



BOX

HeartBox

A Vital Sign Monitoring Device for Developing Countries

*Amit Deliwala, Greg Chan, Sourabh Marathe,
Everett O'Malley, Tom Hoang, Rashid Khamis*

Advisor: Prof. Masoud Salehi

Motivation

Anesthesia monitoring during surgery has been a standard of care in the developed world. By providing high quality monitoring equipment for a low cost, millions of lives can be saved each year.

Our goal is to develop an inexpensive product that provides surgeons in developing nations with crucial metrics needed for successful operations.

Death Rate due to Anesthesia

United States: 1 in 100,000



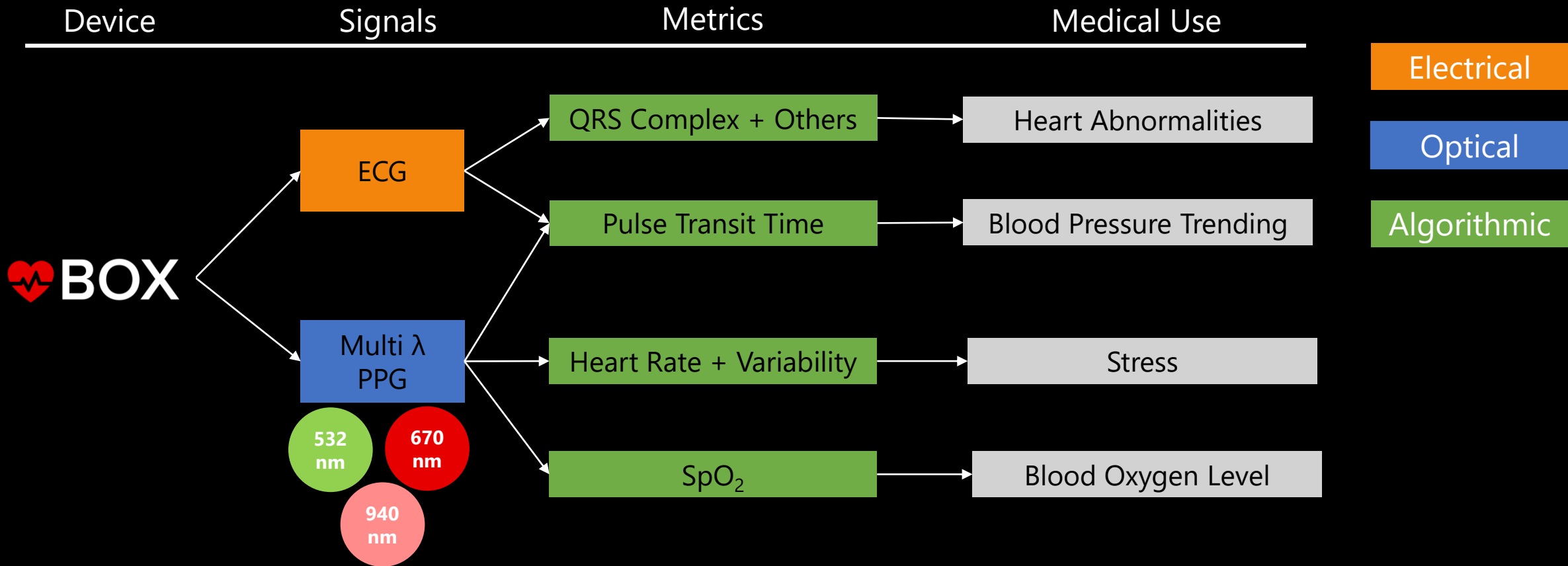
Zambia: 1 in 1900



Togo: 1 in 150



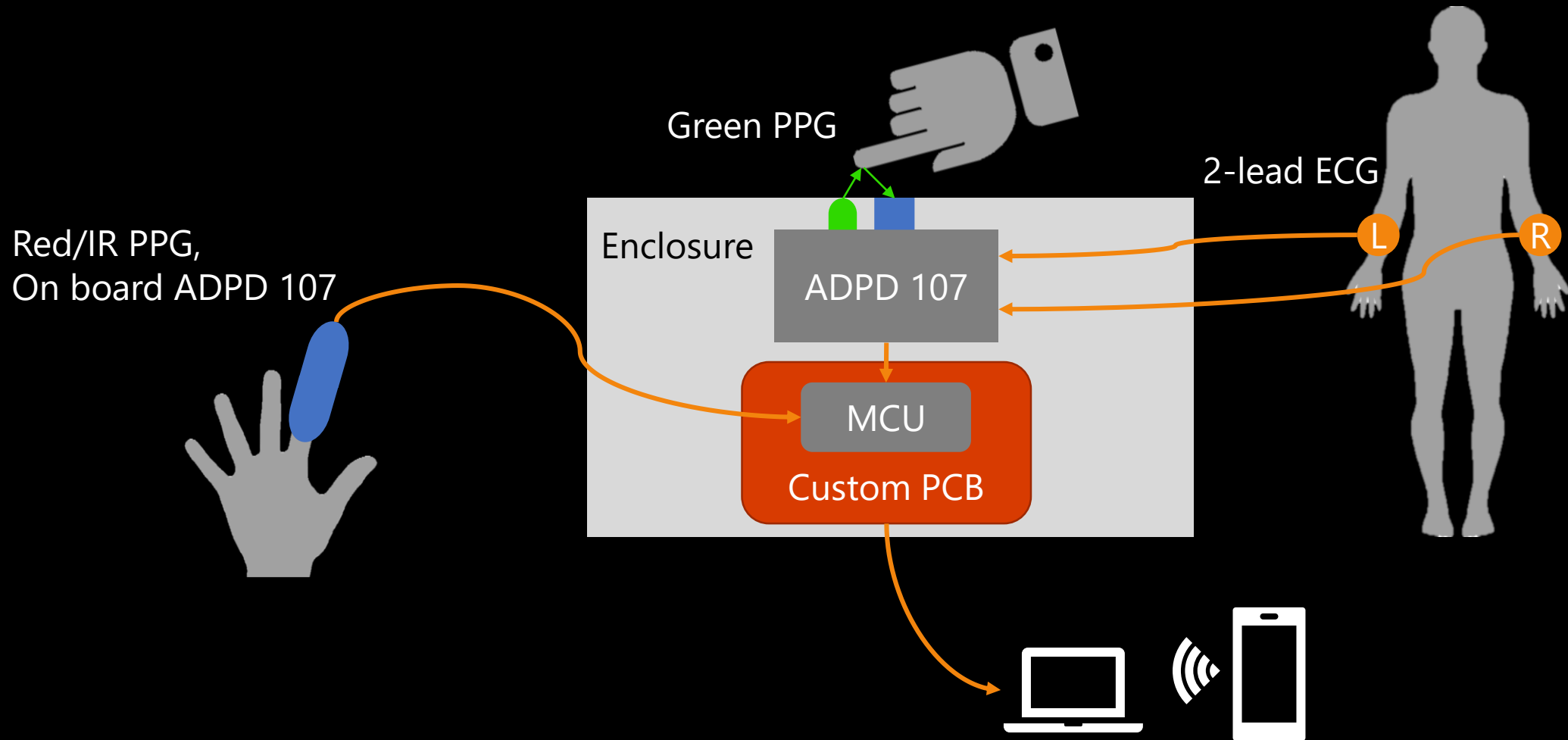
Our Solution



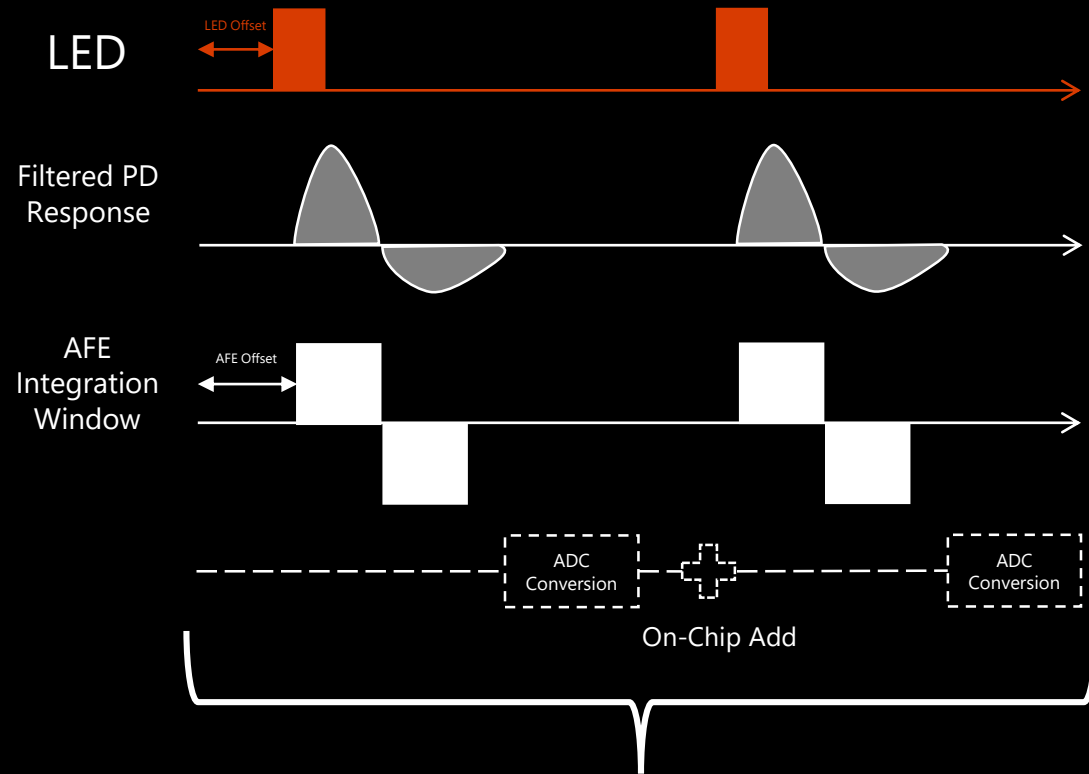
High Volume: < \$15



System Overview



Analog Measurement Methodology



Single sample, N pulses

