

ECE 105: Introduction to Electrical Engineering

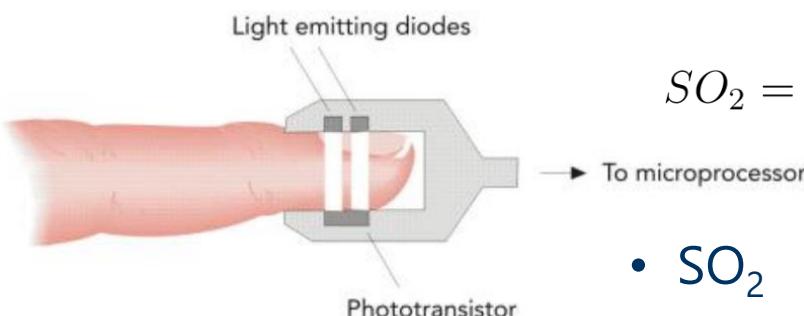
Lecture 12
Bio 2
Yasser Khan
Rehan Kapadia

Pulse oximetry



ECG
Pulse Ox
Respiration
Blood Pressure

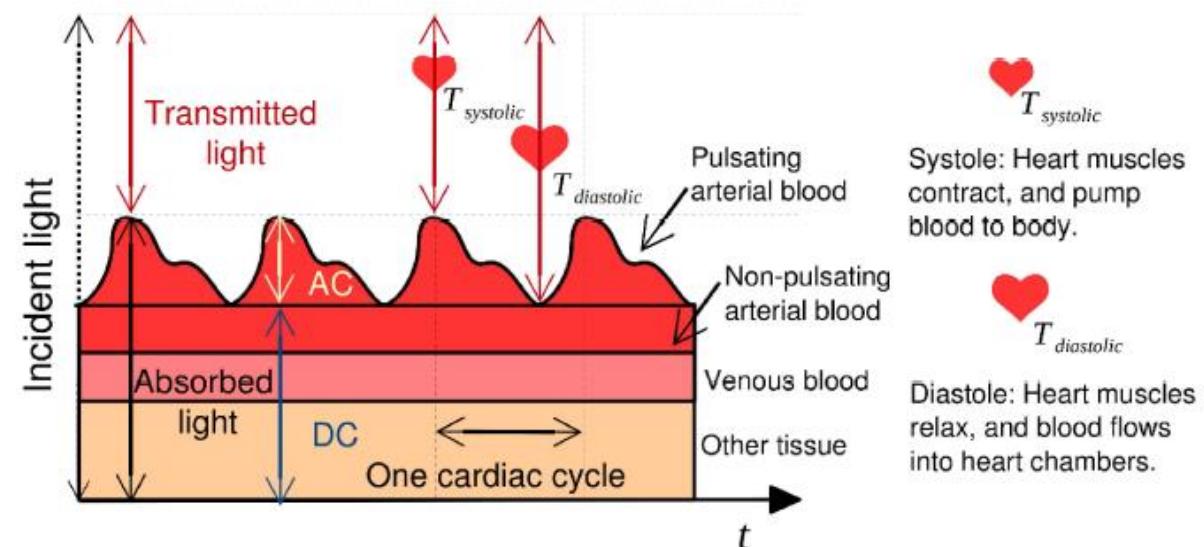
Temperature



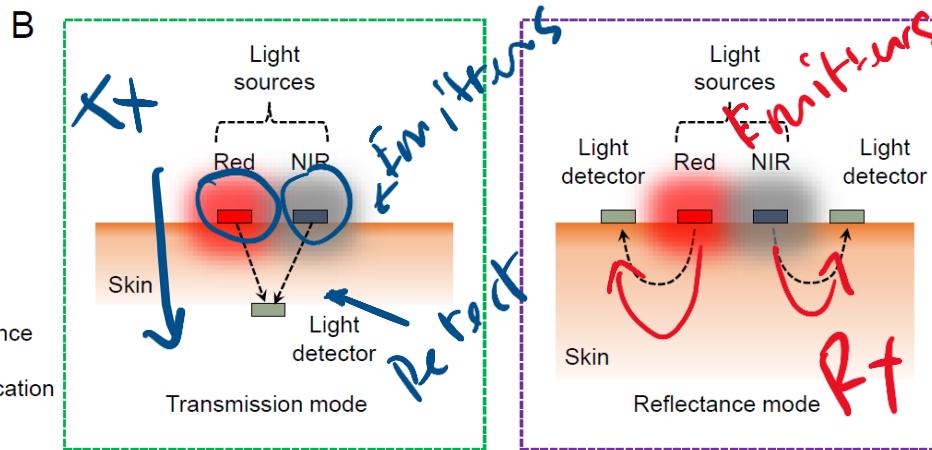
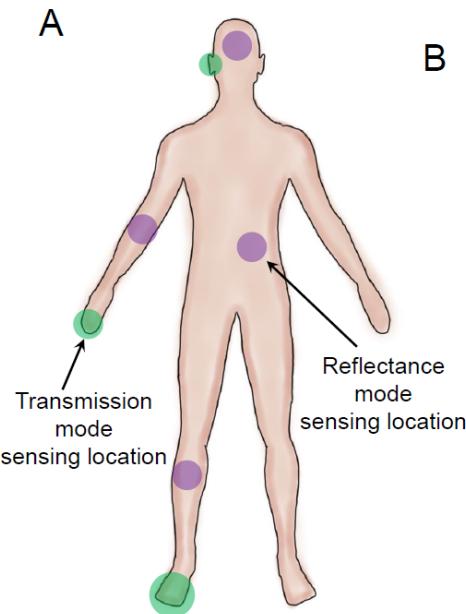
$$SO_2 = \frac{C_{HbO_2}}{C_{HbO_2} + C_{Hb}}$$

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

- 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.

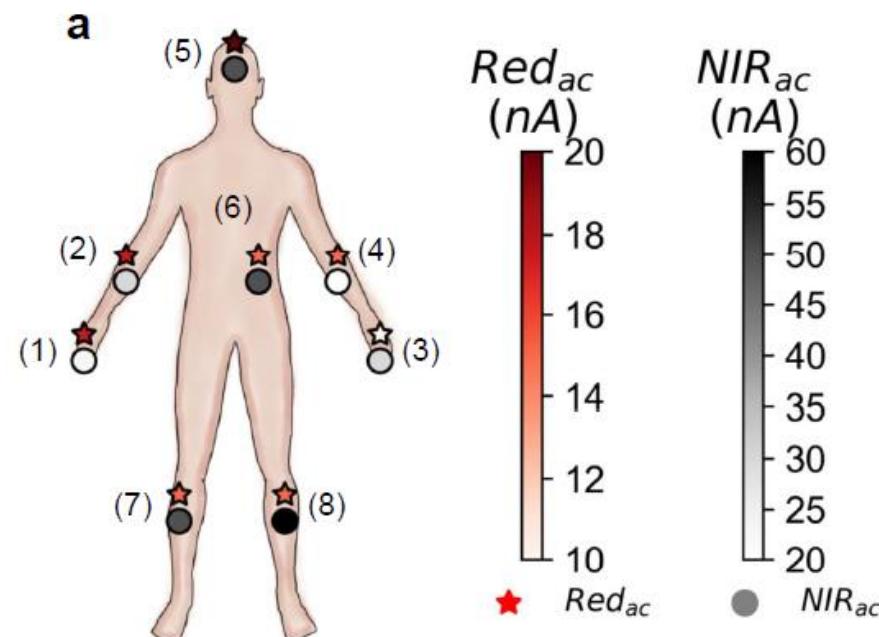


Transmission vs. reflectance oximetry

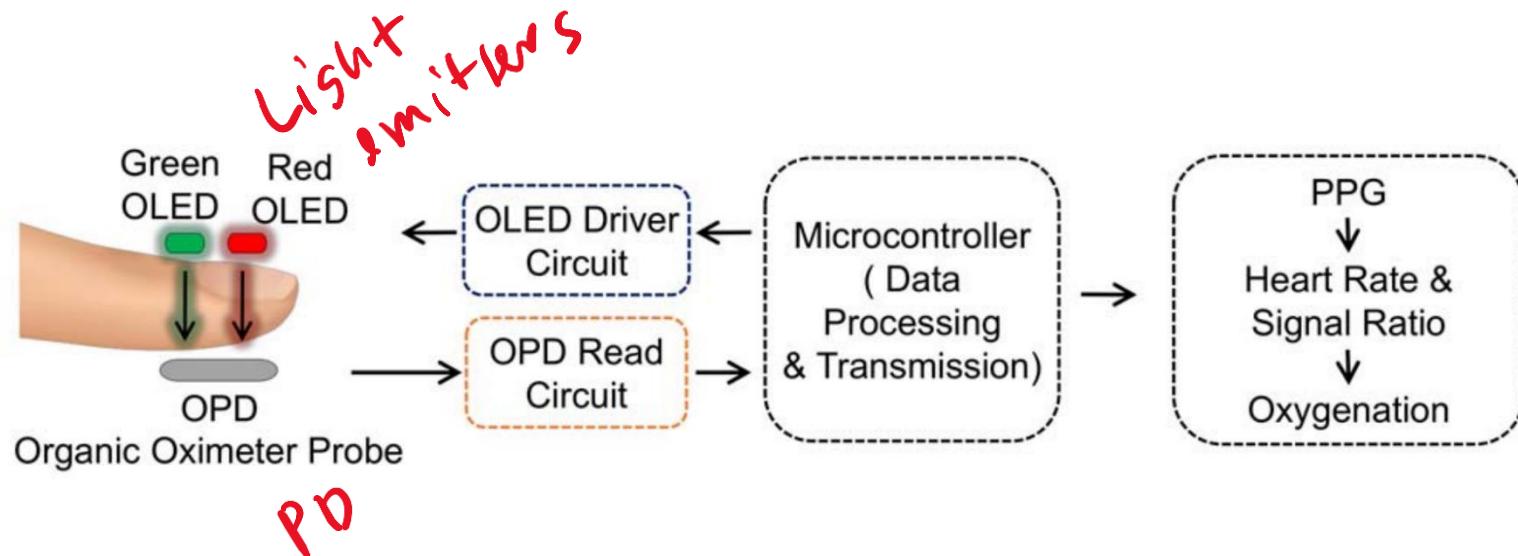


- Transmission-mode pulse oximetry is limited only to tissues that can be transilluminated, such as the earlobes and the fingers.
- If reflected light is used as the signal, the sensor can be used beyond the conventional sensing locations.

- 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.



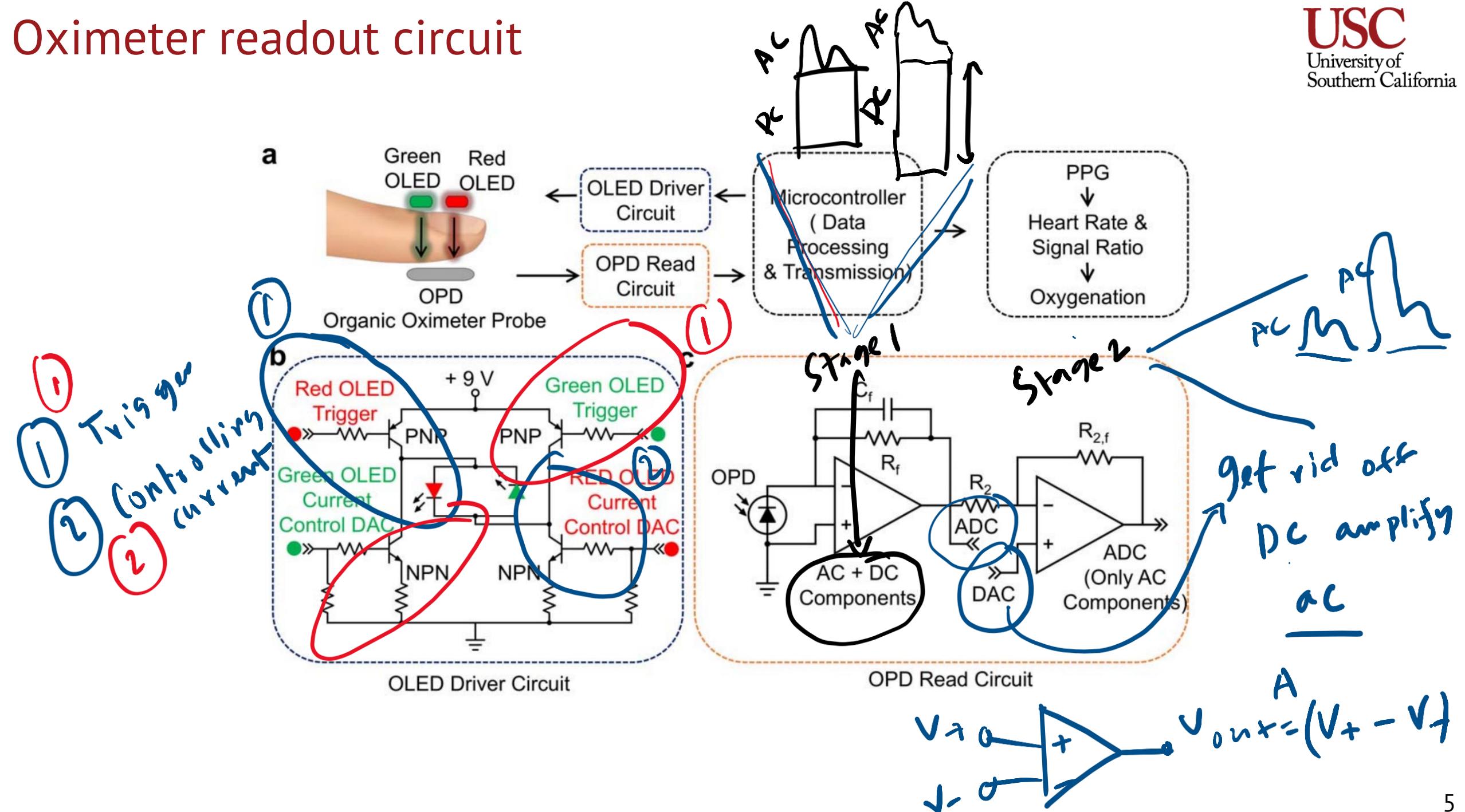
Oximeter readout circuit



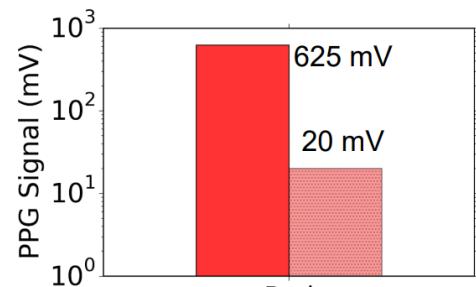
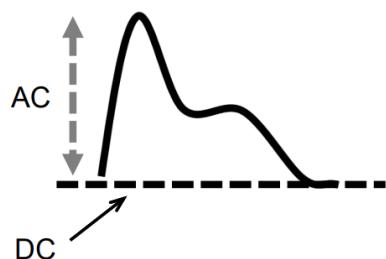
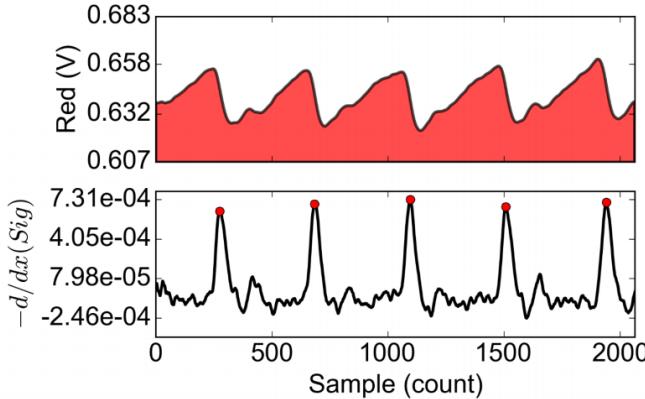
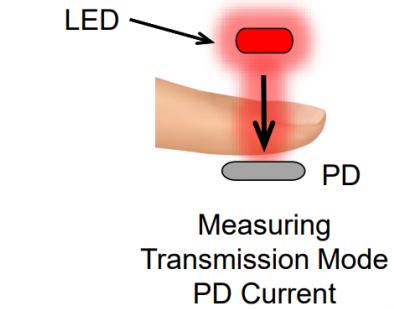
LED driver → ① Trigger to turn on
② Control LED current to change light intensity

