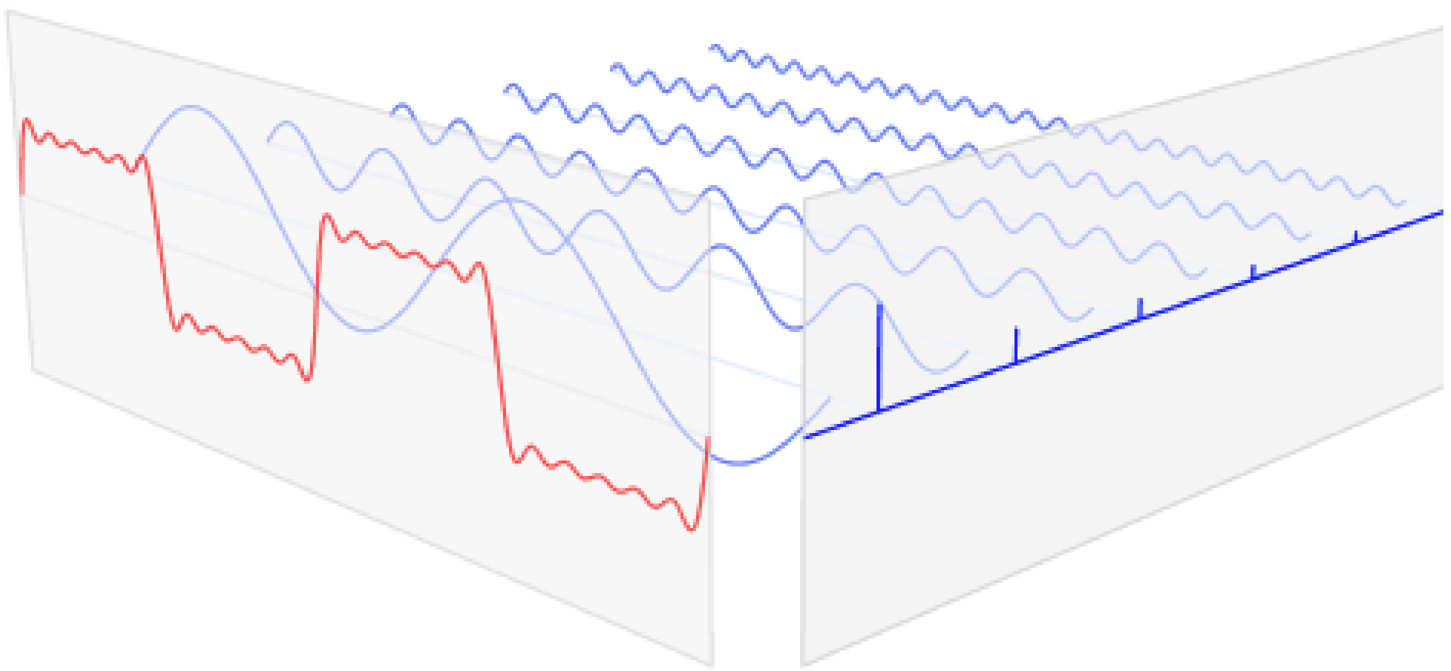
Keep your finger gently on the sensor





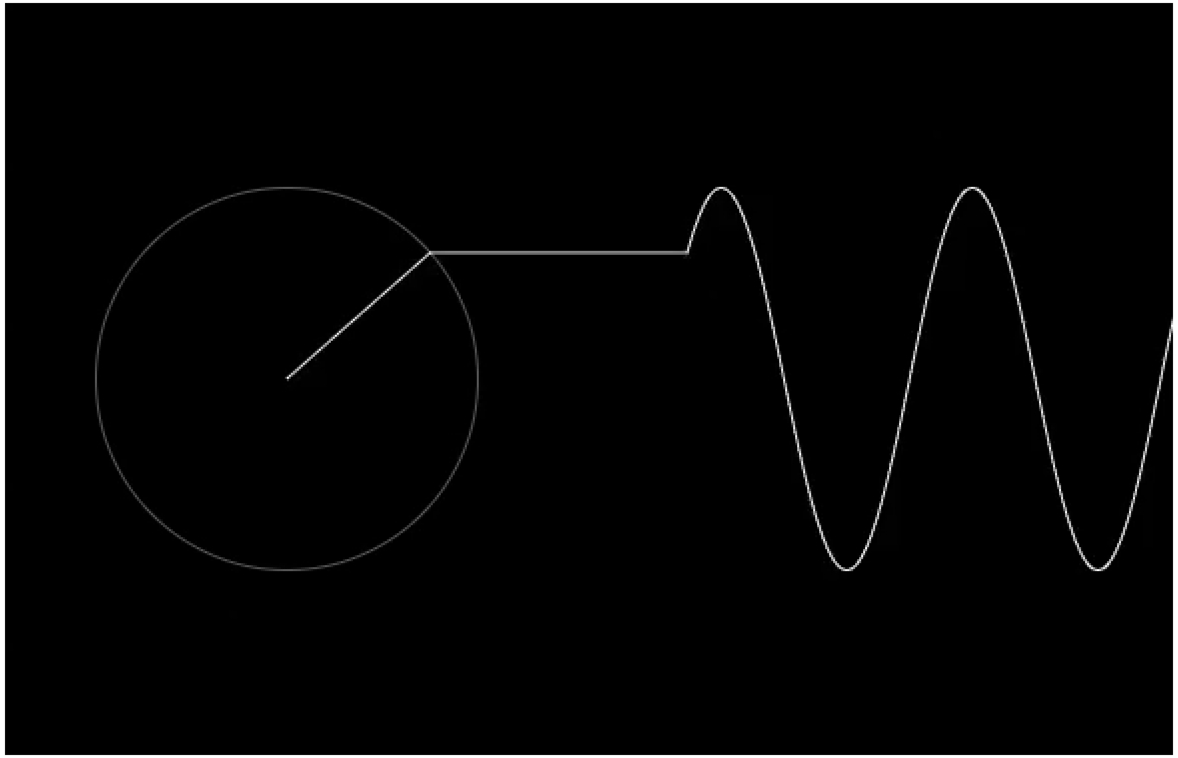
Time domain to frequency domain

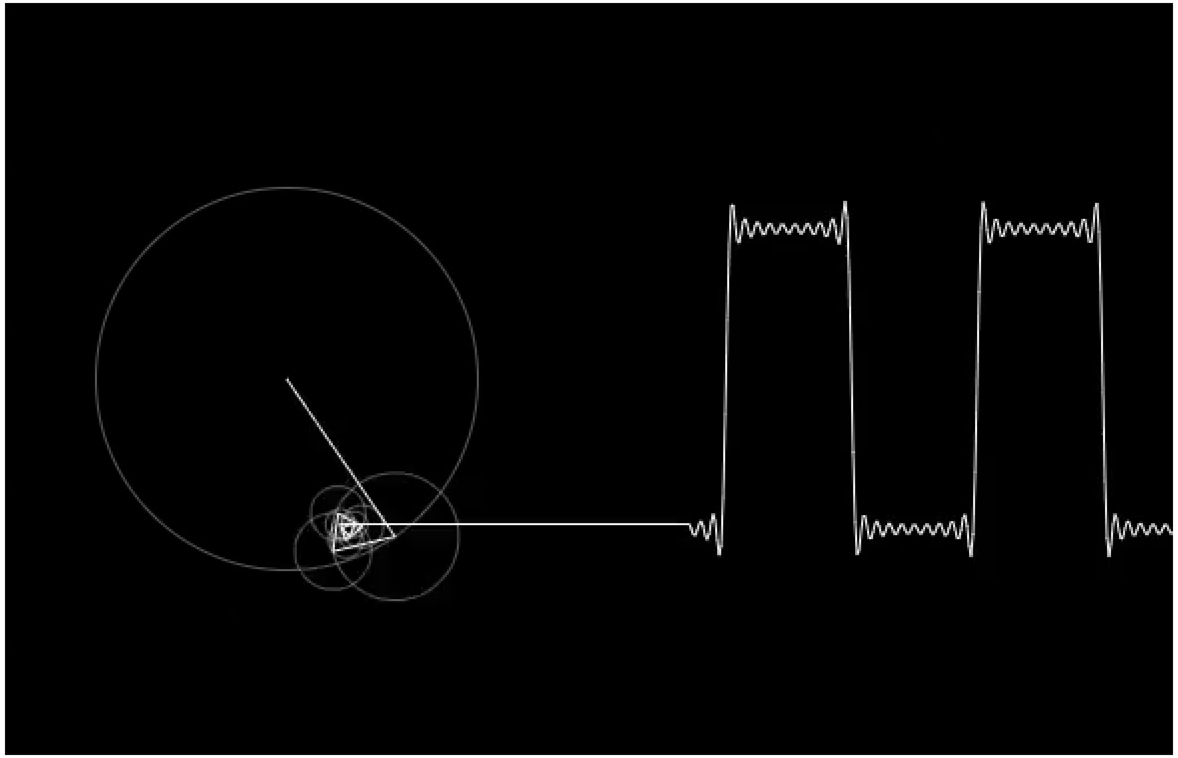
- The Fourier transform is an analysis process, decomposing a complex-valued function