Analog Devices ADPD107

Fully integrated AFE, ADC, LED drivers, and timing core

Used as complete optical transceiver

Tunable Band-Pass filter for ambient light rejection

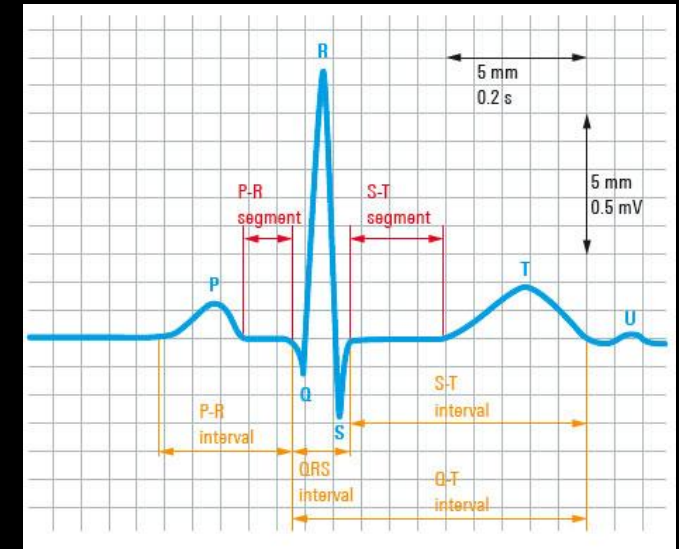
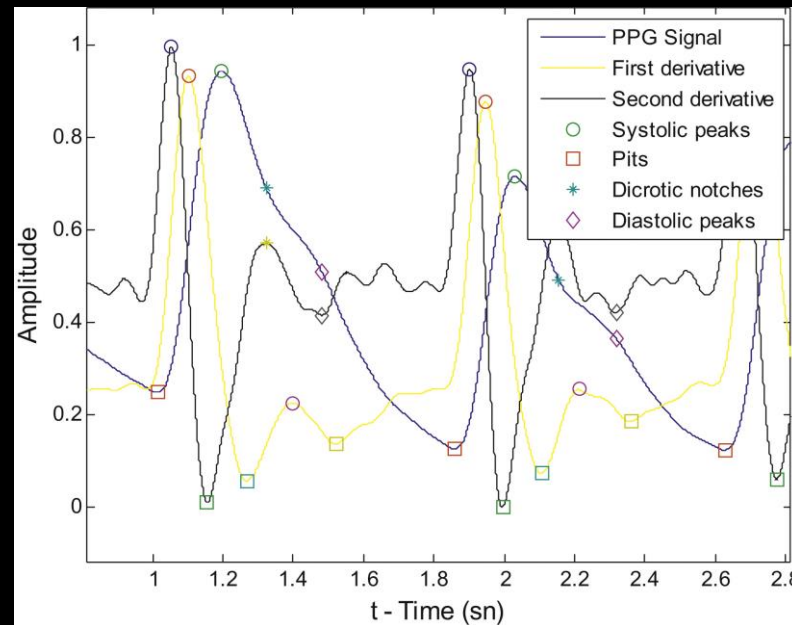
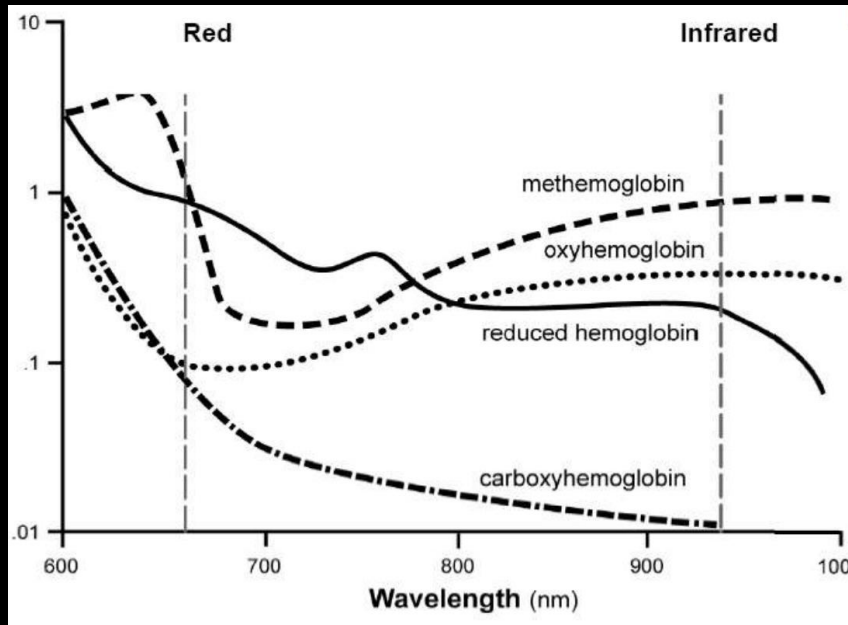


Pulse Oximetry and ECG

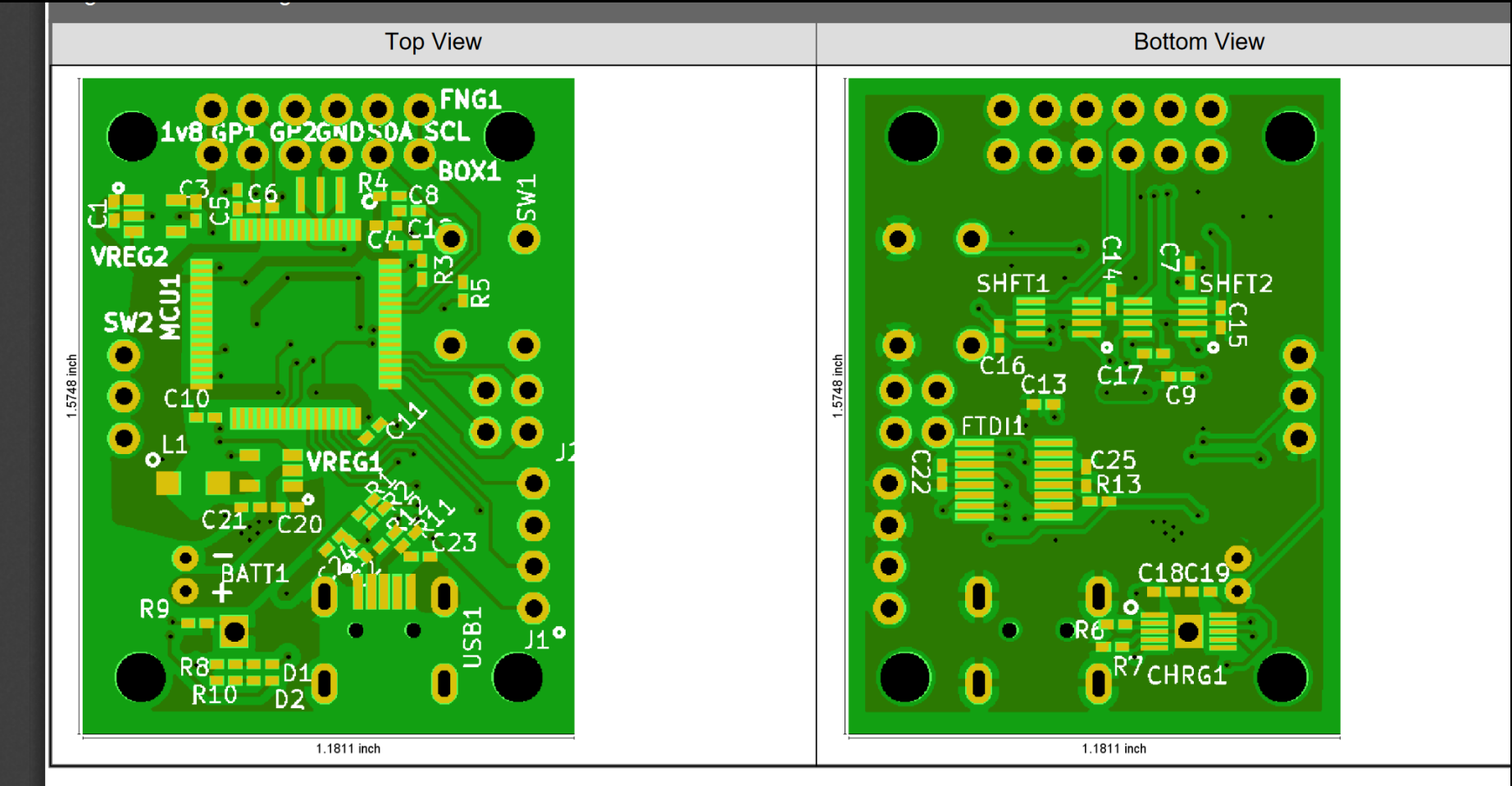
PPG: Absorption of light by human body at certain wavelengths

