
# Development of a Smartphone-based Pulse Oximeter with Adaptive SNR/Power Balancing

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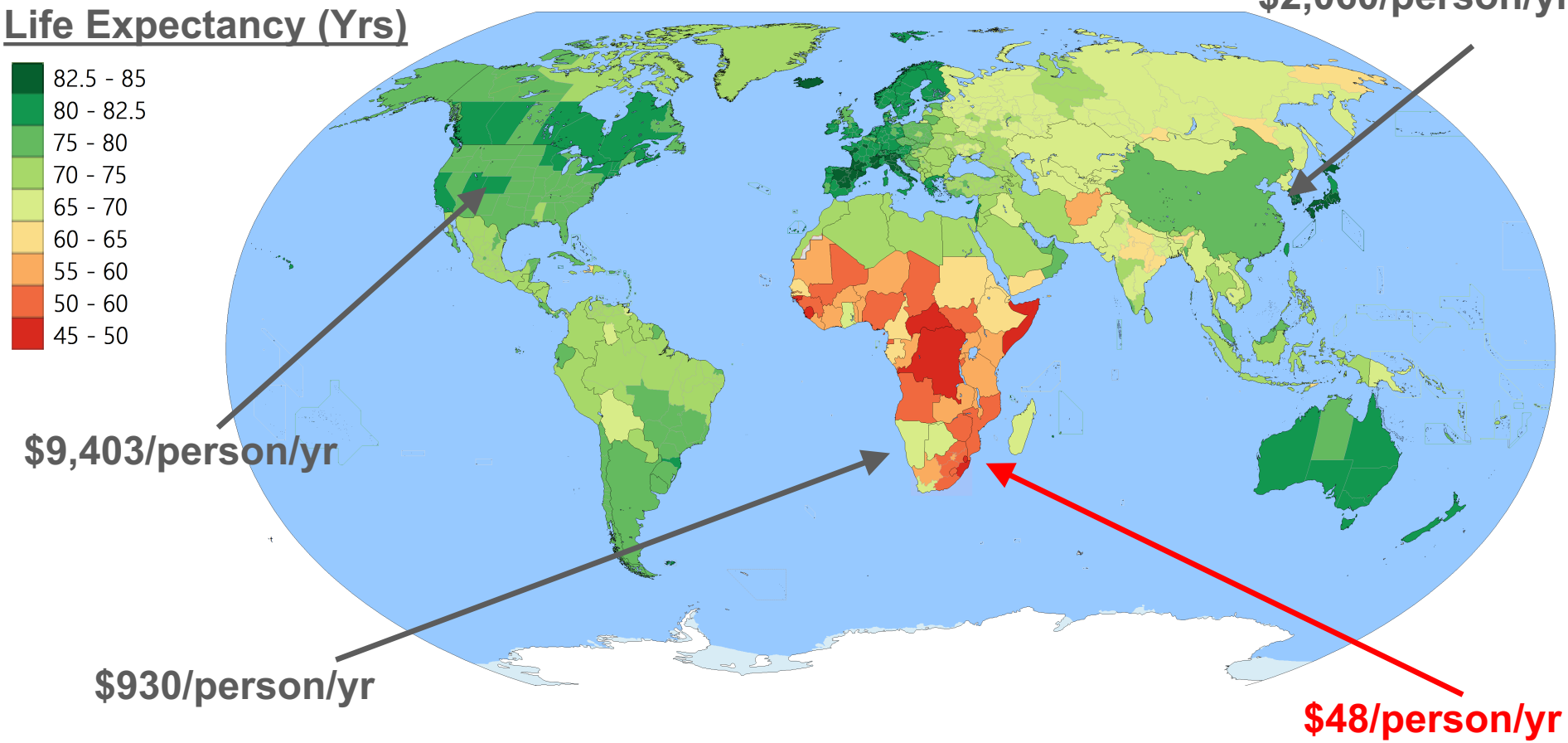
BIO Sensors & Electronics