into its constituent frequencies and their amplitudes.



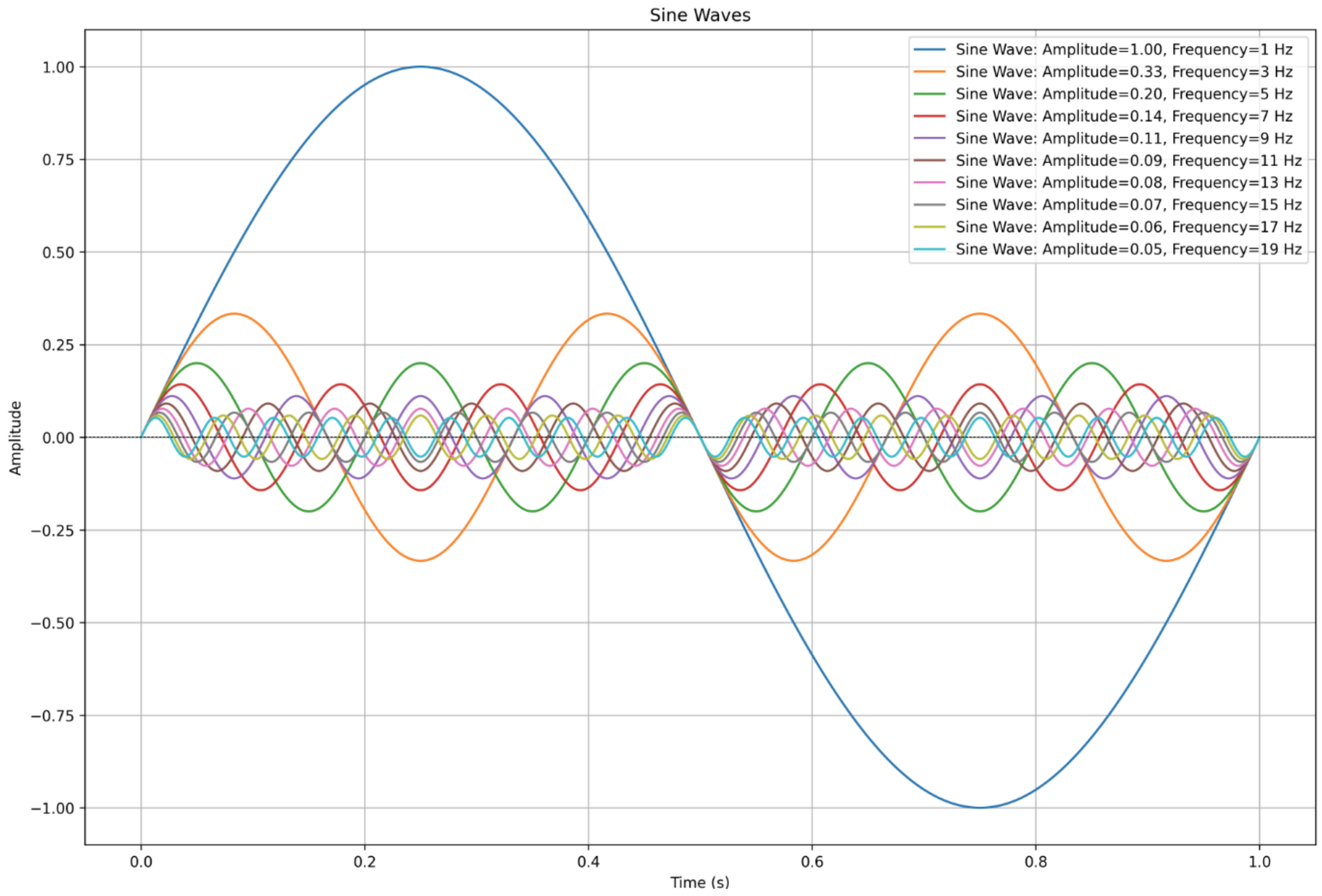
Time domain to frequency domain

- The Fourier transform is an analysis process, decomposing a complex-valued function into its constituent frequencies and their amplitudes.





