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ECE 105: Introduction to Electrical Engineering

Lecture 11

Bio 1

Yasser Khan

Rehan Kapadia

Wearables

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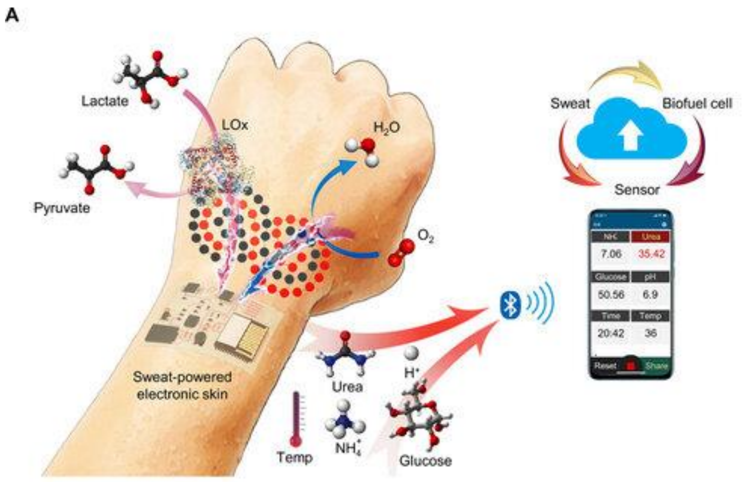
- Wearables include devices for communication, health, fitness tracking, etc.
- Future generations of devices will have new capabilities (therapeutic, haptic, etc.)
- New functionality depends on energy harvesting, conformal contact, etc.
- Wireless communication essential for most important functions (interfacing to mobile devices, etc.)



Vital signs

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- Vital signs include Heart Rate, Blood Pressure, Breathing Rate, Temperature
- Attractive for daily monitoring
- Combining all of these metrics is more useful for preventive care

$380.5 billion by 2028 – wearables alone

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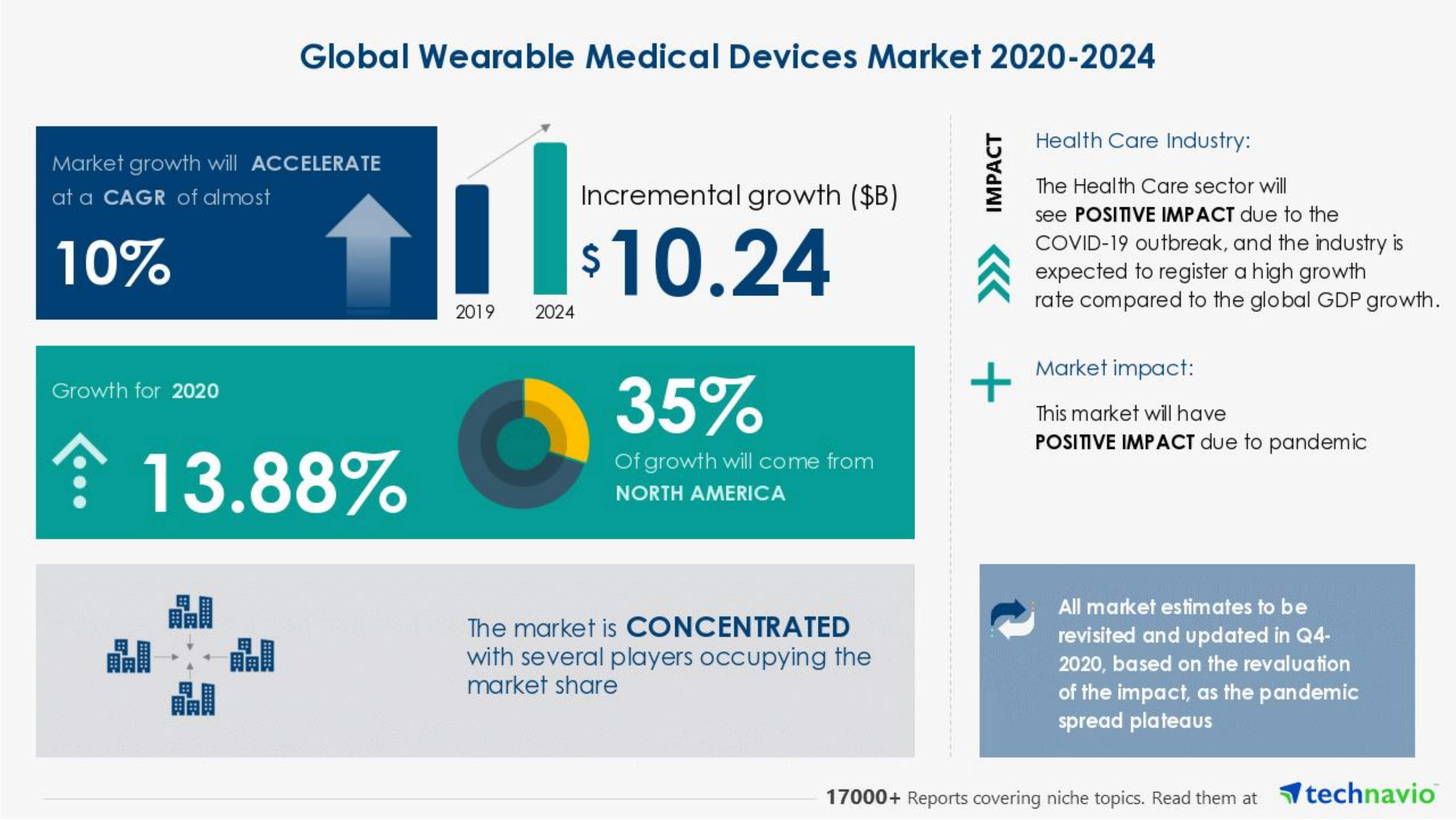
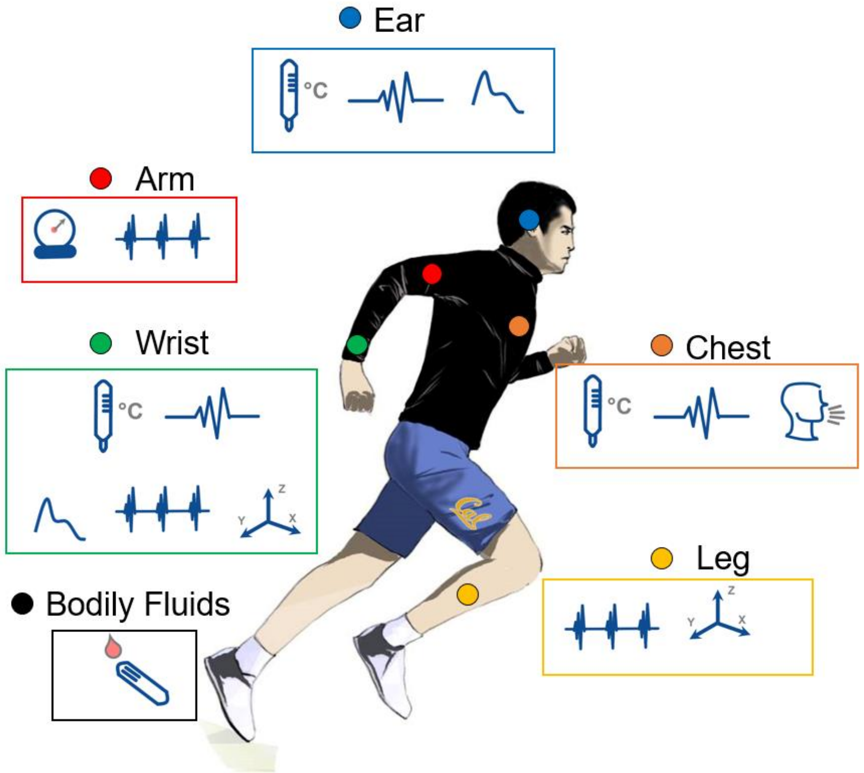


Wearable sensing

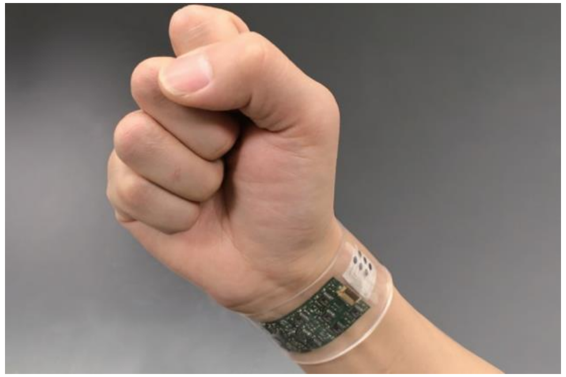


- Flexible sensors can efficiently measure vital signs, and other biosignals from various parts of the body.