PD circuit ① Amplify (AC+DC)
② Measure and get rid off DC
③ Amplify AC

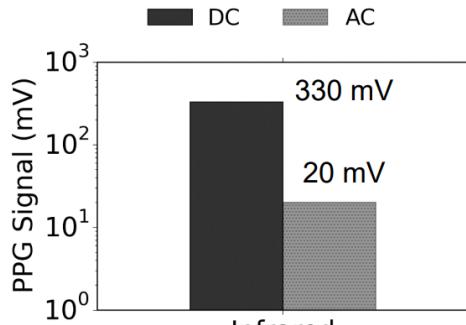
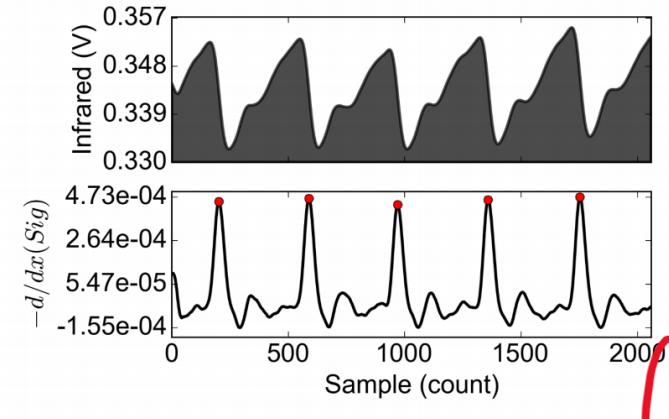
Oximeter readout circuit



Calculating oxygen saturation



dc ac



dc ac

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

65

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

OS

Pulse oximeter basics

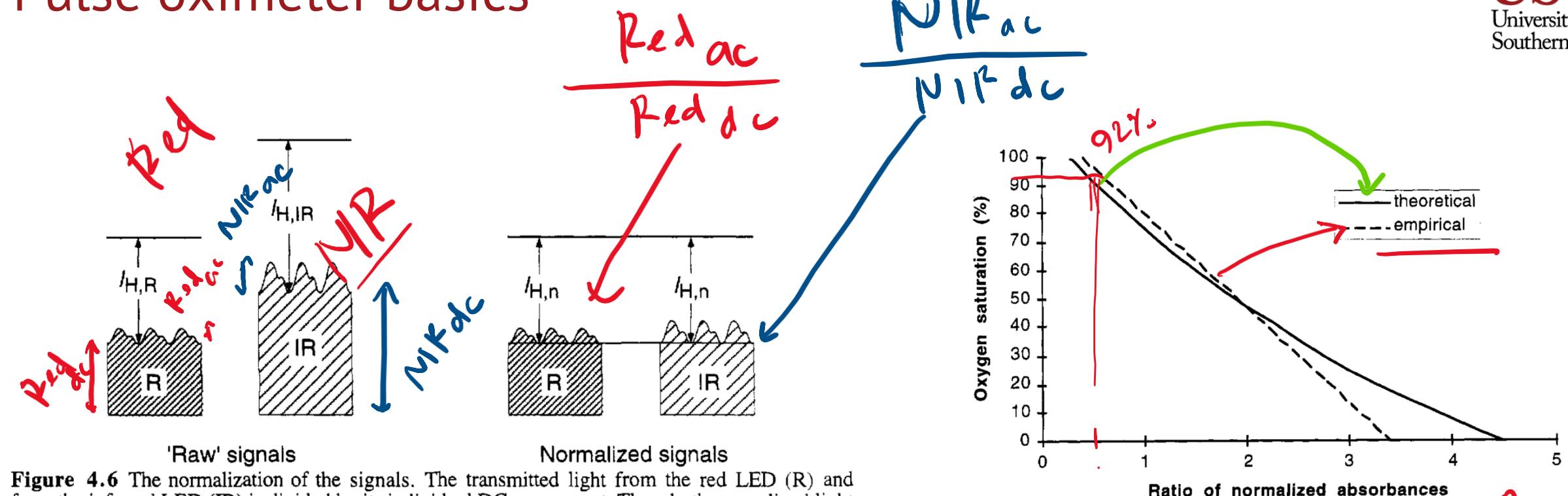


Figure 4.6 The normalization of the signals. The transmitted light from the red LED (R) and from the infrared LED (IR) is divided by its individual DC component. Thus, both normalized light intensities have the same magnitude during diastole. The normalized signals determine the basis for the calculation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

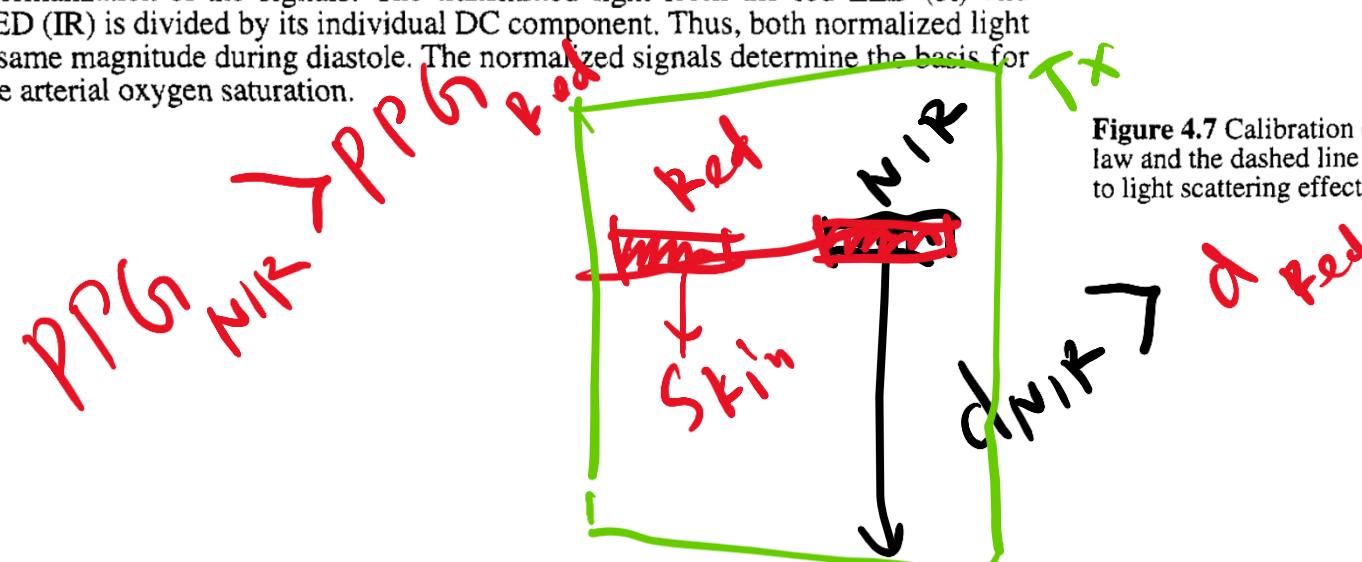
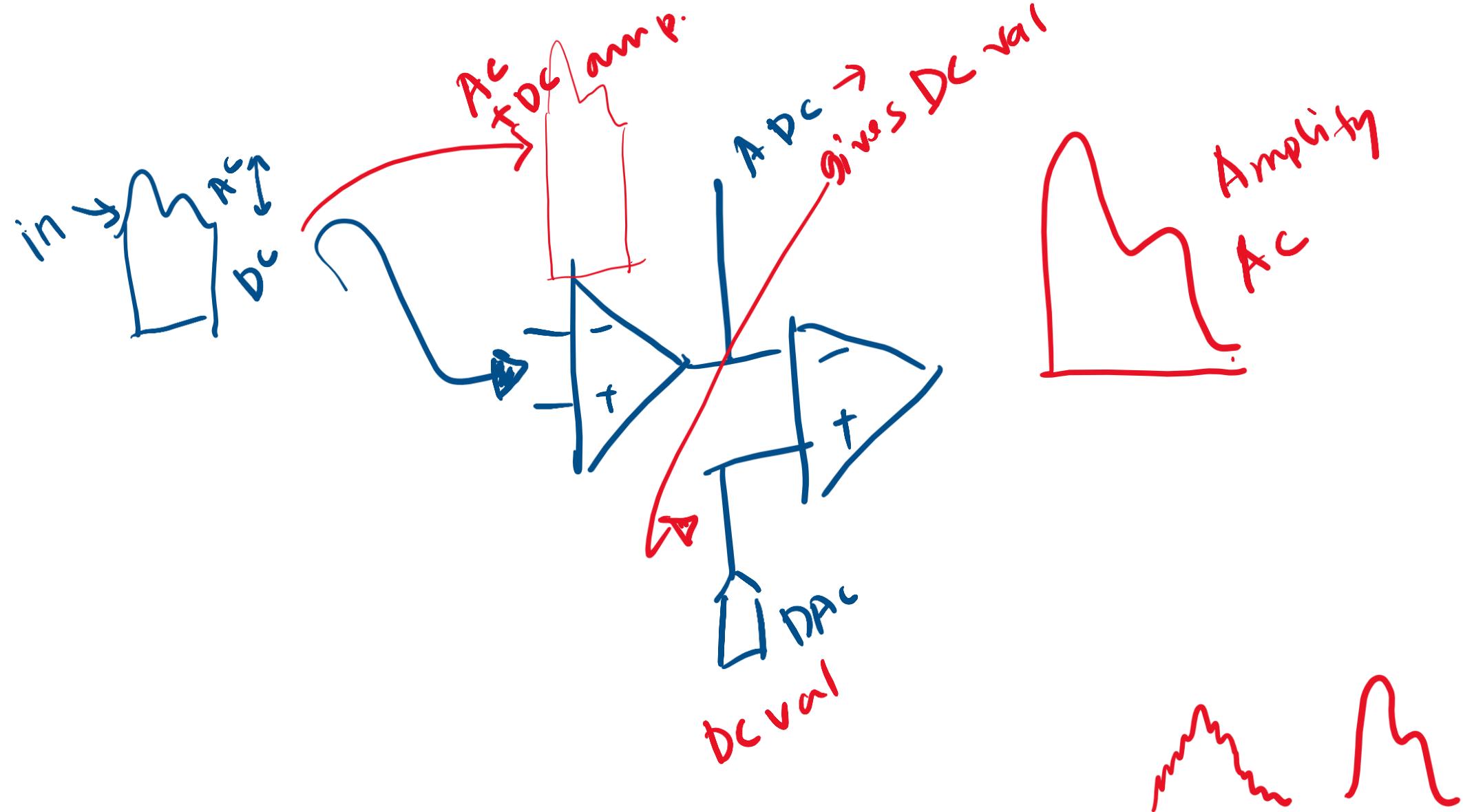
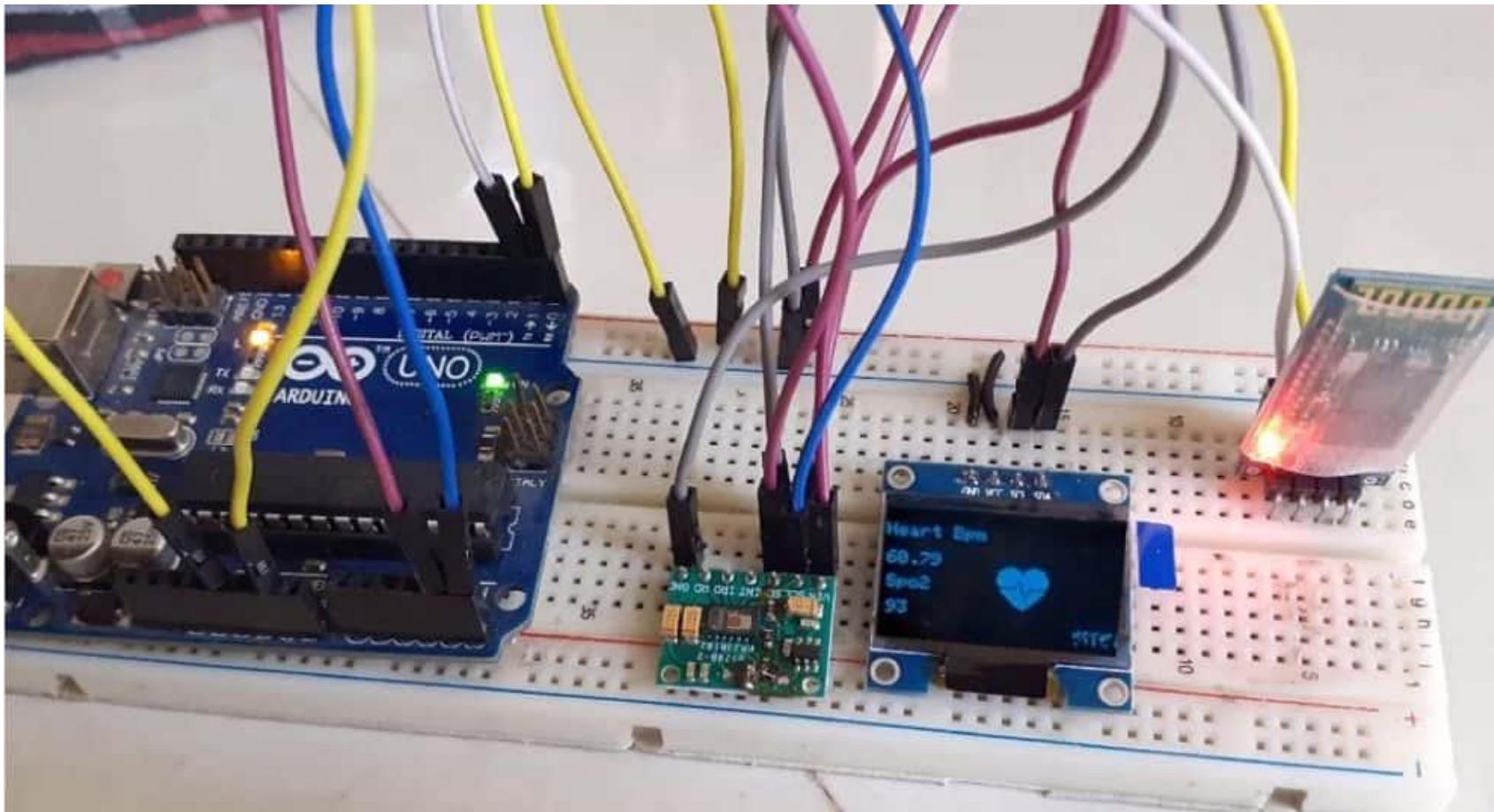


Figure 4.7 Calibration curves for pulse oximeters: the solid line is the theoretical curve by Beer's law and the dashed line is the empirical curve. The difference between these curves is due mainly to light scattering effects. This empirical calibration curve is derived by a second order polynomial.