ECG: Electrical activity of depolarization and repolarization of heart

SpO₂: Correlated to the ratio of red PPG and infrared PPG



Custom PCB



Embedded System Design

Microcontroller: STM32F407

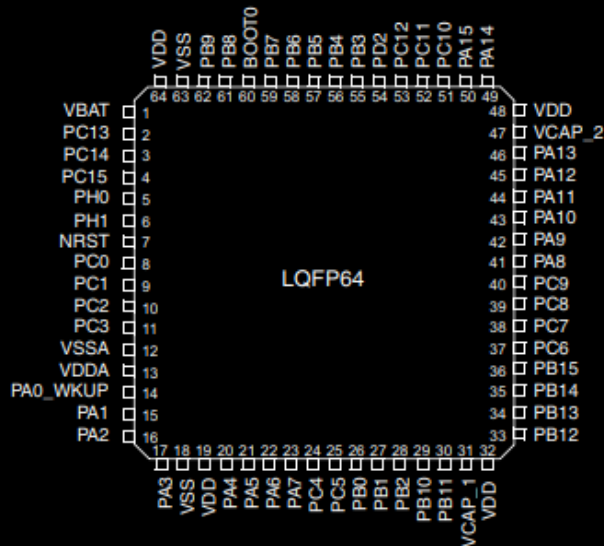
Samples data from two ADPD 107s over I²C

- Reads data from FIFO on part

Communication to display device via UART

- Specified packet format for data

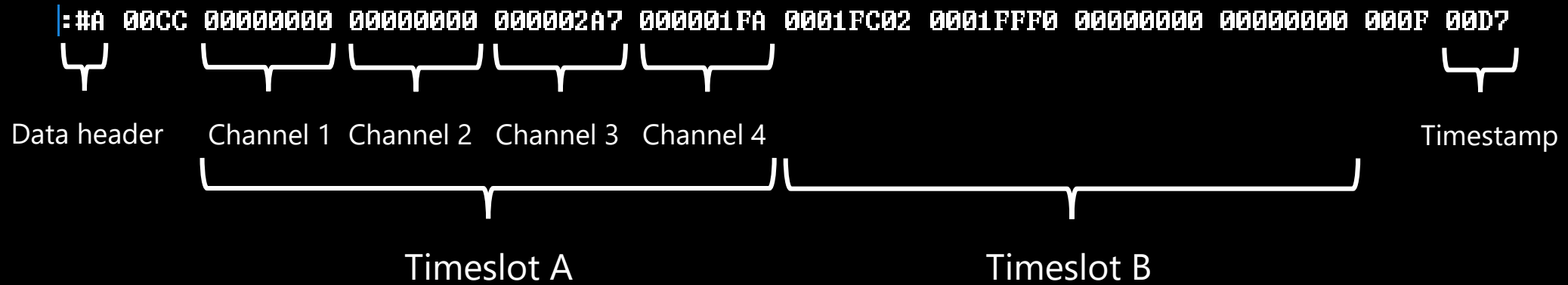
Ability to read/write registers of ADPD 107 parts for configuration



```
Config:, 0xC , 0xF
Config:, 0xD , 0x0
Config:, 0x10 , 0x1
Config:, 0x11 , 0x1931
Config:, 0x4F , 0x2090
Config:, 0x50 , 0x0
Config:, 0x51 , 0x0
Config:, 0x52 , 0x40
Config:, 0x53 , 0xE400
Config:, 0x57 , 0x0
Config:, 0x5F , 0x0
Config:, 0x16 , 0x8080
Config:, 0x17 , 0x8080
Config:, 0x1C , 0x8080
Config:, 0x1D , 0x8080
Config:, 0x12 , 0xA0
Config:, 0x15 , 0x0
Config:, 0x14 , 0x455
Config:, 0x18 , 0x1FC0
Config:, 0x19 , 0x1FC0
Config:, 0x1A , 0x1FC0
Config:, 0x1B , 0x1FC0
Config:, 0x30 , 0x220
Config:, 0x31 , 0x813
Config:, 0x39 , 0x1B00
Config:, 0x42 , 0x1C35
Config:, 0x43 , 0xADA5
Config:, 0x5E , 0x6808
Config:, 0x5B , 0x0
Config:, 0x1E , 0x1FC0
Config:, 0x1F , 0x1FC0
Config:, 0x20 , 0x1FC0
Config:, 0x21 , 0x1FC0
Config:, 0x35 , 0x220
Config:, 0x36 , 0x813
Config:, 0x3B , 0x1B00
Config:, 0x44 , 0x1C35
Config:, 0x45 , 0xADA5
Config:, 0x59 , 0x6808
Config:, 0x5D , 0x0
Config:, 0x58 , 0x0
```