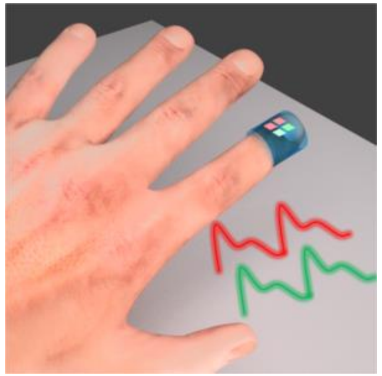
- Types of wearable sensing

- Bioelectronic – ECG, EMG, bioimpedance tomography

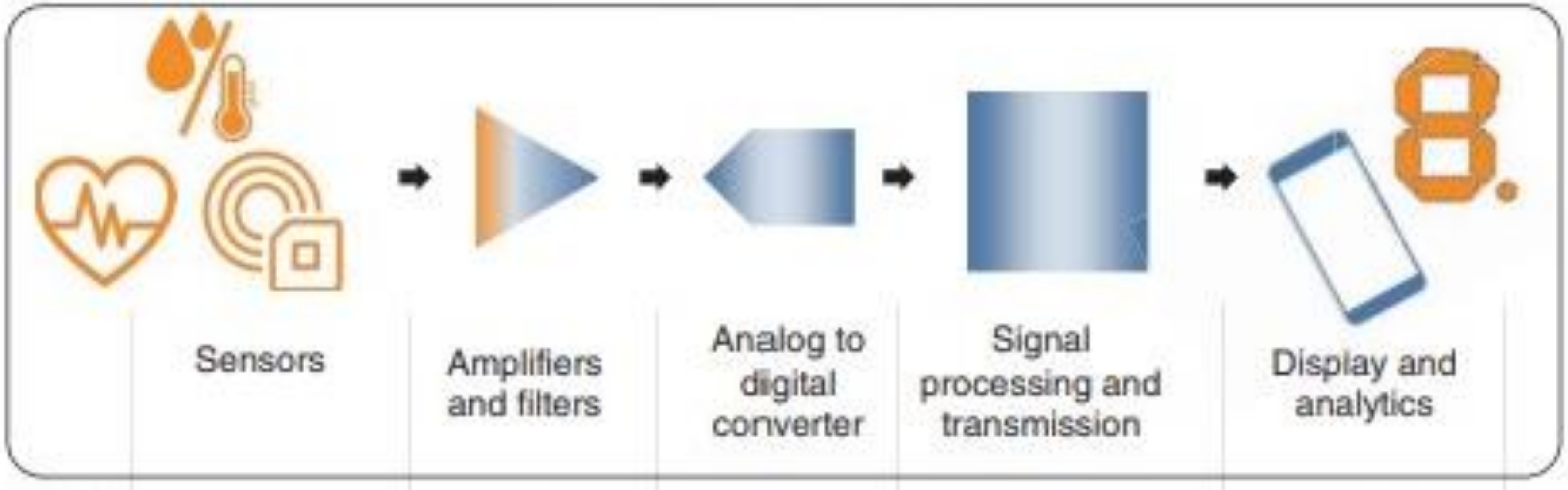
- Biochemical – Sweat sensing



- Biophotonic – Pulse oximetry



Different parts of a bioelectronics system



Pulse oximetry

ECG

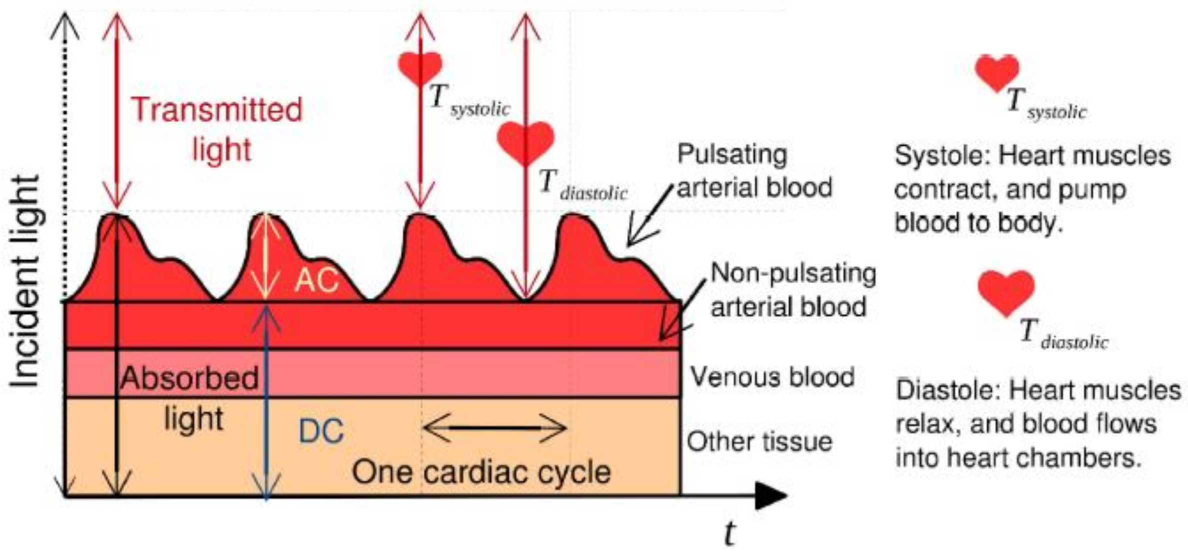
Pulse Ox

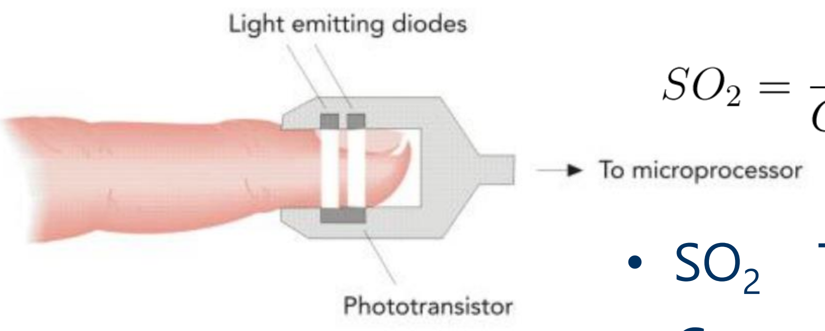
Respiration

Blood Pressure

Temperature

- 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.



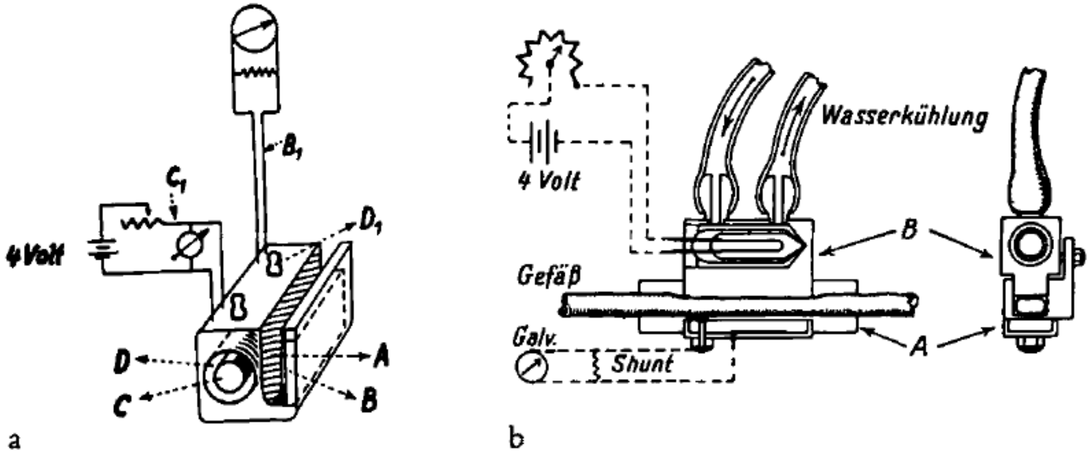


$$SO_2 = \frac{C_{HbO_2}}{C_{HbO_2} + C_{Hb}}$$

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

Oximetry - History

- 1864, The discovery that the colored substance in blood was the carrier of oxygen was made by George Gabriel Stokes (1819-1903)



- 1935, Kurt Kramer (1906-1985) showed that the Lambert-Beer law applied to hemoglobin solutions and approximately to whole blood, and measured saturation by the transmission of red light through unopened arteries.

- 1942, Glenn Allan Millikan (1906-1947) built a light-weight ear "oximeter" during World War II to train pilots for military aviation using a mercury vapor light, yellow and purple filters, and a copper oxide photocell.

1935 1942

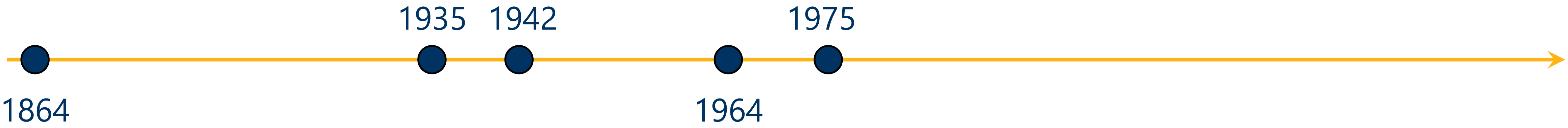
1864

Oximetry - History

- Around 1964, Robert Shaw, a surgeon and inventor in San Francisco, began design and construction of a self-calibrating, eight-wavelength ear oximeter. His concept was to uniquely solve the simultaneous equations by using one more wavelength than the number of separate forms of hemoglobin needing identification.

- 1975, Pulse oximetry was reported by Nakajima, Hirai, Takase, Kuse, Aoyagi, Kishi, and Yamaguchi of the Minoha Corporation. They used fiberoptic bundles to conduct light to and from a finger. Initially the main problem was extreme sensitivity to motion.

Solid state pulse oximeter "probes" on typical locations. Ohmeda Company, Boulder, CO.



Pulse oximetry basics

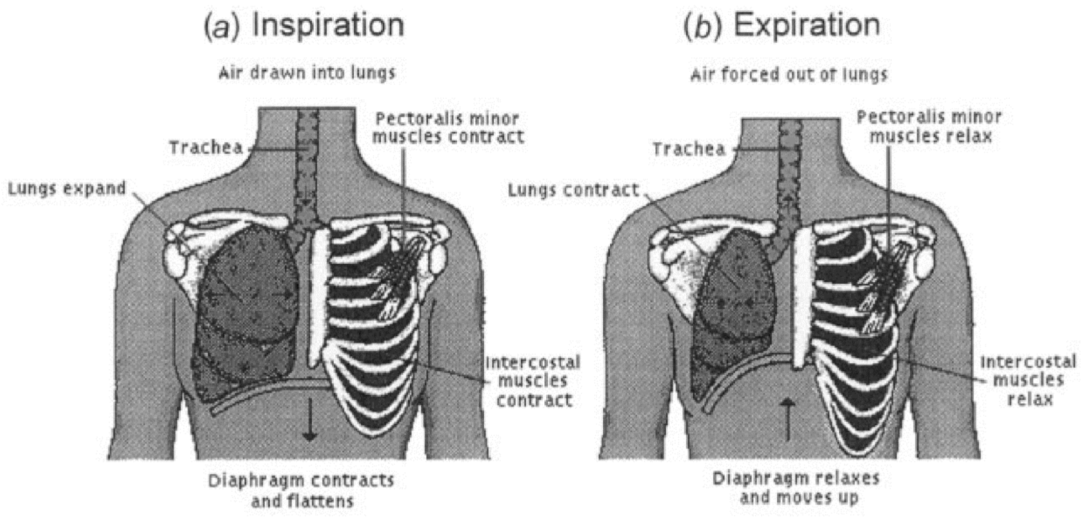


Figure 1.1 During inspiration, (*a*), the diaphragm, intercostal muscles and pectoralis minor muscles contract, causing the lungs to expand and air to enter the lungs. As the diaphragm, intercostal muscles and pectoralis minor relax, the lungs contract, causing air to leave the lungs (*b*), which is referred to as expiration (from Microsoft Encarta).

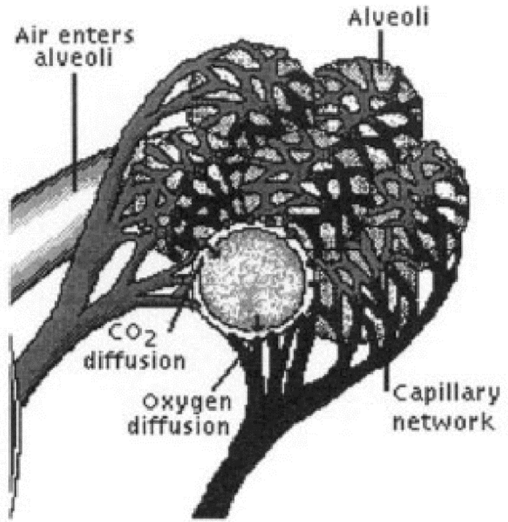


Figure 1.4 The capillaries surround the alveoli, providing the close proximity necessary for diffusion. Carbon dioxide diffuses from the capillary into the alveoli and oxygen diffuses into the blood (from Microsoft Encarta).

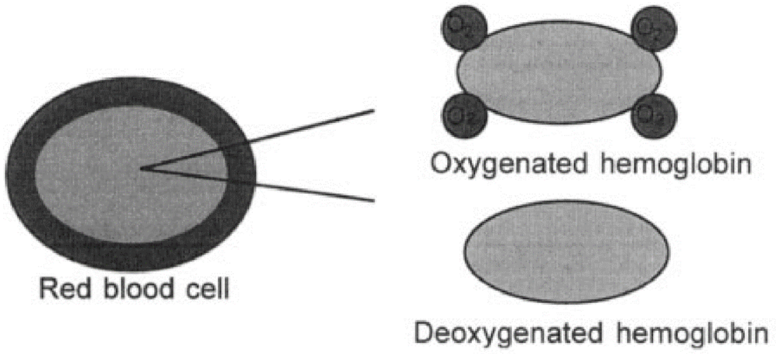
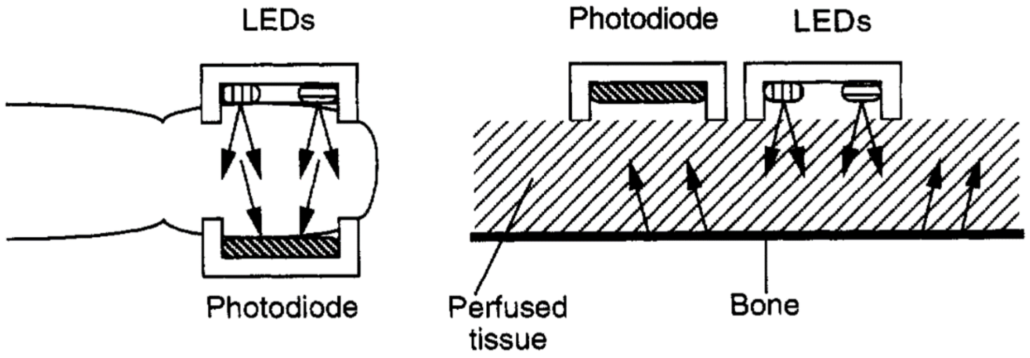


Figure 1.5 Hemoglobin molecules are contained within red blood cells. Each red blood cell contains approximately 265 million molecules of hemoglobin.

Pulse oximeter basics



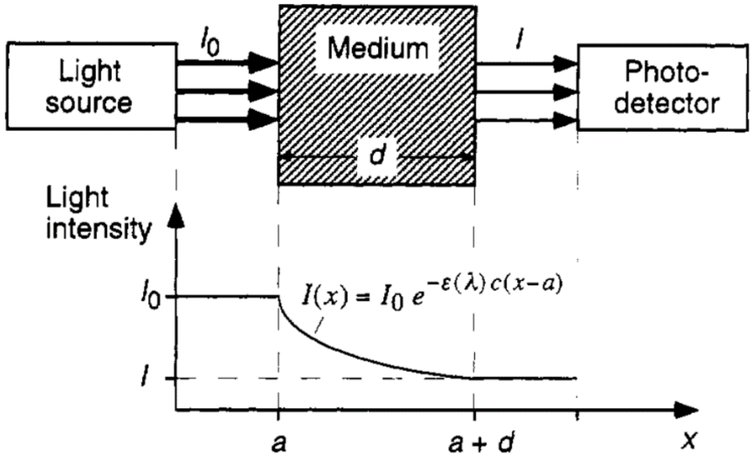


Figure 4.1 Beer's law: Incident light of intensity I_0 travels the distance a from a light source to the medium without being absorbed in the air. The light intensity decreases exponentially with distance in the absorbing medium. The intensity of the transmitted light I is determined by Beer's law. It stays constant after exiting the medium with optical path length d and can be measured by a photodetector.

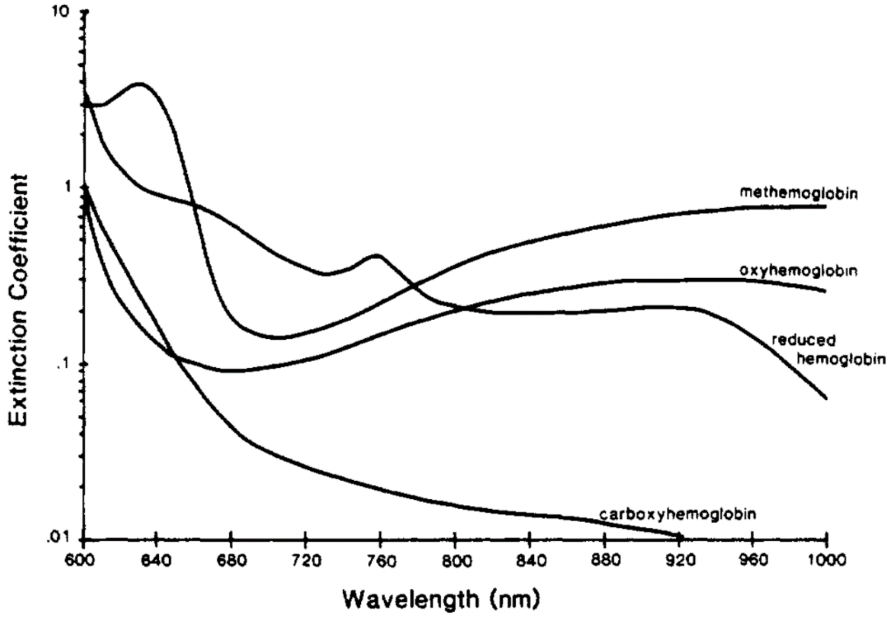


Figure 4.2 Extinction coefficients of the four most common hemoglobin species oxyhemoglobin, reduced hemoglobin, carboxyhemoglobin, and methemoglobin at the wavelengths of interest in pulse oximetry (courtesy of Susan Manson, Biox/Ohmeda, Boulder, CO).

The Beer-Lambert Law

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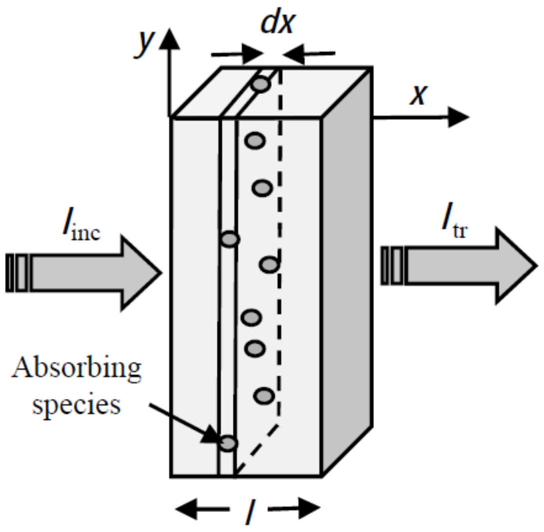

A sample of length l, containing resonating absorbing species, subjected to incident light of intensity I_{inc}, exits the sample as transmitted light of intensity I_{tr}. An infinitesimally thin slice dx absorbs light of intensity dI.

The Beer-Lambert Law

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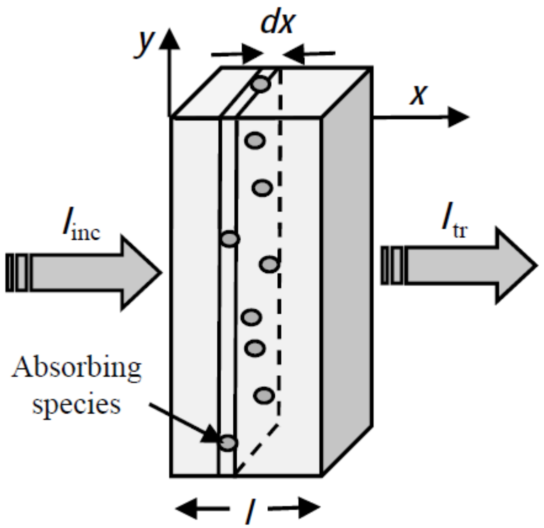
$$I_{tr} = I_{inc} \, e^{-\varepsilon \cdot [C] \cdot l}$$



A sample of length l, containing resonating absorbing species, subjected to incident light of intensity I_{inc}, exits the sample as transmitted light of intensity I_{tr}. An infinitesimally thin slice dx absorbs light of intensity dI.

Absorption

$$A = \varepsilon l [C] = -\log_{10}(T)$$

Transmittan

$$T = \frac{I_{tr}}{I_{inc}}$$

Example 1

The intensity of light of wavelength 254 nm is attenuated to 16% of its incident value after passing through an alcohol solution of 50 mM benzene contained in a 1.0 mm thin quartz cuvette. Calculate the absorbance A and the molar absorption coefficient ε. What would be the transmittance through a 2.0 mm thick cuvette?

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$\lambda = 254\,nm$

$I_{tr} = .16\, I_{inc}$

$[c] = 50\,mM$

$l = 1\,mm$

$A = ? = -\log_{10}(.16) = .8$

$\varepsilon = ?$

$A = \varepsilon \cdot [c] \cdot l$

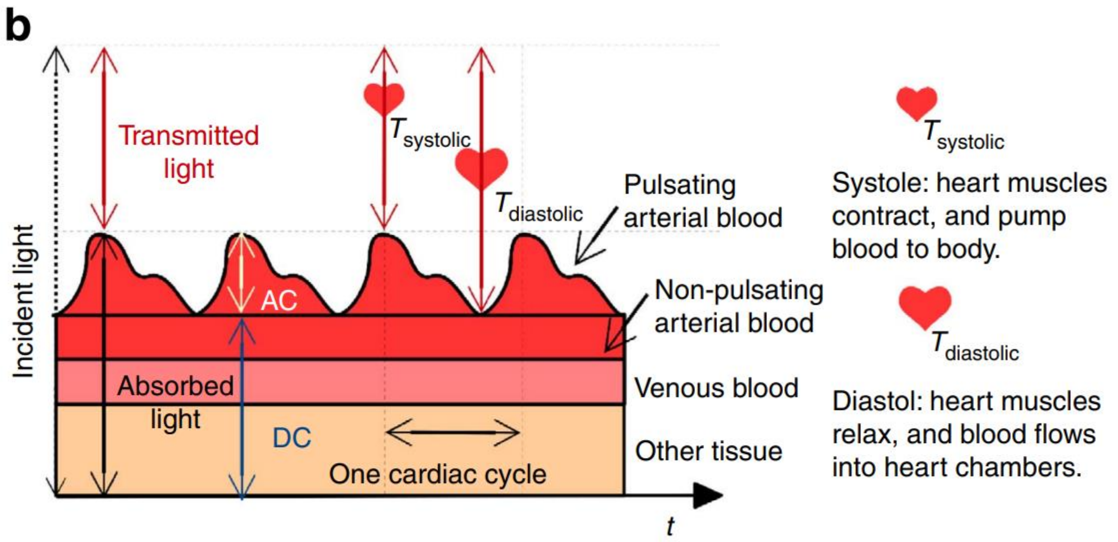
$\varepsilon = \frac{A}{[c]\,l} = \frac{.8}{50\,mM\ 1\,mm} = 160\,cm^{-1}M^{-1}$

$T_{2mm} \Rightarrow A = .8 \times 2 = 1.6$

$1.6 = -\log_{10}(T)$

$T = 10^{-1.6}$

Pulse oximeter basics



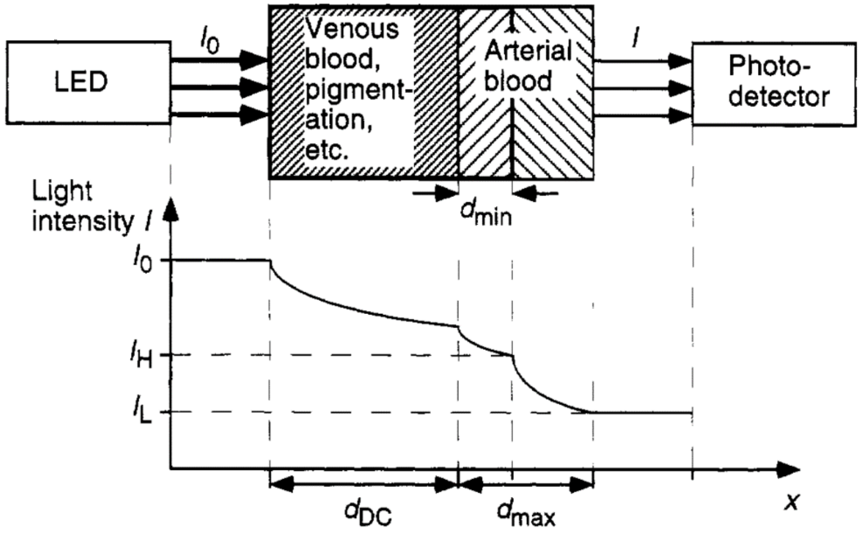


Figure 4.5 Beer's law in pulse oximetry. The DC components of the tissue (e.g. skin pigmentation, bone, venous blood and the nonpulsating part of the arterial blood) absorb a constant amount of the incident light I_0. The effective optical path length in the DC components without the constant level of arterial blood is represented by d_{DC}. During diastole the optical path length through the arteries has a minimum length of d_{min} and the light intensity at the photodetector is maximal (I_H). The optical path length reaches a maximum d_{max} during systole and the hemoglobin in the arteries absorbs a maximum amount, causing I to decrease to a minimum level of I_L.

Pulse oximeter basics

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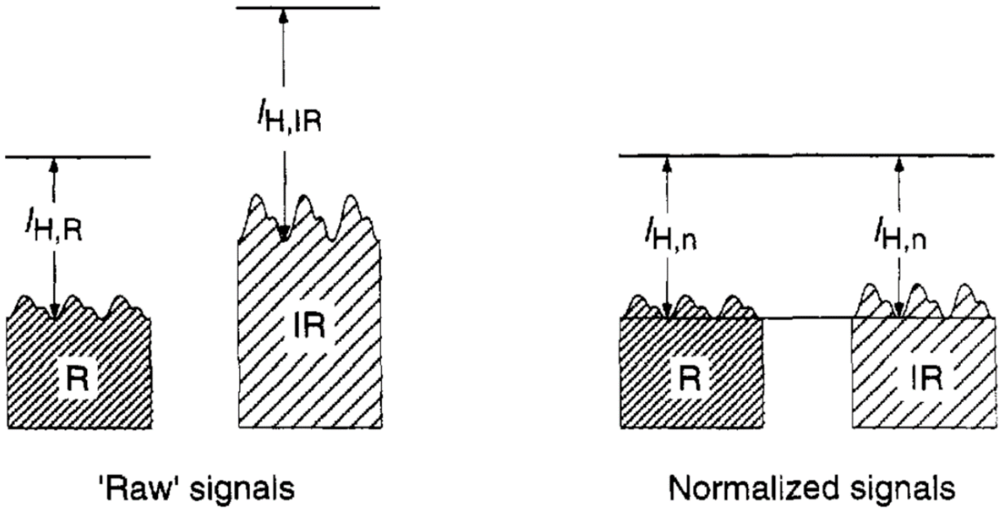

Figure 4.6 The normalization of the signals. The transmitted light from the red LED (R) and from the infrared LED (IR) is divided by its individual DC component. Thus, both normalized light intensities have the same magnitude during diastole. The normalized signals determine the basis for the calculation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

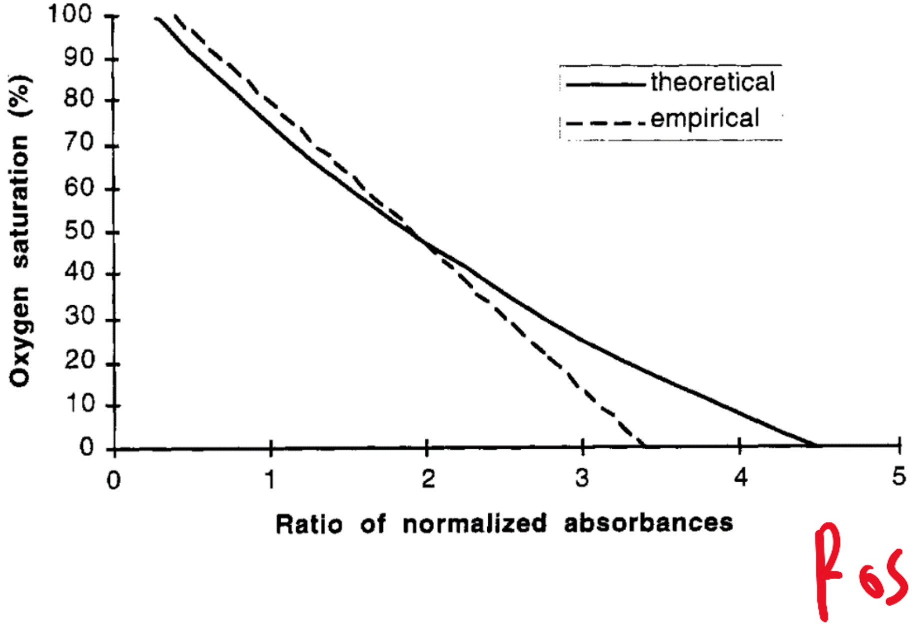

Figure 4.7 Calibration curves for pulse oximeters: the solid line is the theoretical curve by Beer's law and the dashed line is the empirical curve. The difference between these curves is due mainly to light scattering effects. This empirical calibration curve is derived by a second order polynomial.