http://www.BioEE.ucsd.edu

# Motivation

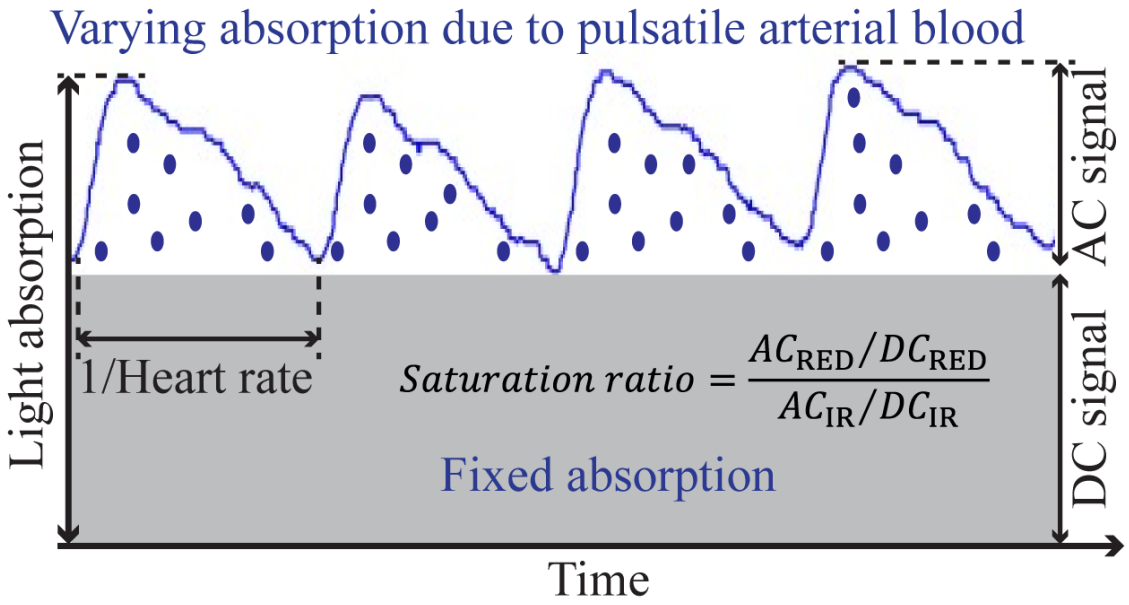



**Millions of people worldwide suffer from preventable diseases, but lack access to adequate healthcare equipment.**

WHO Global health expenditure database, http://www.who.int/nha/expenditure_database/en/

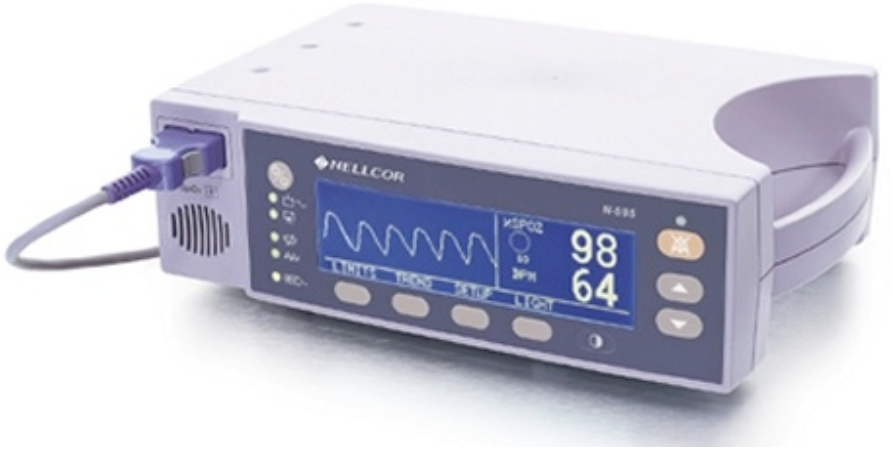
# Pulse Oximetry

- Non-invasive measurement of peripheral oxygen saturation ($SpO_2$) and heart rate (HR)
- Commonly used to monitor:
  - Pregnancies (i.e., preeclampsia)
  - Chronic respiratory illnesses (i.e., COPD, asthma, CF) and pneumonia
  - Cardiovascular diseases
  - Sleep apnea



# Existing Pulse Oximeters

## Clinical-grade




High accuracy due to advanced signal processing and (mostly) stationary patient

***Problem:*** High cost (~$1k) and high power (~10W) → not portable

## Portable


Lower accuracy at a modest cost ($40-$200)