UART Packet Example

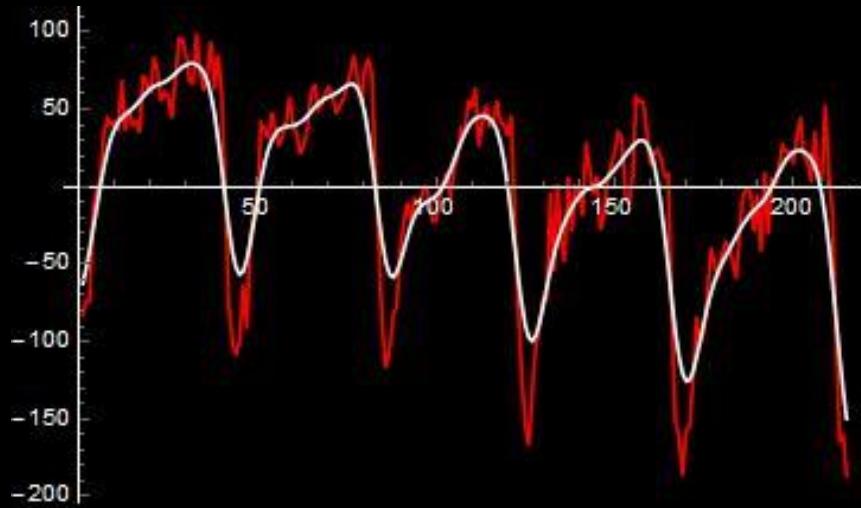


Packet format configurable for different data sizes and meaning



DSP

Low Pass Filtering of PPG Data

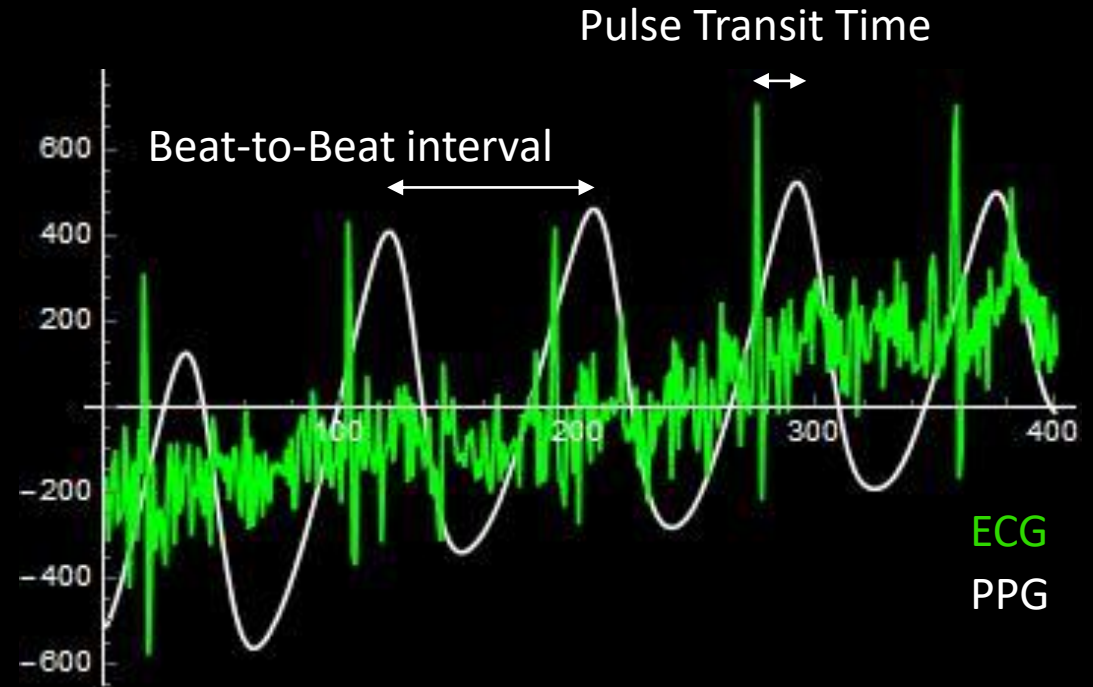


$$SpO_2 = \frac{\frac{AC_R}{DC_R}}{\frac{AC_{IR}}{DC_{IR}}}$$

AC amplitude estimation via $\left| \widetilde{\frac{d}{dt} f(t)} \right|$

Calibration to blood oxygen via commercial SpO_2 meter

