Pulse Oxymetry Intro

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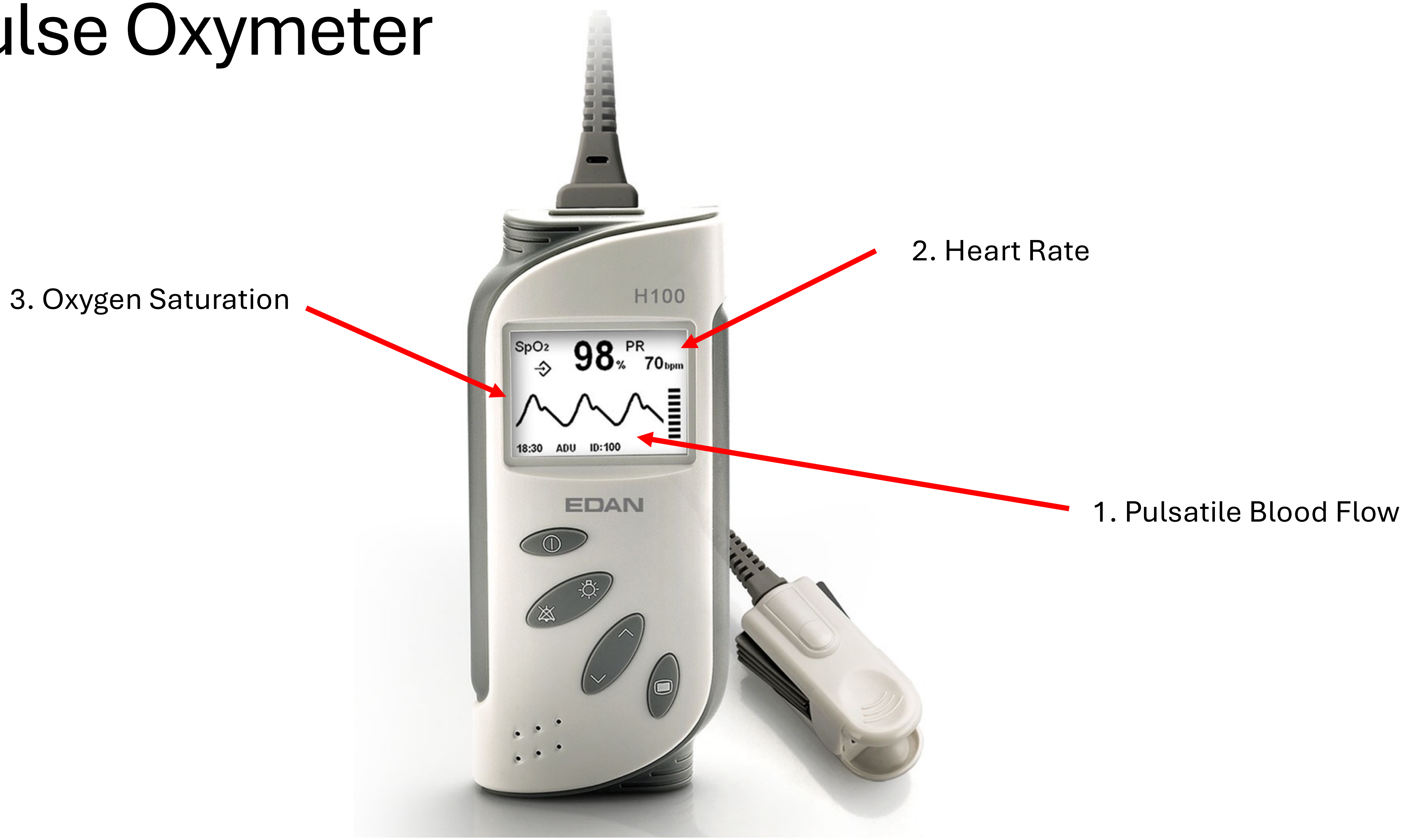
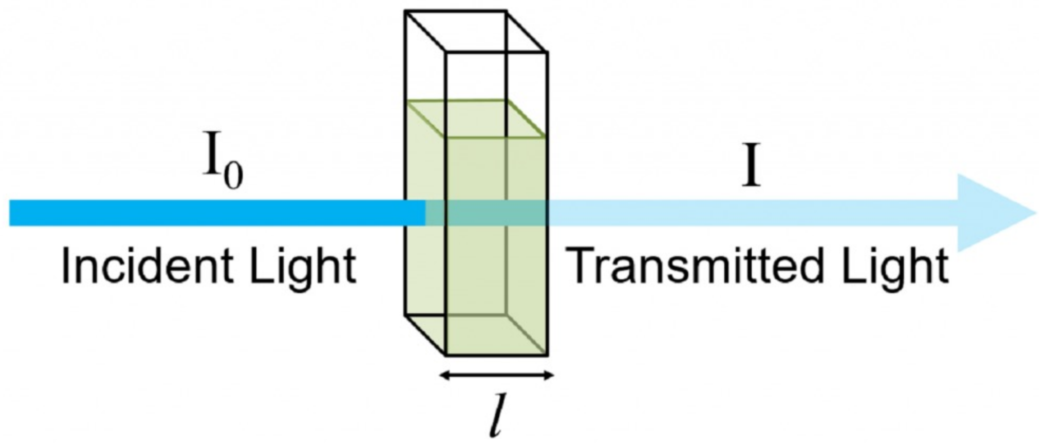
Pulse Oxymeter