***Problem:*** Limited computational power, motion artifacts → not sensitive

**Challenge: Achieving high accuracy at low cost**

# Mobile Phones

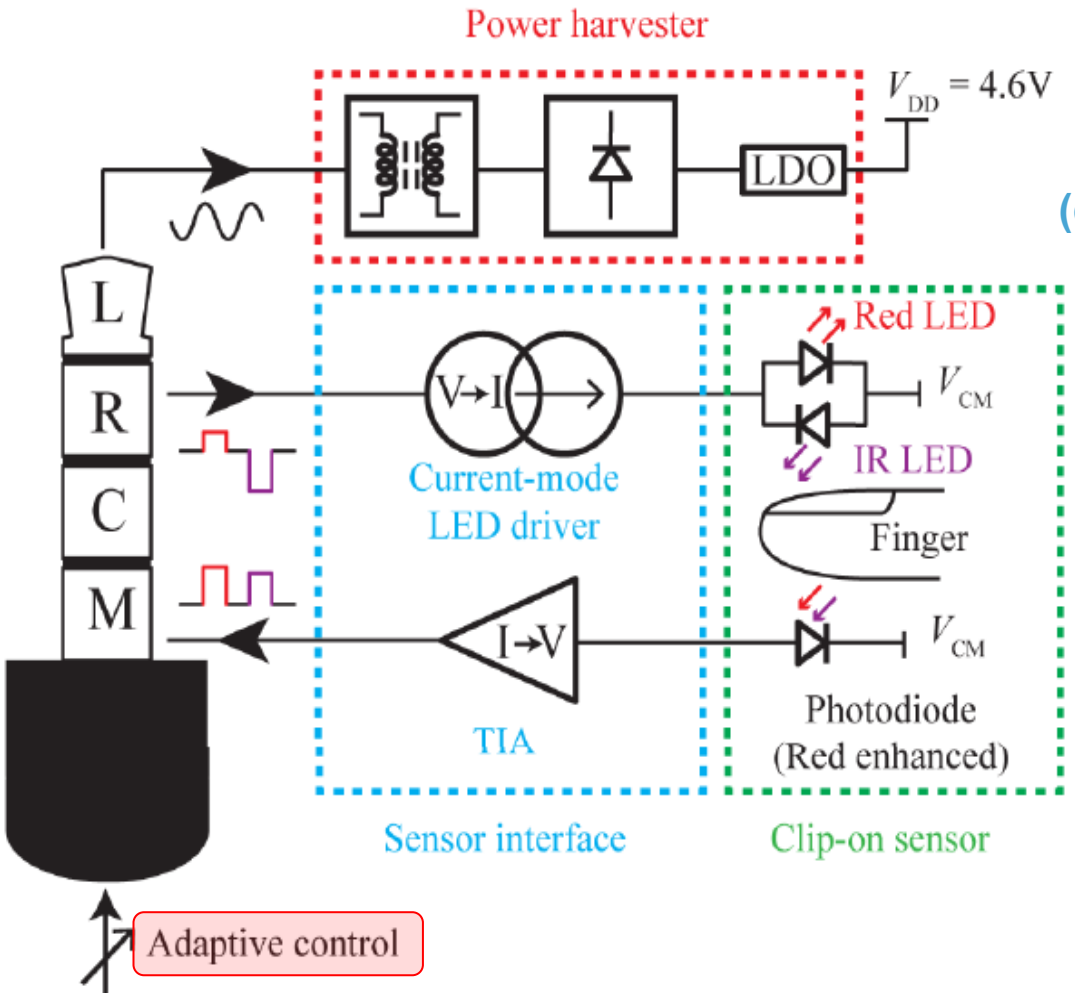
Processor Memory Battery Storage

Display User Input


Inertial Sensors Biometric Sensors Wireless Radios

**How can one tap into the mobile phone for mHealth devices?**

# Smartphone-based Pulse Oximeter

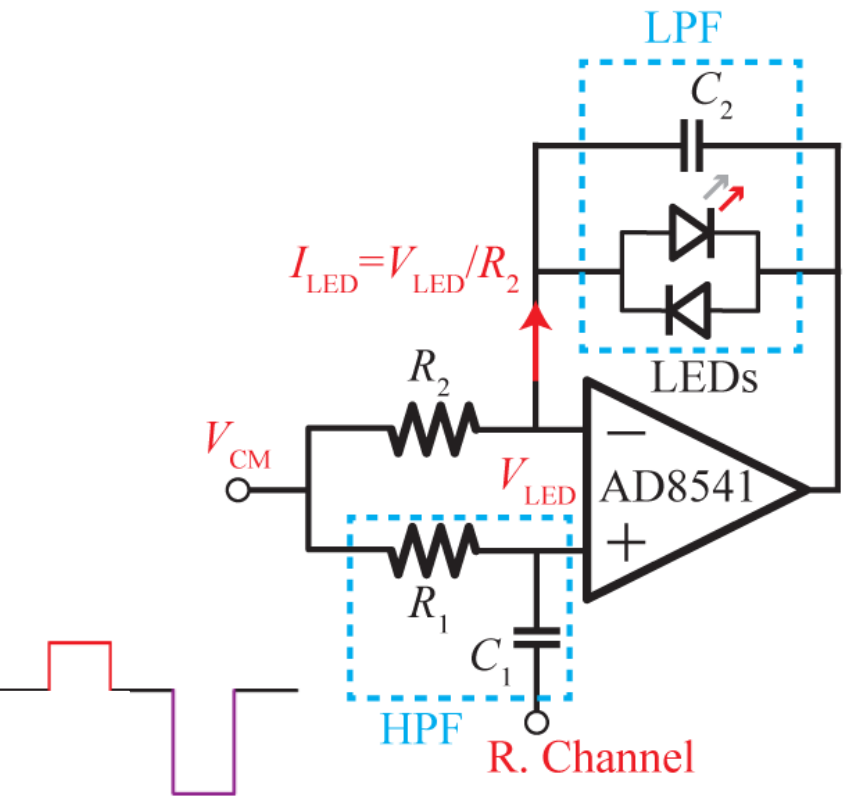


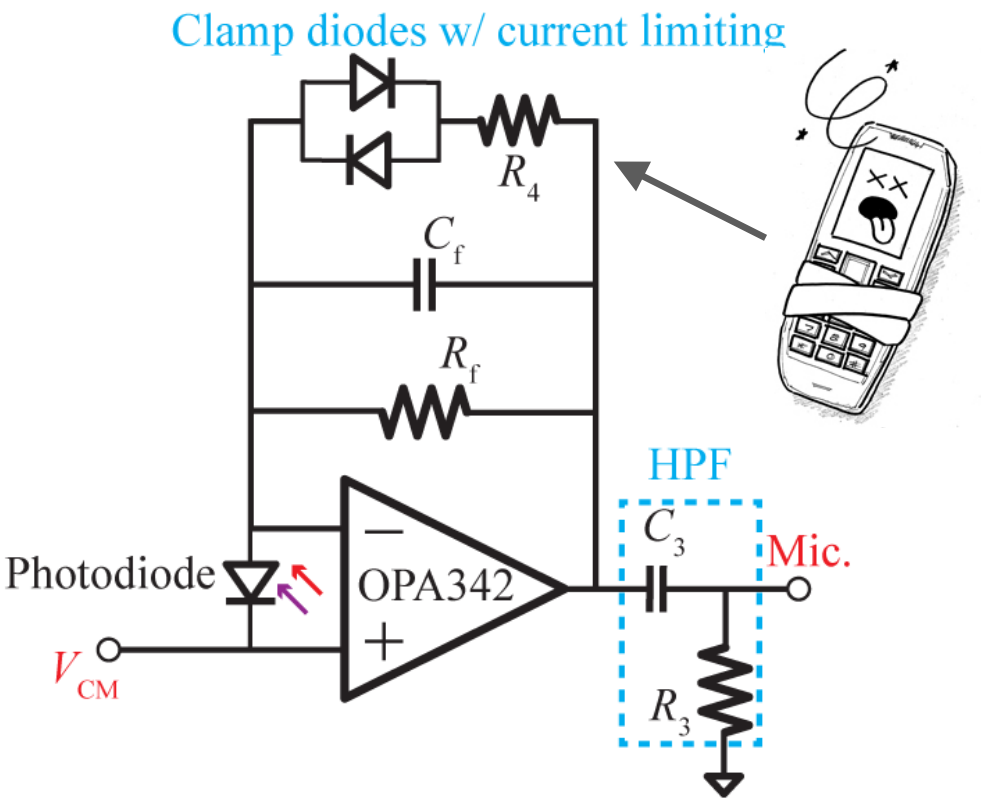

**$P_{av}$ = 5-20 mW**
**(depending on phone)**

Use the infrastructure in a mobile phone to realize a low cost (but high accuracy) portable pulse oximeter

Chengyang Yao, Alexander Sun, and Drew A. Hall, "Efficient Power Harvesting from the Mobile Phone Audio Jack for mHealth Peripherals", *Global Humanitarian Technology Conference (GHTC)*, Seattle, WA, October 8-11, 2015

# Circuit Implementation




**Current-mode LED Driver:**

- Control $V_{LED} \rightarrow I_{LED} \rightarrow$ Light intensity
- AC-coupled to right audio channel
- $C_2$ filters out interference