Oximeter prototype



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 I²C-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

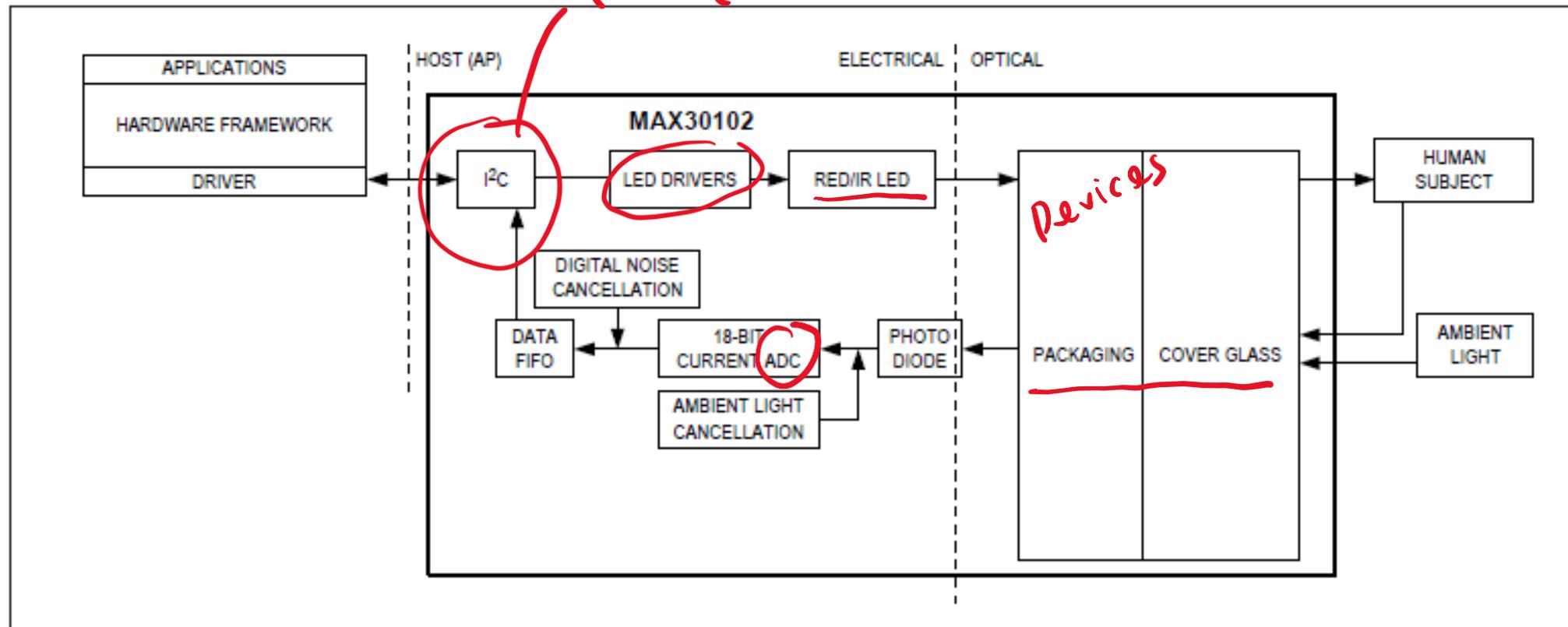
- Heart-Rate Monitor and Pulse Oximeter Sensor in LED Reflective Solution
- Tiny 5.6mm x 3.3mm x 1.55mm 14-Pin Optical Module
 - Integrated Cover Glass for Optimal, Robust Performance
- Ultra-Low Power Operation for Mobile Devices
 - Programmable Sample Rate and LED Current for Power Savings
 - Low-Power 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

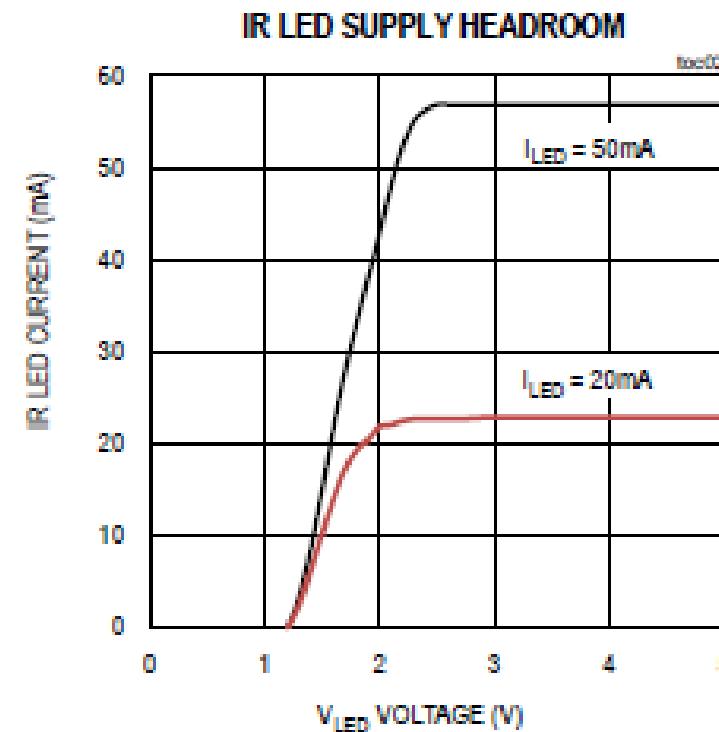
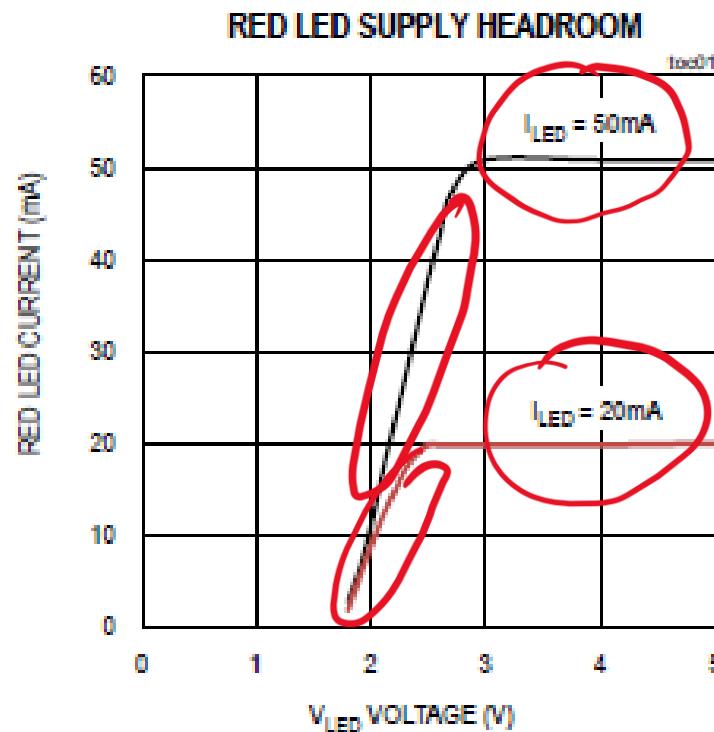
Ordering Information appears at end of data sheet.



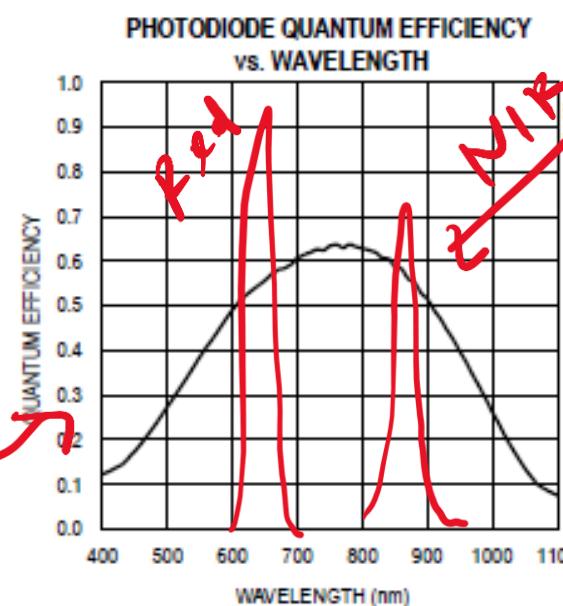
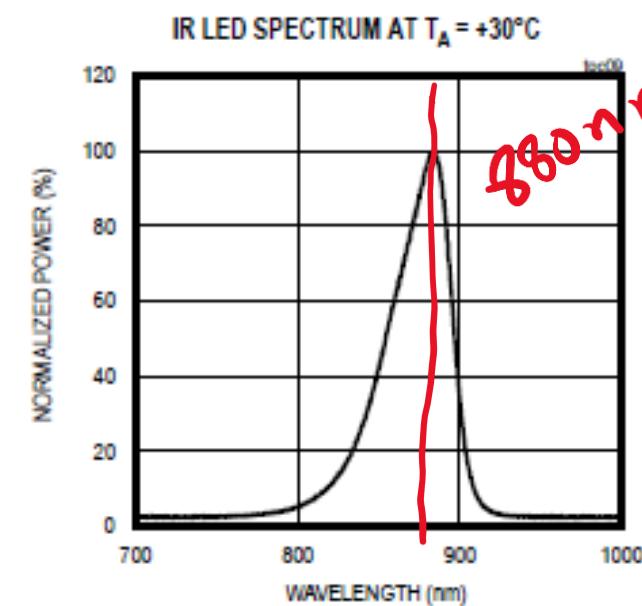
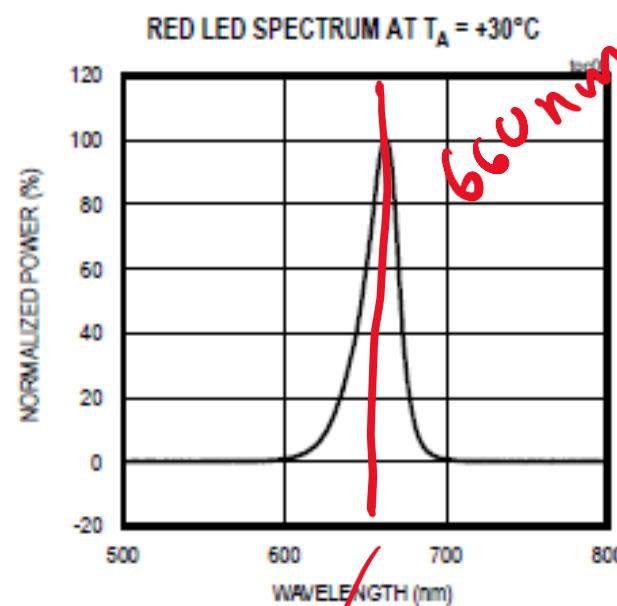
System design

System Diagram

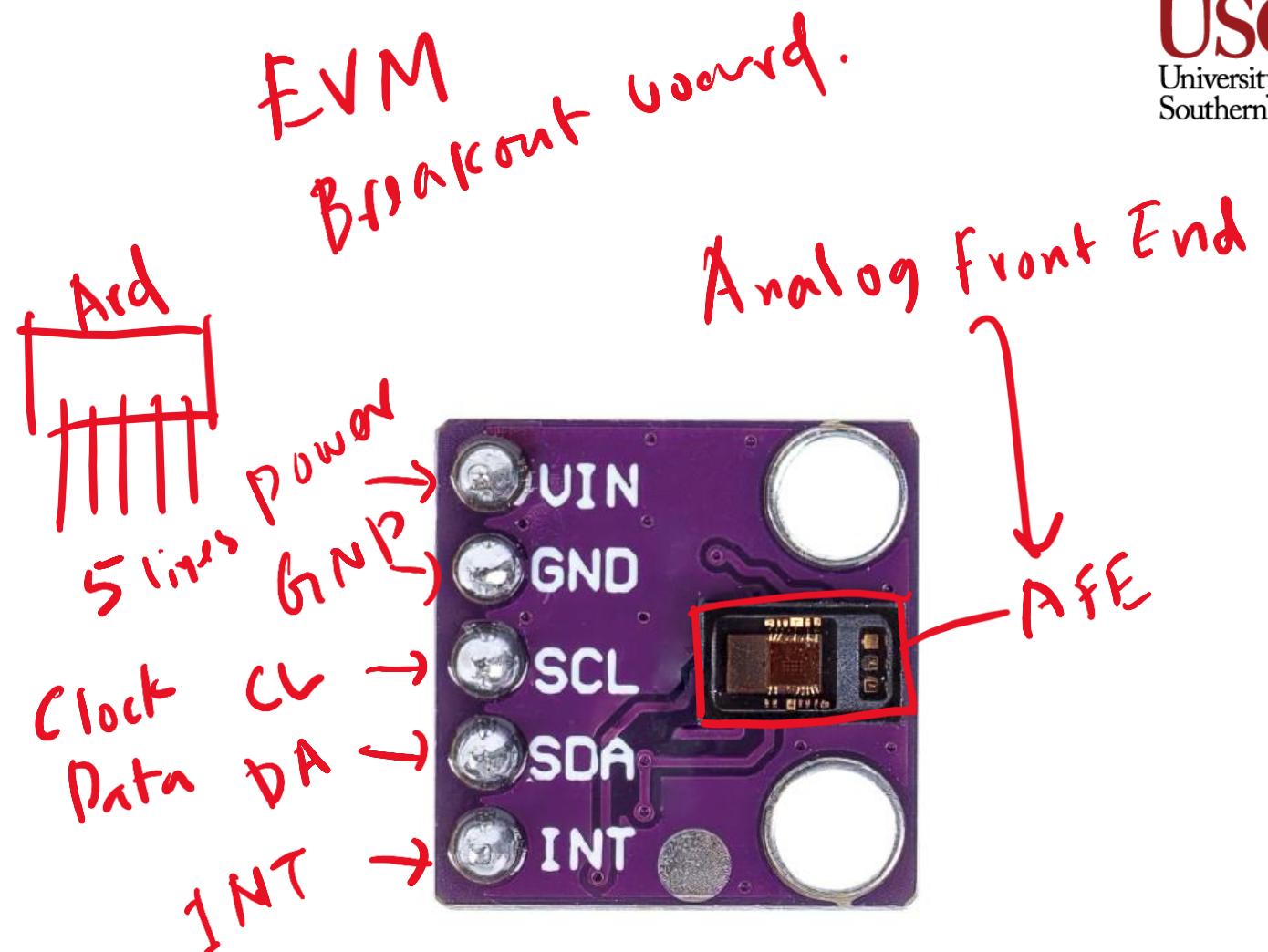
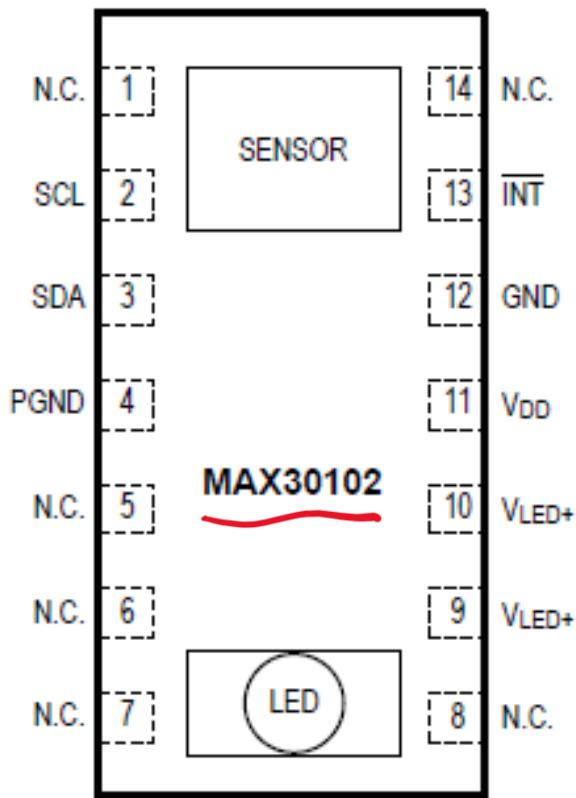