Beer-Lambert Law

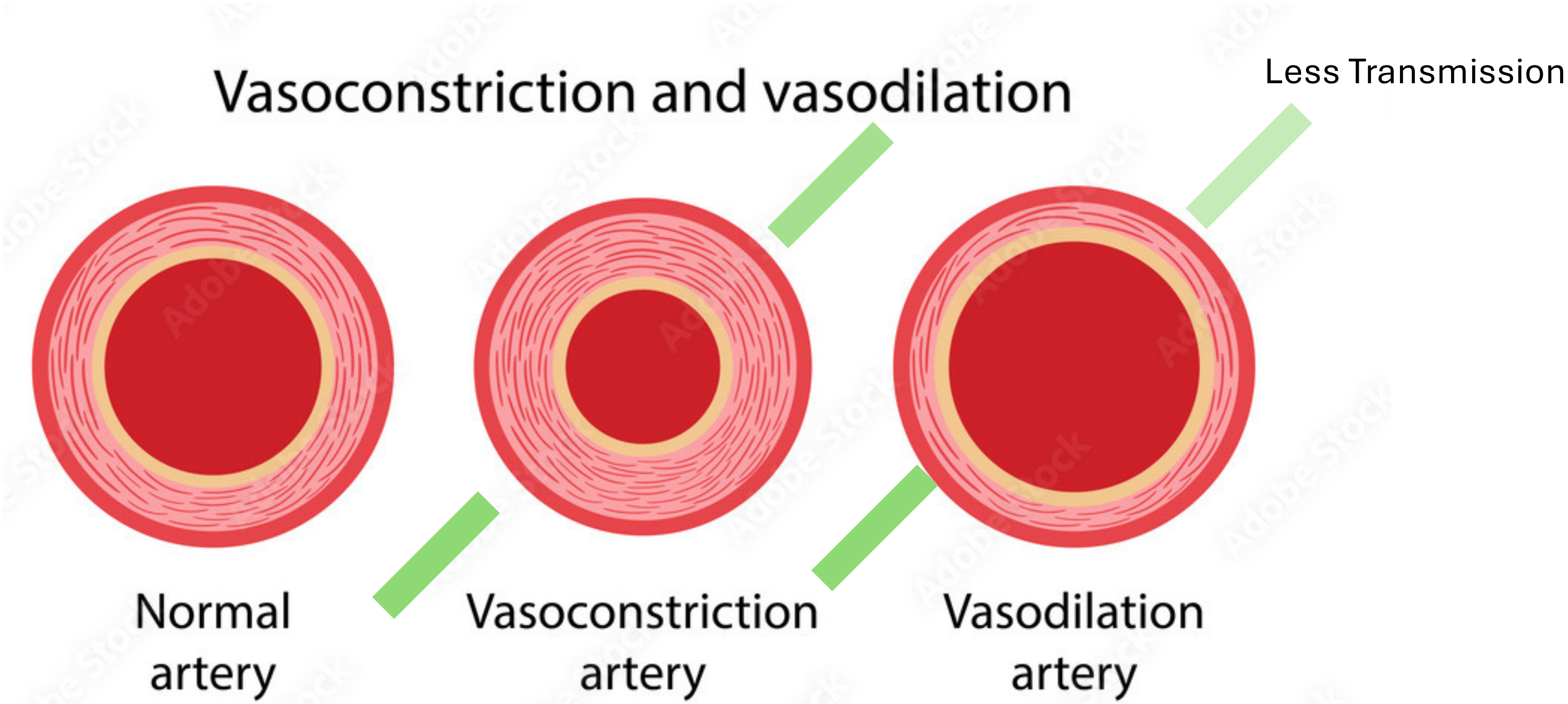
- Absorbance: $A = -\ln\left(\frac{I}{I_0}\right)$

- What affects absorbance?
  - $A = \epsilon \, l \, c$
  - l is the path length [cm]
  - c is the concentration [M]
  - ϵ is the extinction coefficient [cm^{-1} M^{-1}]



If light travels through longer distance across some medium, more light will be absorbed

Vasodilation and Vasoconstriction



Through cardiac cycles, the blood vessels dilates and constricts, leading to different absorptions.

