

eBP: A Wearable System For Frequent and Comfortable Blood Pressure Monitoring From User's Ear

Nam Bui[†], Nhat Pham[†], Jessica Jacqueline Barnitz[†], Zhanan Zou[†], Phuc Nguyen[†], Hoang Truong[†], Taeho Kim[†], Nicholas Farrow[†], Anh Nguyen[†], Jianliang Xiao[†], Robin Deterding[‡], Thang Dinh[§] and Tam Vu[†]

[†]University of Colorado Boulder, [‡]Children's Hospital Colorado, [§]Virginia Commonwealth University
[firstname.lastname@colorado.edu](mailto:{firstname.lastname}@colorado.edu), Robin.Deterding@childrenscolorado.org, tndinh@vcu.edu

Presented by Pargorn Puttapirat
in Wireless Network and Mobile Computing Class
Xi'an Jiaotong University, 2019

Copyright statement:

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

MobiCom '19, October 21–25, 2019, Los Cabos, Mexico

© 2019 Association for Computing Machinery. ACM ISBN 978-1-4503-6169-9/19/10... \$15.00 <https://doi.org/10.1145/3300061.3345454>



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Outline

1. Why do we need continuous blood pressure (BP) measuring devices?
2. Fundamental of BP measurement
3. Overview of eBP
4. Hardware design
5. In-ear blood pressure estimation algorithm
6. Signal processing
7. Evaluation / testing
8. Discussion



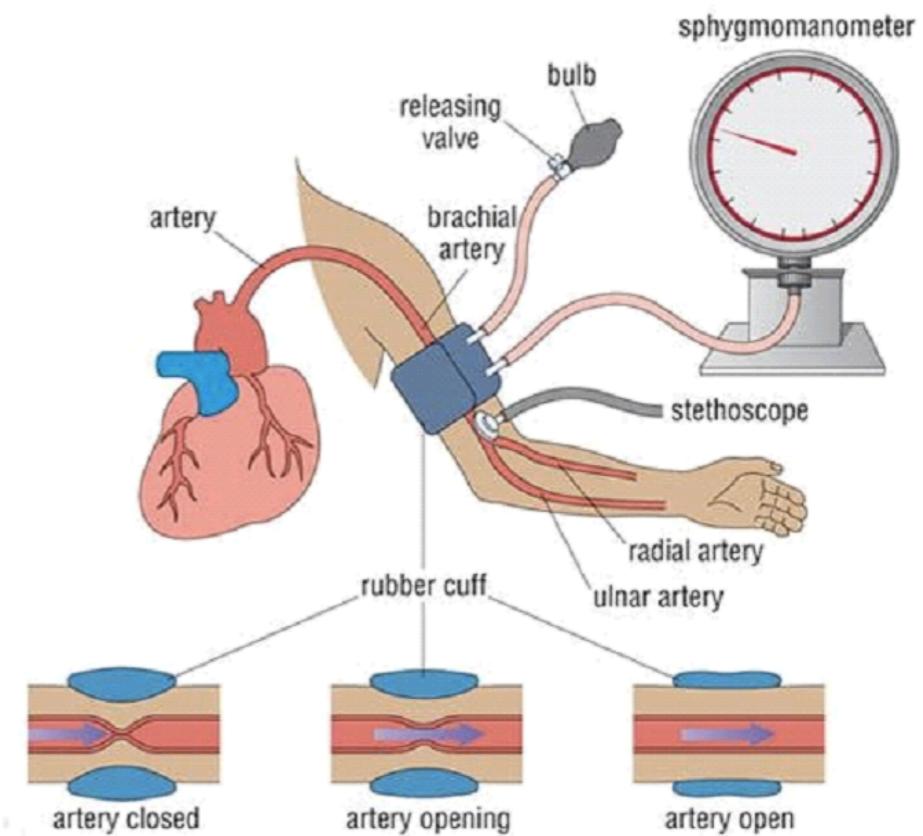
Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Why do we need continuous BP measurement?



sphygmomanometer

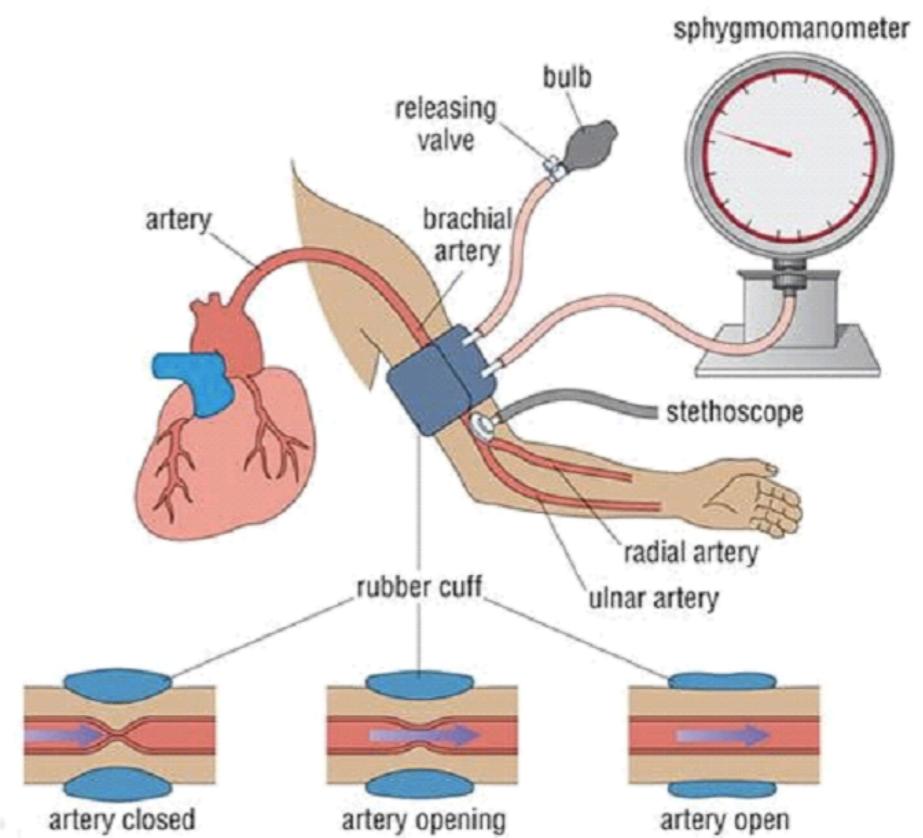
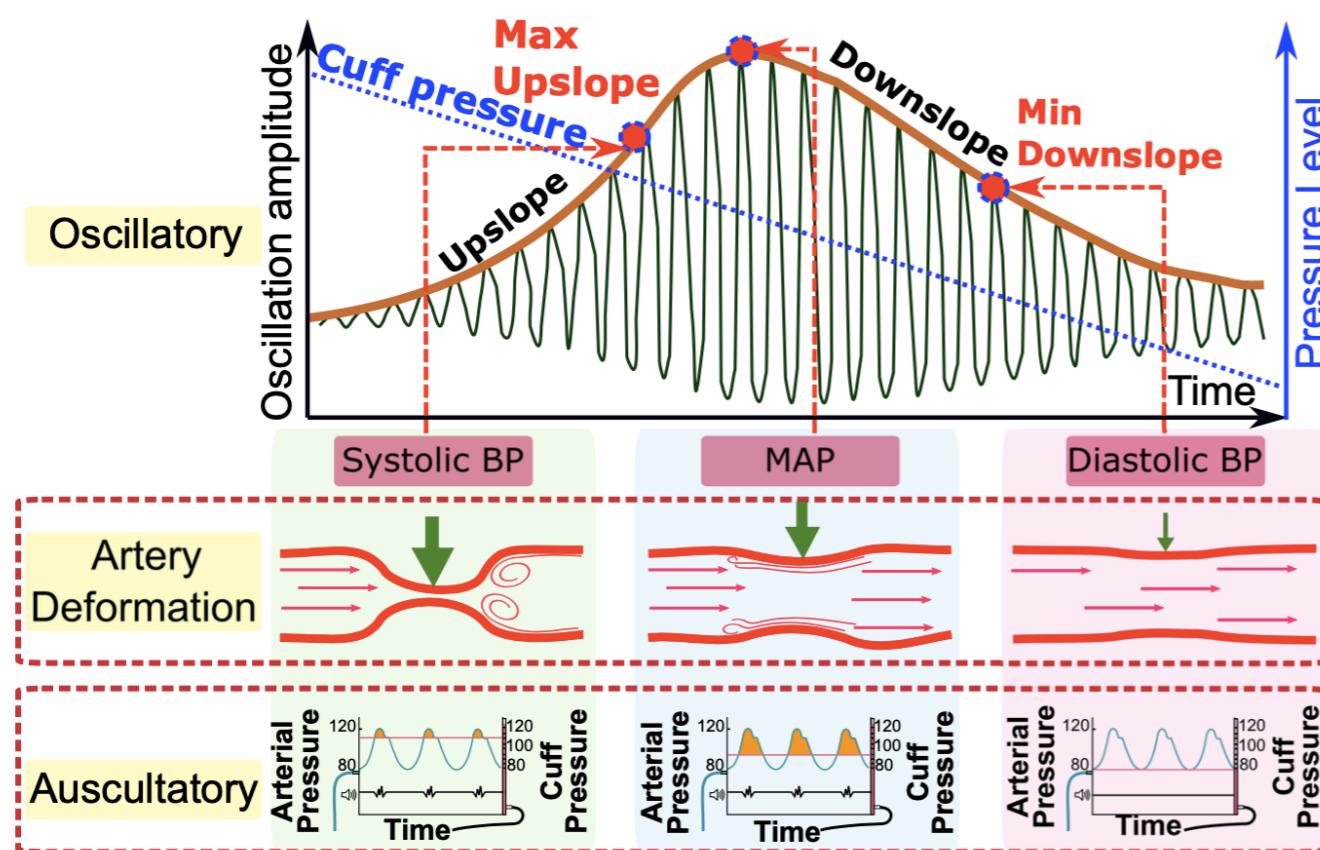
Image by Jacek Halicki