Heart Rate Variability is used to measure stress



Pulse Transit Time can be used measure blood pressure trends

Pulse peaks are measured using zero crossings of $\frac{d}{dt} f(t)$

$$HRV = \sigma\{\widetilde{BB}\}$$



Performance

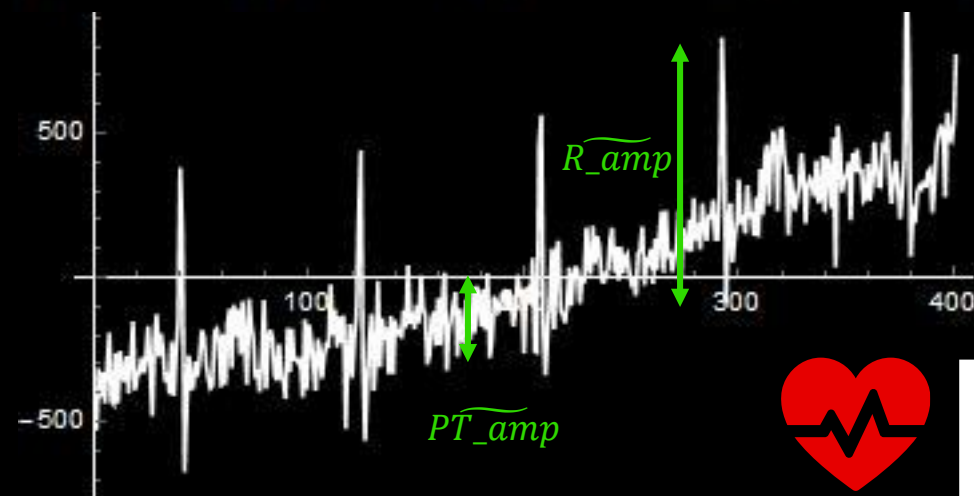
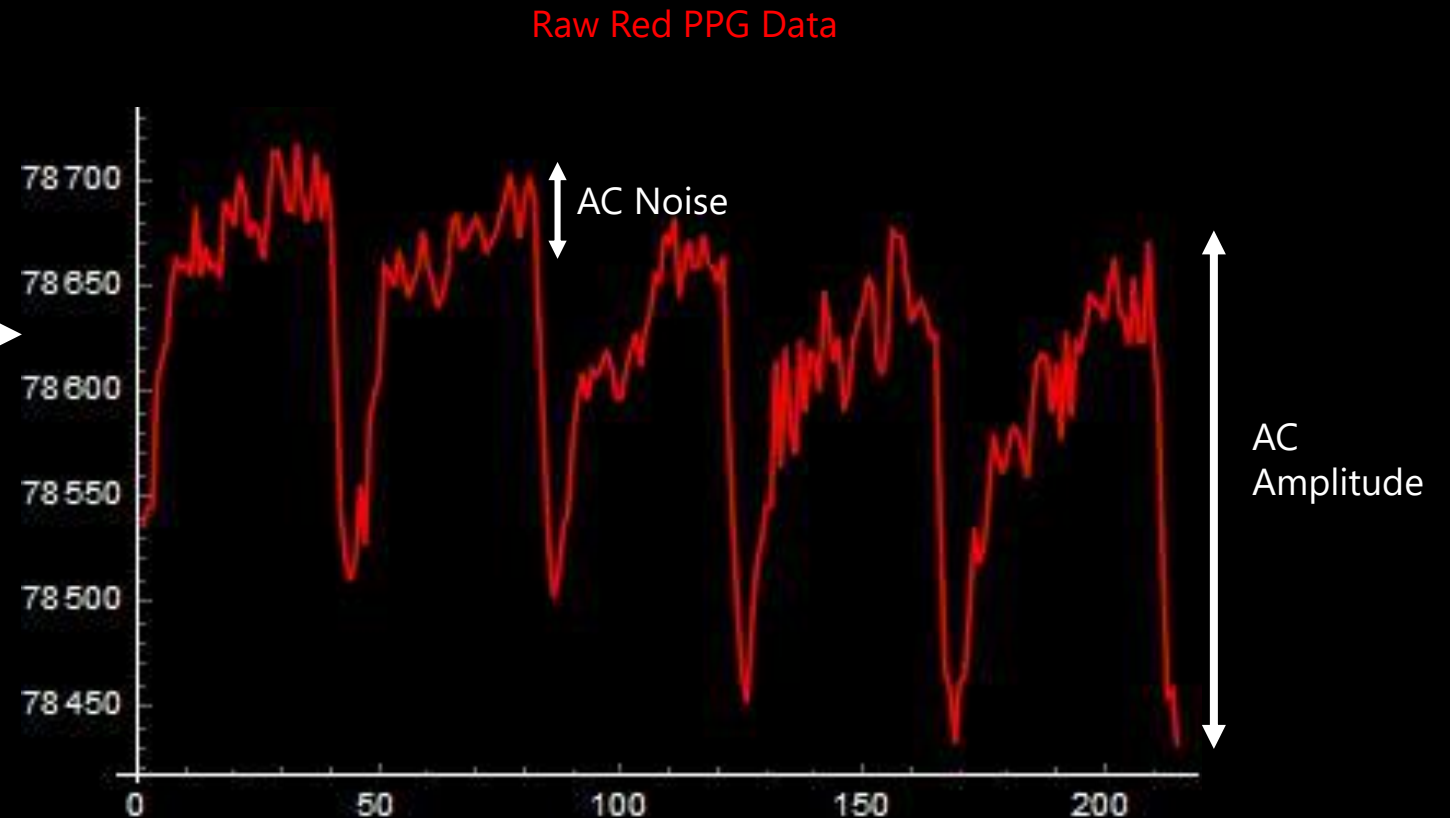
$$SNR_{ppg} = SNR_{\frac{AC}{DC}} * SNR_{AC}$$