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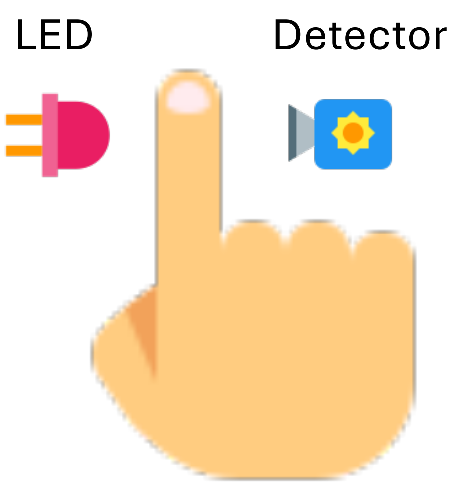
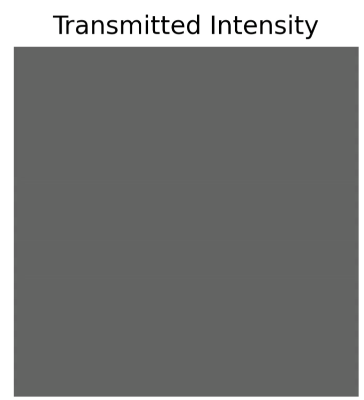
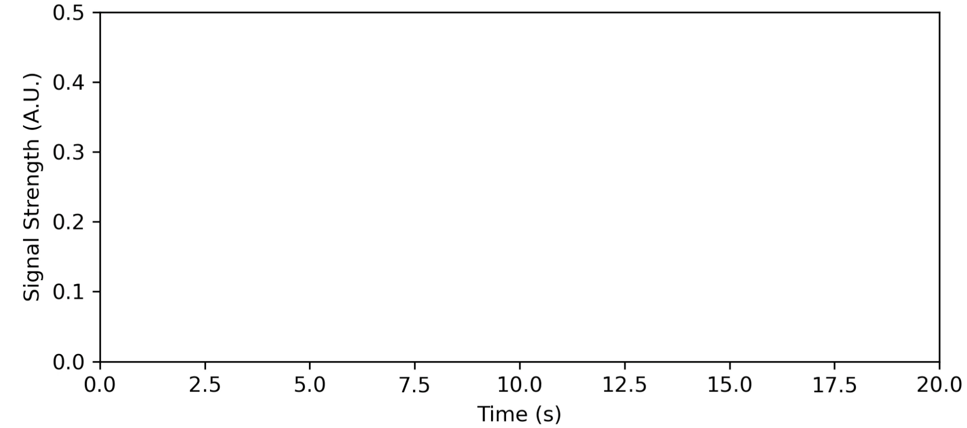
I. Pulsatile Blood Flow

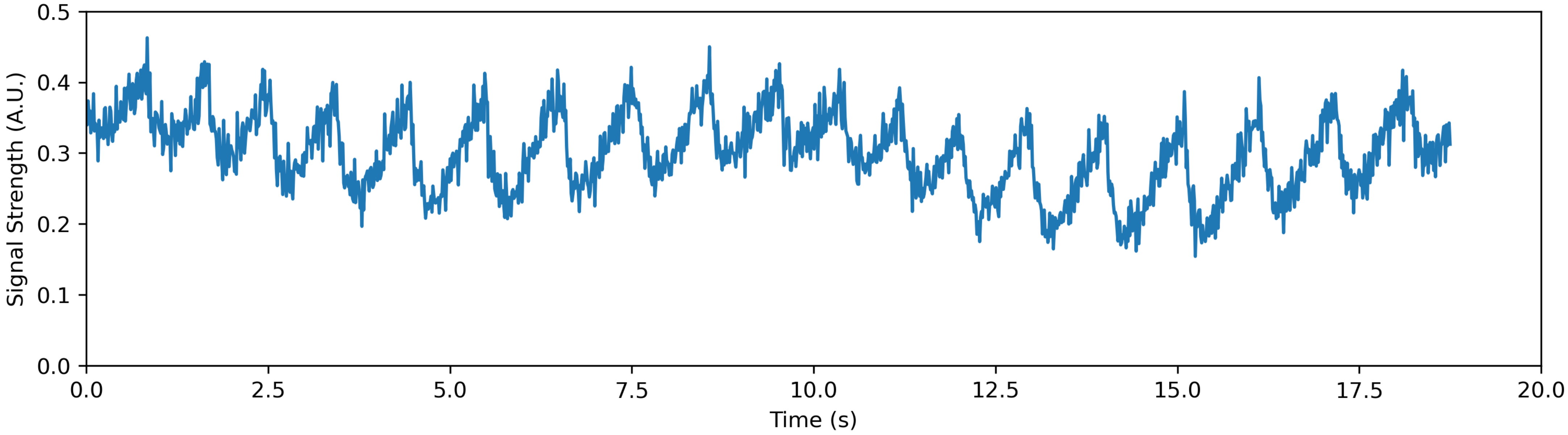






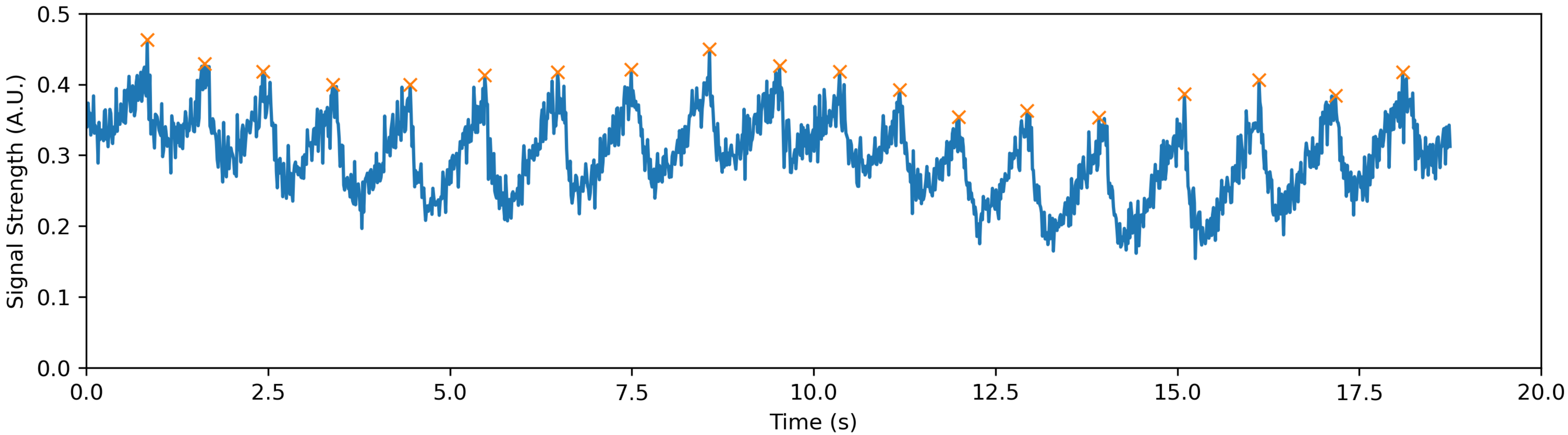
Transmission/Absorption is proportional to blood volume at that moment