LED – PD spectrum



Connection



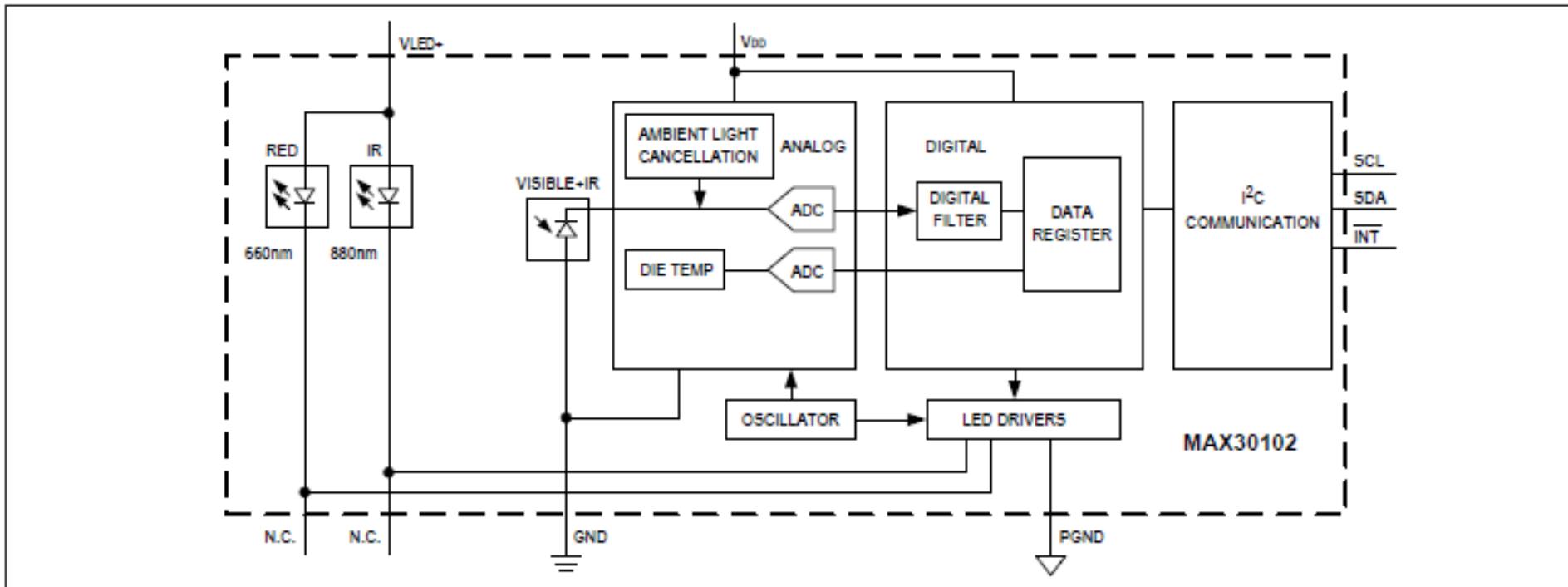
Pin Description

PIN	NAME	FUNCTION
1, 5, 6, 7, 8, 14	N.C.	No Connection. Connect to PCB pad for mechanical stability.
2	SCL	I ² C Clock Input
3	SDA	I ² C Data, Bidirectional (Open-Drain)
4	PGND	Power Ground of the LED Driver Blocks
9	V _{LED+}	LED Power Supply (anode connection). Use a bypass capacitor to PGND for best performance.
10	V _{LED+}	
11	V _{dd}	Analog Power Supply Input. Use a bypass capacitor to GND for best performance.
12	GND	Analog Ground
13	INT	Active-Low Interrupt (Open-Drain). Connect to an external voltage with a pullup resistor.



How does the AFE work

Functional Diagram



Timing in SpO₂ Mode

The internal FIFO stores up to 32 samples, so that the system processor does not need to read the data after every sample. The temperature does not need to be sampled very often—once a second or every few seconds should be sufficient.

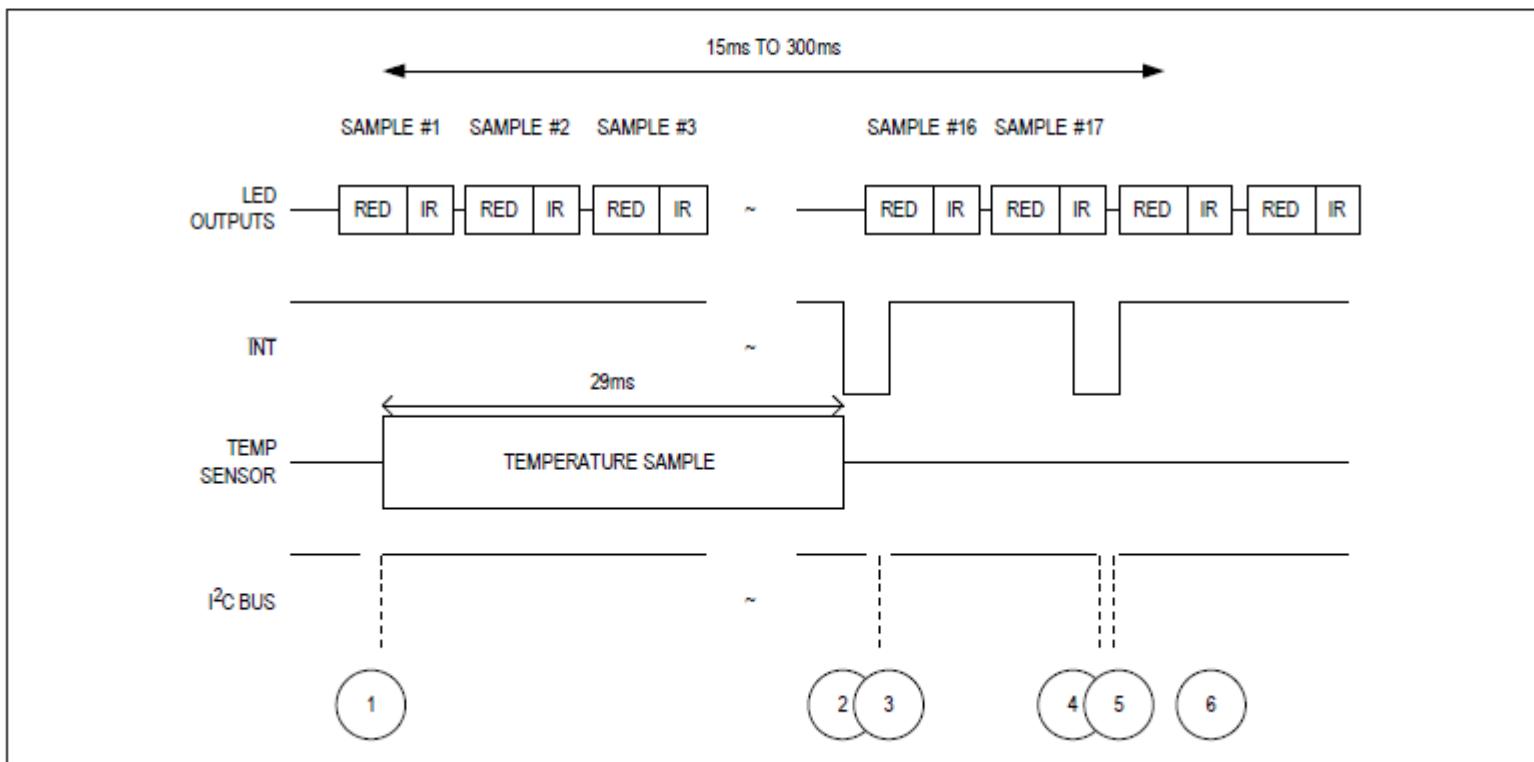


Figure 4. Timing for Data Acquisition and Communication When in SpO₂ Mode

Data capture

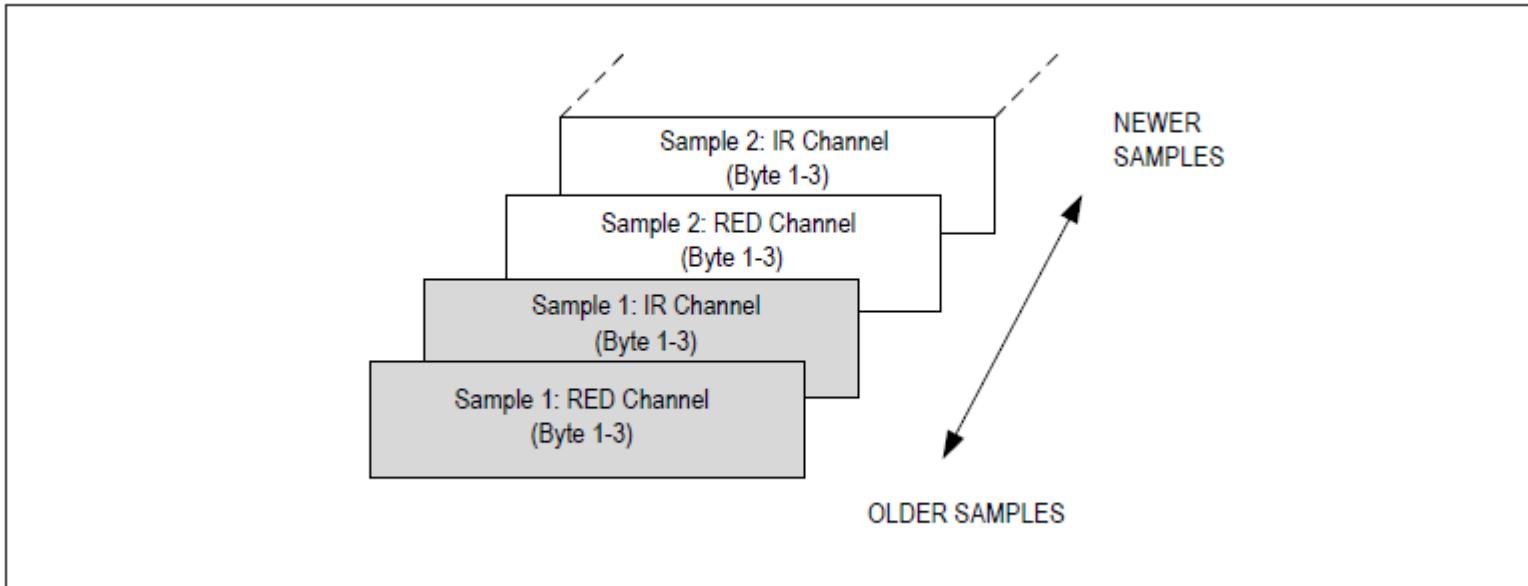


Figure 2. Graphical Representation of the FIFO Data Register. It shows IR and Red in SpO₂ Mode.

Bits 4:2: SpO₂ Sample Rate Control

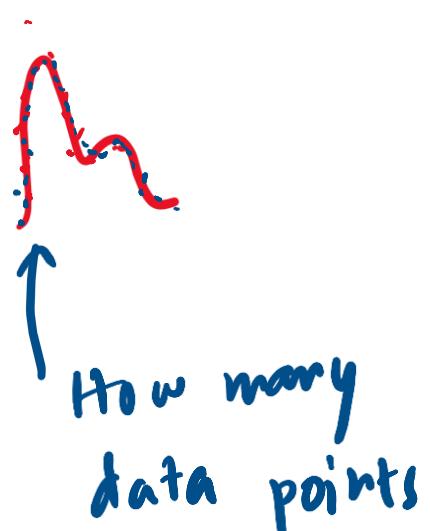
These bits define the effective sampling rate with one sample consisting of one IR pulse/conversion and one Red pulse/conversion.

The sample rate and pulse width are related in that the sample rate sets an upper bound on the pulse width time. If the user selects a sample rate that is too high for the selected LED_PW setting, the highest possible sample rate is programmed instead into the register.