Medical PPG SNR is 80-100 dB

$$SNR_{ppg} = \frac{AC}{DC} * \frac{AC}{AC_{noise}} = \mathbf{68 \text{ dB}}$$

$$SNR_{ecg} = \frac{R_{amp}}{PT_{amp}} = \mathbf{25 \text{ dB}}$$

DC Level →



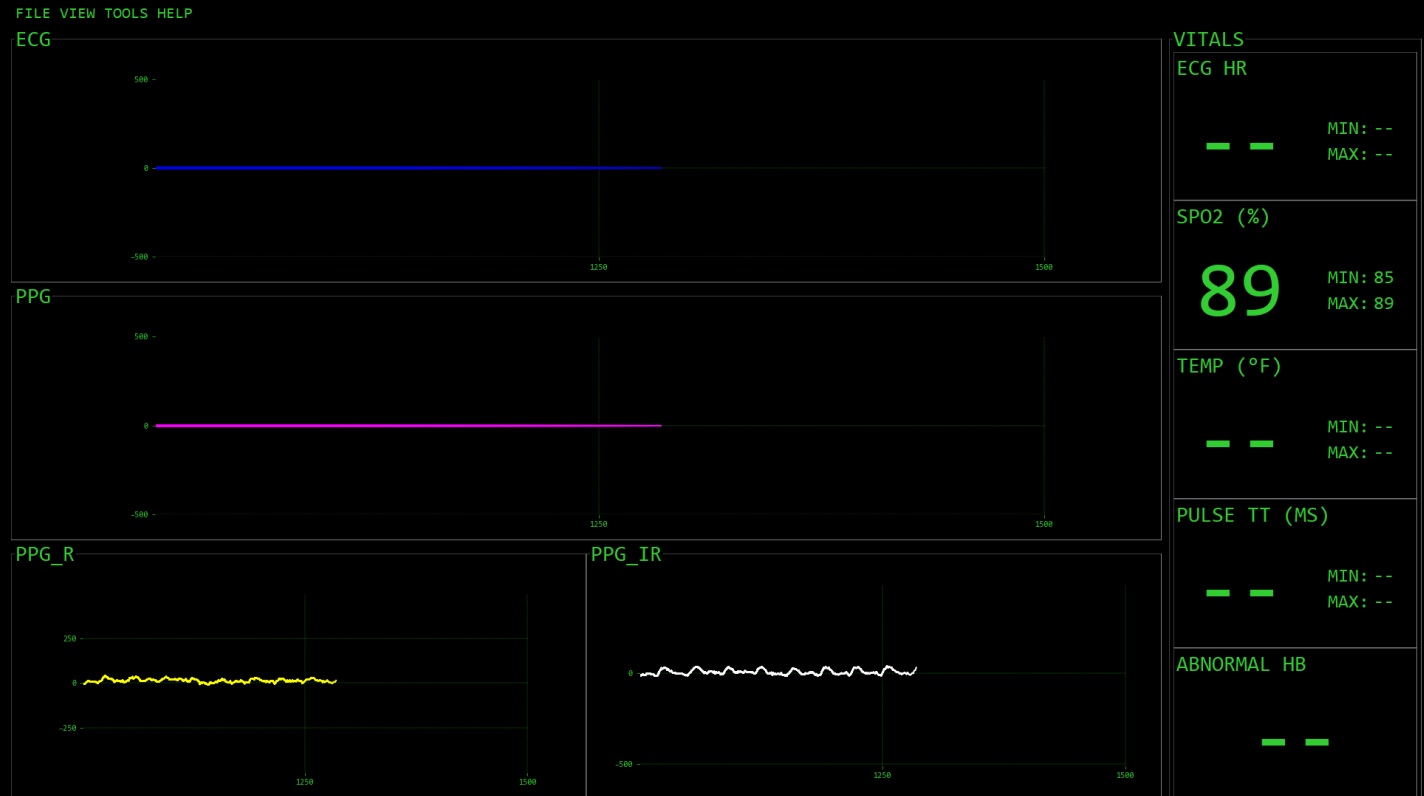
Desktop/Tablet GUI: Viewer Mode

Designed for simple, intuitive monitoring of vital signs

Uses Tkinter/matplotlib:

Alternative: PyQt/PyQwt

Advantage: lightweight dev environment, faster to implement for beginners



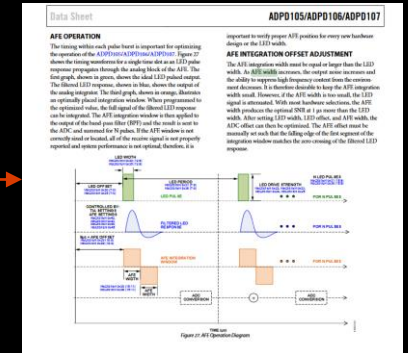
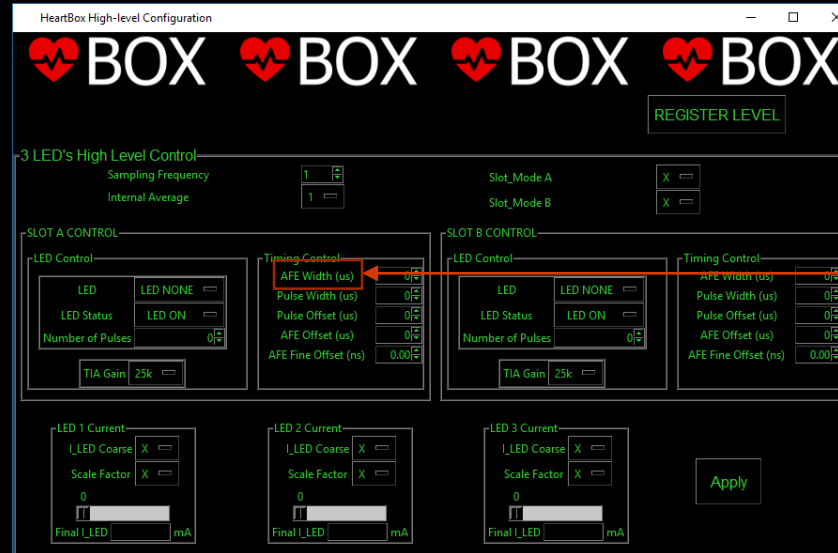
Desktop/Tablet GUI: Developer Mode