II. Heart Rate



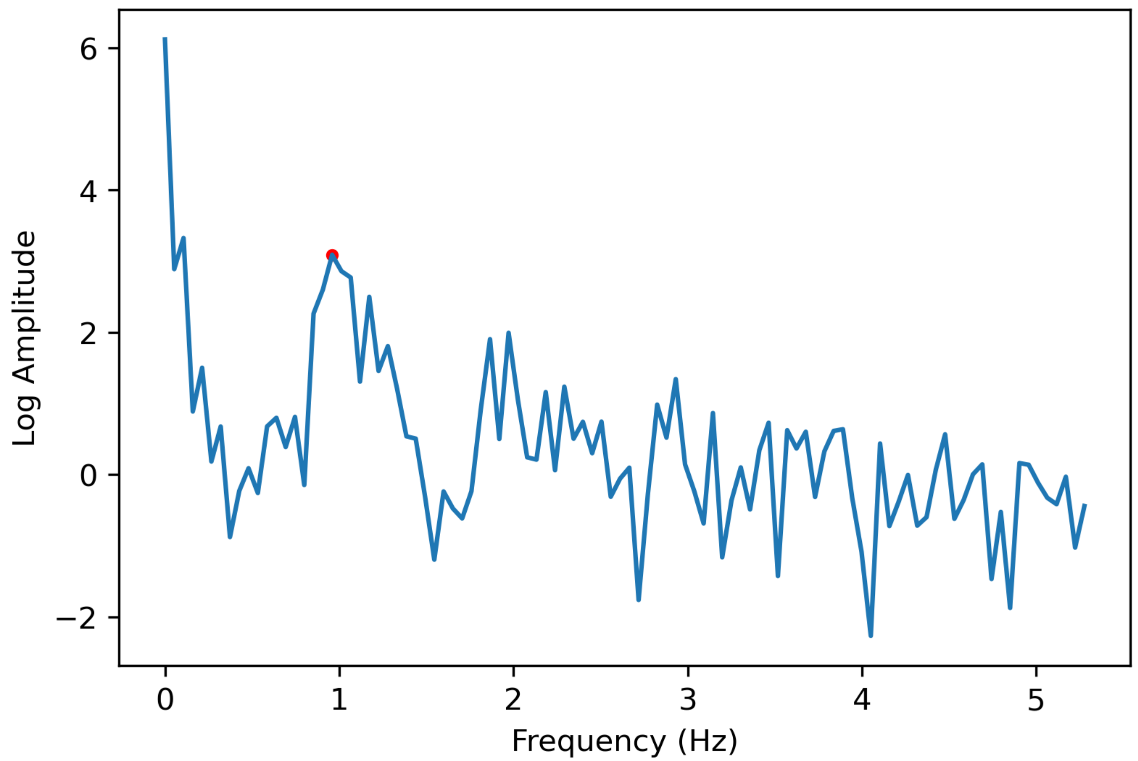
How do we find out what is the heart rate?

II. Heart Rate – Peak Finding



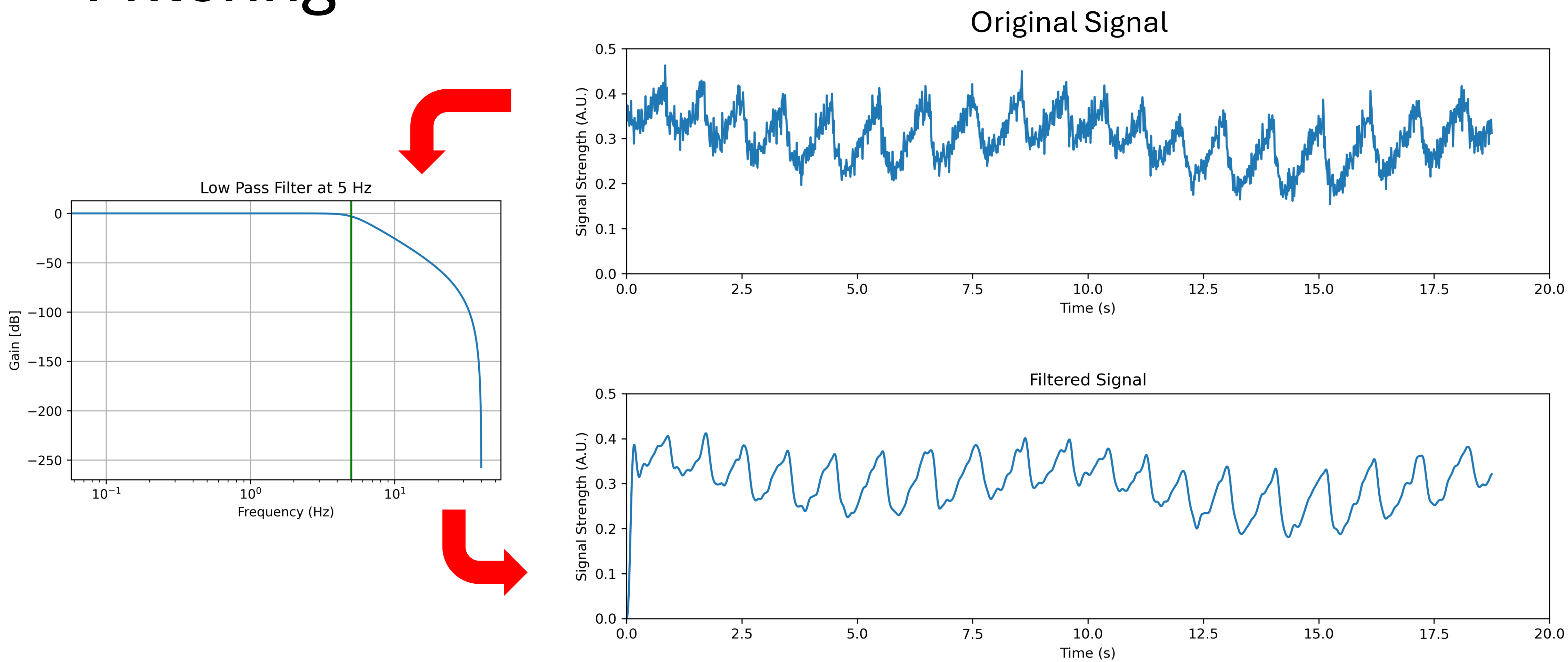
Heart rate = 0.96 Hz (58 BPM)