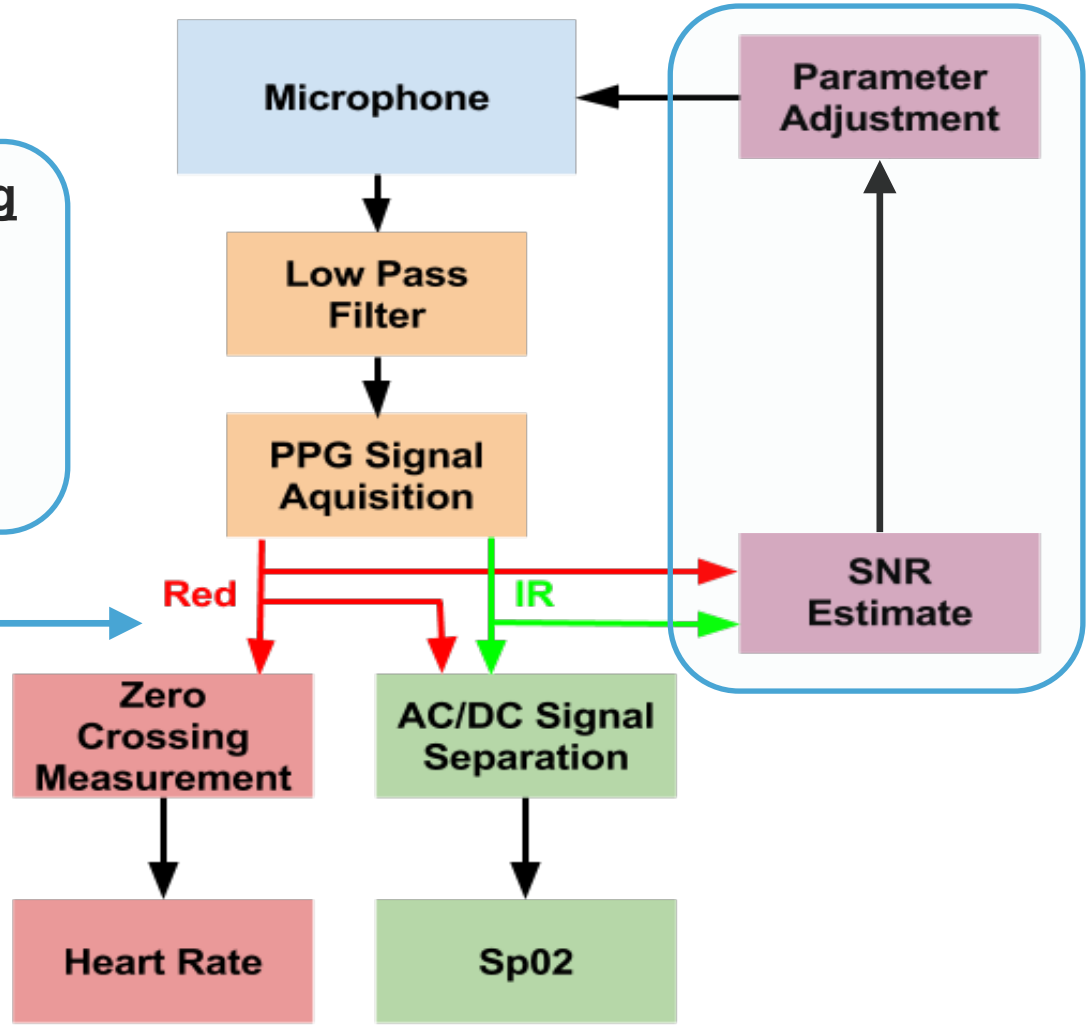
**Photoreceiver:**

- Zero-bias photodiode → low dark current → save voltage headroom
- AC-coupled to mic. Channel
- Clamp diodes to protect mic input

# Signal Processing

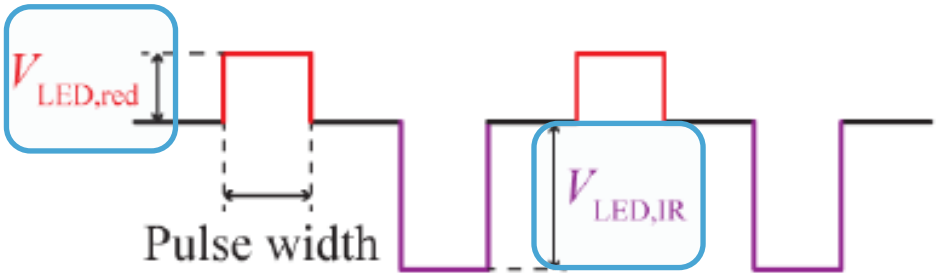
**Advanced Signal Processing**

- Quality index assessment
- Motion artifact removal
- Powerline interference removal
- etc.