Time domain to frequency domain



What makes a square wave

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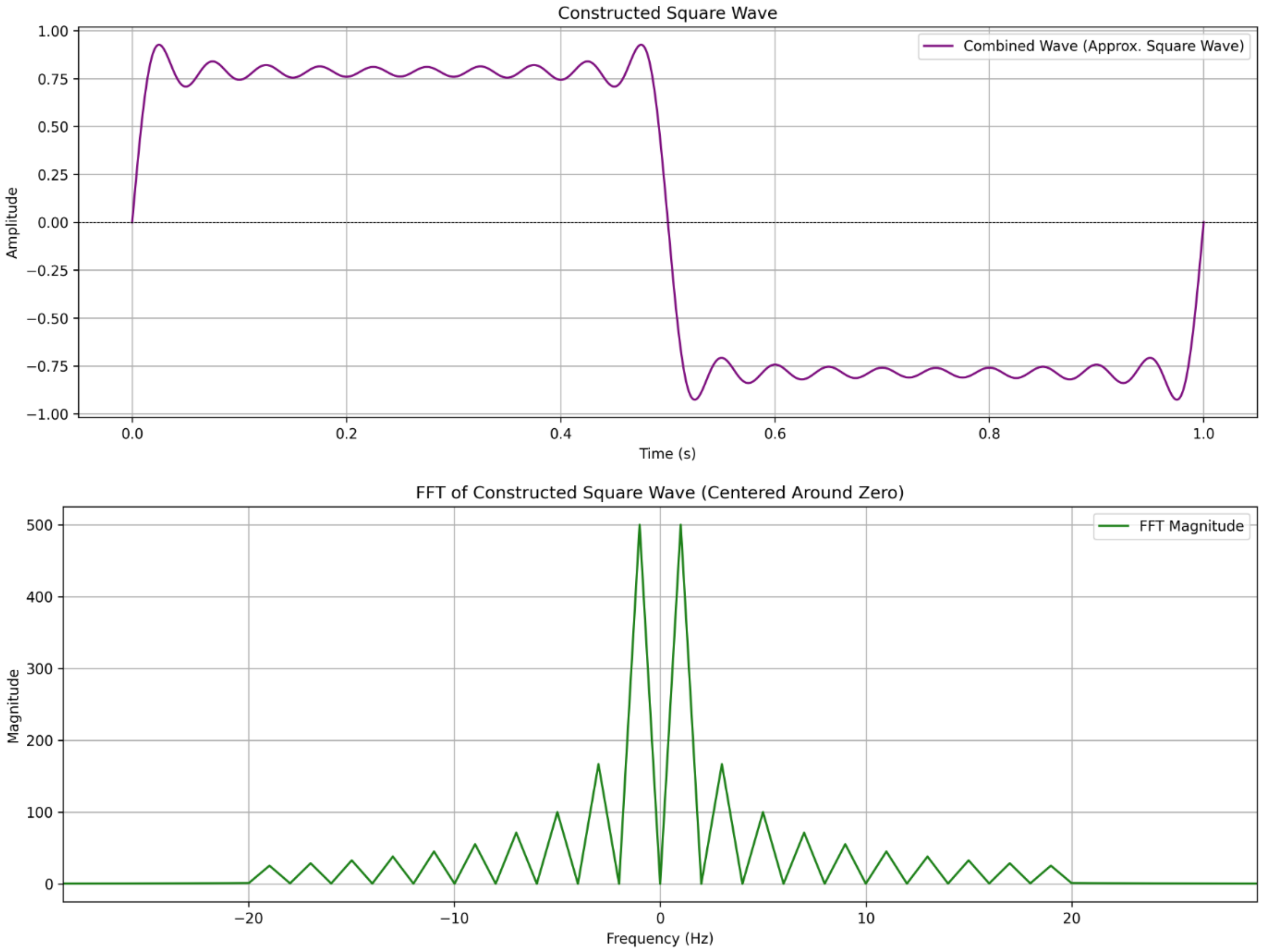
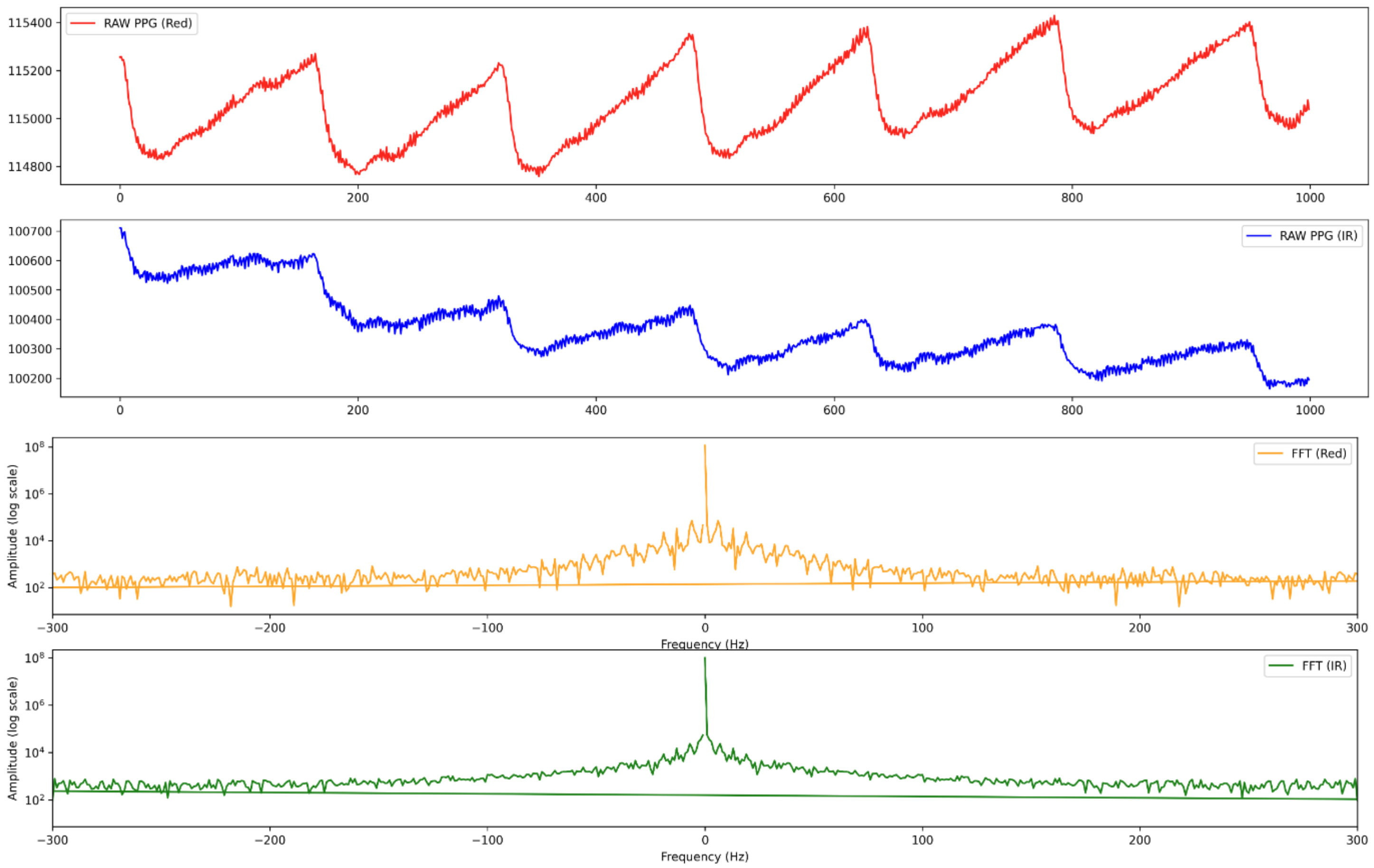
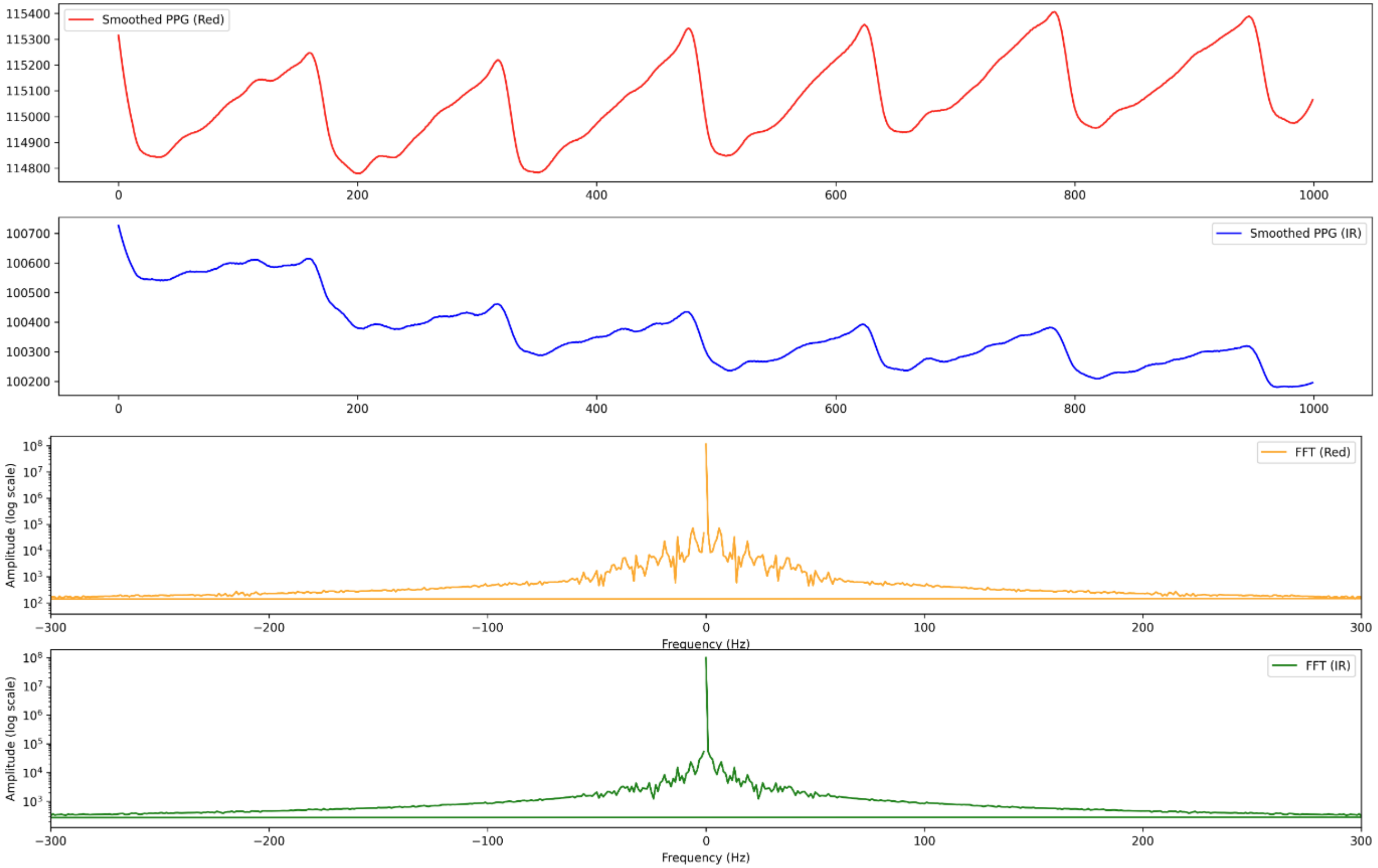