II. Heart Rate – Fourier Transform



Heart rate = 0.96 Hz (58 BPM)

Filtering



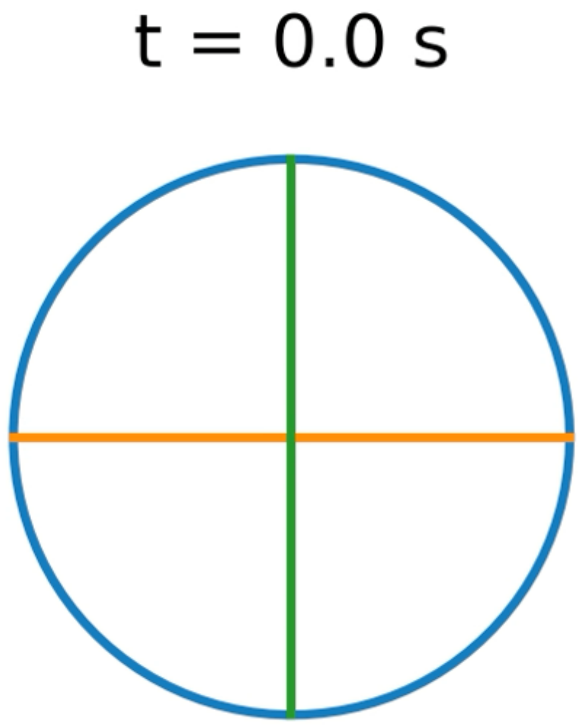
Q: Digital filtering or analog filtering?

Aliasing - An Introduction

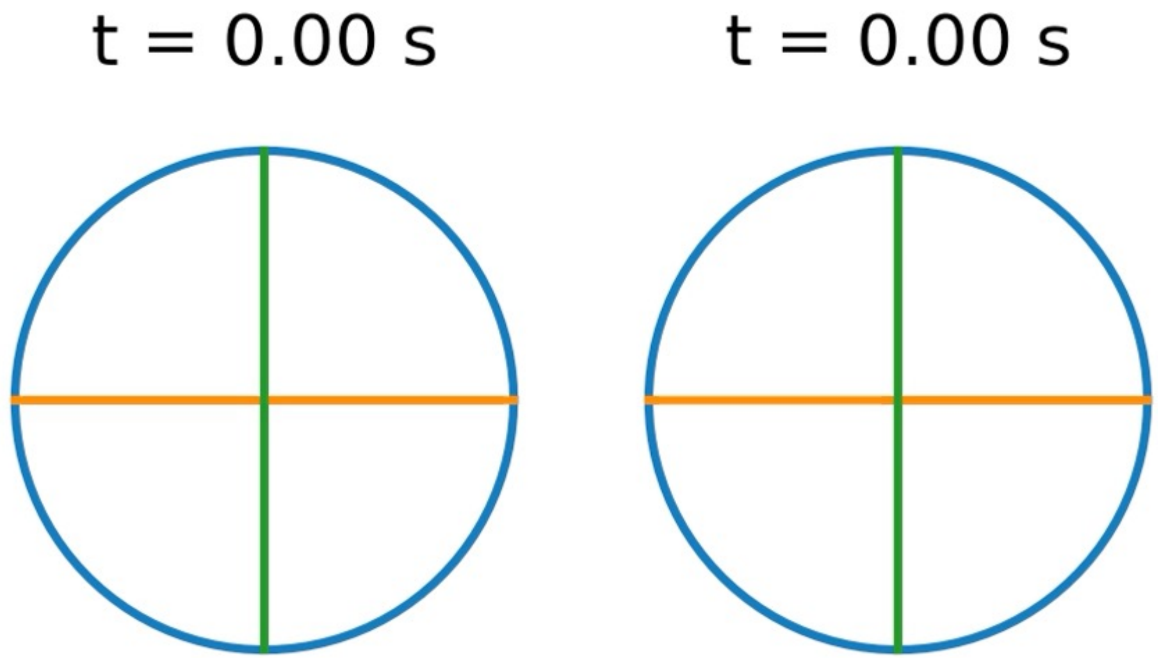
Sampling rate = 1 Hz

Q: How fast and in which direction is this wheel spinning?