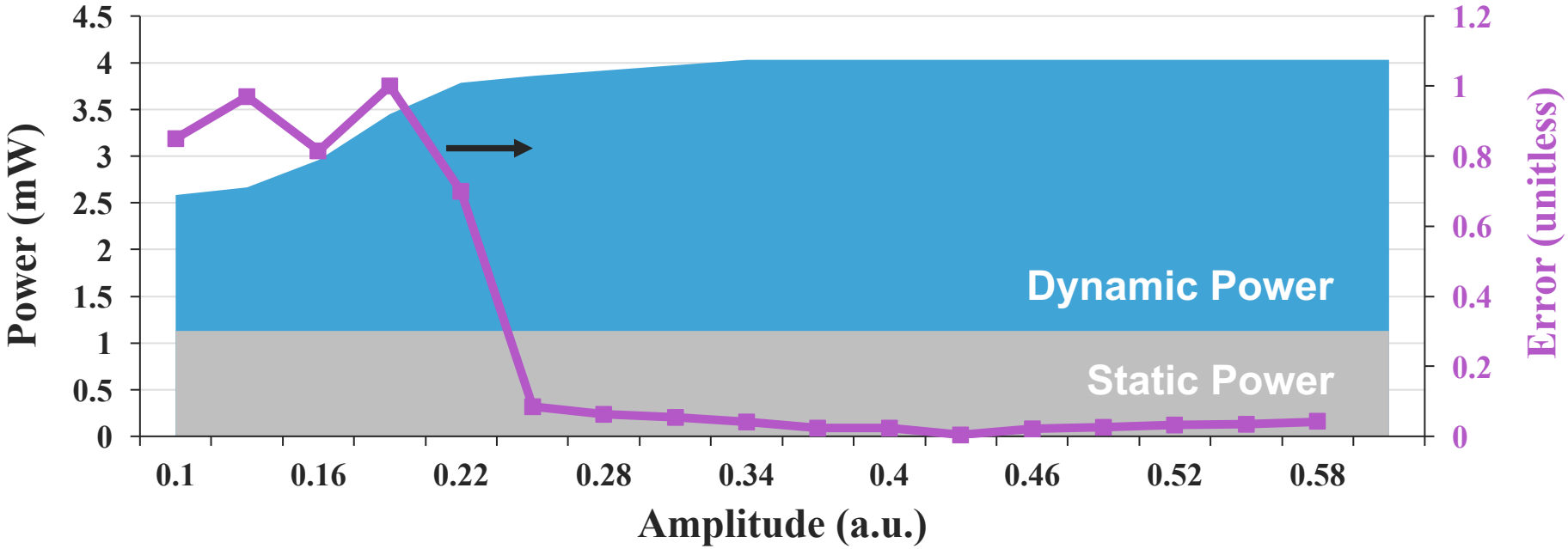



**Signal processing entirely done on the phone! Easily updated, adaptive, and more computationally intensive algorithms possible.**