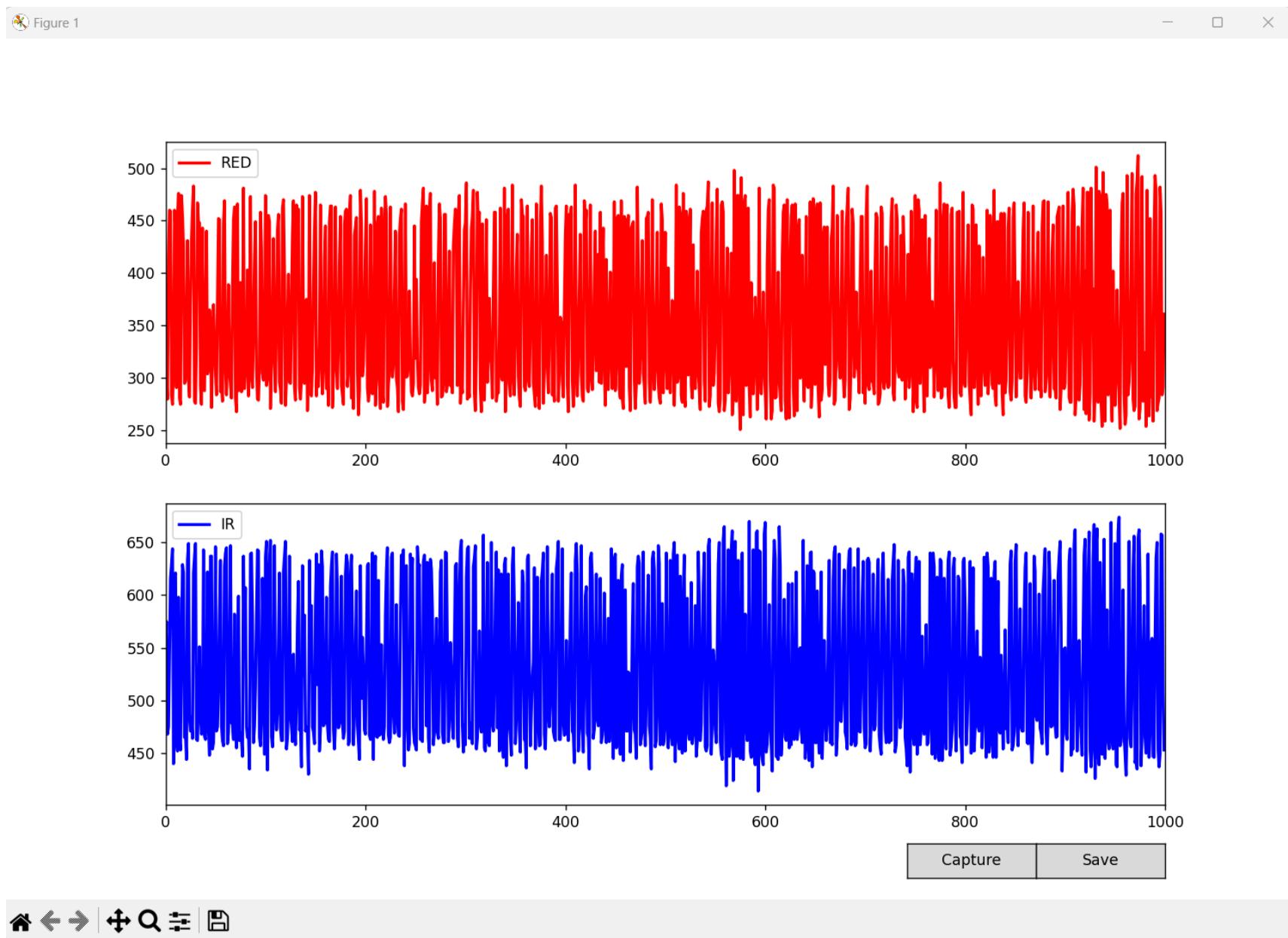
Table 6. SpO₂ Sample Rate Control

SPO ₂ _SR[2:0]	SAMPLES PER SECOND
000	50
001	100
010	200
011	400
100	800
101	1000
110	1600
111	3200

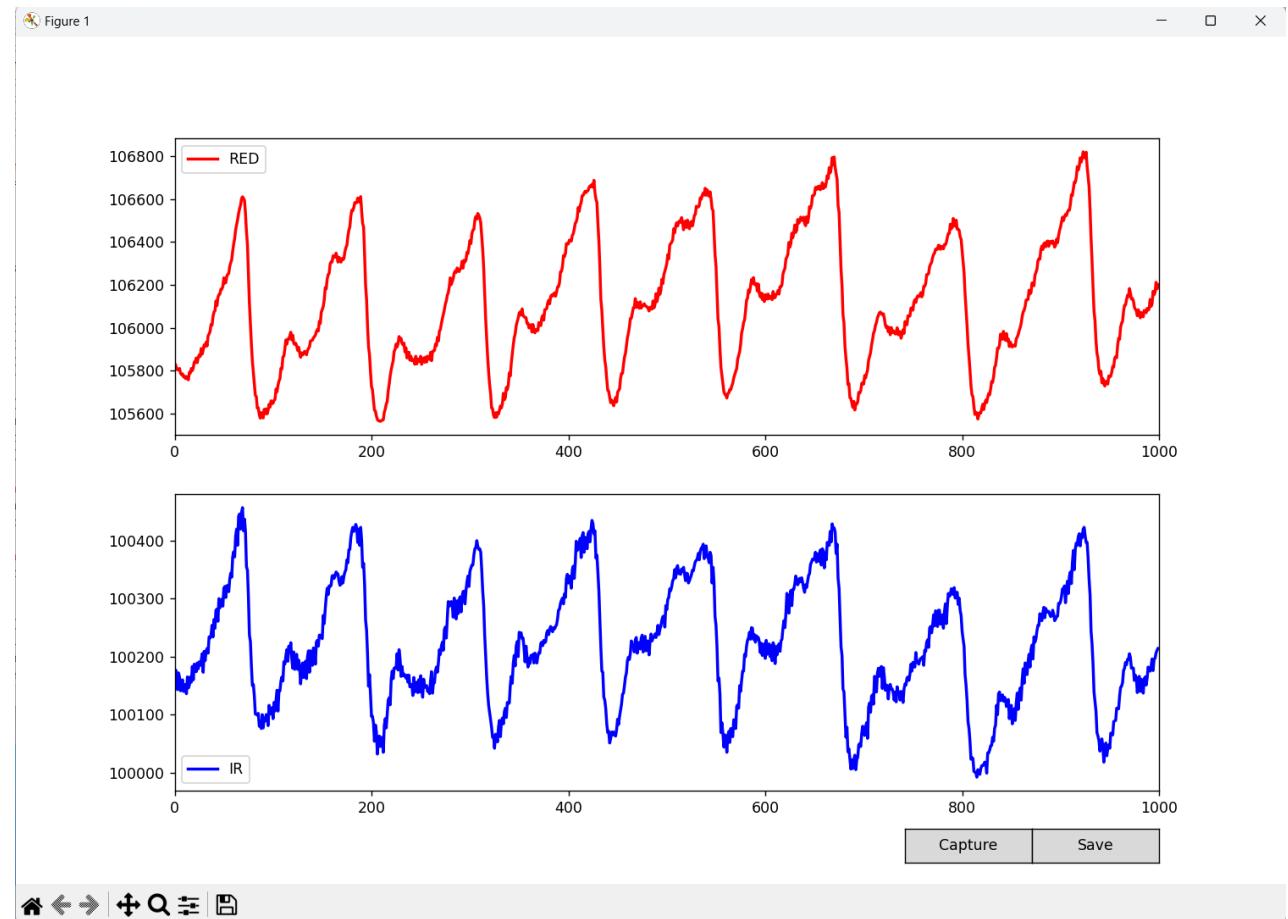
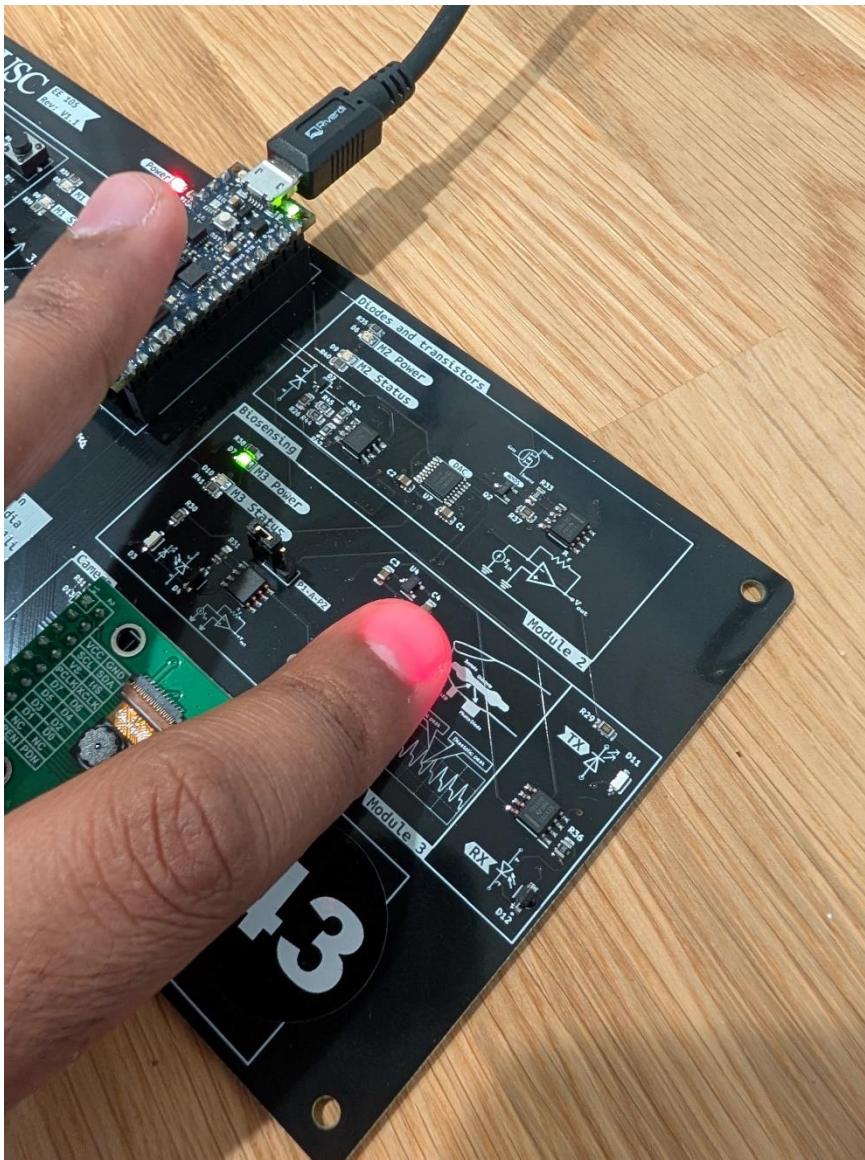
See Table 11 and Table 12 for Pulse Width vs. Sample Rate information.