A: We cannot know...



If we sample at a faster rate…



Aliasing: Because we have a finite sampling rate, higher frequency info might appear to be lower frequency info.

How to fix aliasing

- Problem: The sampled signal could map to infinitely many solutions
- Q: What if we know the wheel cannot spin faster than 0.5 rev/s?

- Solution: We low-pass filter the signal before we sample in time.

- Nyquist Rate: $f_s \geq 2f_{max}$

Nyquist Sampling

- One of the most important theories that lead to our digital world

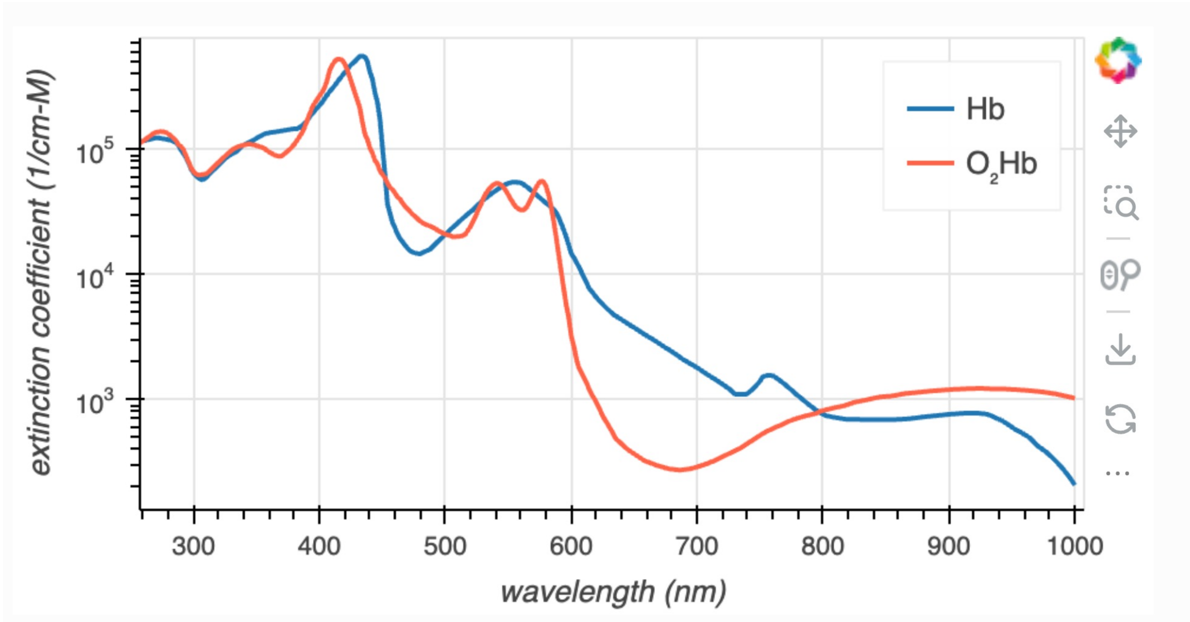
- Q: What is the highest audible frequency for human ears?
- A: ~20 kHz

- A common sampling rate for a .mp3 file is 44,100 Hz.
- It is about 2x of 20 kHz.

III. Oxygen Saturation

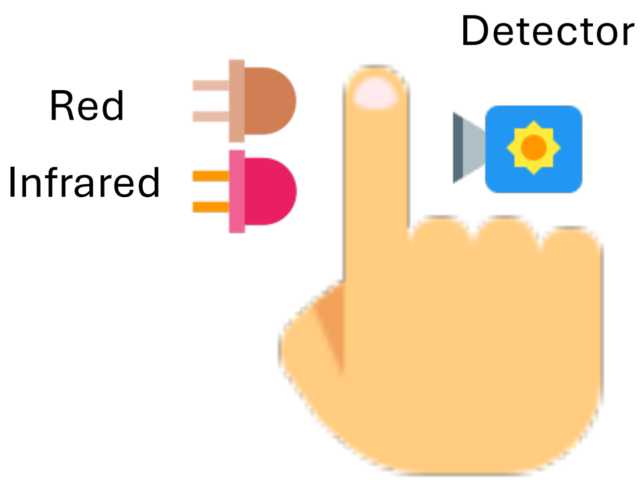
- Recall $A = \epsilon \, l \, c$
  - l is the path length [cm]
  - c is the concentration [M]
  - ϵ is the extinction coefficient [cm^{-1} M^{-1}]