Calculating oxygen saturation

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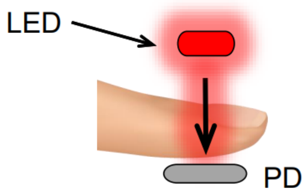
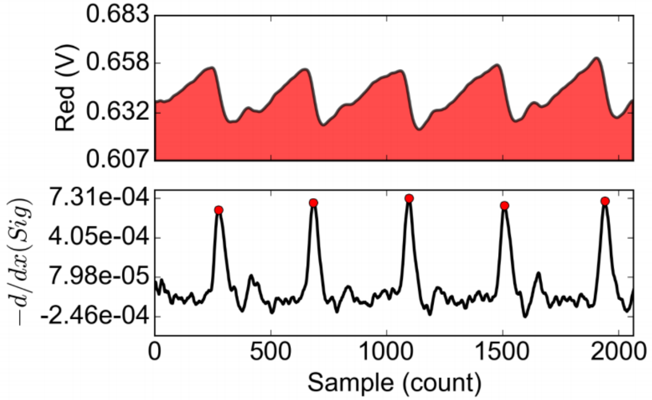
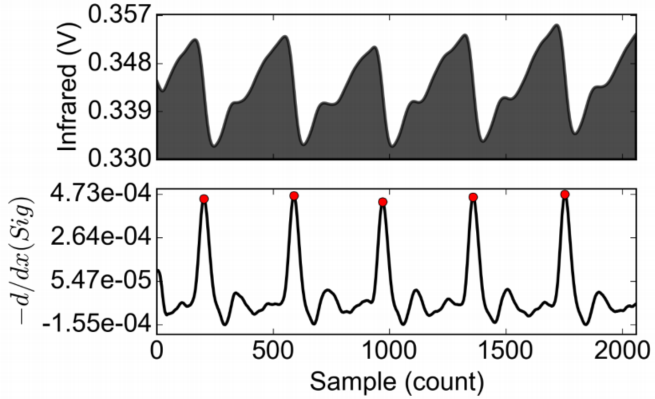


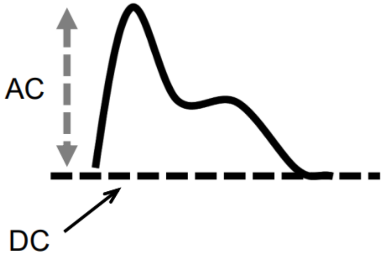
Measuring Transmission Mode PD Current

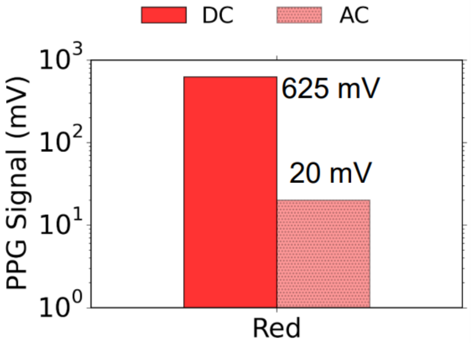


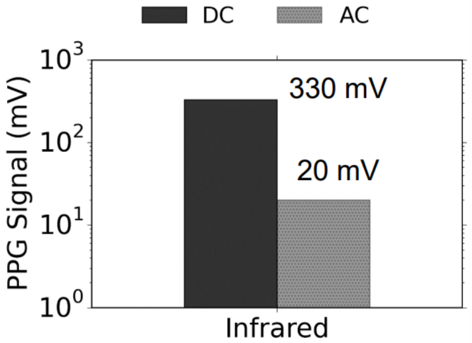


$$R = \frac{AC_{rd}/DC_{rd}}{AC_{ir}/DC_{ir}}$$

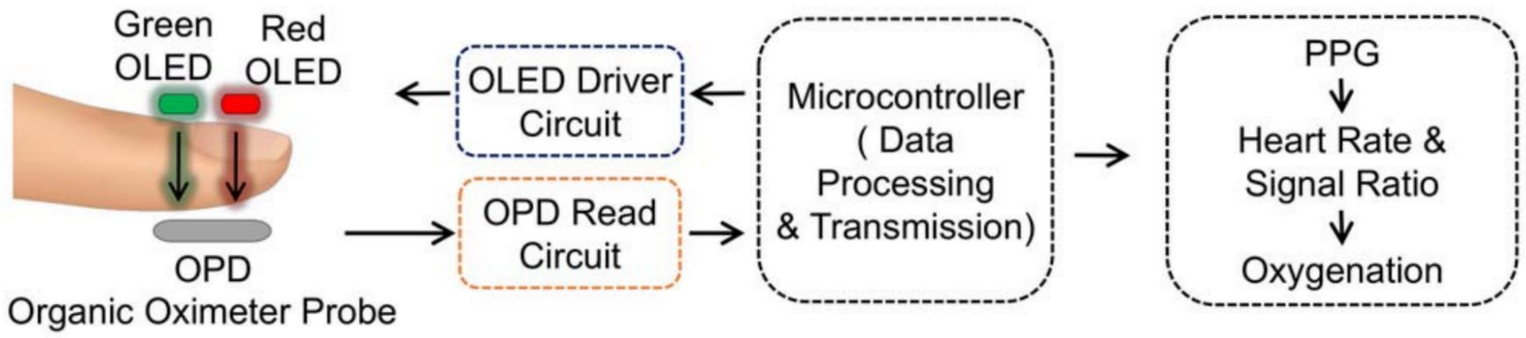
$$R = \frac{20mV/625mV}{20mV/330mV} = .528$$



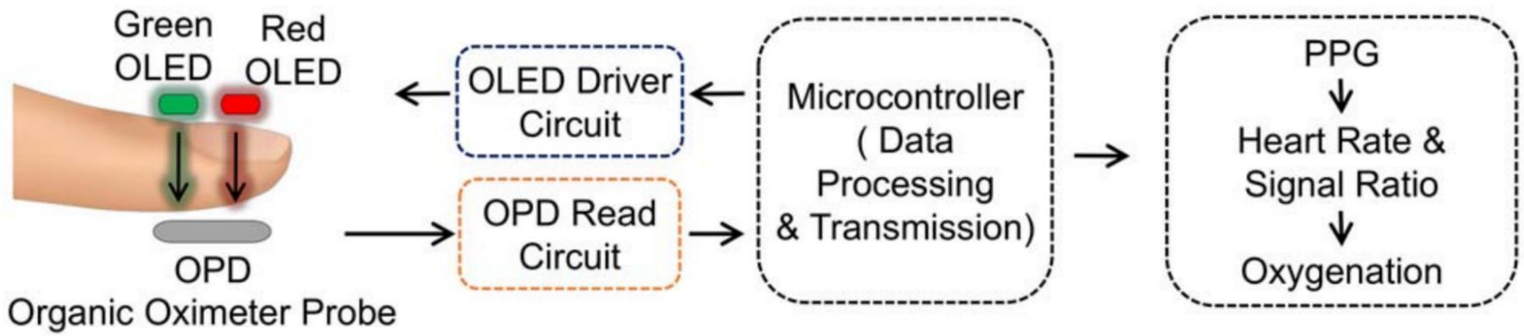


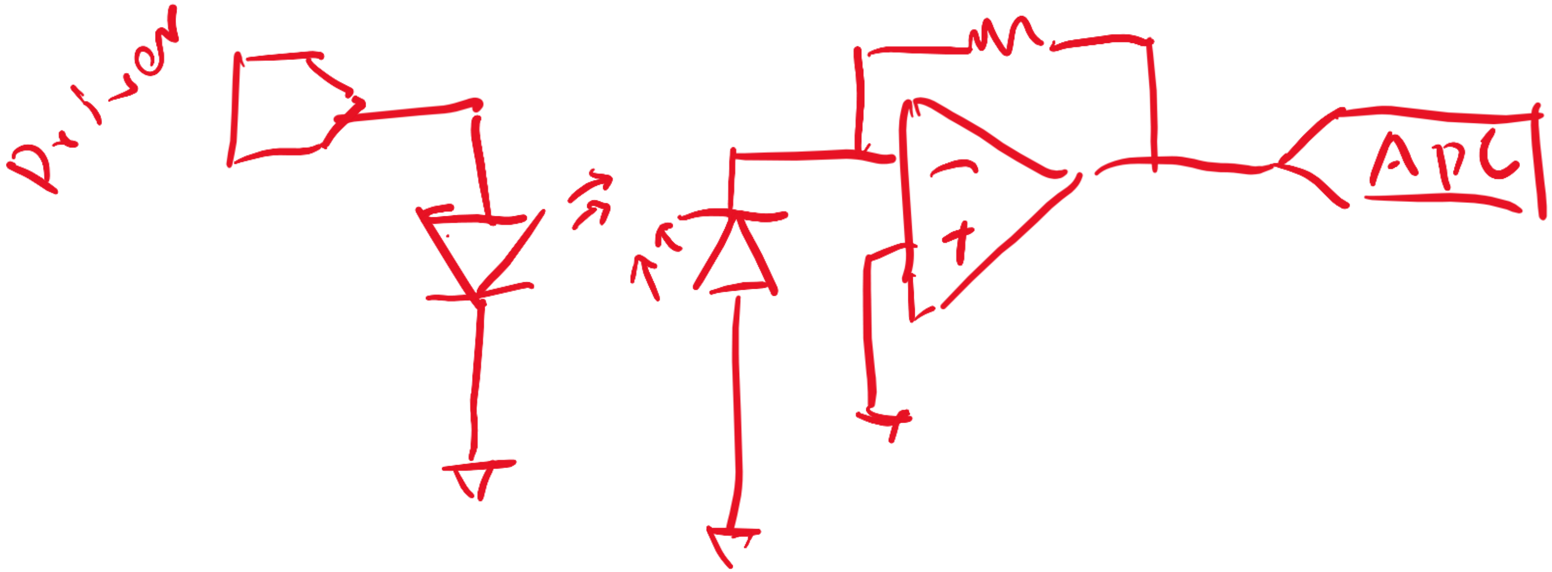


Oximeter readout circuit

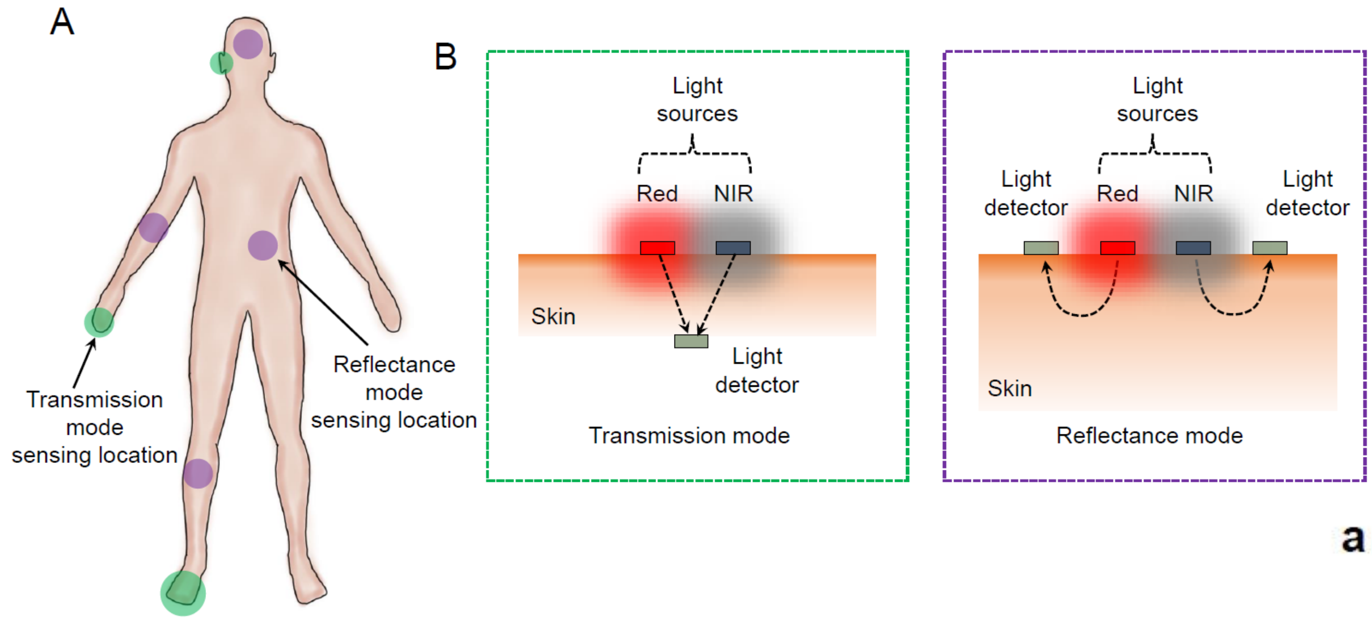


Oximeter readout circuit

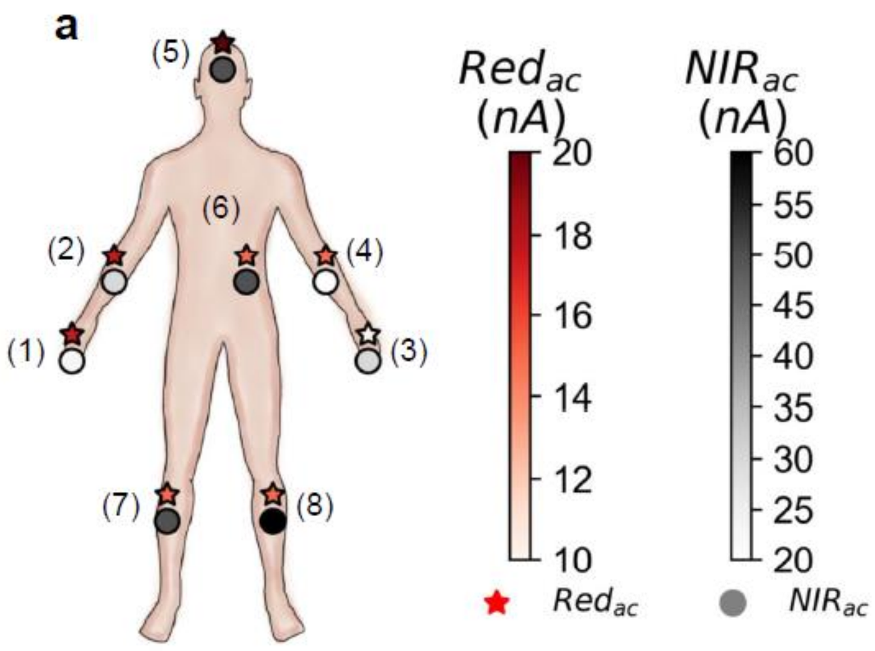




Transmission vs. reflectance oximetry

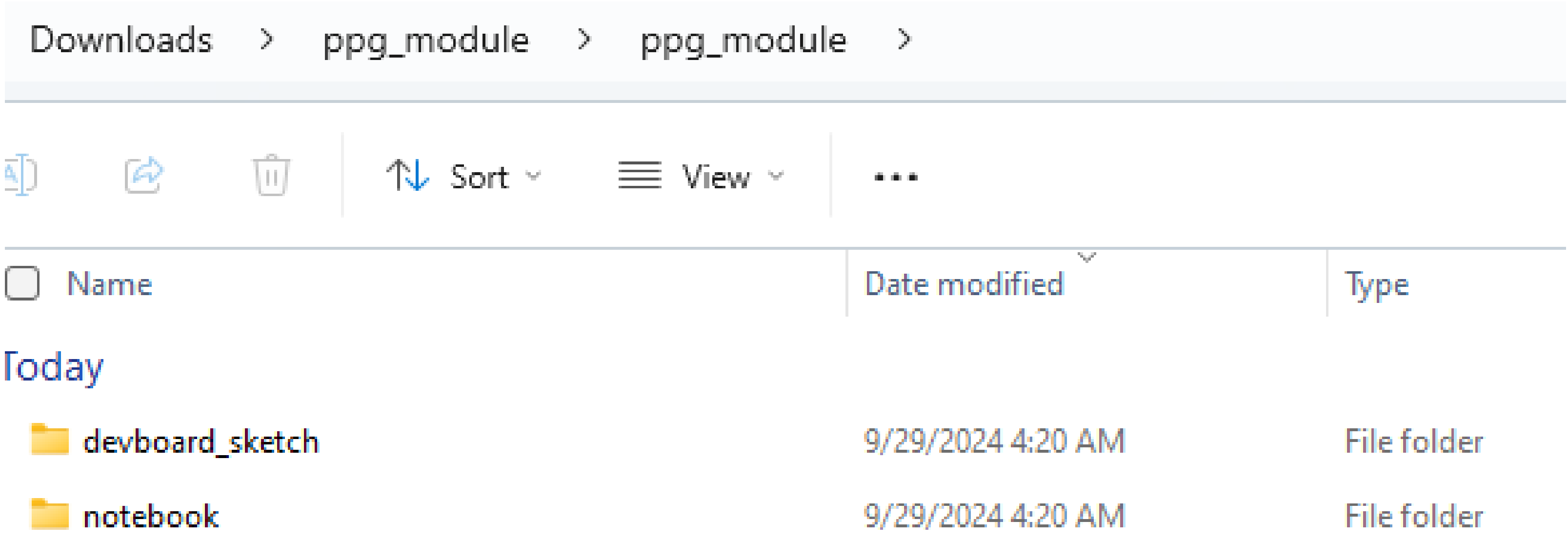


- Transmission-mode pulse oximetry is limited only to tissues that can be transilluminated, such as the earlobes and the fingers.
- If reflected light is used as the signal, the sensor can be used beyond the conventional sensing locations.

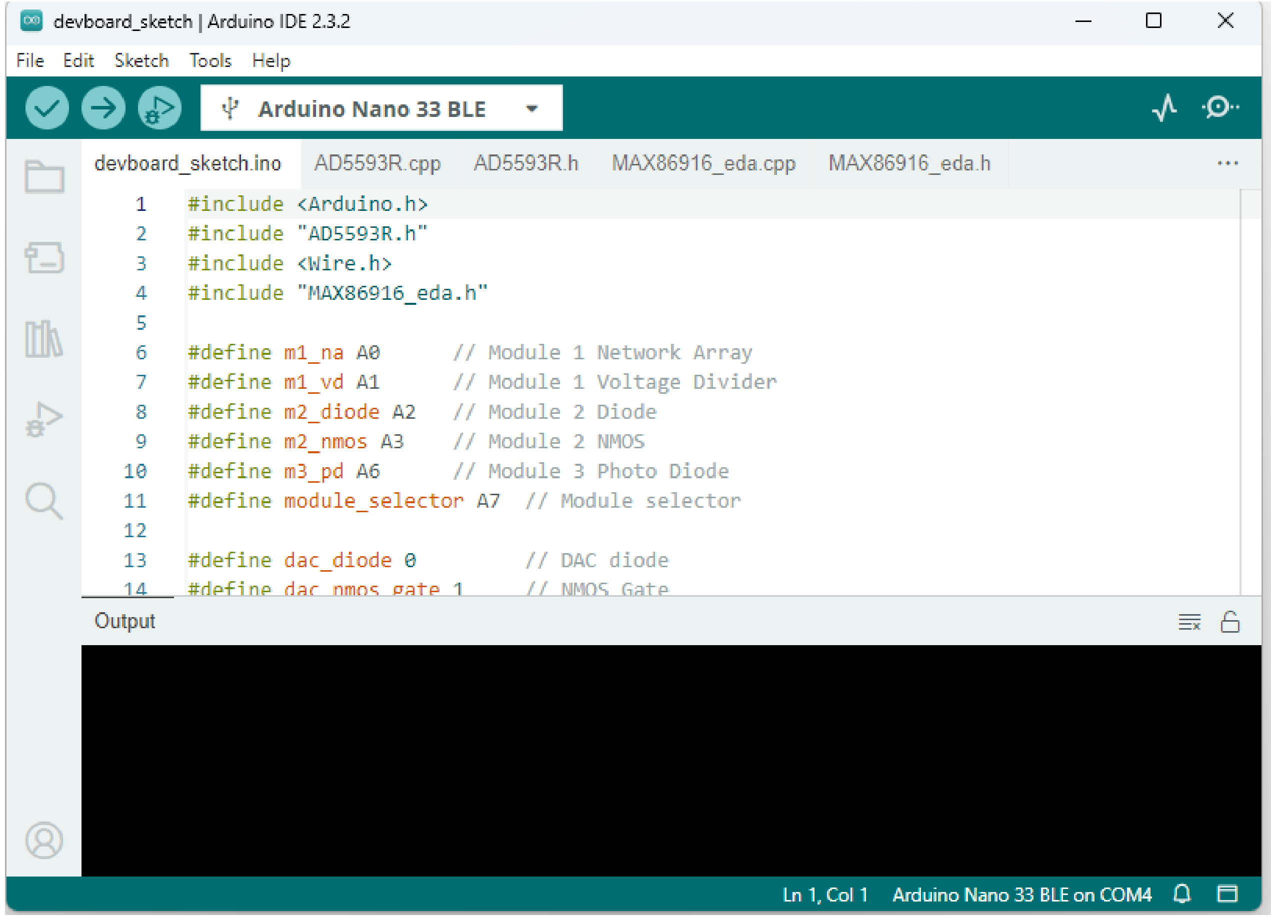


- AC signal is the highest at the forehead for both Red and NIR channels.
- Arms provide mid-range AC amplitude, while signal strength is low in the legs and chest area.
- Forehead is the best location for reflectance pulse oximetry.

Collect PPG signal



Upload ard code



Open python IDLE – open python file

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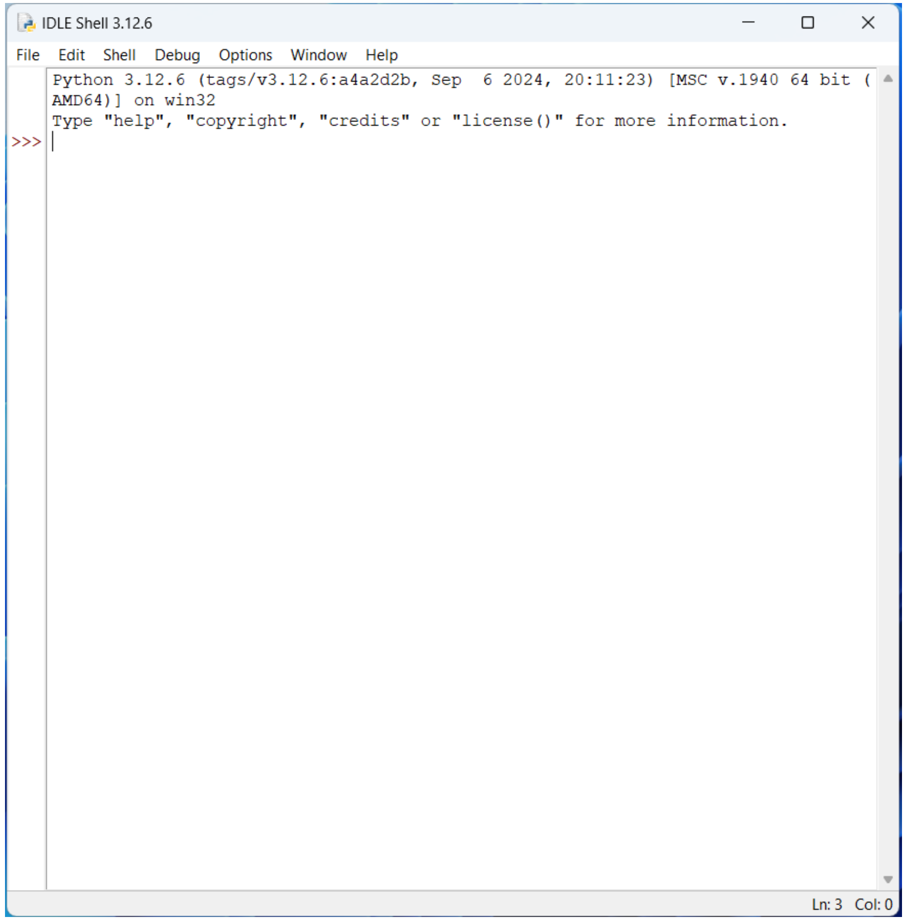
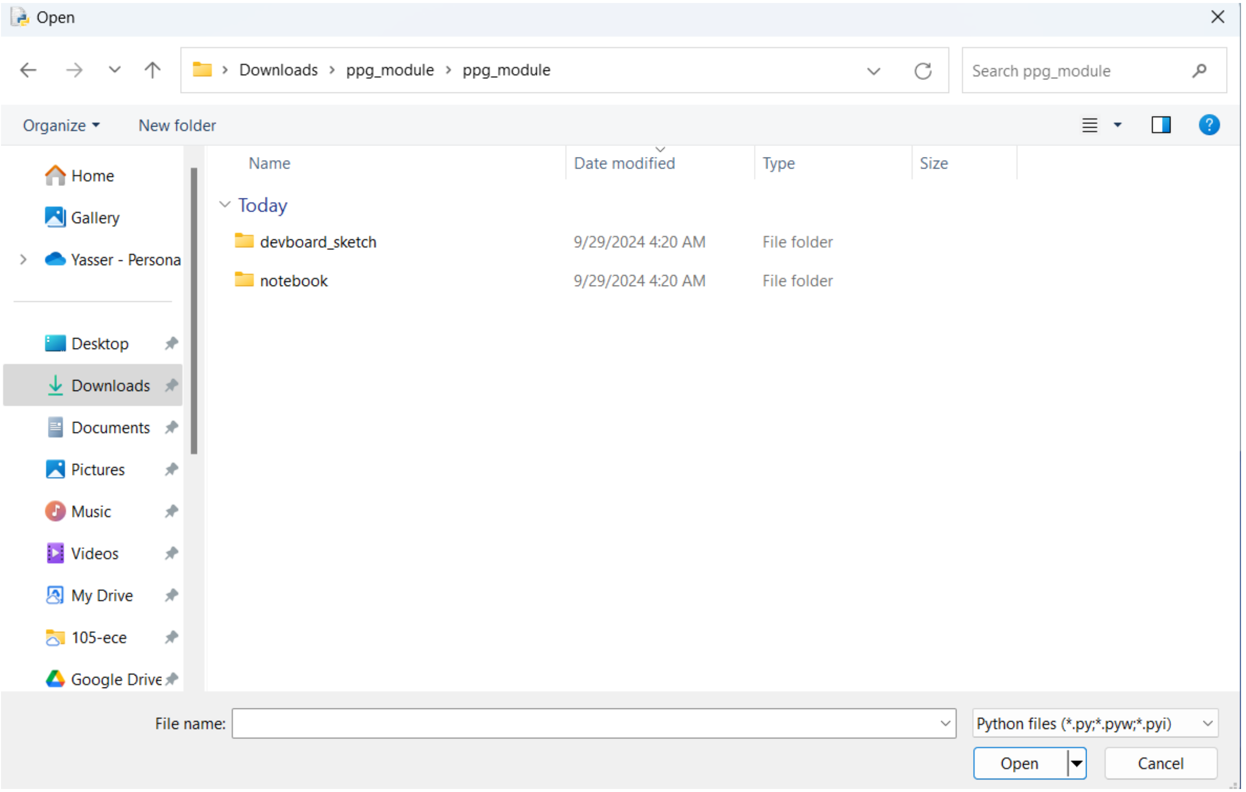
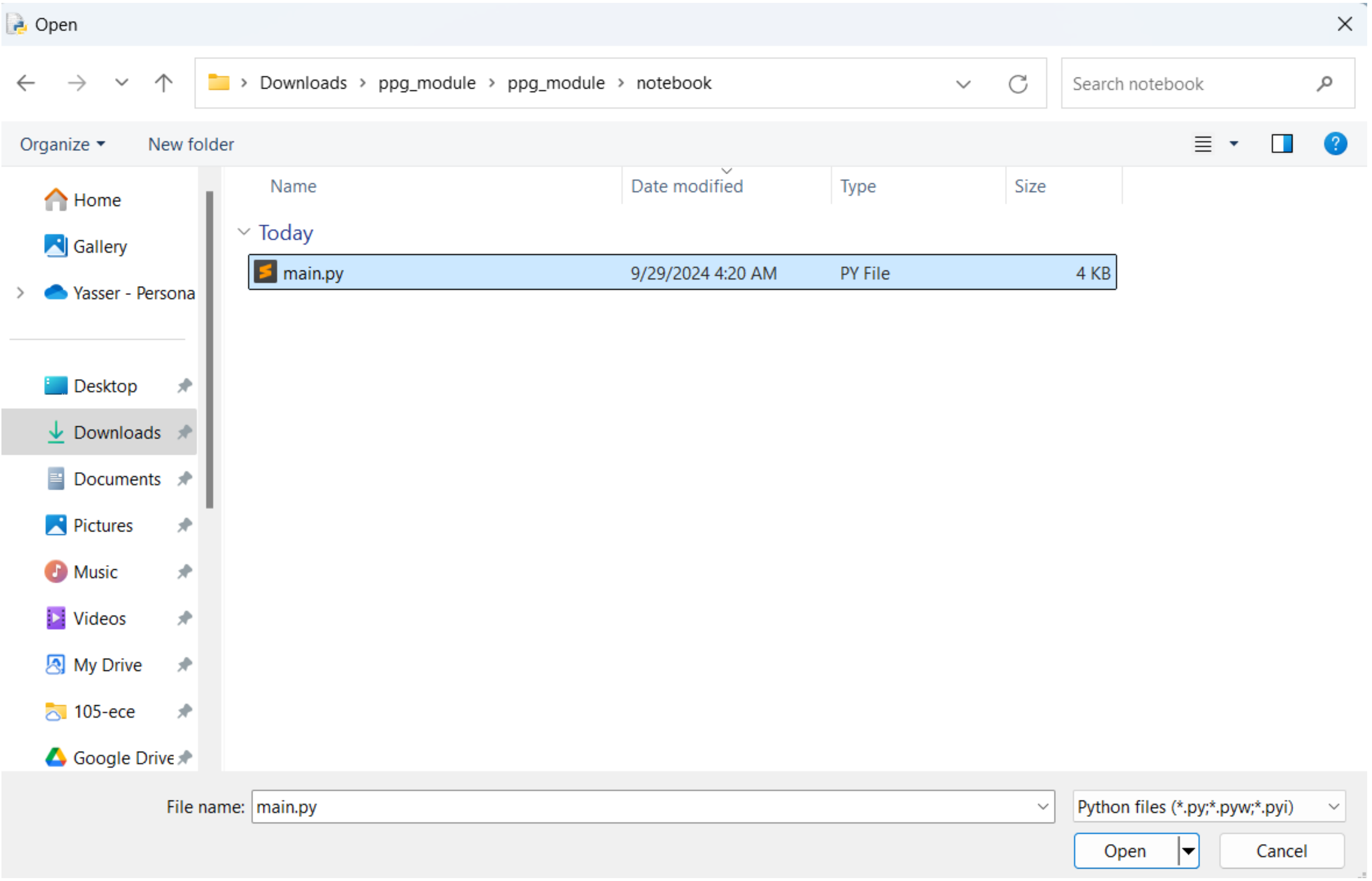




Open main.py



Open
Downloads › ppg_module › ppg_module › notebook
Search notebook
Organize
New folder
Home
Gallery
Yasser - Persona
Desktop
Downloads
Documents
Pictures
Music
Videos
My Drive
105-ece
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Name
Date modified
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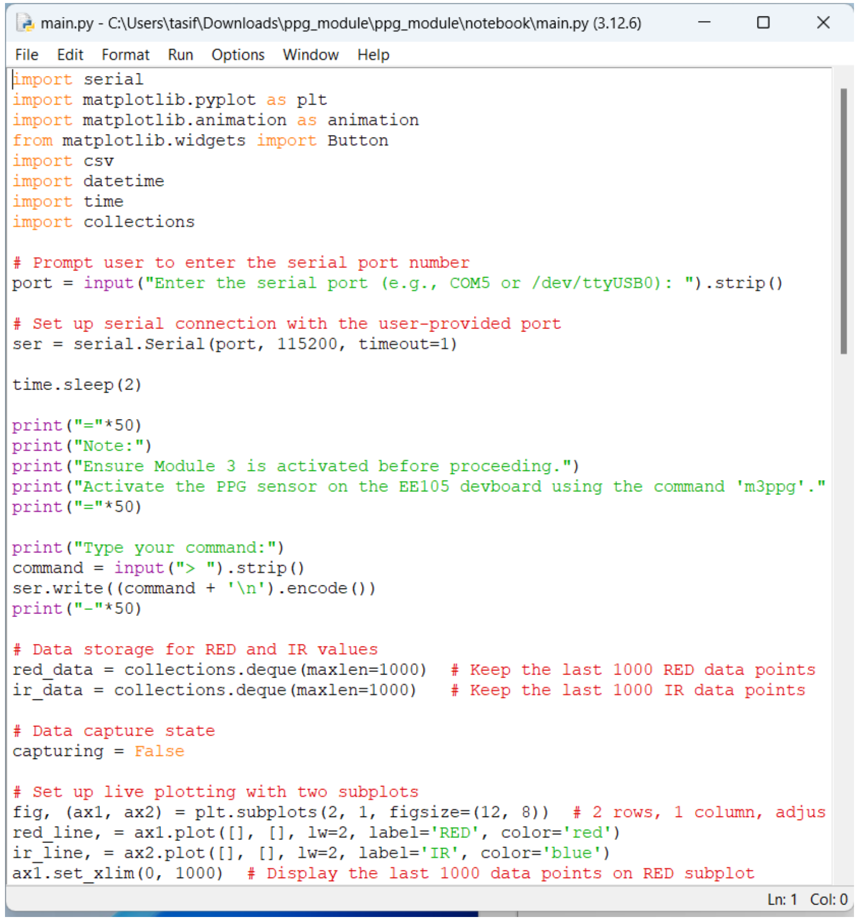
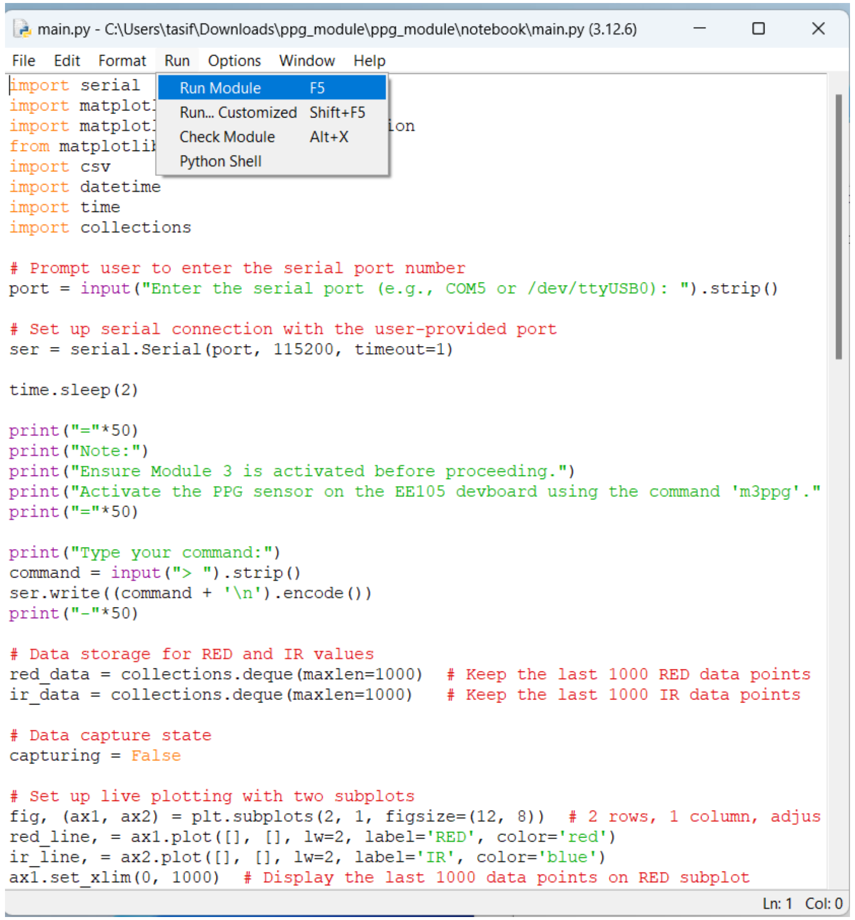
Today
main.py
9/29/2024 4:20 AM
PY File
4 KB
File name:
main.py
Python files (*.py;*.pyw;*.pyi)
Open
Cancel

Run module


main.py - C:\Users\tasif\Downloads\ppg_module\ppg_module\notebook\main.py (3.12.6)
File Edit Format Run Options Window Help
import serial
import matplotlib.pyplot as plt
import matplotlib.animation as animation
from matplotlib.widgets import Button
import csv
import datetime
import time
import collections
# Prompt user to enter the serial port number
port = input("Enter the serial port (e.g., COM5 or /dev/ttyUSB0): ").strip()
# Set up serial connection with the user-provided port
ser = serial.Serial(port, 115200, timeout=1)
time.sleep(2)
print("="*50)
print("Note:")
print("Ensure Module 3 is activated before proceeding.")
print("Activate the PPG sensor on the EE105 devboard using the command 'm3ppg'."
print("="*50)
print("Type your command:")
command = input("> ").strip()
ser.write((command + '\n').encode())
print("-"*50)
# Data storage for RED and IR values
red_data = collections.deque(maxlen=1000) # Keep the last 1000 RED data points
ir_data = collections.deque(maxlen=1000) # Keep the last 1000 IR data points
# Data capture state
capturing = False
# Set up live plotting with two subplots
fig, (ax1, ax2) = plt.subplots(2, 1, figsize=(12, 8)) # 2 rows, 1 column, adjus
red_line, = ax1.plot([], [], lw=2, label='RED', color='red')
ir_line, = ax2.plot([], [], lw=2, label='IR', color='blue')
ax1.set_xlim(0, 1000) # Display the last 1000 data points on RED subplot
Ln: 1 Col: 0


main.py - C:\Users\tasif\Downloads\ppg_module\ppg_module\notebook\main.py (3.12.6)
File Edit Format Run Options Window Help
Run Module F5
Run... Customized Shift+F5
Check Module Alt+X
Python Shell
import serial
import matplot
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from matplotlil
import csv
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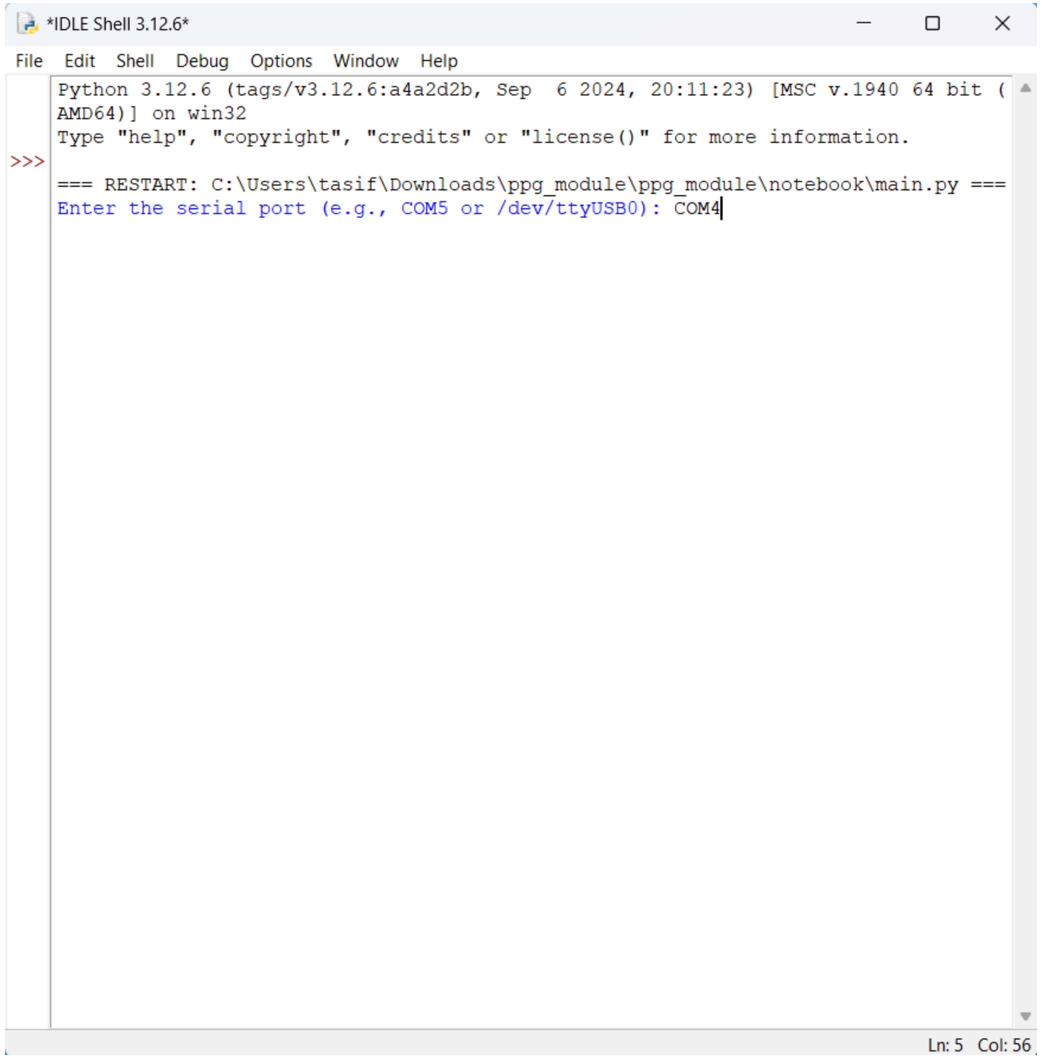
Ln: 1 Col: 0

Type in which port – check where your Ard in connected



Command – m3ppg

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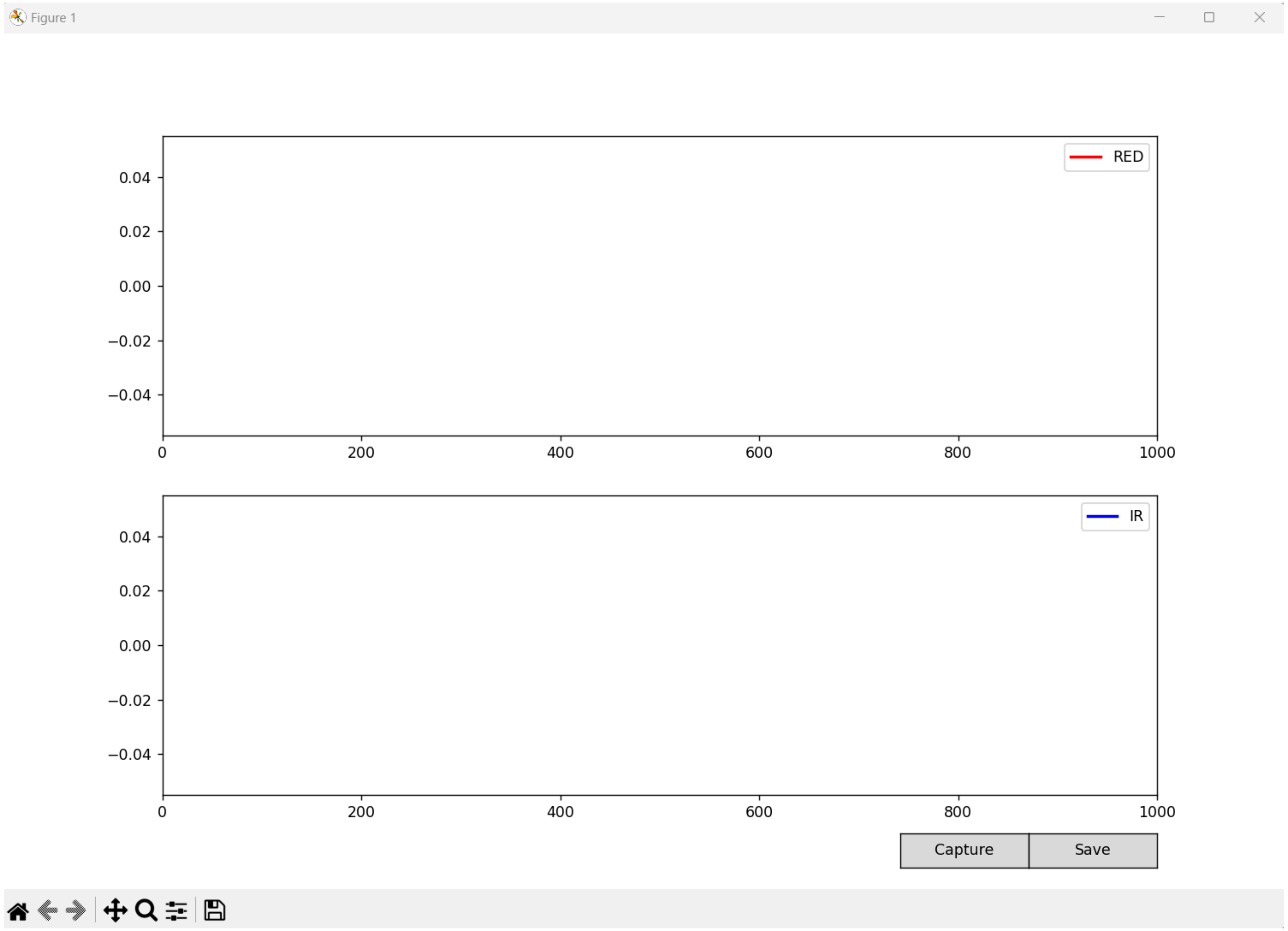
IDLE Shell 3.12.6

File Edit Shell Debug Options Window Help

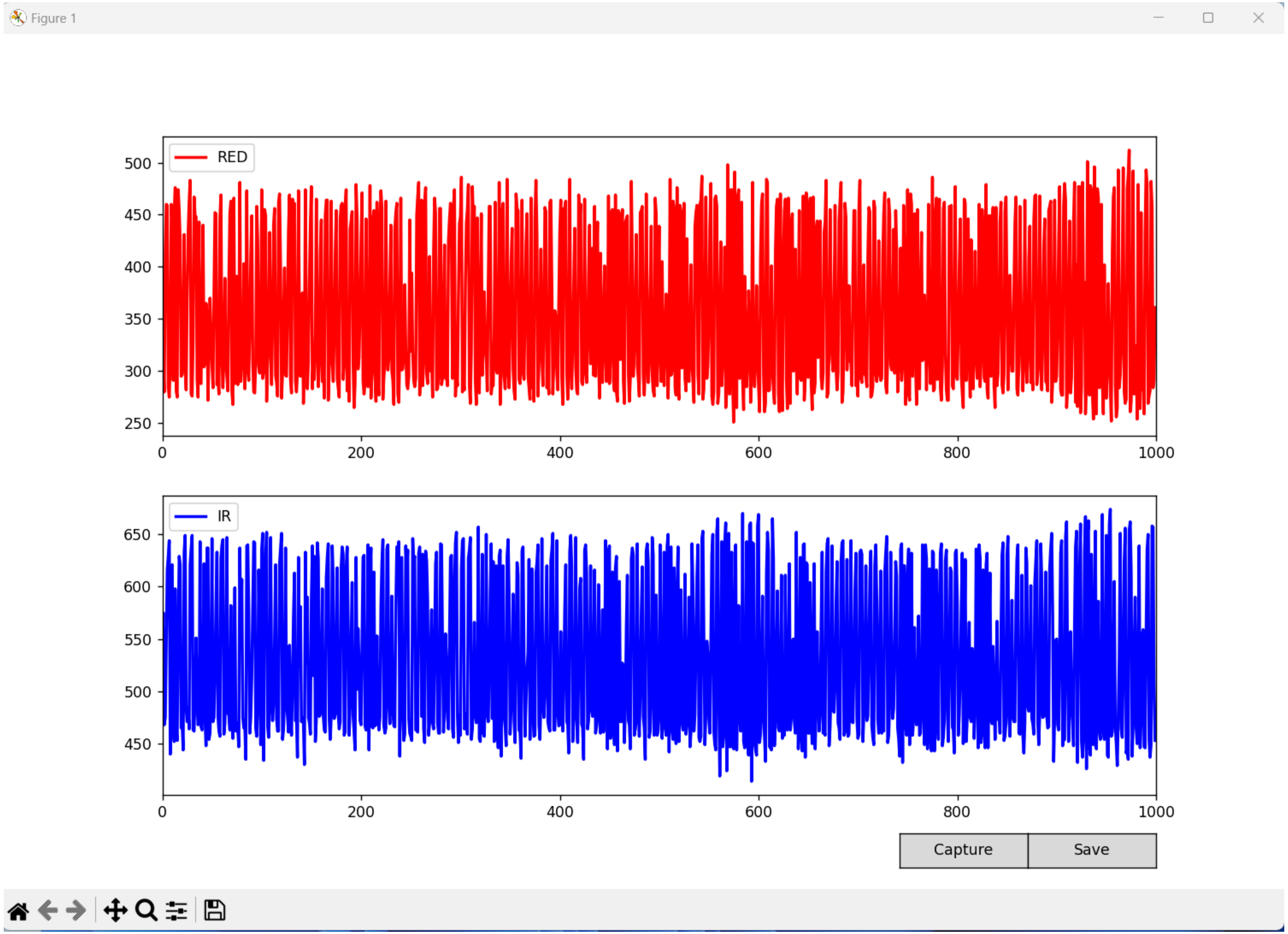
```
Python 3.12.6 (tags/v3.12.6:a4a2d2b, Sep  6 2024, 20:11:23) [MSC v.1940 64 bit (
AMD64)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
=== RESTART: C:\Users\tasif\Downloads\ppg_module\ppg_module\notebook\main.py ===
Enter the serial port (e.g., COM5 or /dev/ttyUSB0): COM4
==================================================
Note:
Ensure Module 3 is activated before proceeding.
Activate the PPG sensor on the EE105 devboard using the command 'm3ppg'.
==================================================
Type your command:
> m3ppg
```