Going back to the PPG data collected

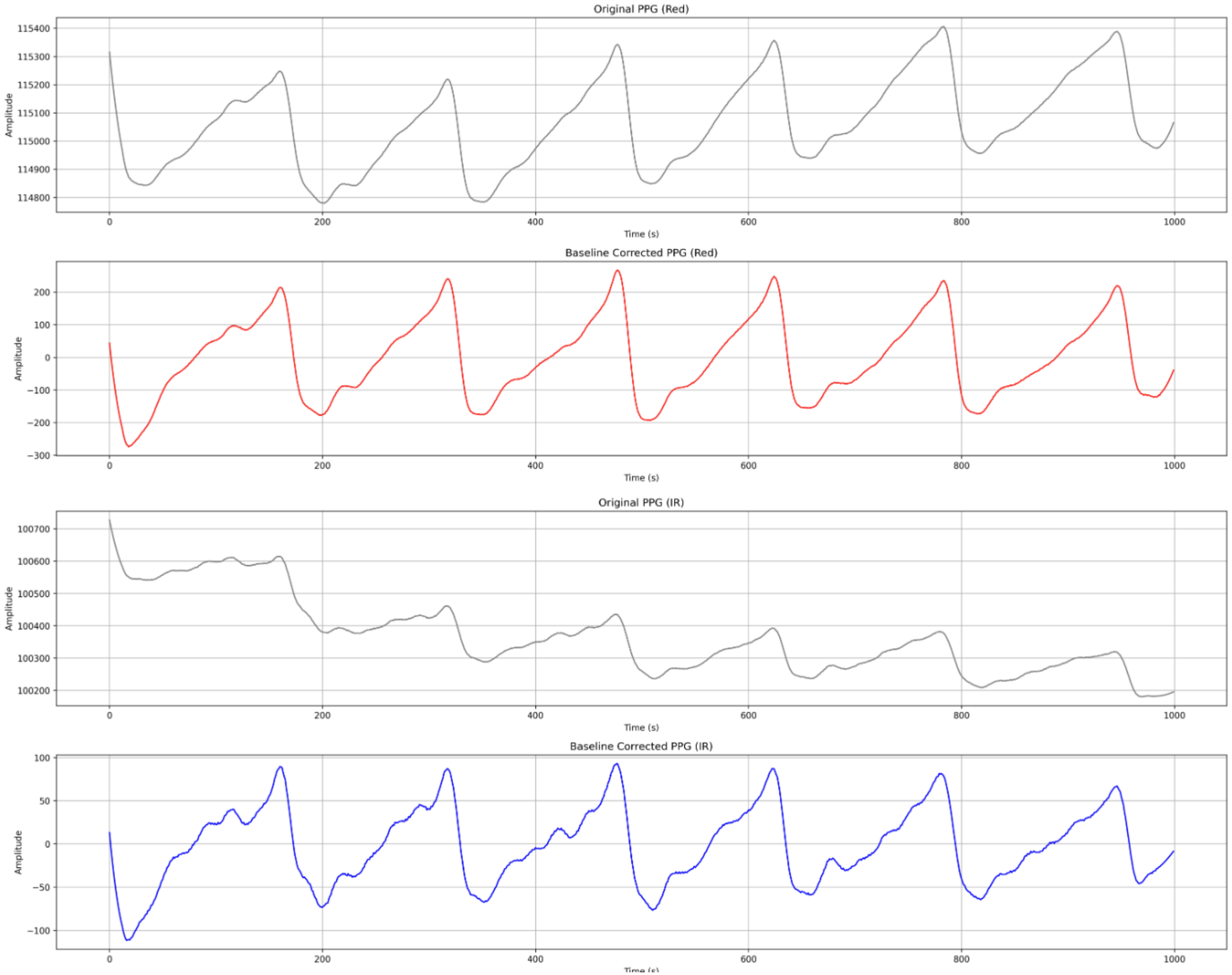


Smoothing

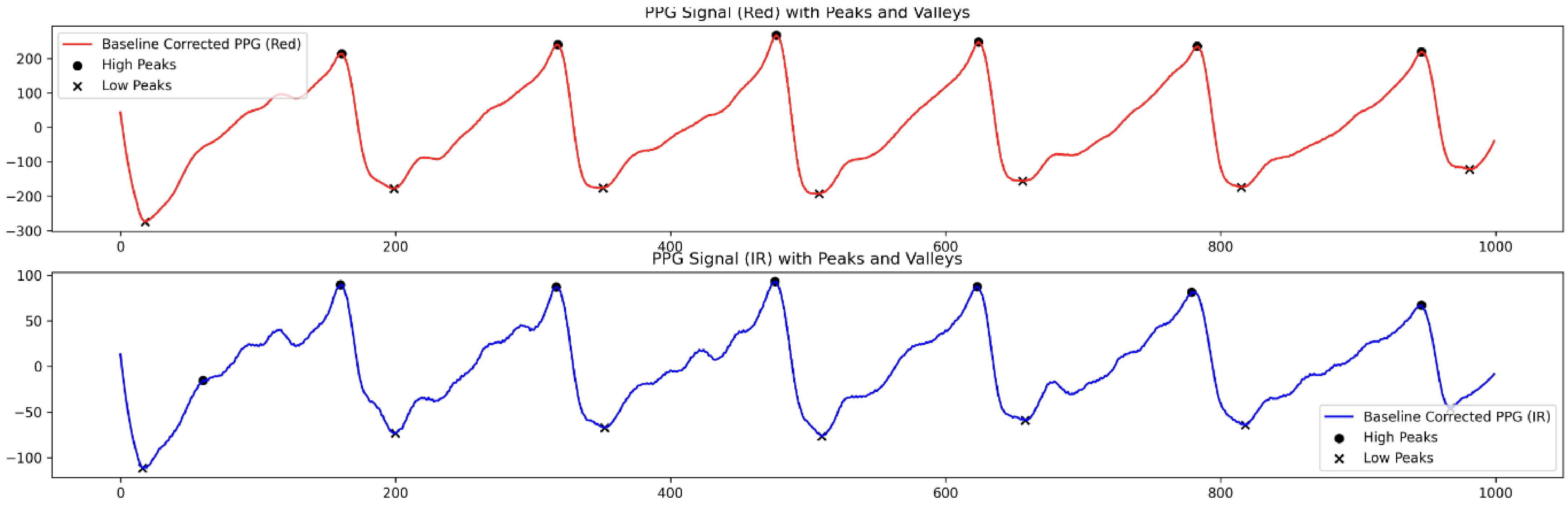


Smoothed PPG (Red)
115400
115300
115200
115100
115000
114900
114800
0
200
400
600
800
1000
Smoothed PPG (IR)
100700
100600
100500
100400
100300
100200
0
200
400
600
800
1000
FFT (Red)
Amplitude (log scale)
−300
−200
−100
0
100
200
300
Frequency (Hz)
FFT (IR)
Amplitude (log scale)
−300
−200
−100
0
100
200
300
Frequency (Hz)

