Comparison of waveform parameters from open-source vs commercial photoplethysmography

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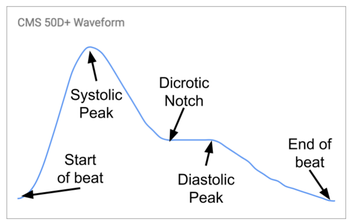
Photoplethysmography

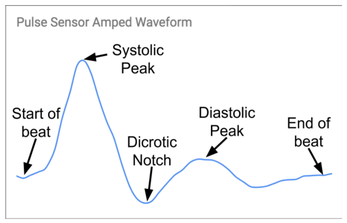
- **Photoplethysmography**: using light to measure the blood volume as a function of time.
- Transmissive **PPG**: light source & detector are on opposite sides of appendage; often uses red & infrared LED sources
- Reflective **PPG:** source & detector are at same skin location; often uses green LED source
- Both **PPG** types give pulmonary information but are processed in different ways.

Can an inexpensive open-hardware/software PPG system match the performance of a commercial one?

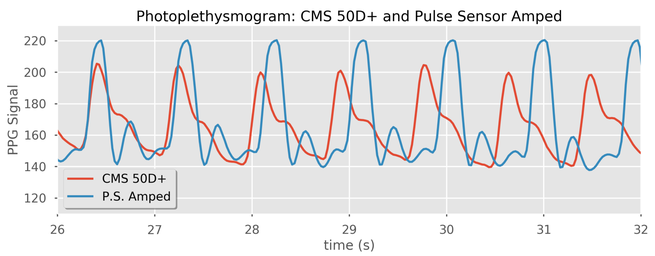
- This study compares data from the CMS 50D+ commercial pulse oximeter and the Pulse Sensor Amped.
- The CMS 50D+ produces PPG waveforms using transmission.
- The Pulse Sensor Amped produces PPG waveforms using reflection.
- The Pulse Sensor Amped requires a microcontroller to handle data collection and transmission.

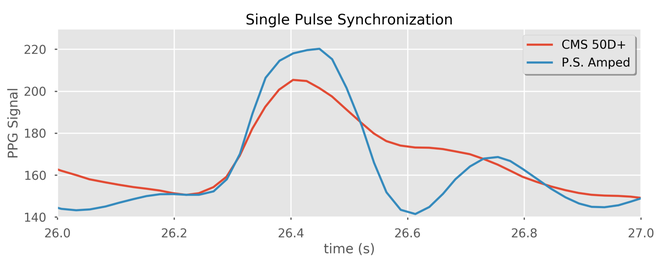
CMS 50D+ & Pulse Sensor Amped PPG Waveforms





Synchronized PPG Waveform Data Collection





Open vs Closed Systems

Characteristics of PPG System Datasets

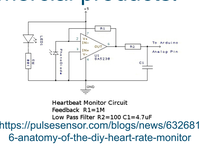
- **High resolution PPG Signal** (sampling frequency of 500 Hz)
- **Heart rate** (rolling average beats per minute)
- **Interbeat Interval** (peak-to-peak time in milliseconds)

Challenges of Closed PPG Systems

- Closed systems don't provide open access to the data, the hardware design, or the software of the system.
- The CMS 50D+ has been reverse engineered by others and could be used here for comparison.
- In other cases, researchers don't have a clear way to directly access data, hardware, or algorithms for commercial products.


CMS 50D+ Circuit Board


https://www.flickr.com/photos/sparkfun/14076544444



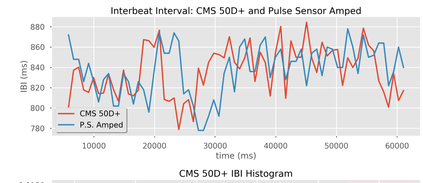
https://pulsesensor.com/blogs/news/6326816-anatomy-of-the-diy-heart-rate-monitor

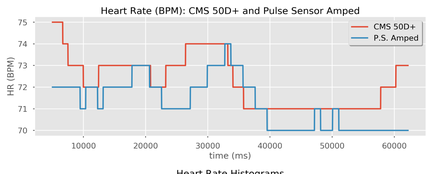
Free and Open Source Software (FOSS)

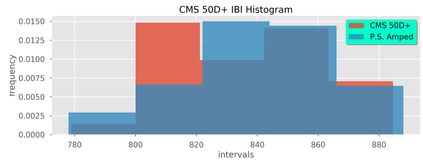
- FOSS means free programming tools, well-established algorithms & software packages, and active communities of users.
- My project was possible because of FOSS.
- **All code** for this project is released as **open source** and can be found via the link in the references section

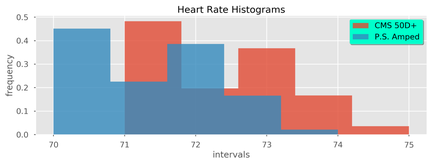
GitHub python jupyter ARDUINO

CMS 50D+ vs Pulse Sensor Amped







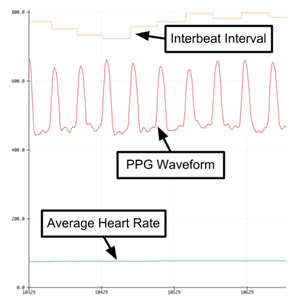


Peak to Peak IBI (n = 67)			
IBI (ms)	Mean	Median	Std. Dev.
CMS 50D+	836.21	838.59	±24.22
P.S. Amped	837.67	840.00	±24.41

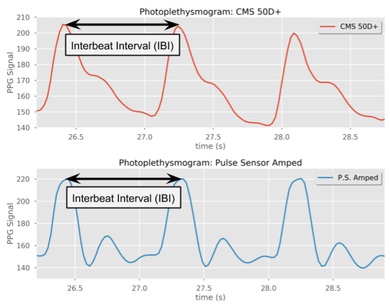
Average Heart Rate (n = 67)			
HR (BPM)	Mean	Median	Std. Dev.
CMS 50D+	72.26	72.00	±1.19
P.S. Amped	71.26	71.00	±1.13

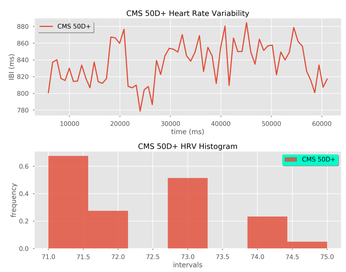
The open system performed on par with the commercial system.

Pulmonary Health Parameters



https://pulsesensor.com/pages/getting-advanced

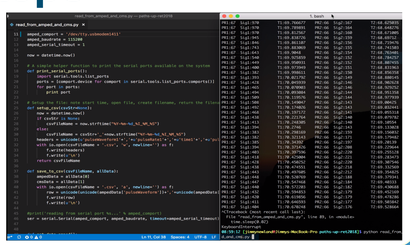




- Interbeat Interval (**IBI**) – time between successive peaks in the PPG waveform
- Heart Rate (**HR**) – average number of beats per minute
- Heart Rate Variability (**HRV**) – a measure of the variation in the IBI over time

Next Steps

- Create **larger data set**.
- Creating system with **portability and functionality** in mind
- More **sophisticated analysis** of the algorithms
- Better **synchronization**, **filtering**, & **de-trending**
- Create a **database of waveforms**



Acknowledgements & References

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PATHS-UP
Precise Advanced Technologies and Health Systems for Underserved Populations

NSF EXPEDITIONS IN COMPUTING

For a complete list of references, videos, code, & more, visit: https://wp.me/P3rYuP-6SAshp