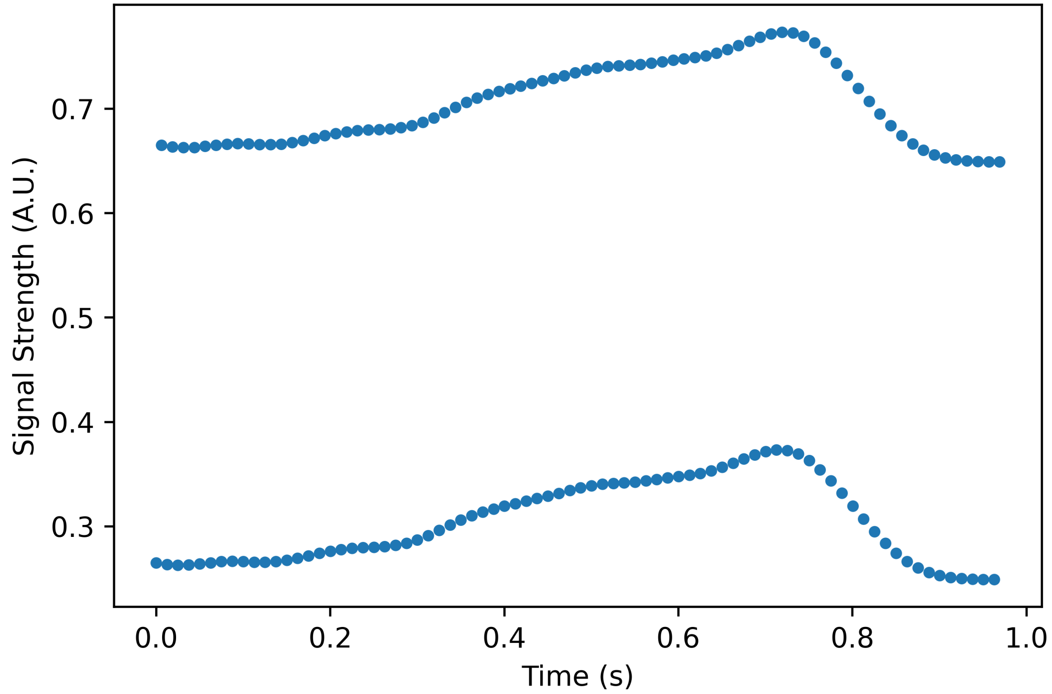
- ϵ is wavelength dependent



Measure the transmission at two wavelengths

- Switch on the red LED, record signal
- Switch on the infrared LED, record signal
- Repeat…