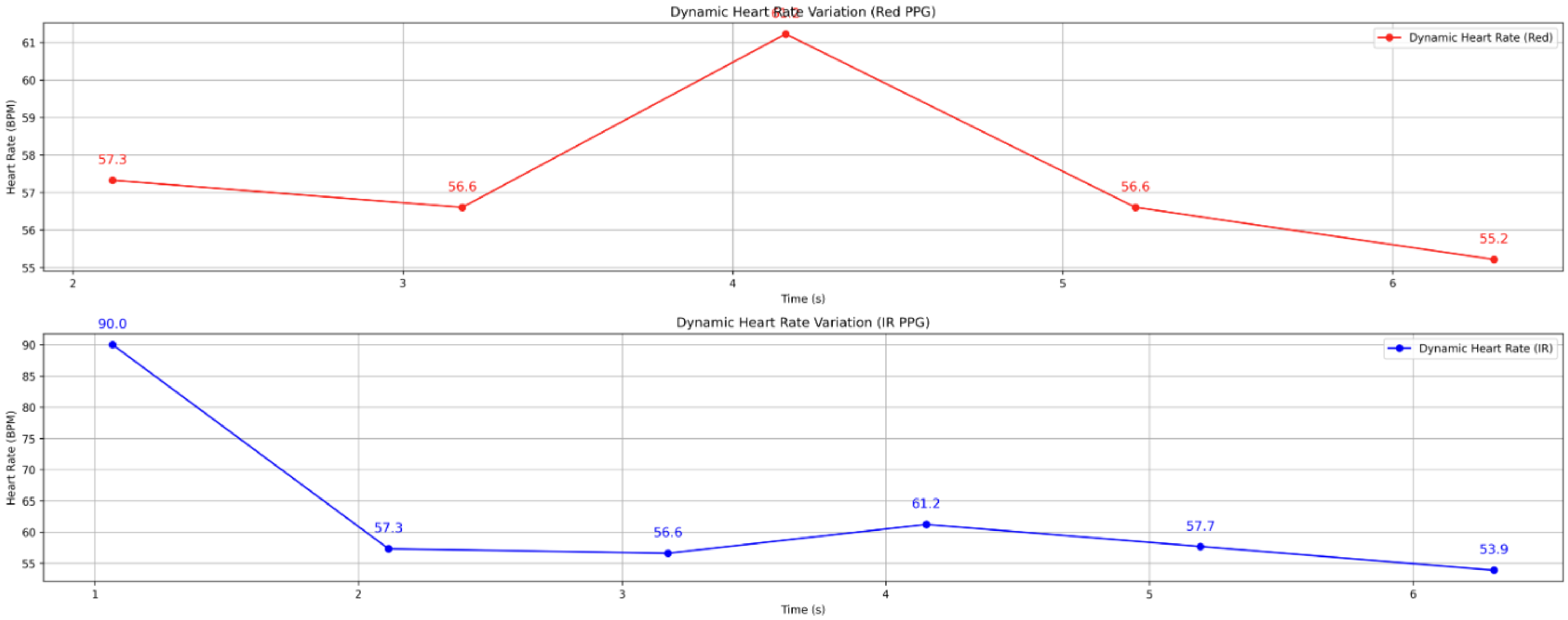
Drift correction



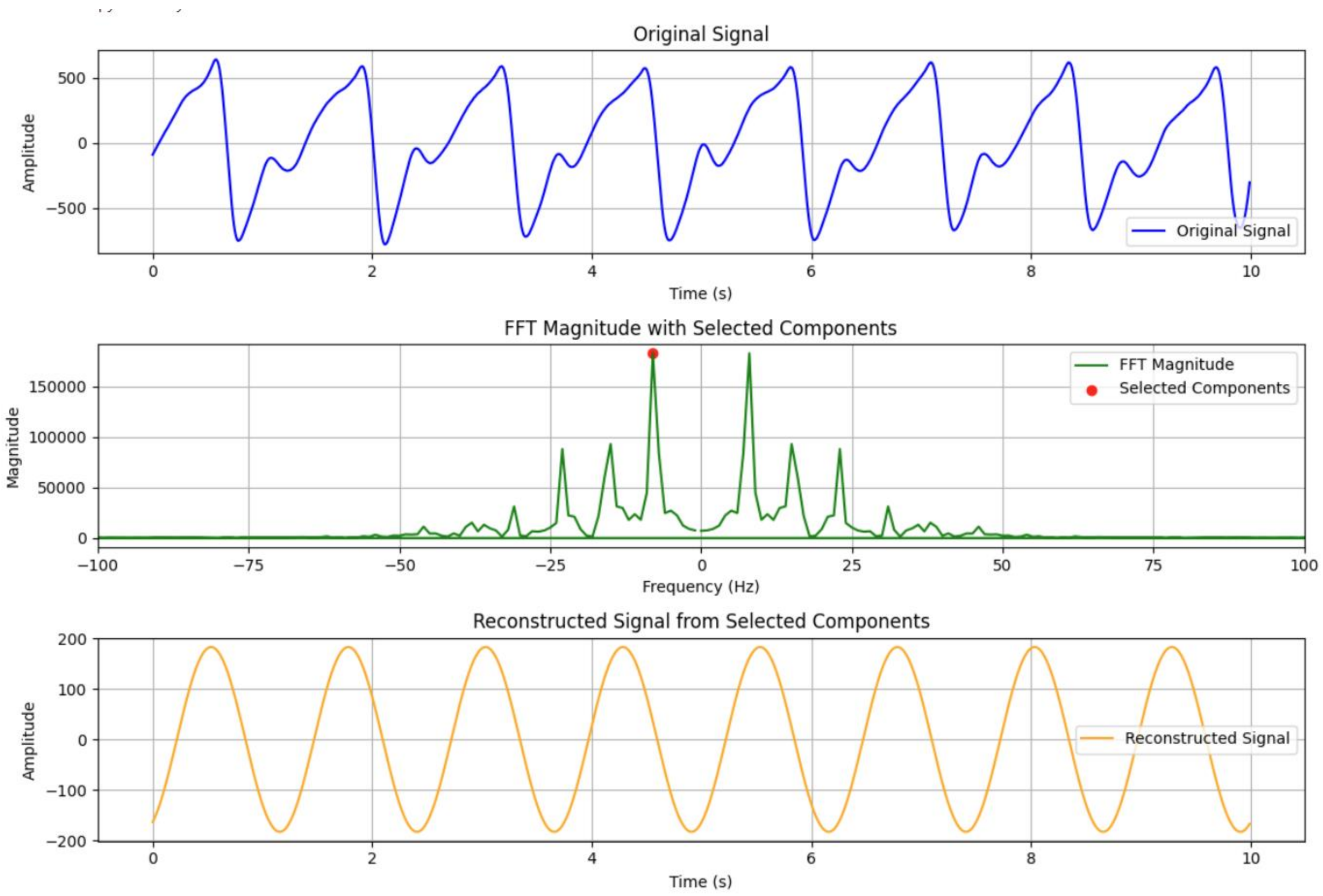
Peak detection



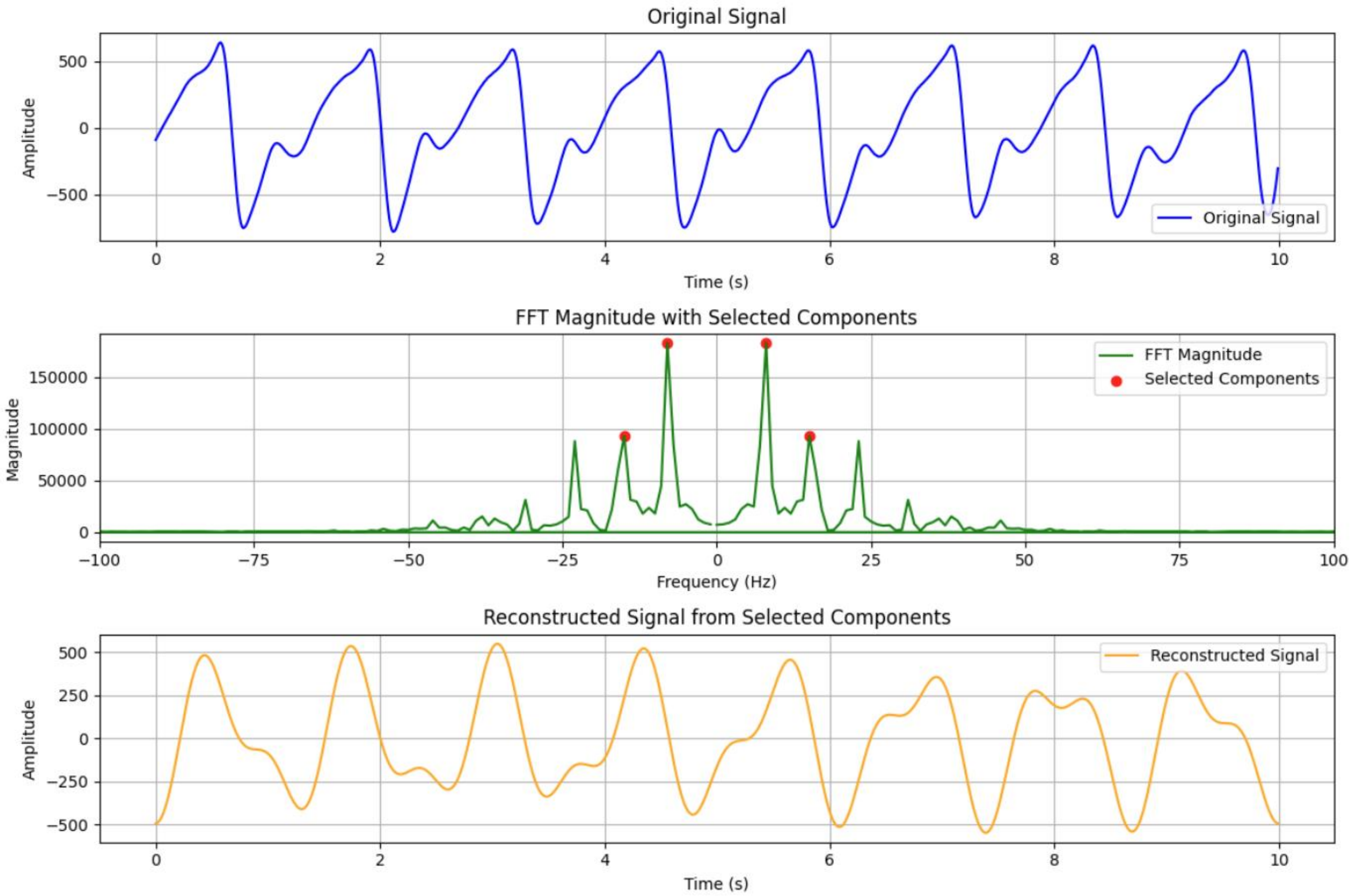
Heart rate


Dynamic Heart Rate Variation (Red PPG)
Dynamic Heart Rate (Red)
Heart Rate (BPM)
Time (s)
57.3
56.6
56.6
55.2
Dynamic Heart Rate Variation (IR PPG)
Dynamic Heart Rate (IR)
Heart Rate (BPM)
Time (s)
90.0
57.3
56.6
61.2
57.7
53.9