Press capture

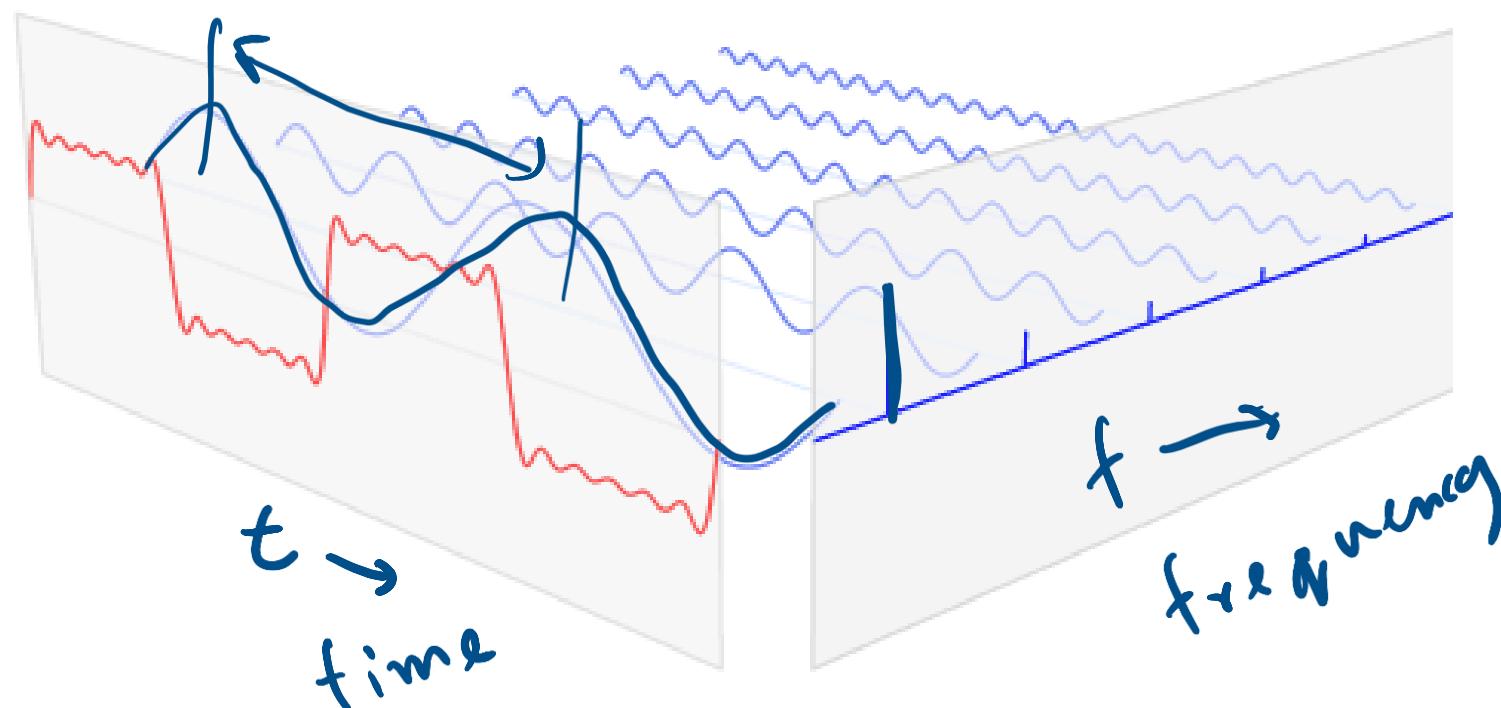


Keep your finger gently on the sensor



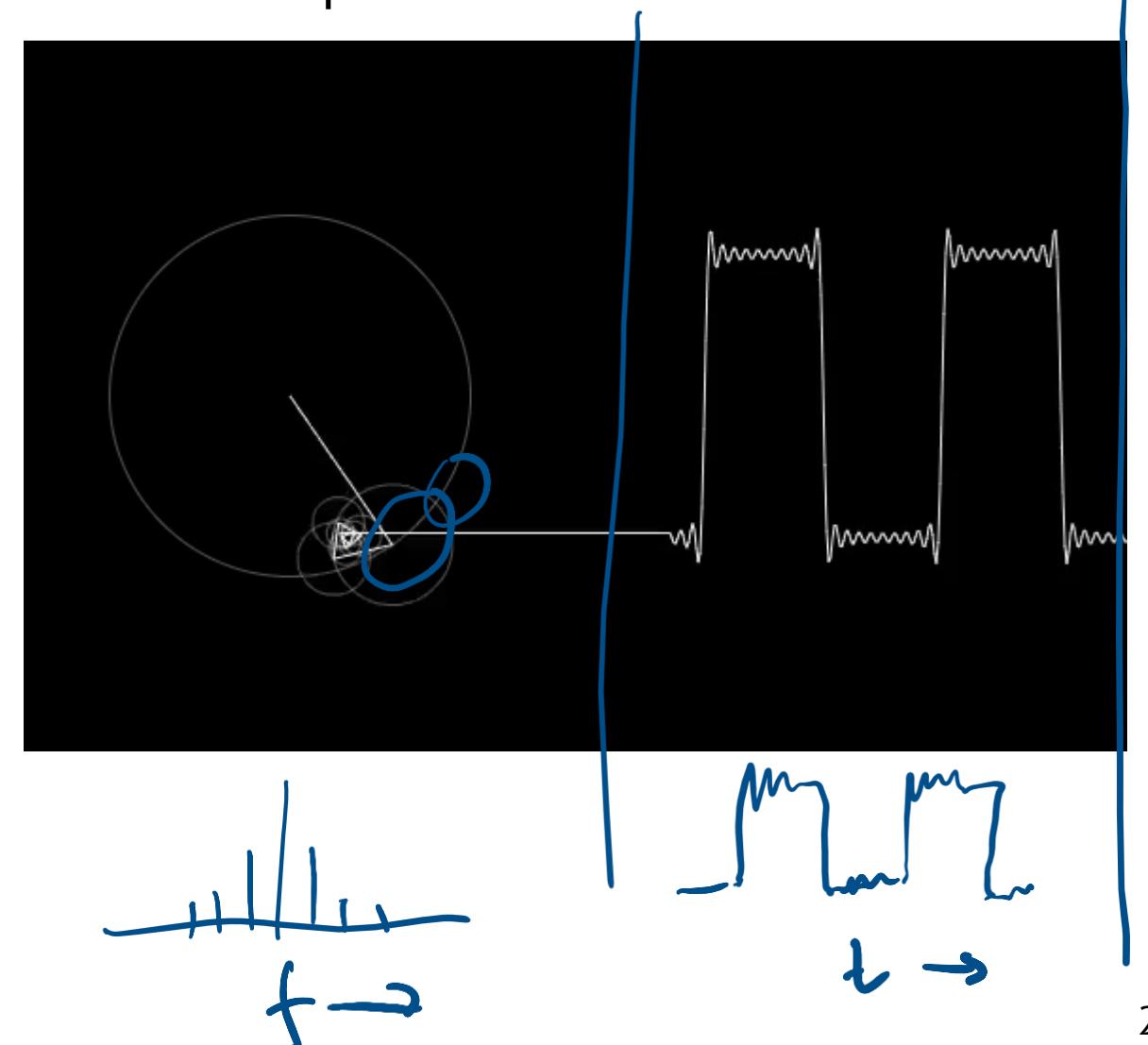
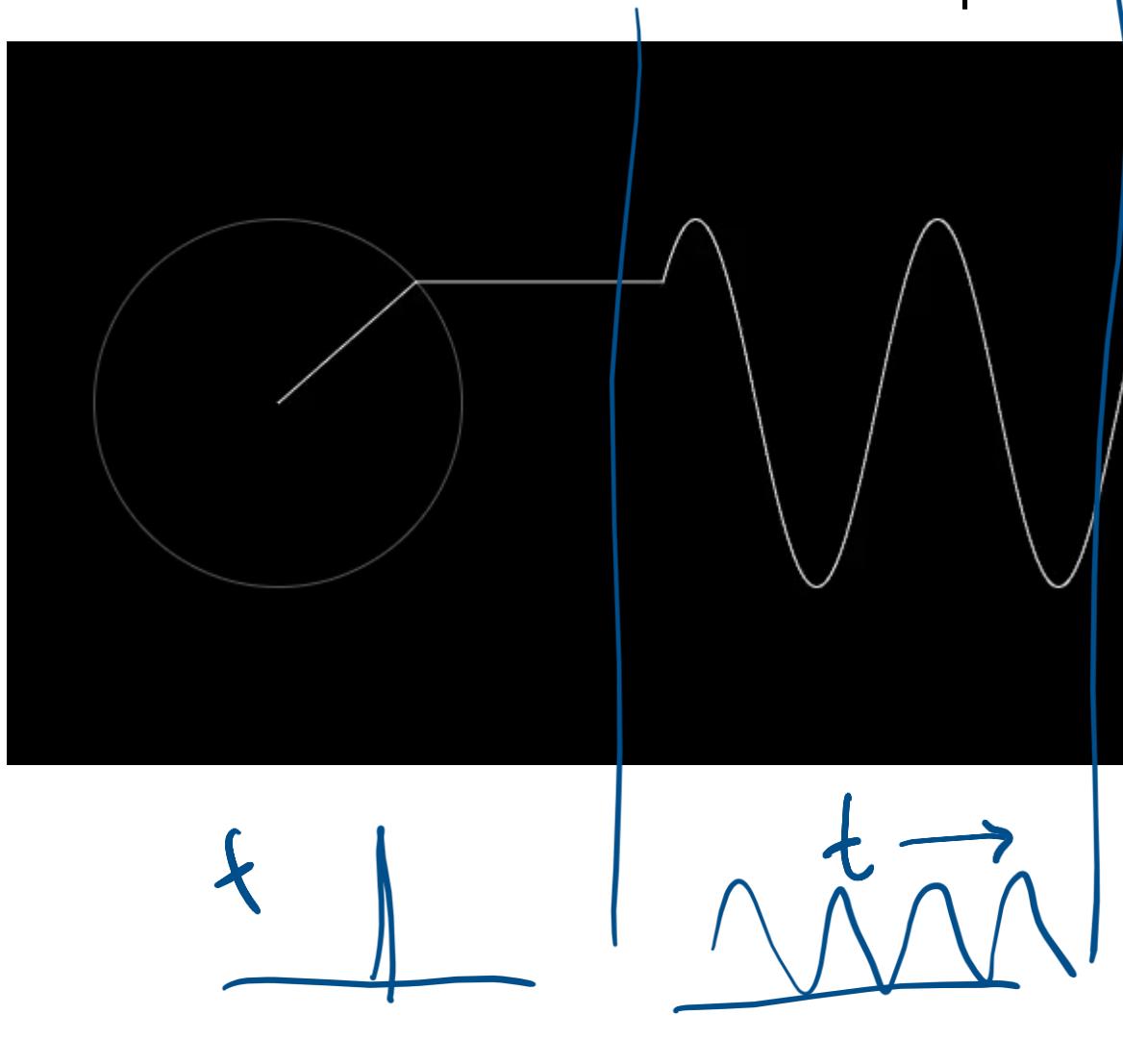
Time domain to frequency domain

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

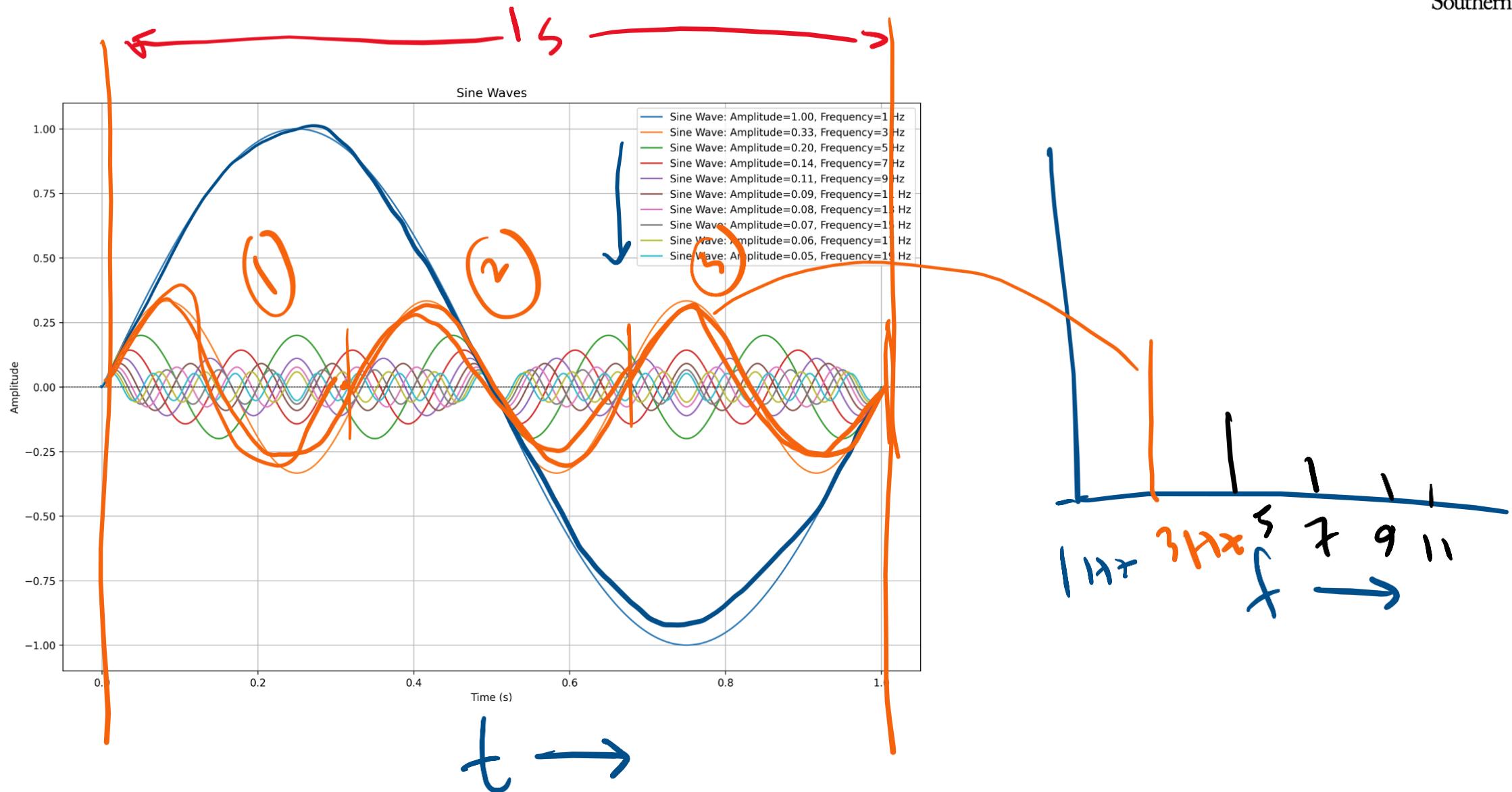


Time domain to frequency domain

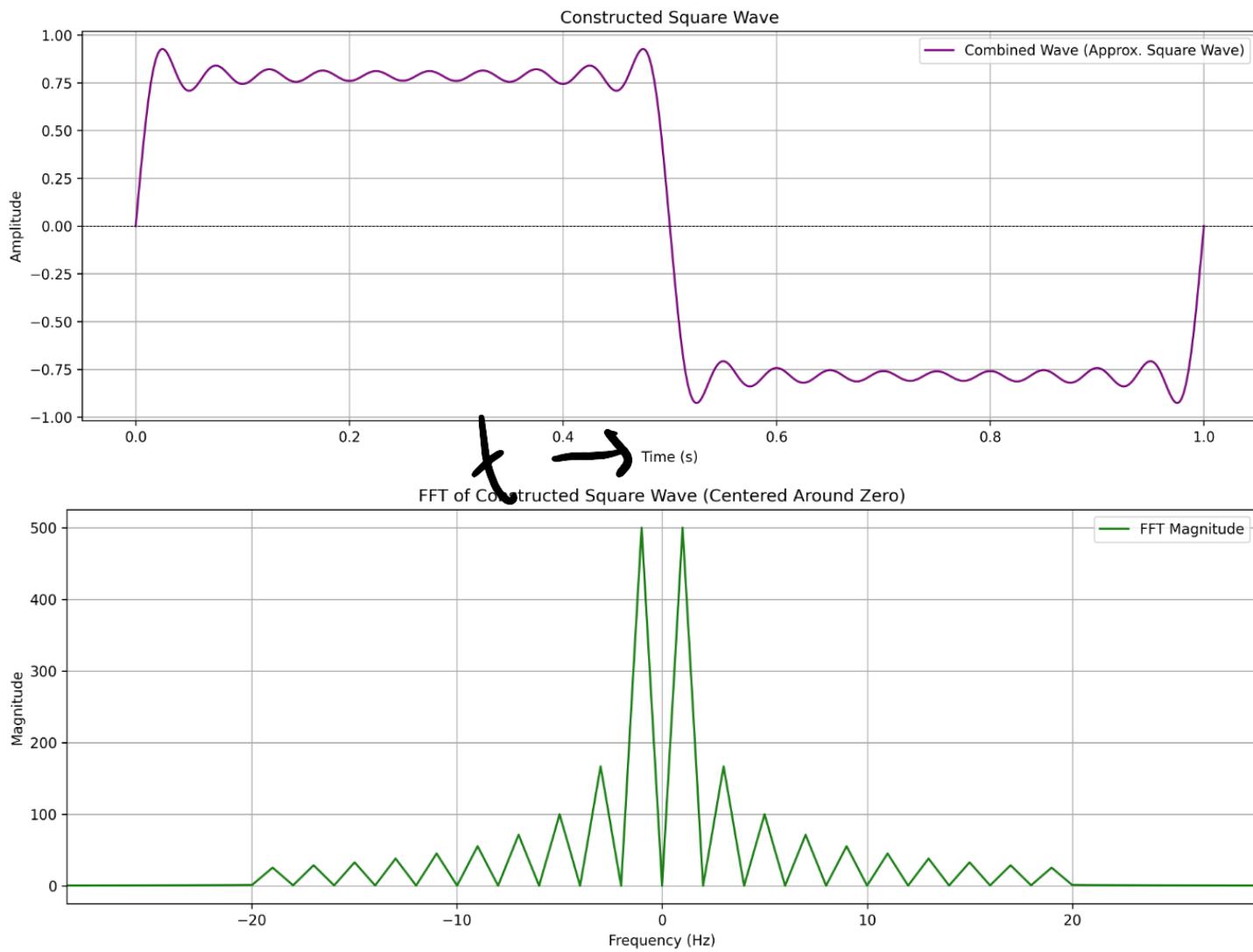
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Time domain to frequency domain