<https://instrumentationforum.com/t/sphygmomanometer-principle/5357>

- **Example:** hemodialysis, organ transplant, some type of hypertension
- **Measurement needed:** every 30 minutes for 24 hours.

Fundamental of BP measurement



<https://instrumentationforum.com/t/sphygmomanometer-principle/5357>



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

How did they calculate the ratio?

Proportional Relations Between Systolic, Diastolic and Mean Pulmonary Artery Pressure are Explained by Vascular Properties

TACO KIND,¹ THEO J. C. FAES,² ANTON VONK-NORDEGRAAF,¹ and NICO WESTERHOF^{1,3}

¹Department of Pulmonary Diseases, Institute for Cardiovascular Research, VU University Medical Center, Amsterdam, The Netherlands; ²Department of Physics and Medical Technology, Institute for Cardiovascular Research, VU University Medical Center, Amsterdam, The Netherlands; and ³Department of Physiology, Institute for Cardiovascular Research, VU University Medical Center, Amsterdam, The Netherlands

(Received 6 August 2010; accepted 22 October 2010; published online 11 November 2010)

Associate Editor Steven C. George oversaw the review of this article.

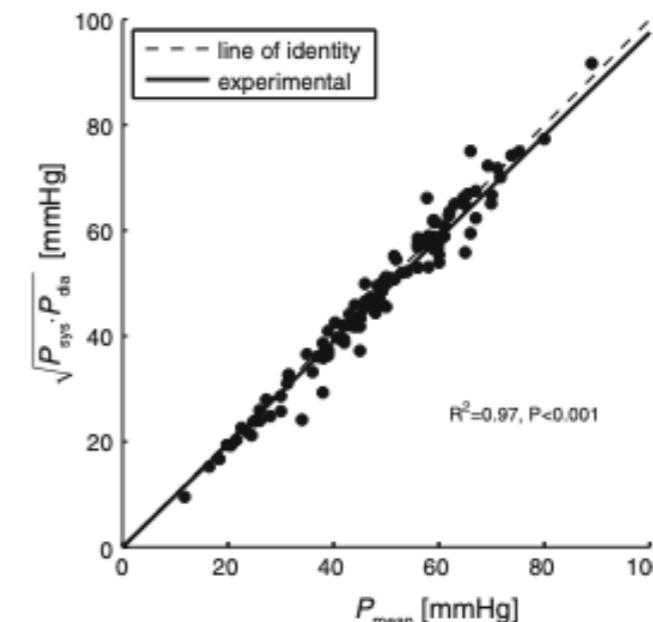
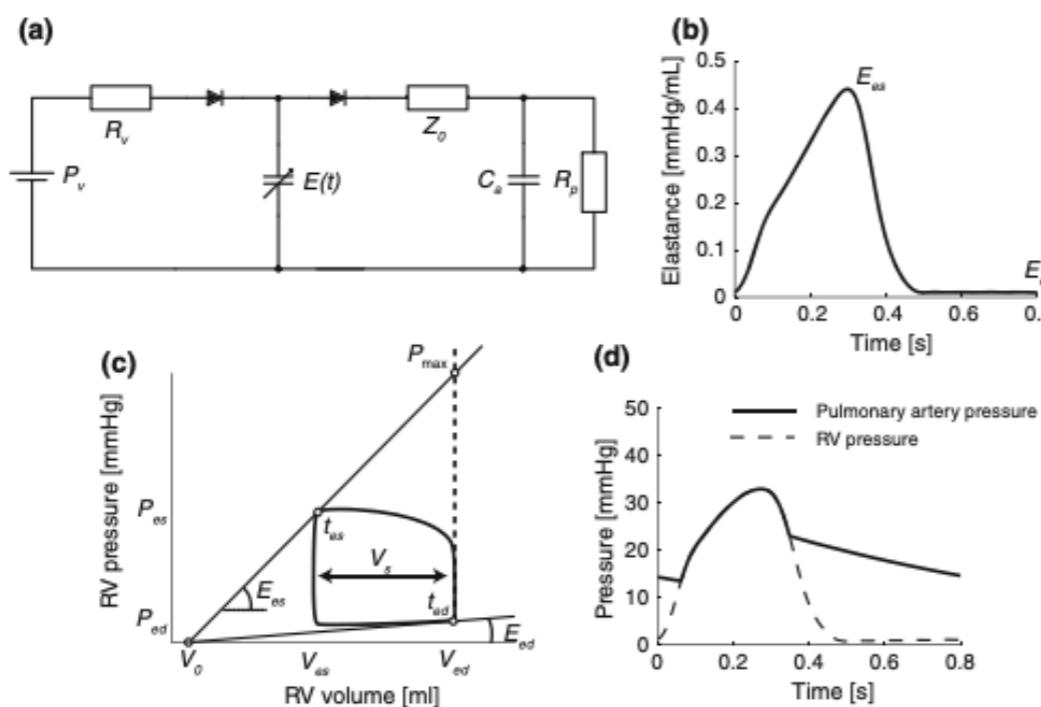


FIGURE 6. Relation between P_{mean} and $\sqrt{P_{sys} \cdot P_{dia}}$. Clearly, all points are close to the line of identity (gray line), implicating that P_{mean} is the geometric mean of P_{sys} and P_{dia} .⁴

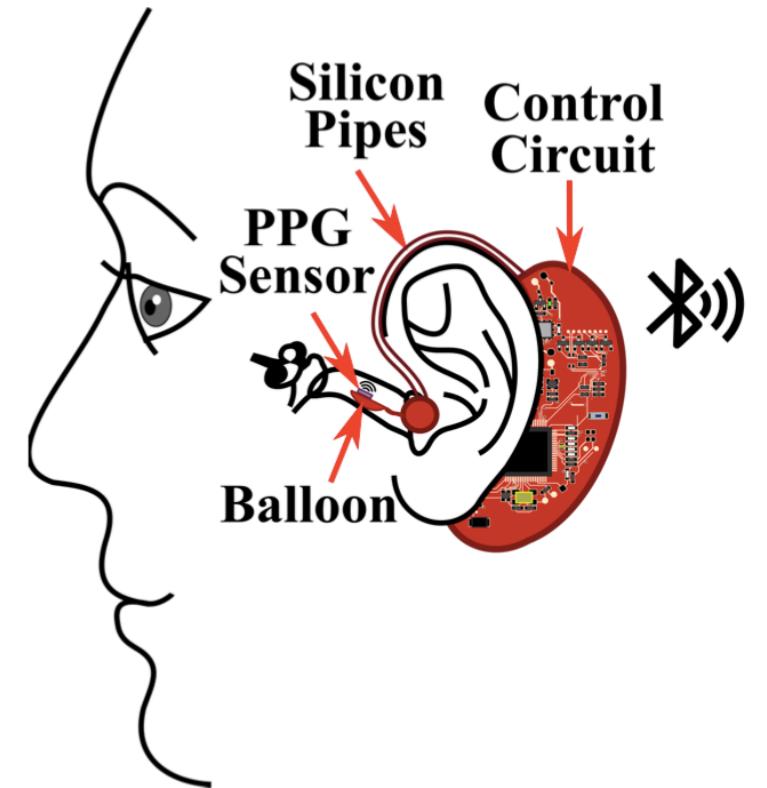
$$P_M = \beta P_S + (1 - \beta) P_D,$$



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Contribution

1. Novel concept for in-ear BP measurement.
2. Blocking-free optical-oscillometric approach.
3. Has prototype device that works.
4. Novel algorithm for data processing.
5. Experiment.



Outline

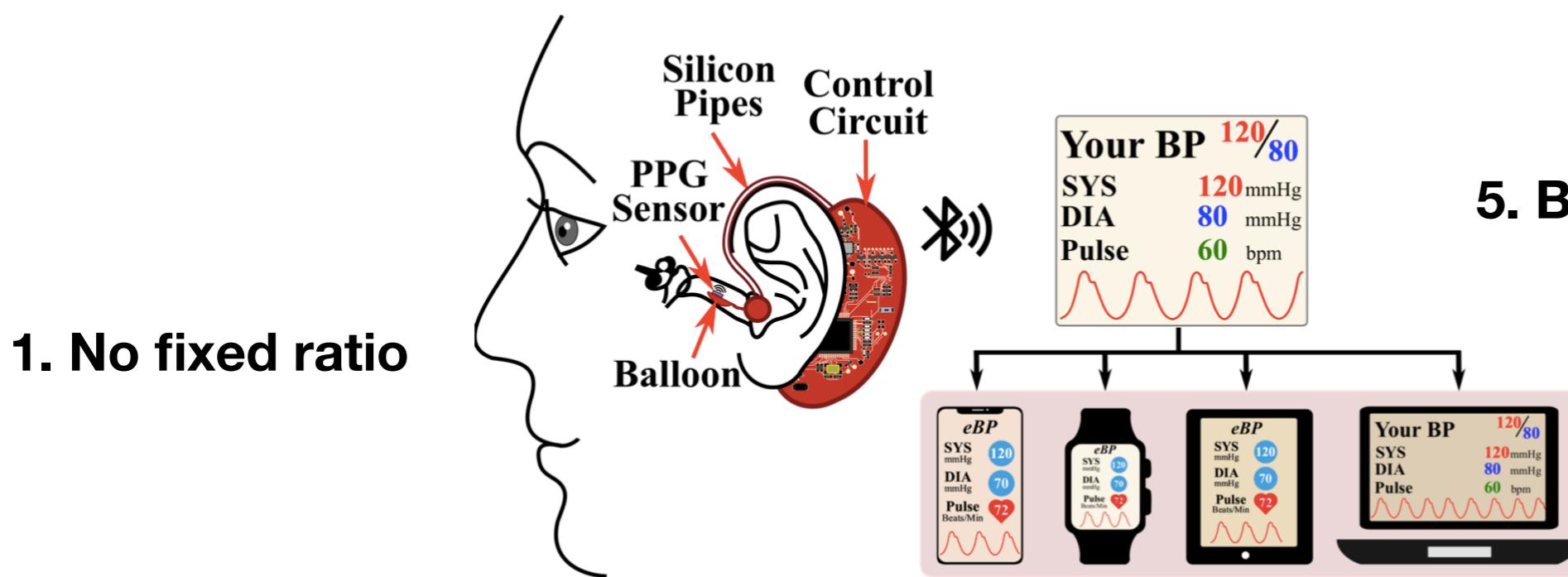
1. Why do we need continuous blood pressure (BP) measuring devices?
2. Fundamental of BP measurement
3. **Overview of eBP**
4. Hardware design
5. In-ear blood pressure estimation algorithm
6. Signal processing
7. Evaluation / testing
8. Discussion



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Overview of eBP

3. Firm attachment (hardware design)



1. No fixed ratio

2. Good contact between artery and sensor

4. Signal processing algorithm

5. Biocompatible probe

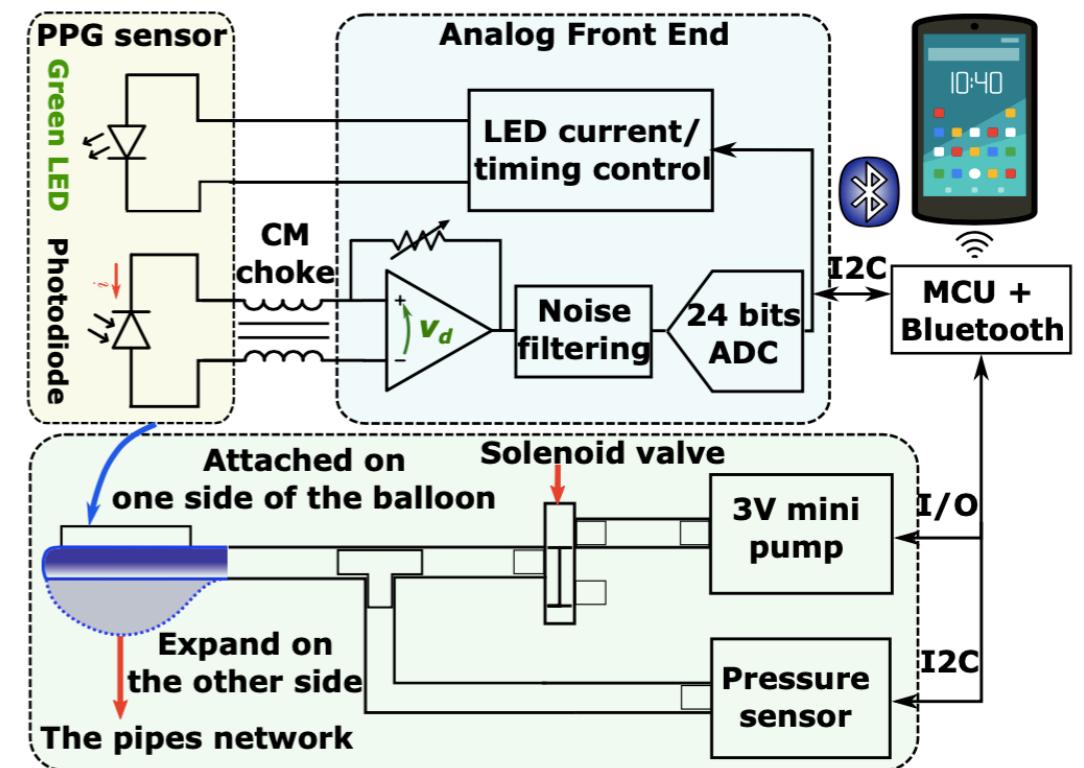
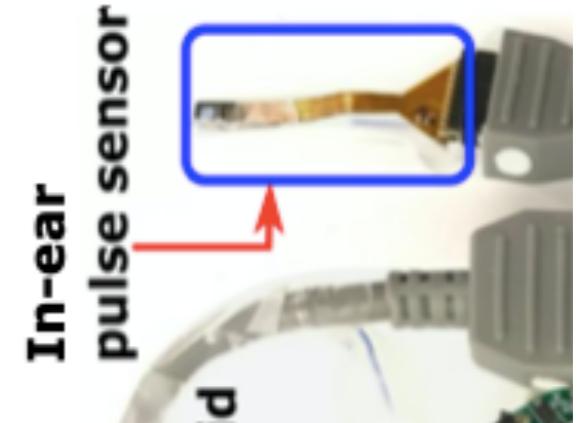


Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

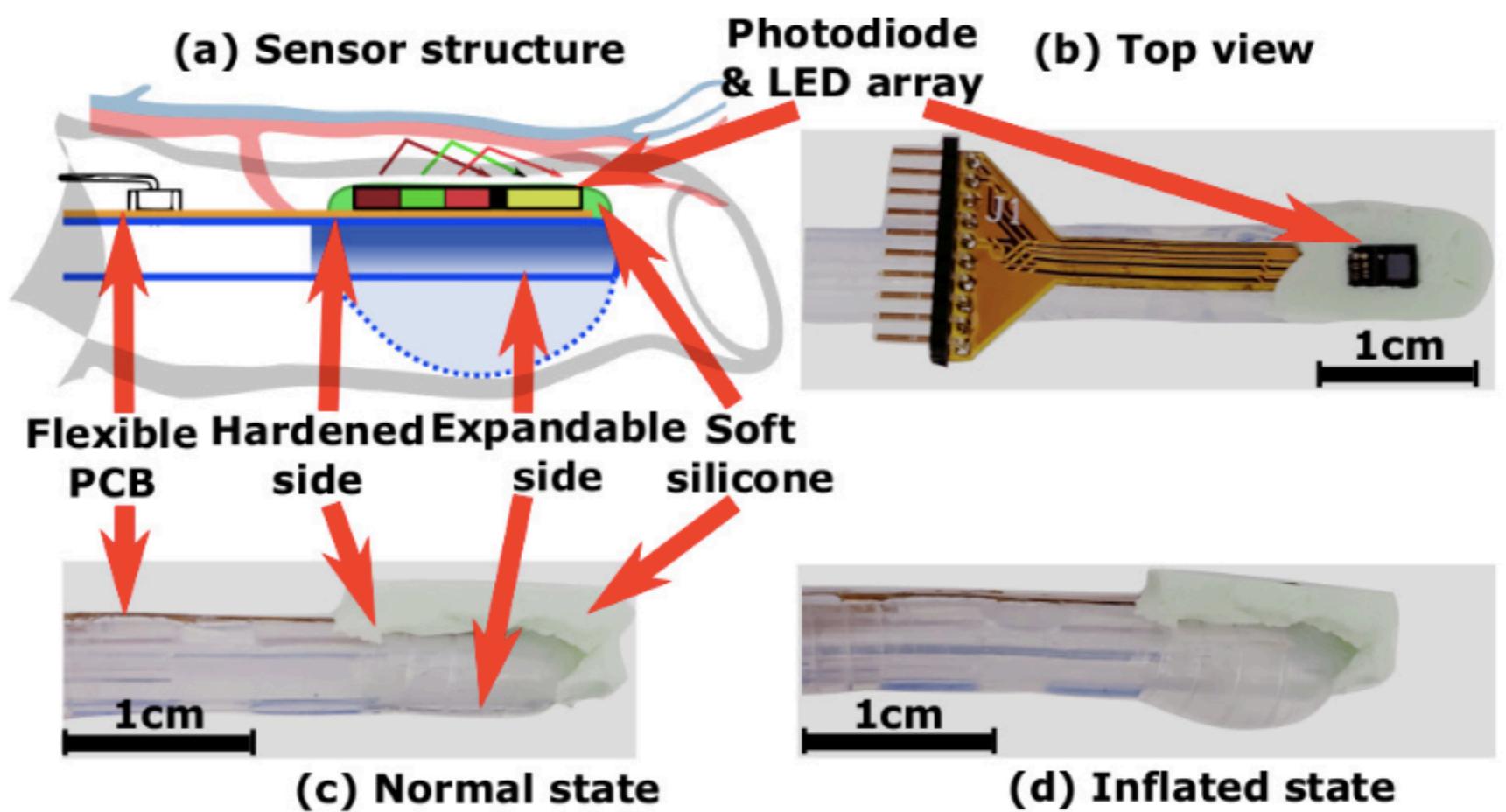
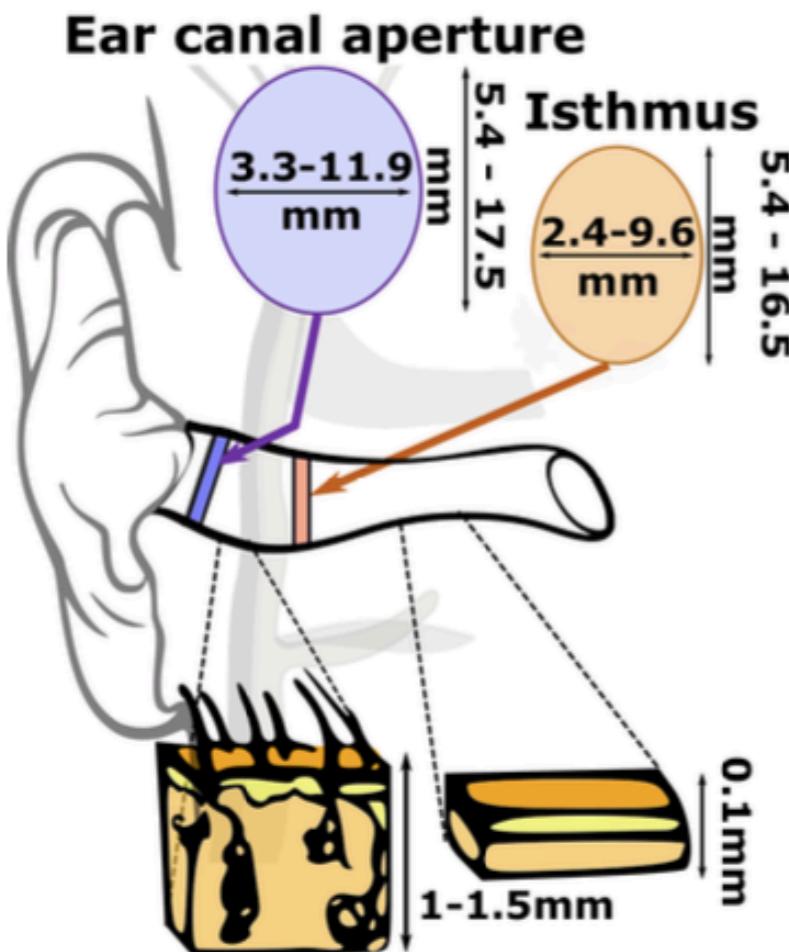
Overview of eBP

1. No fixed ratio
2. Good contact between artery and sensor
3. Firm attachment (hardware design)
4. Signal processing algorithm
5. Biocompatible probe

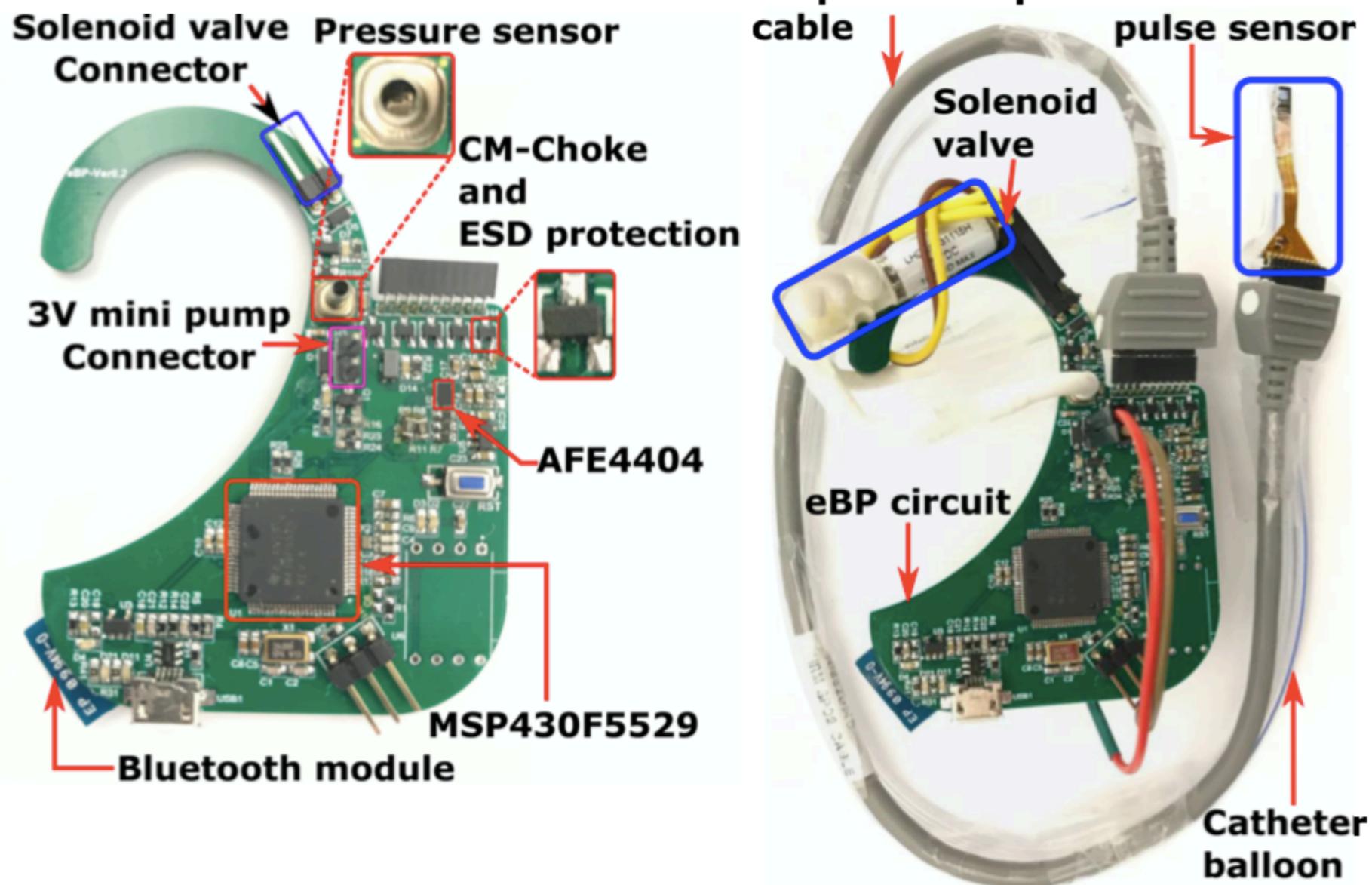
$$P_M = \beta P_S + (1 - \beta)P_D,$$



Hardware design



Hardware design



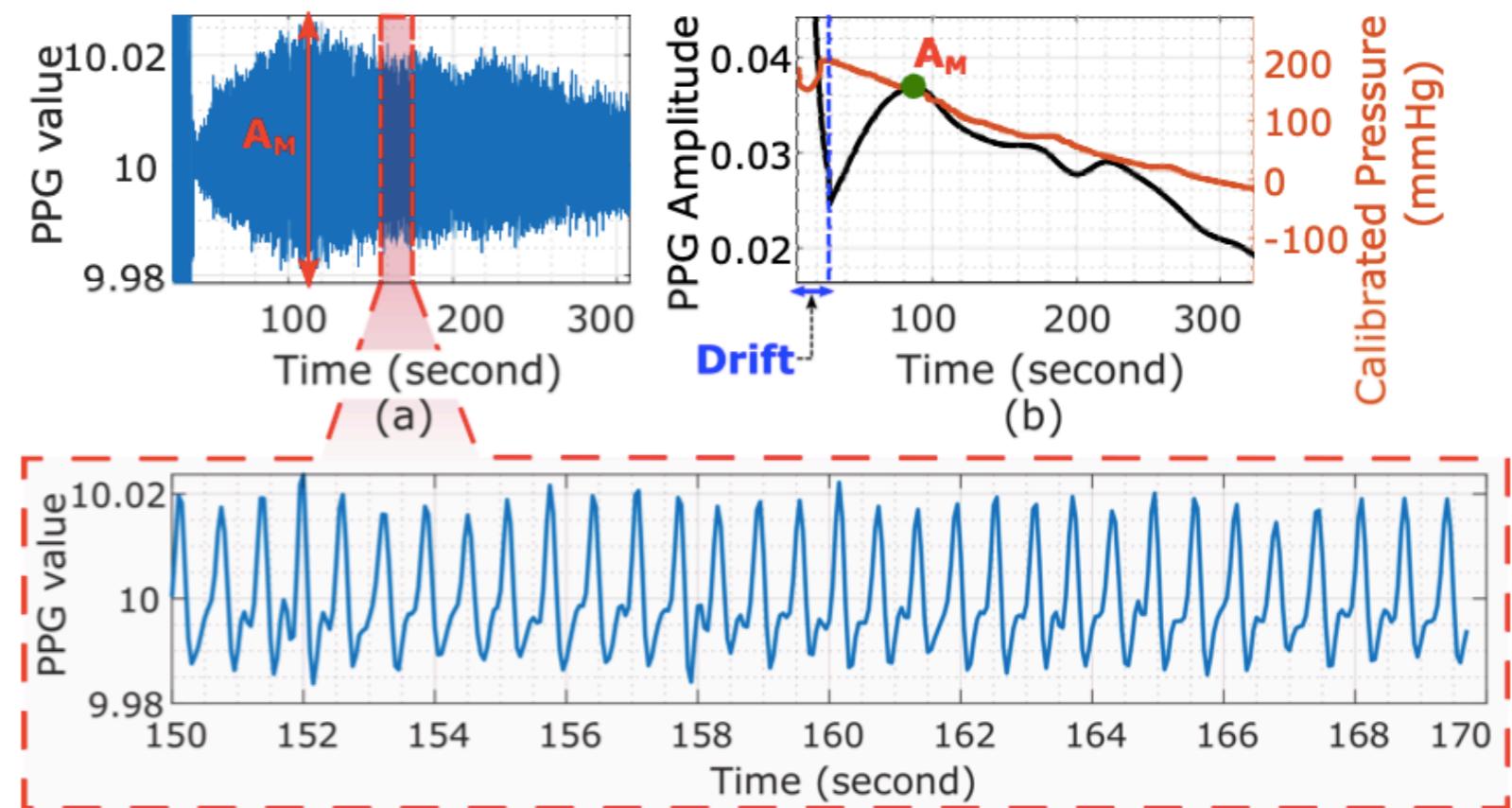
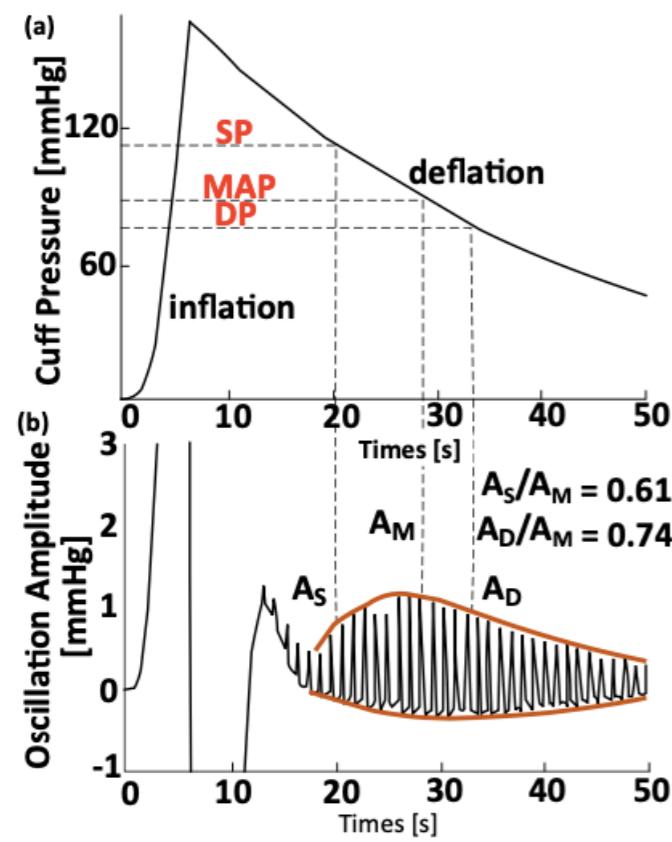
Outline

1. Why do we need continuous blood pressure (BP) measuring devices?
2. Fundamental of BP measurement
3. Overview of eBP
4. Hardware design
- 5. In-ear blood pressure estimation algorithm**
6. Signal processing
7. Evaluation / testing
8. Discussion

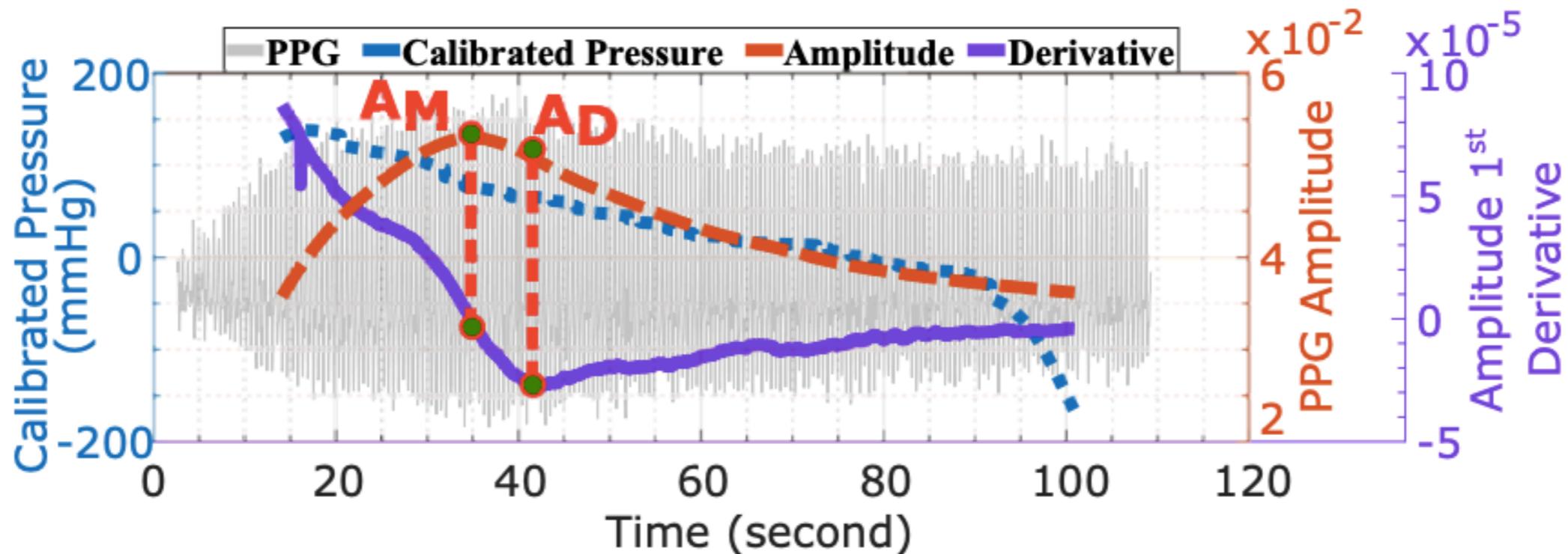
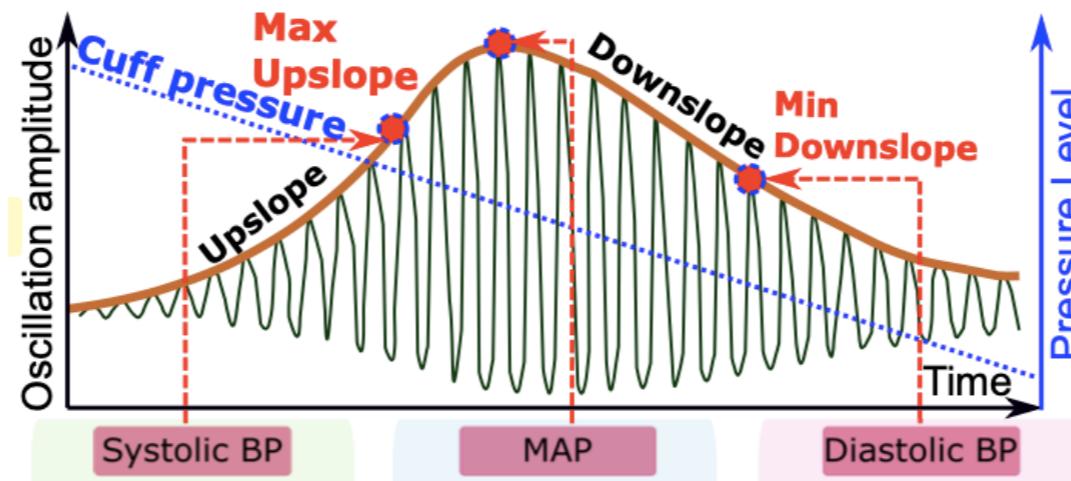


Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

In-ear blood pressure estimation algorithm



In-ear blood pressure estimation algorithm



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Outline

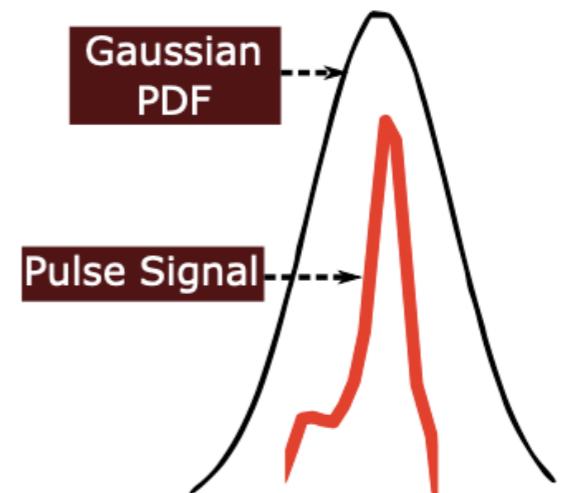
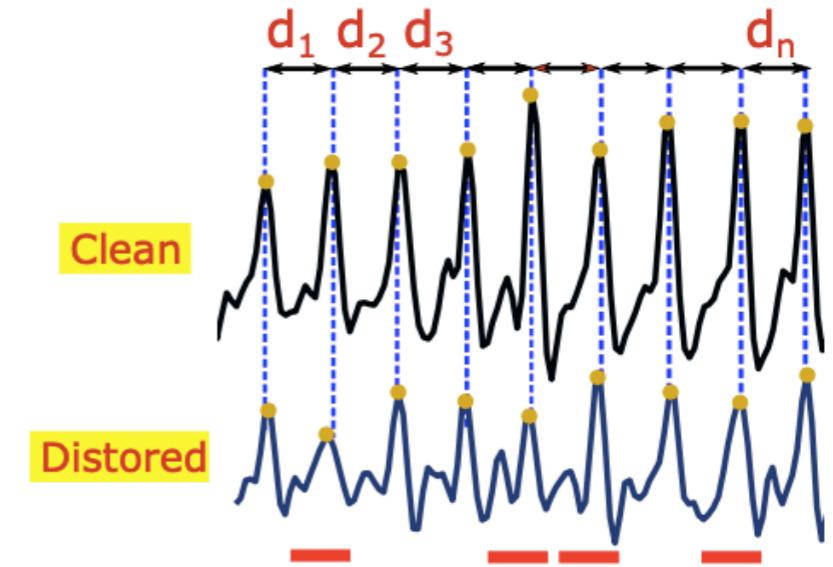
1. Why do we need continuous blood pressure (BP) measuring devices?
2. Fundamental of BP measurement
3. Overview of eBP
4. Hardware design
5. In-ear blood pressure estimation algorithm
6. **Signal processing**
7. Evaluation / testing
8. Discussion



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Signal processing

- Peak interval variability + threshold
- Entropy variance + threshold
- Filters: bandpass, Gaussian, median filters.
- PPG Peak detection



Outline

1. Why do we need continuous blood pressure (BP) measuring devices?
2. Fundamental of BP measurement
3. Overview of eBP
4. Hardware design
5. In-ear blood pressure estimation algorithm
6. Signal processing
7. **Evaluation / testing**
8. Discussion



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.

Evaluation

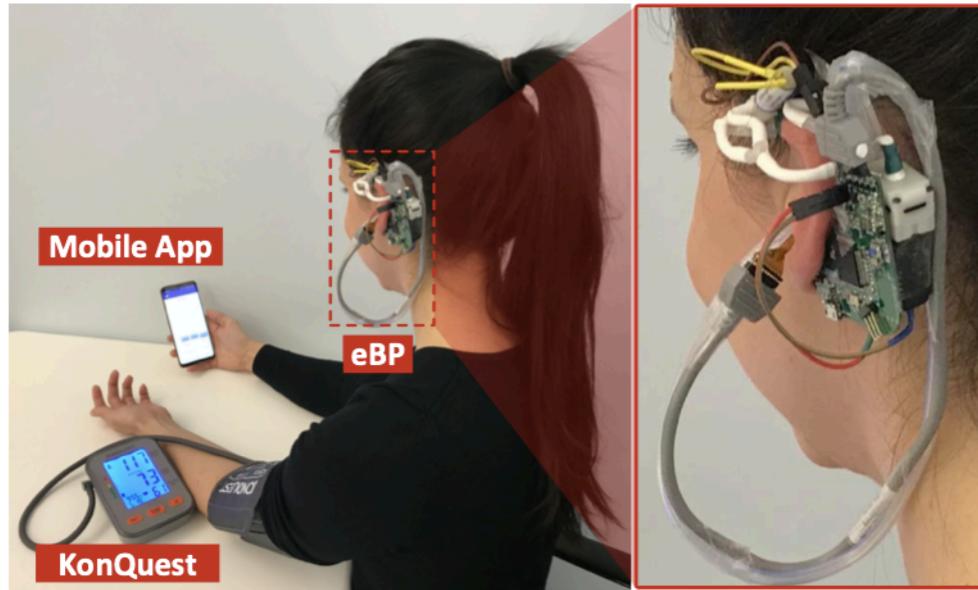
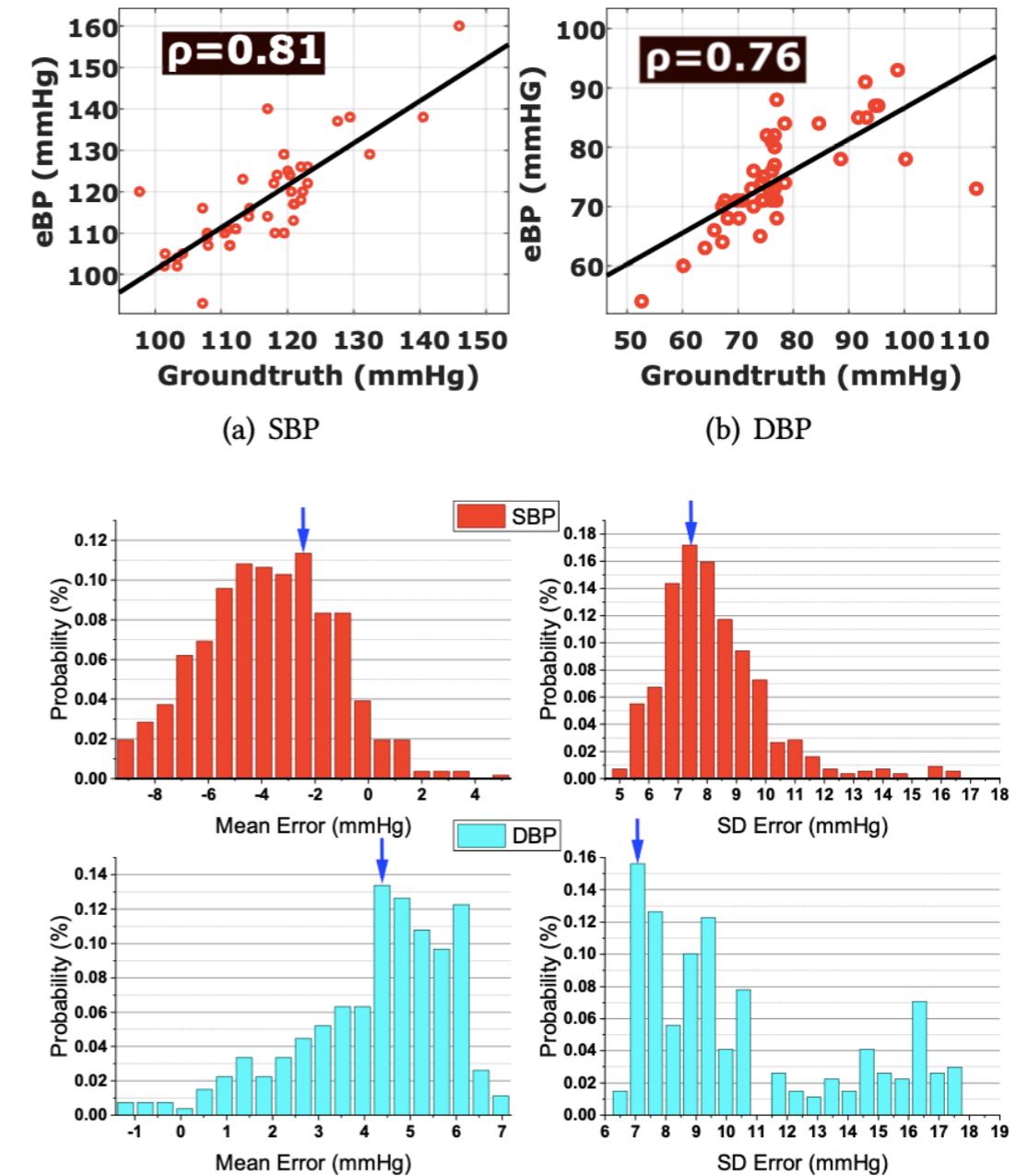


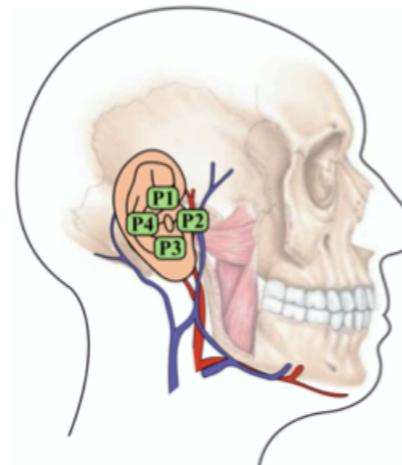
Table 1: Demographic description of participants

Demographic data of study population	
Age (years)	18 - 35 years old
Blood Pressure	Systolic: 93-146 , Diastolic: 53-113
Gender Ratio	Male: 24, Female: 11

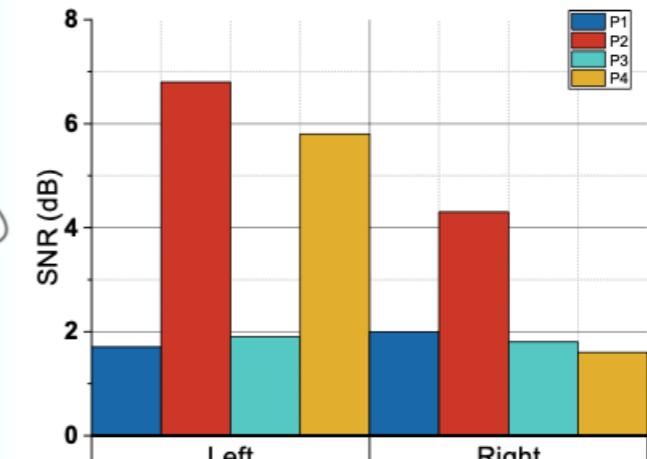


Discussion

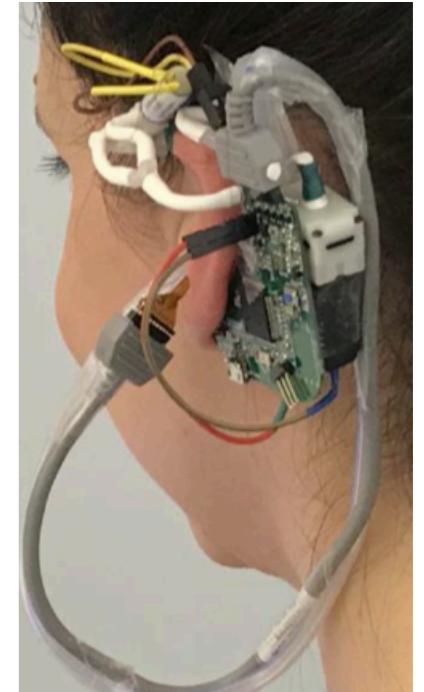
- Balloon design
- Sensor placement
- High idle current draw
- Leveraging on-chip processing data
- Miniaturization
- Systole ratio estimation in atrial fibrillation (AF)



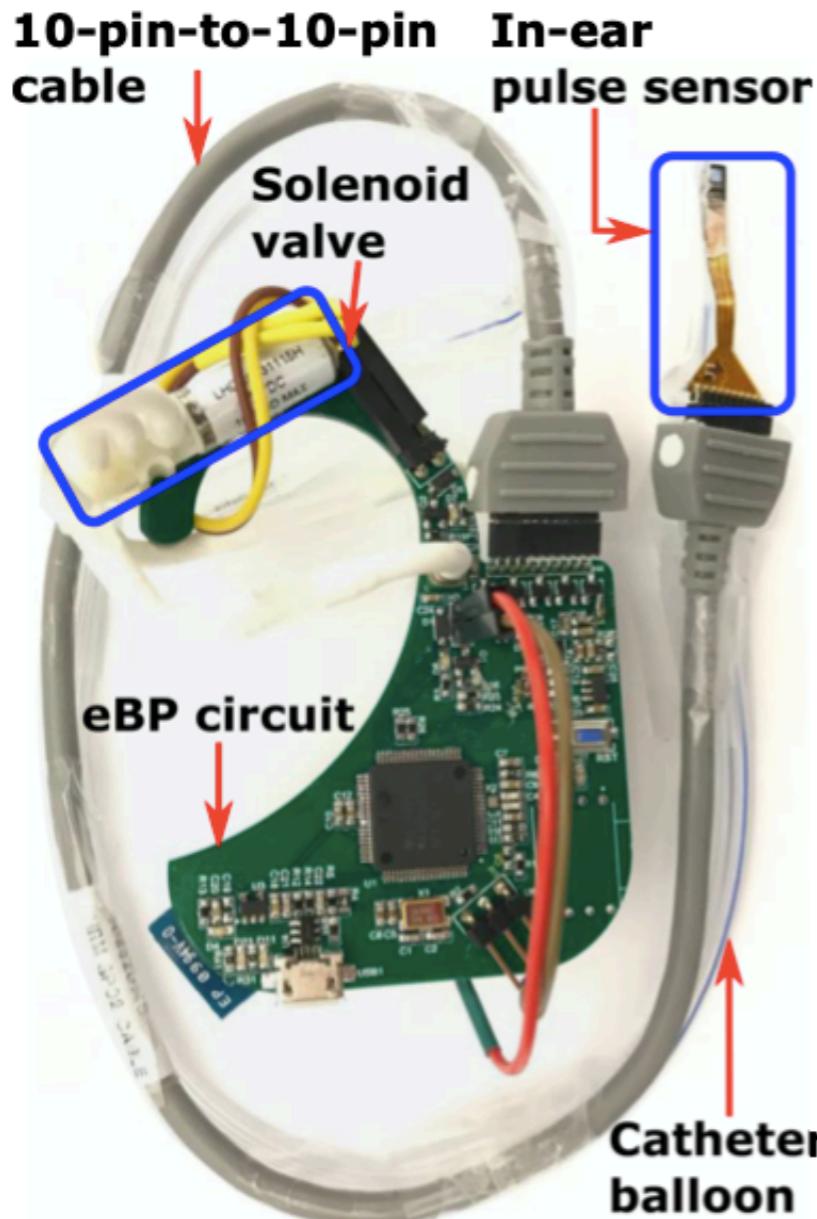
(a) Setup



(b) SNR



Conclusion



- In-ear BP by observing the behavior of pulse amplitude
- Tested on 35 subjects
- Errors are within the acceptable margins regulated by FDA's AAMI protocol
- This is a new concept for BP monitoring

Slide availability:

<https://pargorn.puttapirat.com/courses/>



Additional part of this presentation is licensed under a Creative Commons Attribution 4.0 International License.