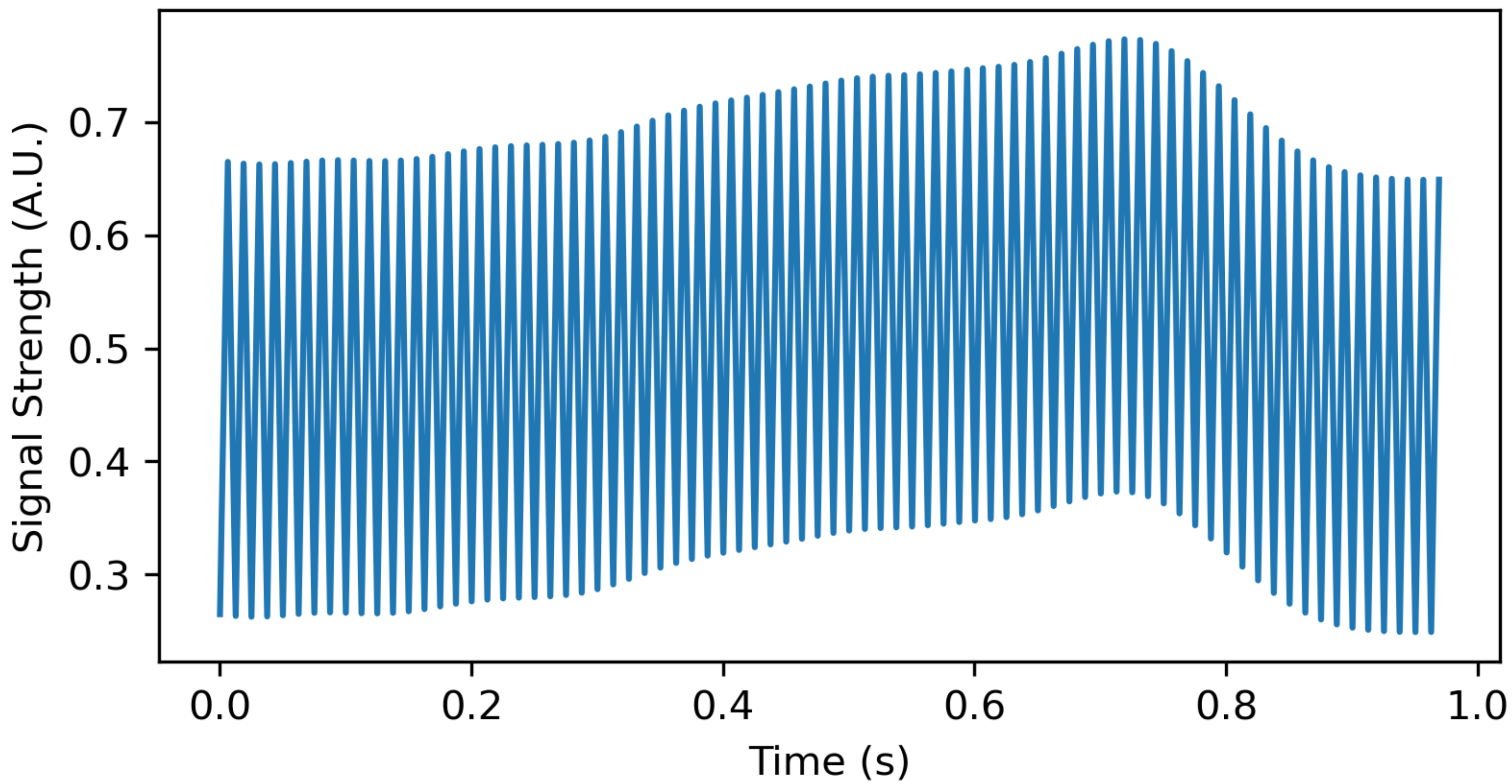




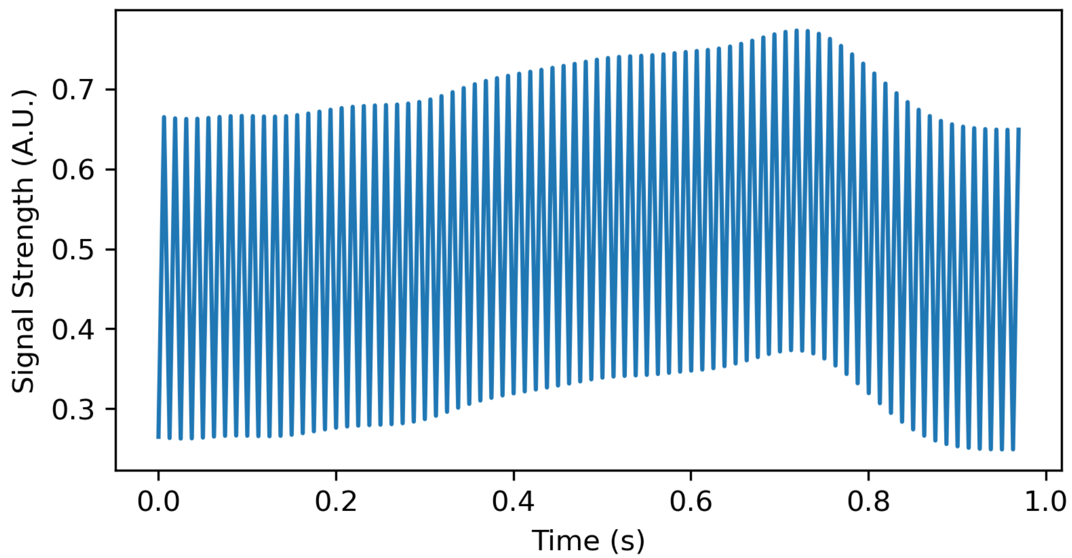
Can we perform analog filters on this signal?

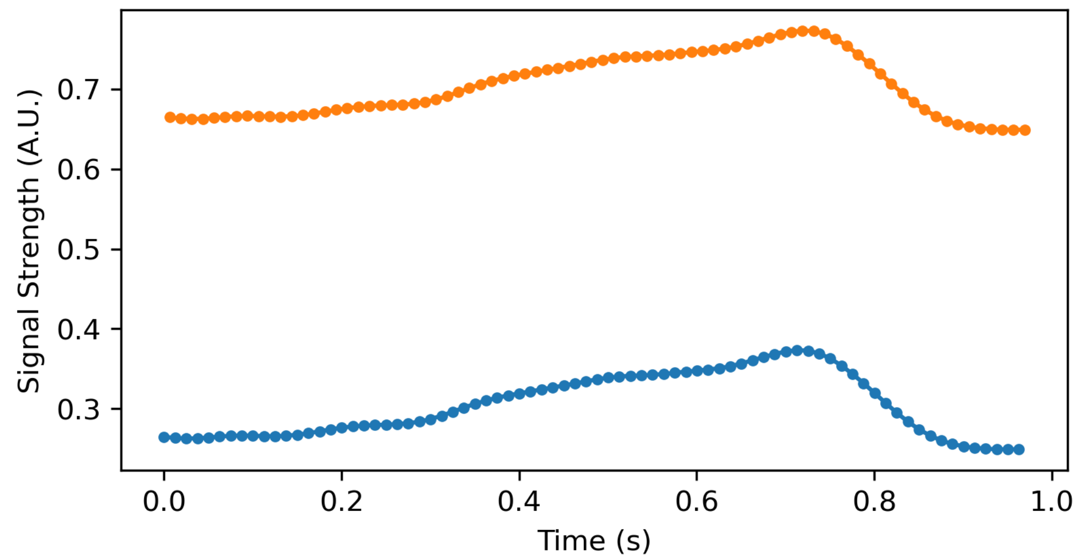
Well, not really…

The signals from the two channels are entangled in time.
We want to filter the two channels separately
These sharp edges between consecutive data points are not part of either ‘signal’ that we are interested in



Disentangle the signal in time





How to do this? Hint: Sample-and-Hold

Now we can perform analog filters on either signal and compute the SpO_2 level digitally.

To calculate the SpO_2, you need to use the peak and valley values of both signals (refer to webpage).

Do not freak out if your SpO_2 is not anywhere near 100%.

Specifications

1. Stream pulsatile blood flow
2. Measure blood pulse in real-time
3. Measure SpO_2 in real-time

Pulse Oxymeter Project Grading

In-class demo (Dec 5, 10:30a-11:55a)

Project writeups (Dec 10, 11:59 pm)

- S1: Overview [1]
- S2: Design [2], schematic [2], code [2]
- S3: User Documentation [4]
- S4: Demo (movies + data) [4]
- S5: Analysis of data [2]
- S6: Next steps [1]

Grading Scheme

- Demo [2] (+ feedback)
- Writeup [18] (as shown)
- Late: score/$(1.1)^N$

S5: Analysis of Data

- Sample trace of data
- Calculate pulse
- Calculate SpO_2