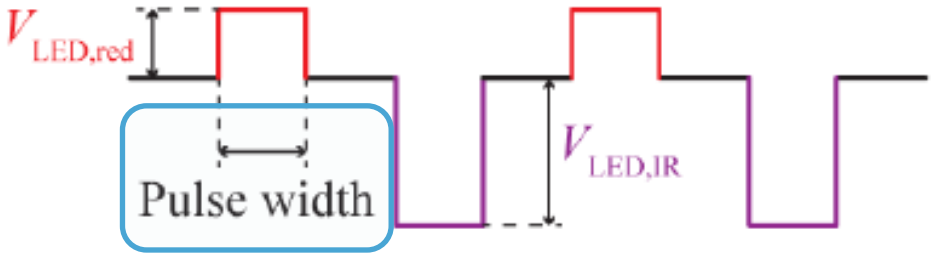
# Power and SNR Optimization




$$Error = \sqrt{(HR_{\%Err}HR_{\sigma})^2+(SpO_{2,\%Err}SpO_{2,\sigma})^2}$$



# Power and SNR Optimization

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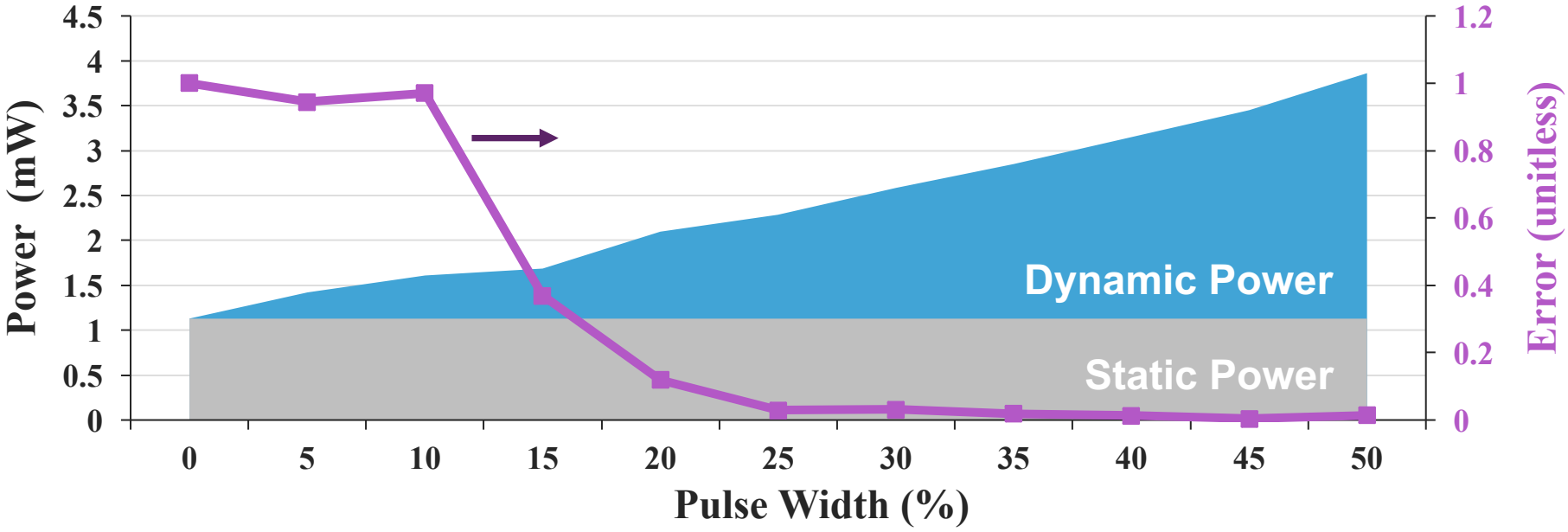
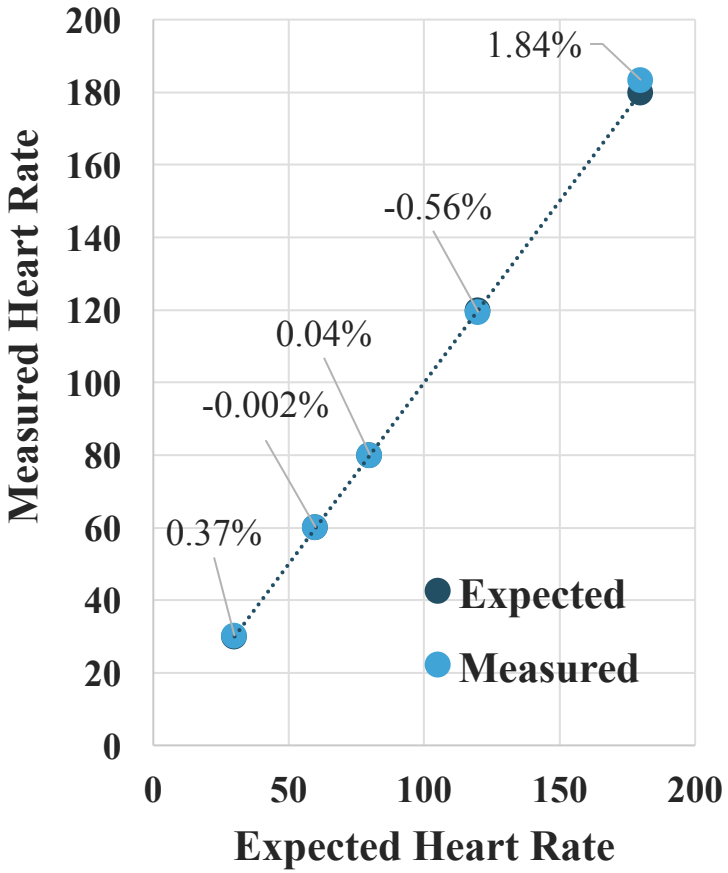