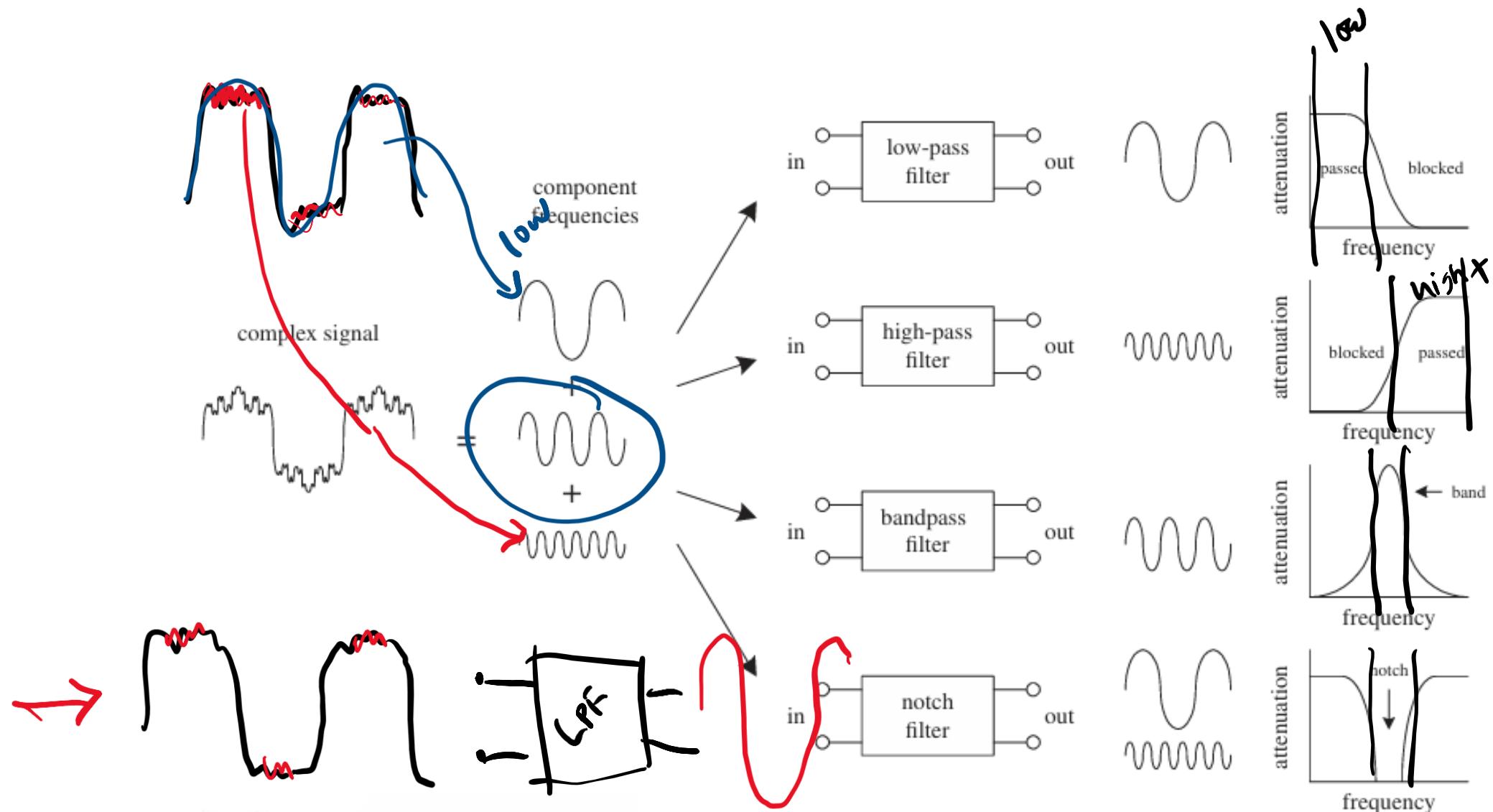


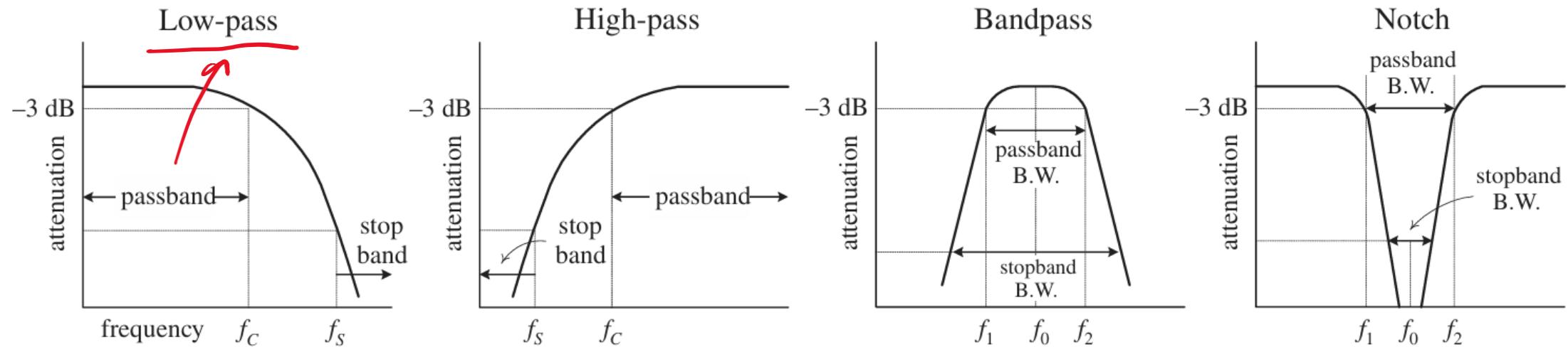
What makes a square wave



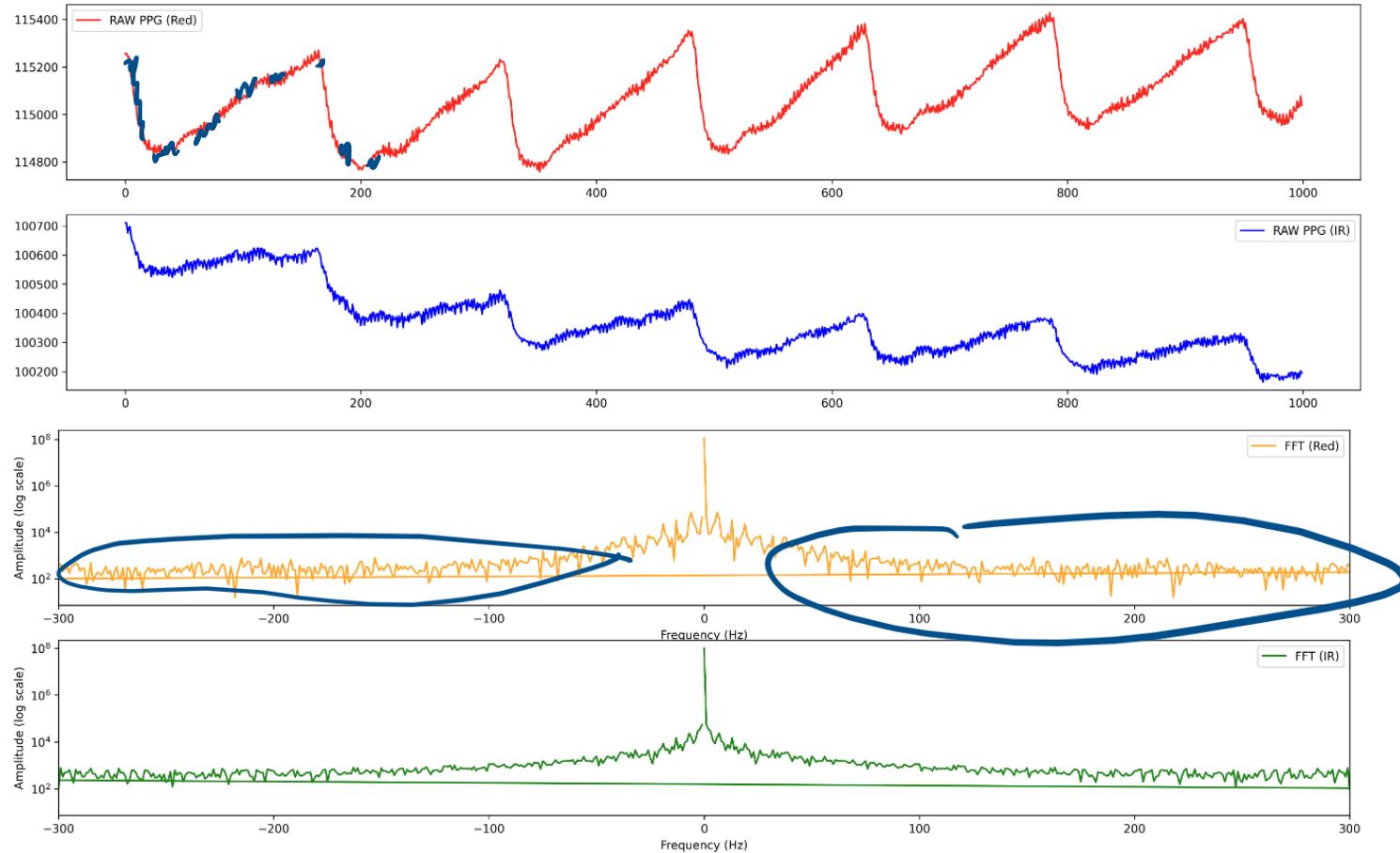
f →

Filters



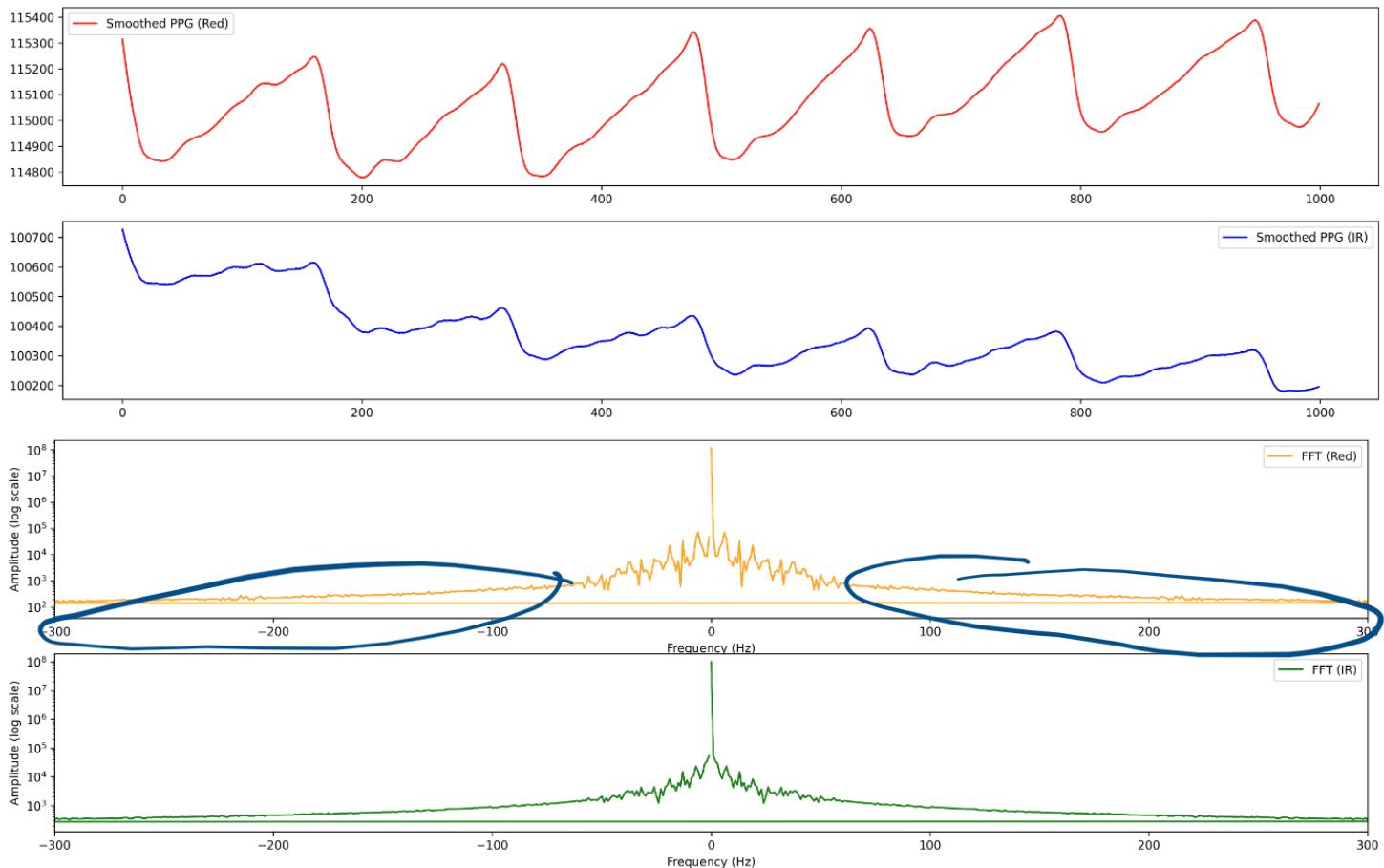


Going back to the PPG data collected

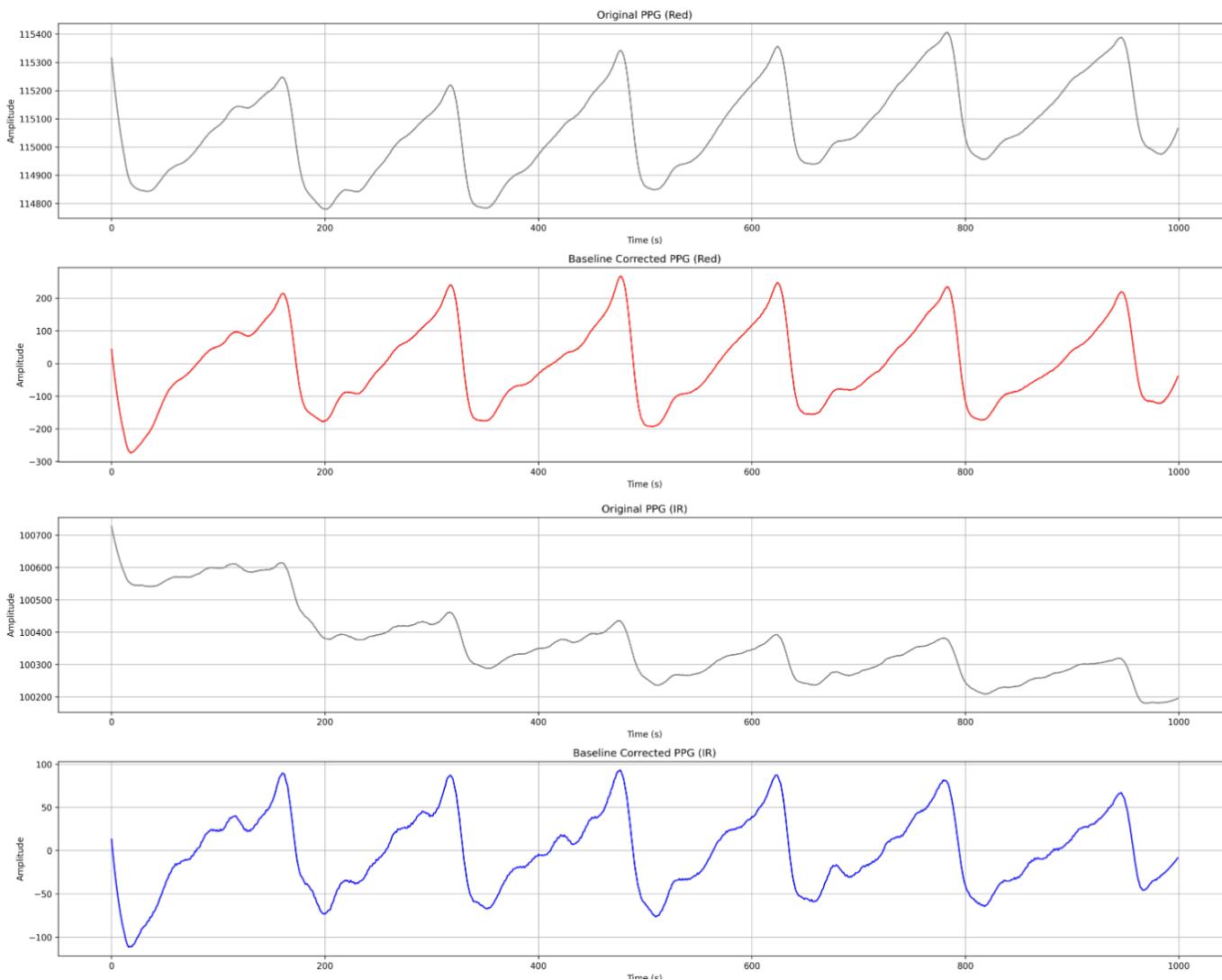


Smoothing

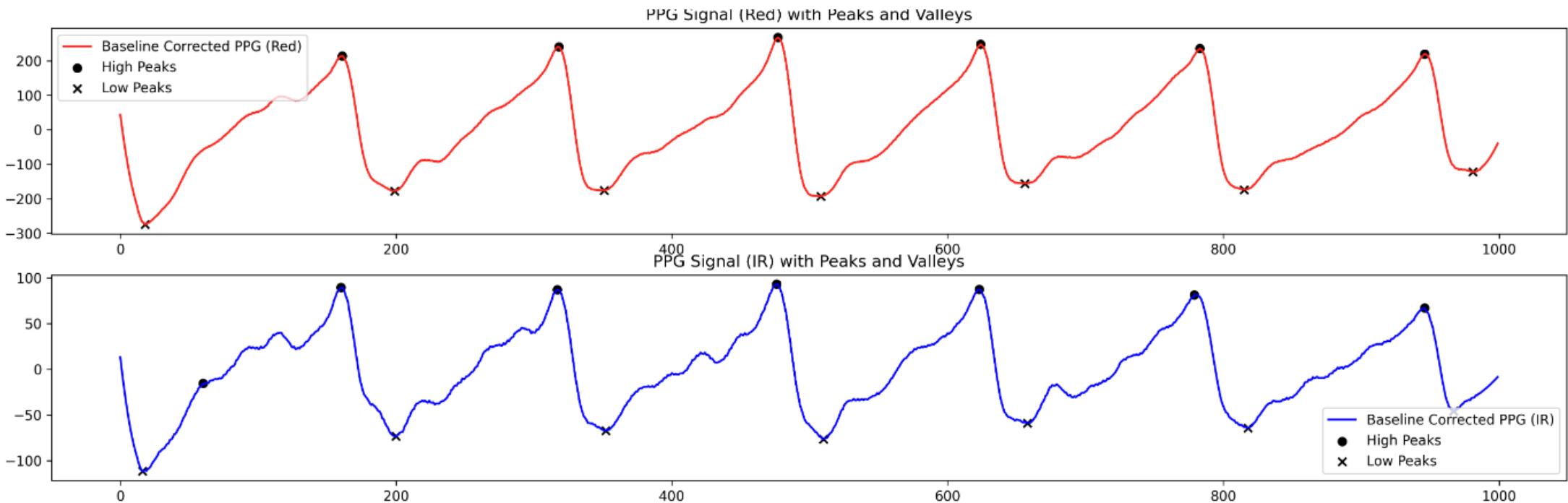