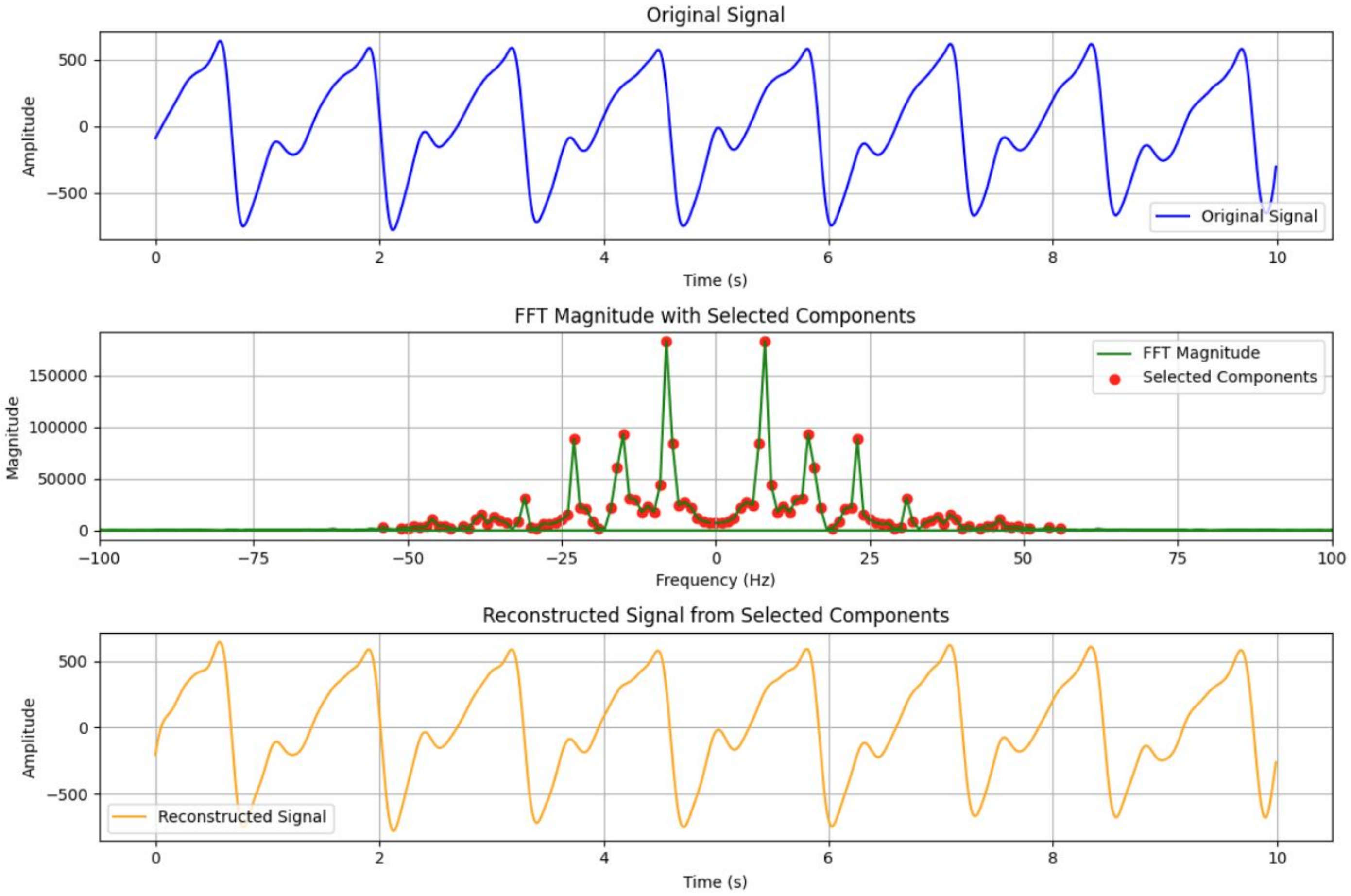
Using single component to find heart rate



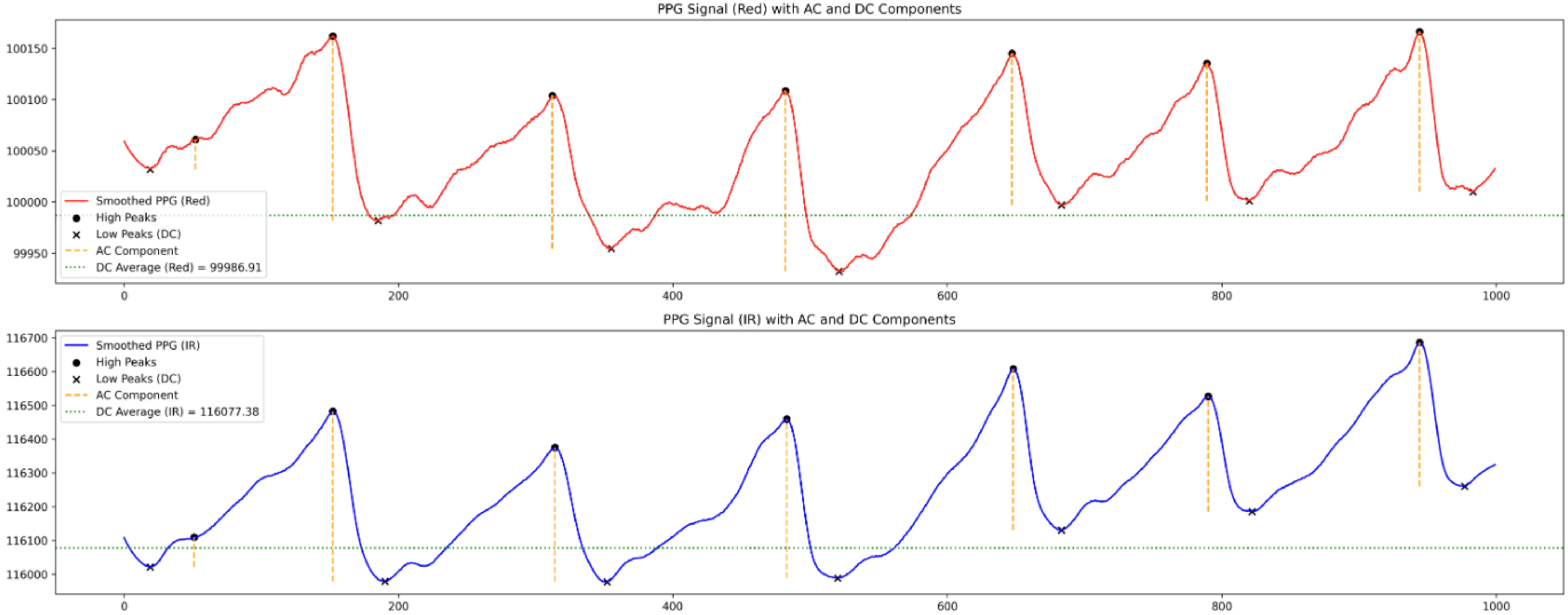
4 components in the PPG signal – signal loss



Taking all the components provides the original signal



Ratio of the ratios




```
(Red PPG Signal) DC Average: 99986.91, AC Average: 139.15
(IR PPG Signal) DC Average: 116077.38, AC Average: 386.22
Red signal ratio (red_ac/red_dc): 0.0013916875411345753
IR signal ratio (ir_ac/ir_dc): 0.0033272520894769473
Ratio of Ratios (Red ratio/ IR ratio): 0.4182693416997304
```

SpO2 calculation