# Measurement Results




| | | %Error Heart Rate | | | | %Error $SpO_2$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Subject | 1 | 2 | 3 | μ | 1 | 2 | 3 | μ |
| This Work | Gal. S6 | -6 | 1 | 1.8 | 3.2 | 5.3 | 1.4 | 1.8 | 2.8 |
| | Note 4 | 4.2 | 0 | -6 | 3.4 | 4.9 | 0 | -6 | 3.7 |
| | Note 3 | 3.2 | 0 | -2 | 1.6 | -3 | 0 | -2 | 1.6 |
| | LG V10 | 0 | 4 | -3 | 2.5 | -2 | 4.3 | -3 | 3.1 |
| iOximeter | Gal. S6 | 5.3 | 4 | 0 | 3.1 | -1 | -1 | 0 | 0.7 |
| | Note 4 | 4.9 | 0 | 3.4 | 2.8 | 1 | 1 | -2 | 1.3 |
| | Note 3 | -3 | 6 | 3.5 | 4.1 | -2 | -2 | -2 | 2.0 |
| | LG V10 | -2 | 3 | 0 | 1.6 | 2.1 | -5 | -3 | 3.4 |

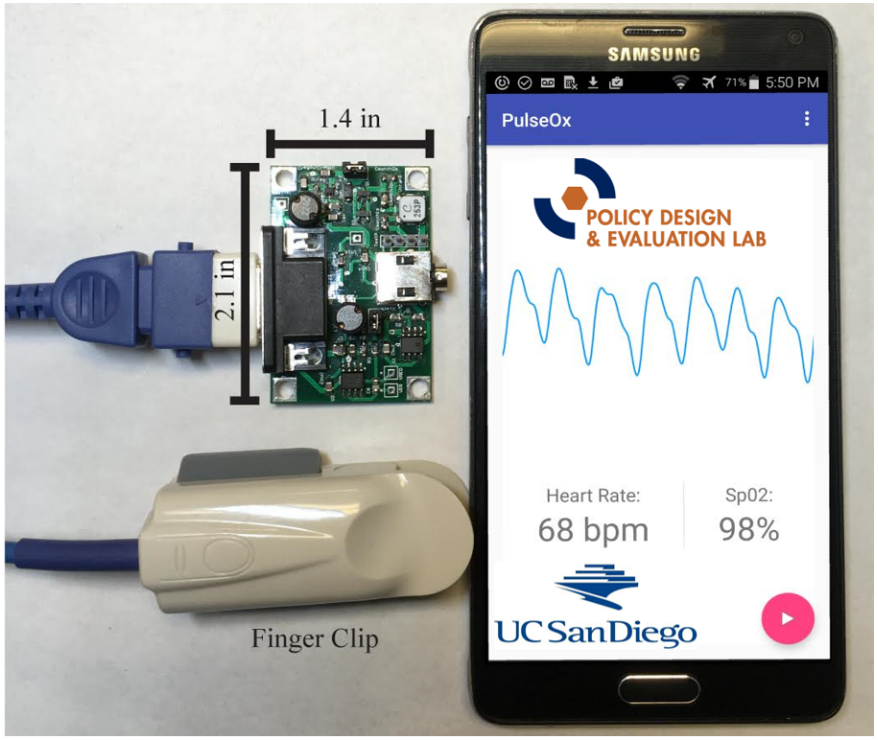
**BE Biomedical PS-2110 Patient Simulator**

**Masimo RAD 87 used to collect true HR and $SpO_2$**

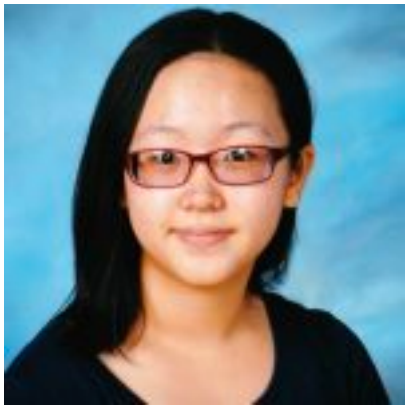
**Despite low-cost and simplicity, HR accuracy < 1.8% and $SpO_2$ < 3.7%**

# Conclusion

- Developed a low-cost (BOM < $20) smartphone-based pulse oximeter
- Adaptive SNR and advanced signal processing techniques enabled by using the smartphone for all computation



# Thanks!

Gabby Kang

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