Gets rid of
high freq noise



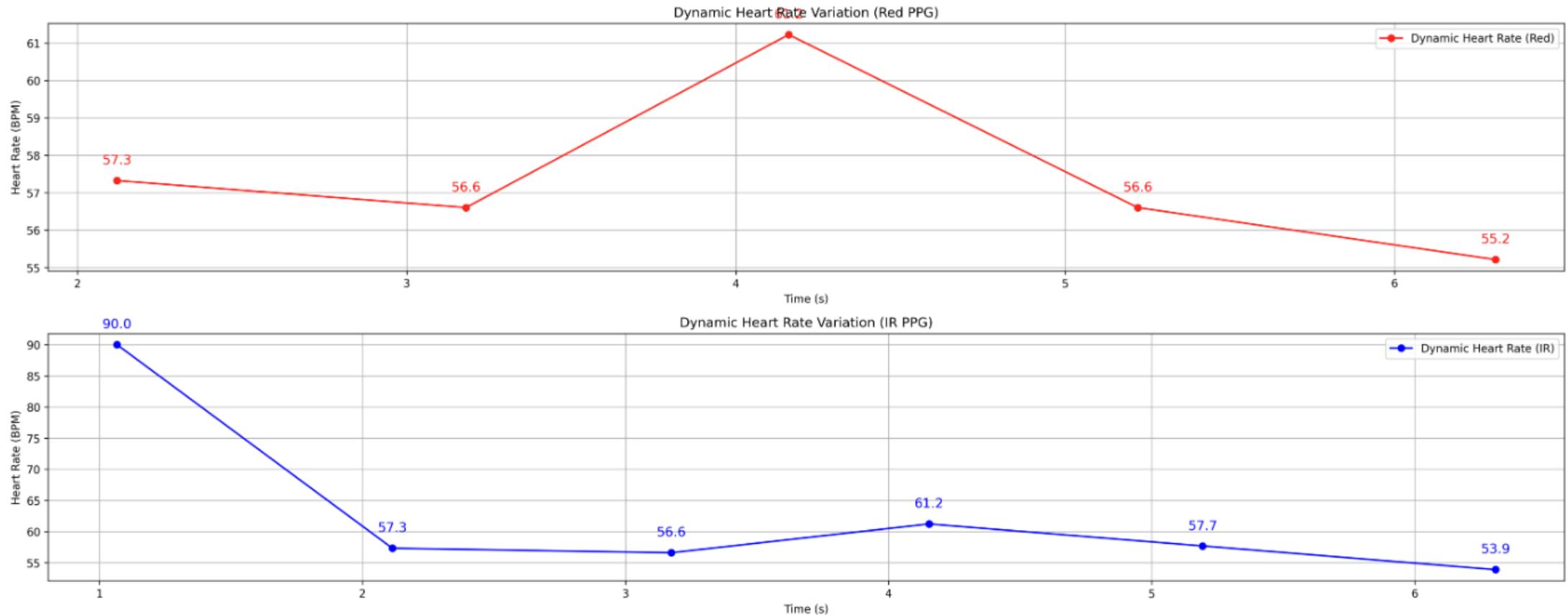
Drift correction



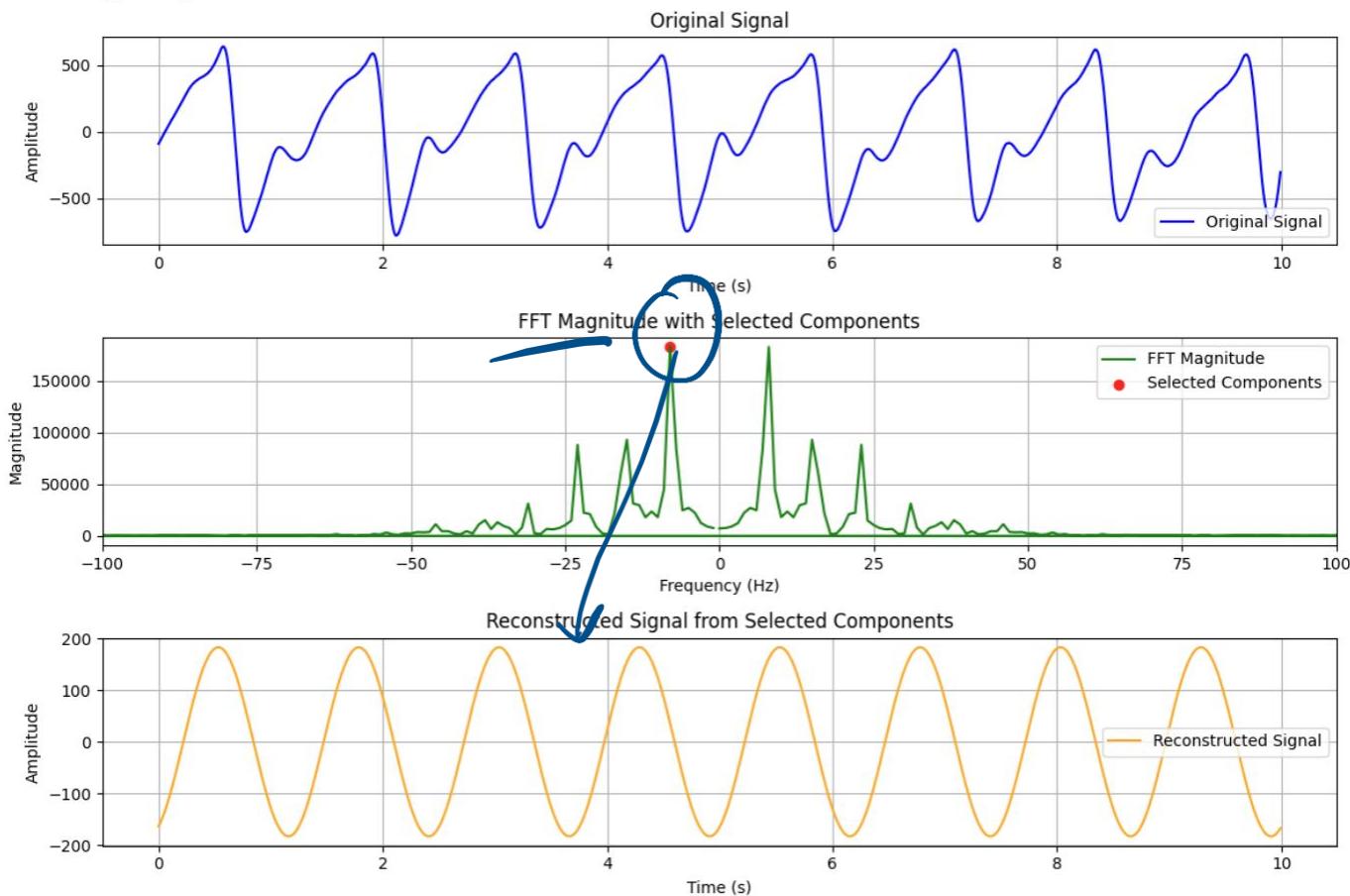
Peak detection



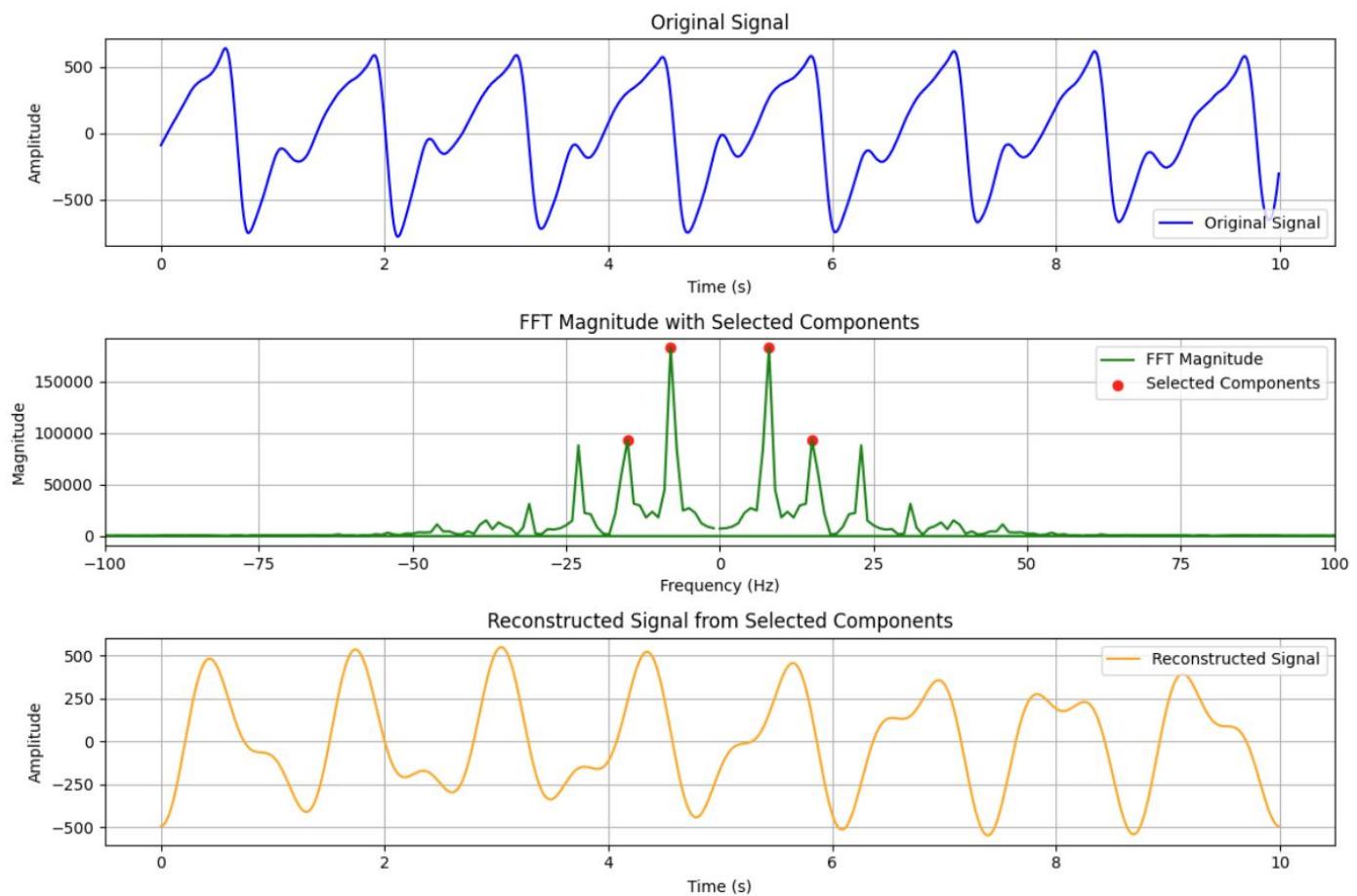
Heart rate



Using single component to find heart rate



4 components in the PPG signal – signal loss



Taking all the components provides the original signal