Ln: 12 Col: 7

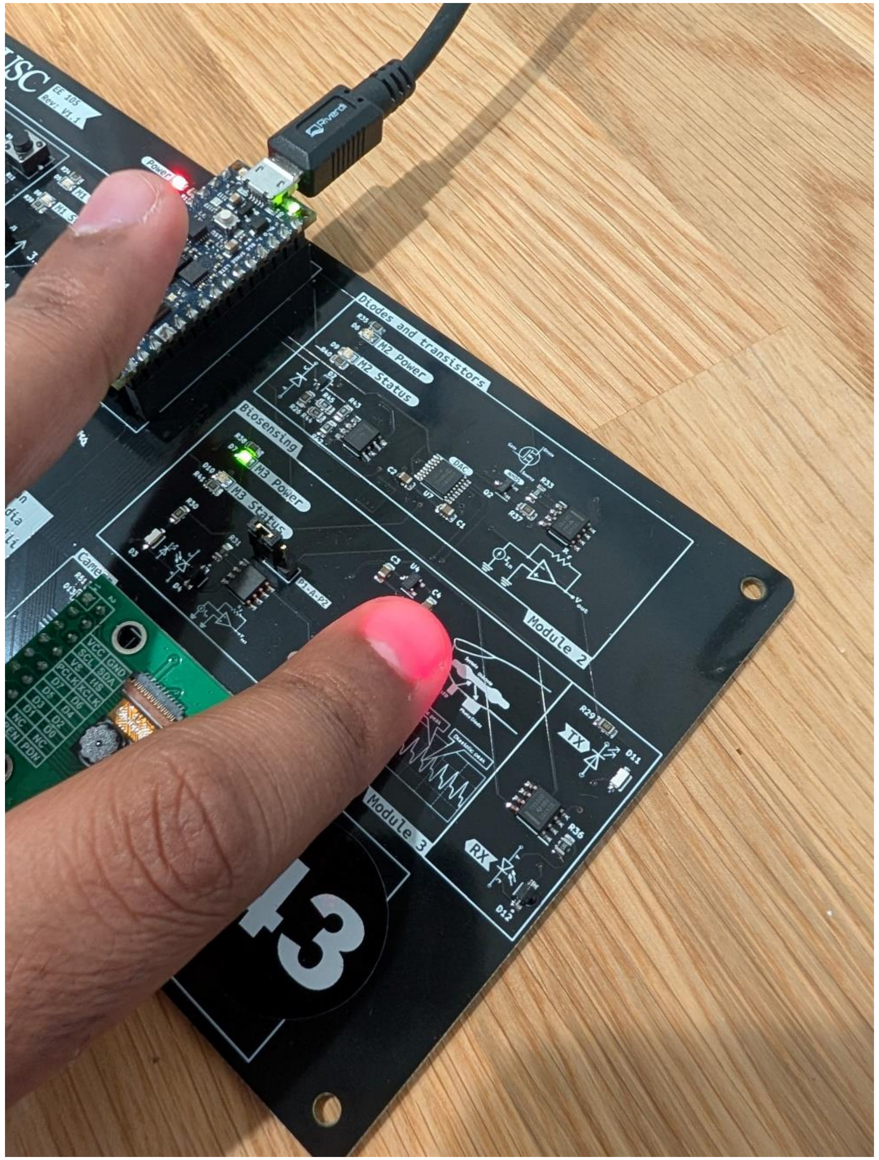
Opens a recording window

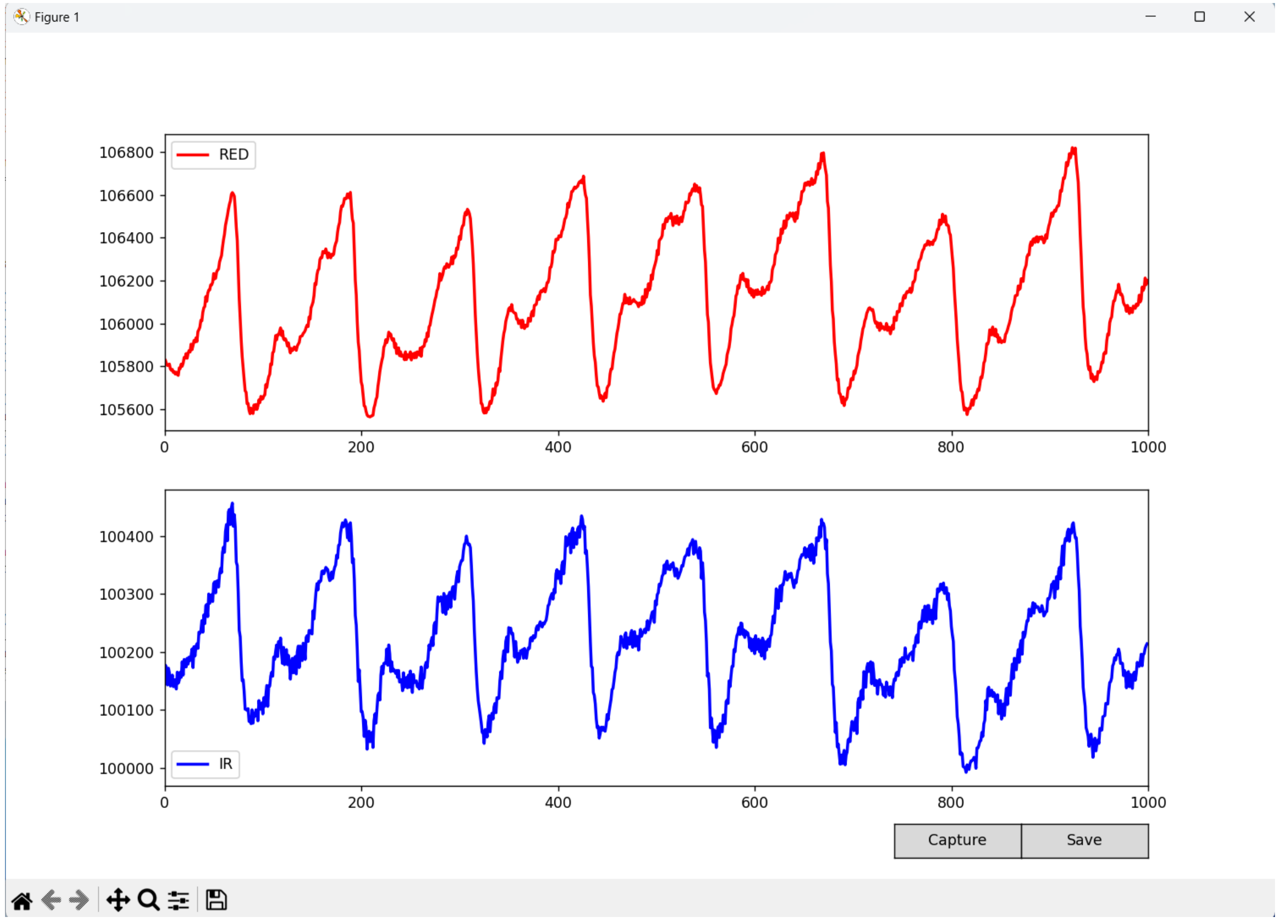


Press capture



Keep your finger gently on the sensor





Click save – a new file will be saved

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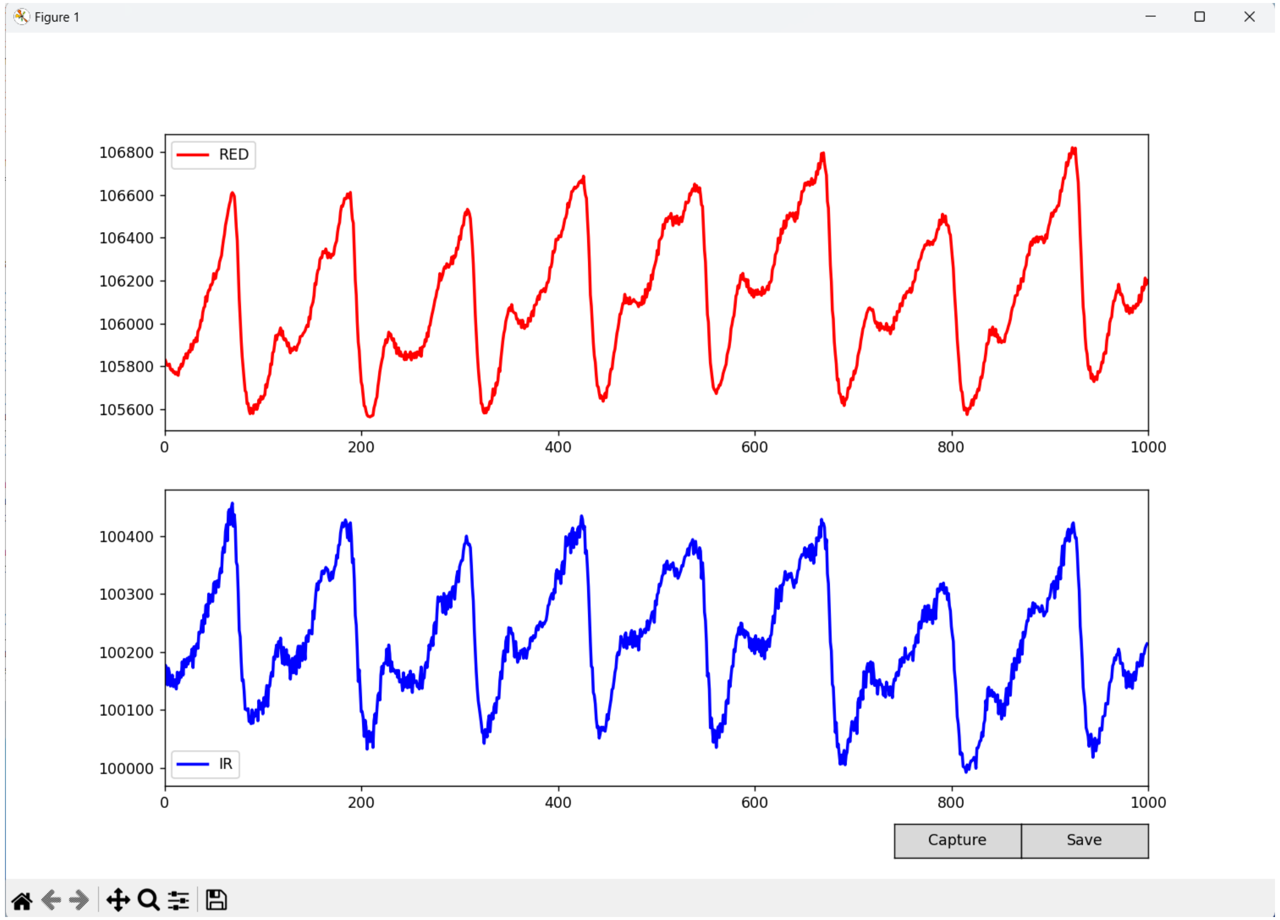

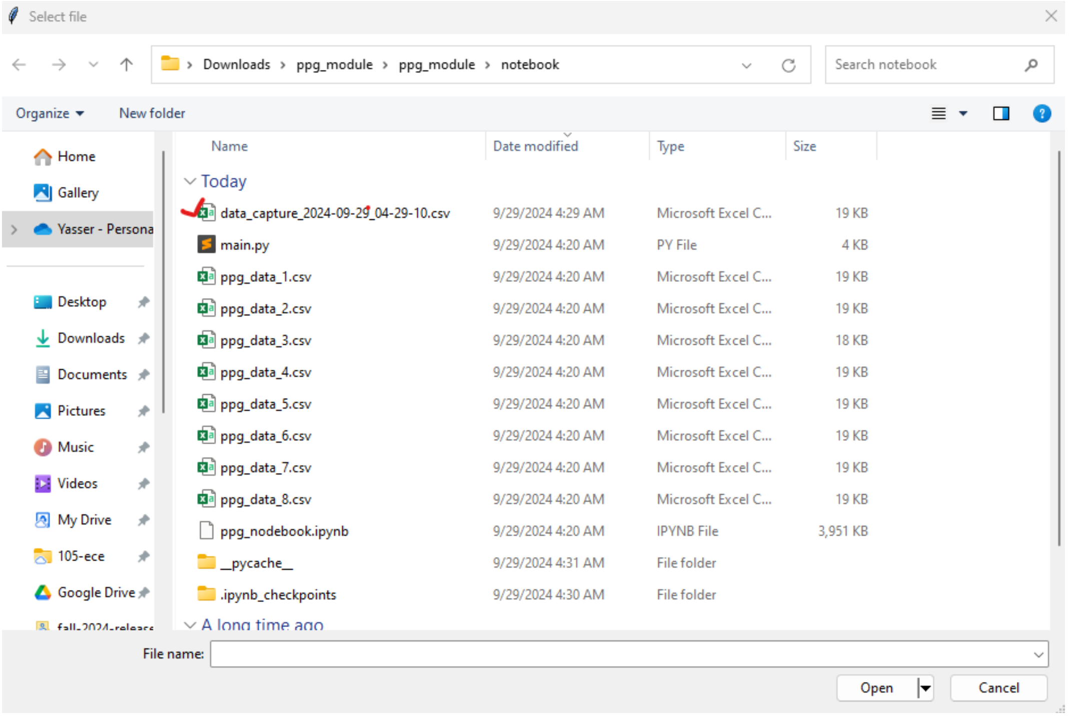

Open jupyter notebook select the new csv file – check the raw data on notebook

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