Allows for quick, understandable configuration of ADPD part, needed for attuned patient profiles

Integration of datasheet for bookmarked pages

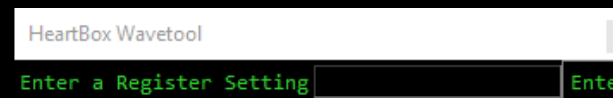
Two modes of configuration:
High-level LED control for quick adjustments to a measurement

Register-level control for full reins of part operation

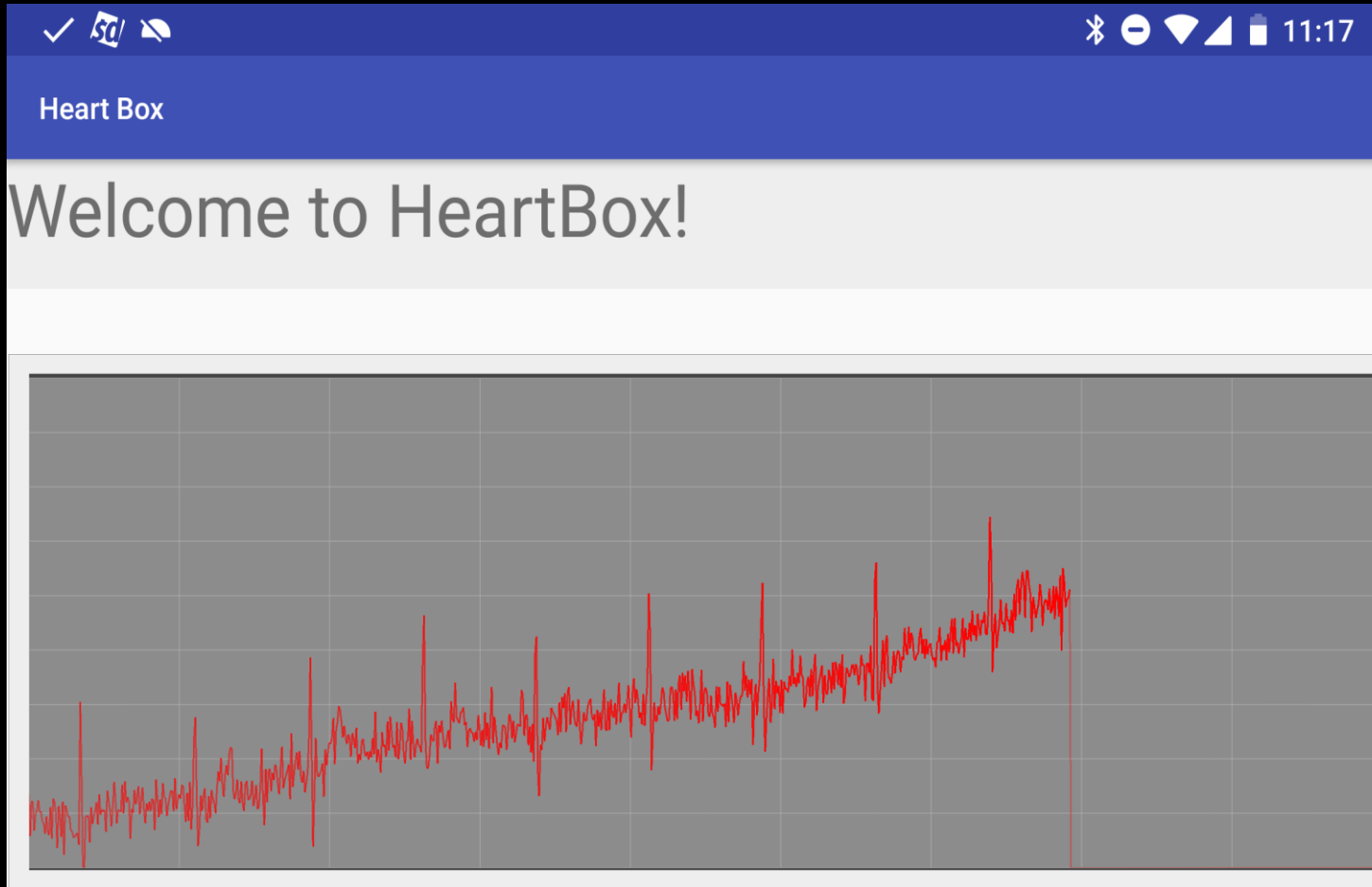


Clicking on a metric will open relevant datasheet (example: above is the explanation of AFE width with an included diagram, below is a register listing for AFE width adjustment)

0x09	SLOTA_AFE_WINDOW	[15:0]	SLOTA_AFE_WIDTH[4:0]	SLOTA_AFE_OFFSET[5:3]
		[7:0]	SLOTA_AFE_OFFSET[2:0]	SLOTA_AFE_OFFSET[4:0]



Android



Android app displays ECG, PPG, and SPO2

- Easy to modify and develop on as needed
- Can be used on any Android devices operating version 4.0 or later (2011)
- △ App can serve as a low cost substitute to otherwise expensive display systems



Comparison to Similar Products



GE Procure B40 Vitals Monitor - **\$5,295**
3 Lead ECG
GE TruSignal SpO₂
Non-invasive blood pressure

Lifebox - **\$250**
Fingerclip SpO₂
Built for developing countries



Heartbox - **<\$15**
Fingerclip SpO₂
2 lead ECG
Non-invasive blood pressure trending



Questions?

Special Thanks to:

