All Electrical and Real-time ECG, Respiration, Airflow, and Skin Conductance Monitoring System

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Outline

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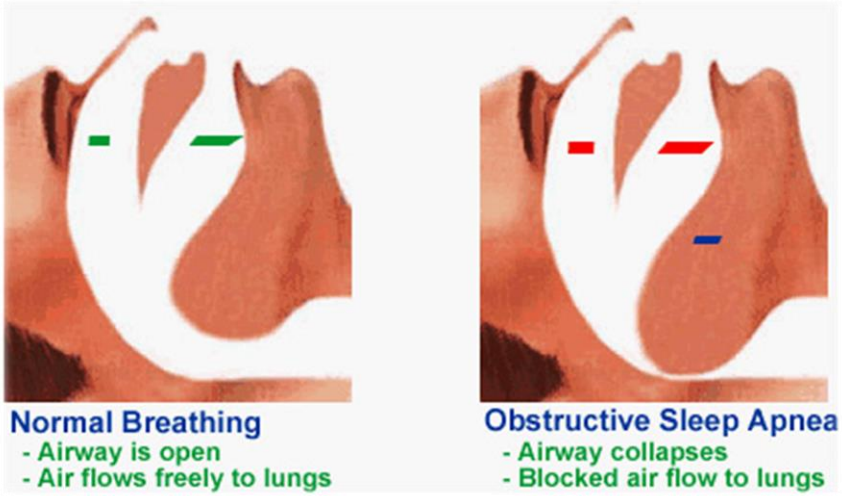
- **Proposed System**
- **Measurement Results**
- **Conclusions**

Introduction



[WatchPAT]

[ApneaLink]

- **Sleep apnea in U.S**
  - **4% males, 2% females**
    - **18 million people[1]**
- **Previous methods for sleep apnea monitoring**
  - **SpO2, Snoring sound, Heart rate, Body position..**

➔ **Skin conductance has been neglected in sleep apnea monitoring!**

[1] A. Malhotra, and D. P. White, "Obtrusive sleep apnea," *Lancet '02*

Skin Conductance and Sleep Apnea

Recording place	OSAS group ($n = 15$)	Non-apneic group ($n = 7$)	Control group ($n = 26$)
Right hand (x ± SD)	1.56 ± 0.19 s*	1.50 ± 0.14 s*	1.32 ± 0.10 s
Left hand (x ± SD)	1.54 ± 0.18 s*	1.48 ± 0.13 s*	1.30 ± 0.10 s
Right foot (x ± SD)	2.08 ± 0.42 s	2.00 ± 0.14 s	1.77 ± 0.20 s
Left foot (x ± SD)	2.08 ± 0.42 s	2.07 ± 0.15 s	1.77 ± 0.20 s

- **Skin conductance**
  - **Absent or delayed in patients with sleep apnea[2]**
  - **It can be a useful non-invasive technique for assessment of sleep apnea!**

[2] B. Zakrezewska-Pniewska, et al., "Sympathetic Skin Response in Obstrustive Sleep Apnea Syndrome," *Acta Neuribol Exp '98*

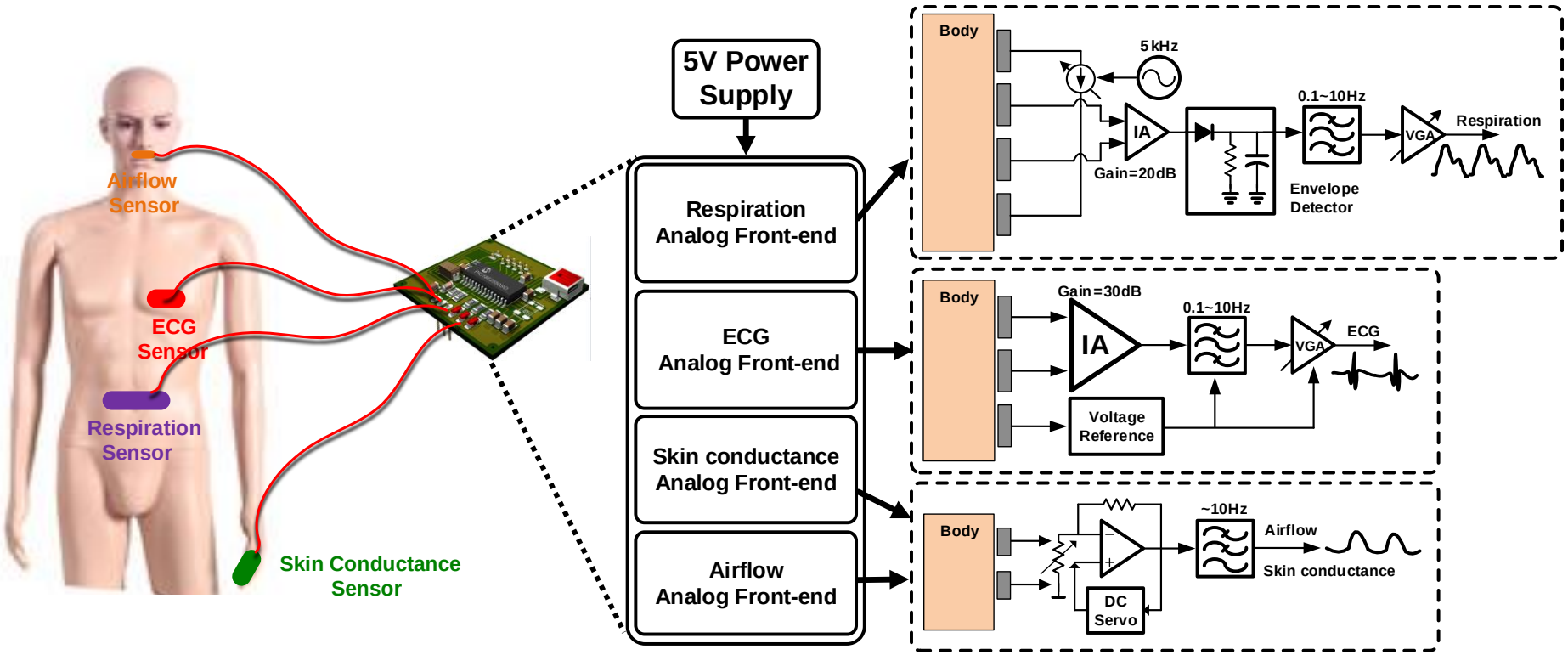
Multi-signals Measurement

- **ECG, Airflow, Respiration, and Skin conductance**
  - **Portable device for sleep apnea monitoring**

- **Unwanted interference with each AFEs**
  - **Problematic!**

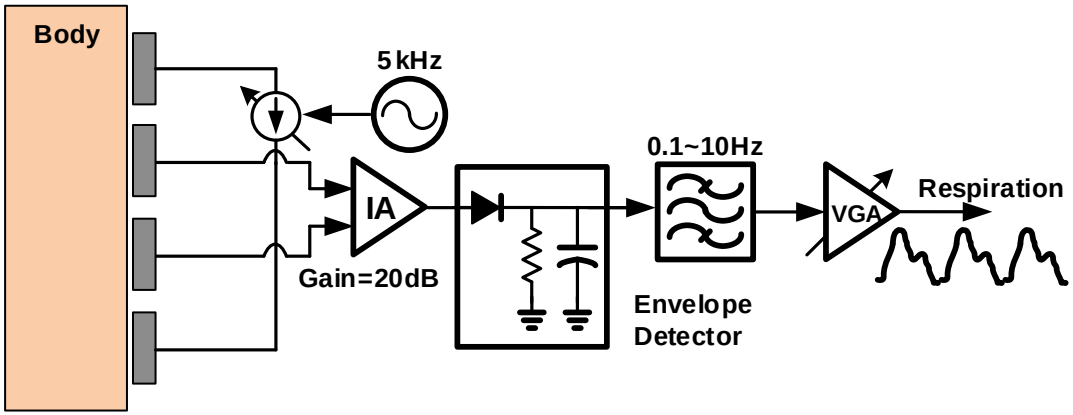
➔ **Cost-effective and interference-free system!**

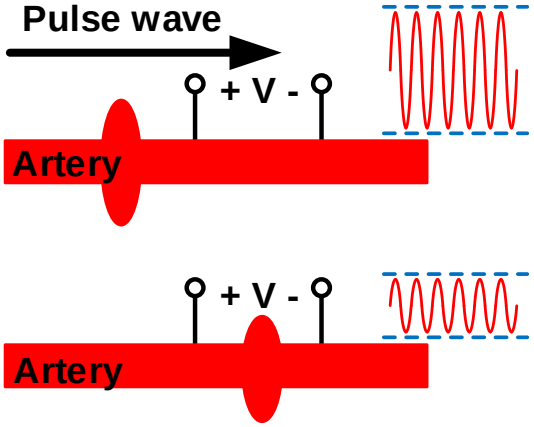
System Description



- **Respiration, ECG, Skin conductance, Airflow**
  - **Measurement without any interference**
- **PCB implementation with all electrical components**
  - **Cost-effective solution (1 thermistor + 16 op-amp)**

Respiration Analog-front-end

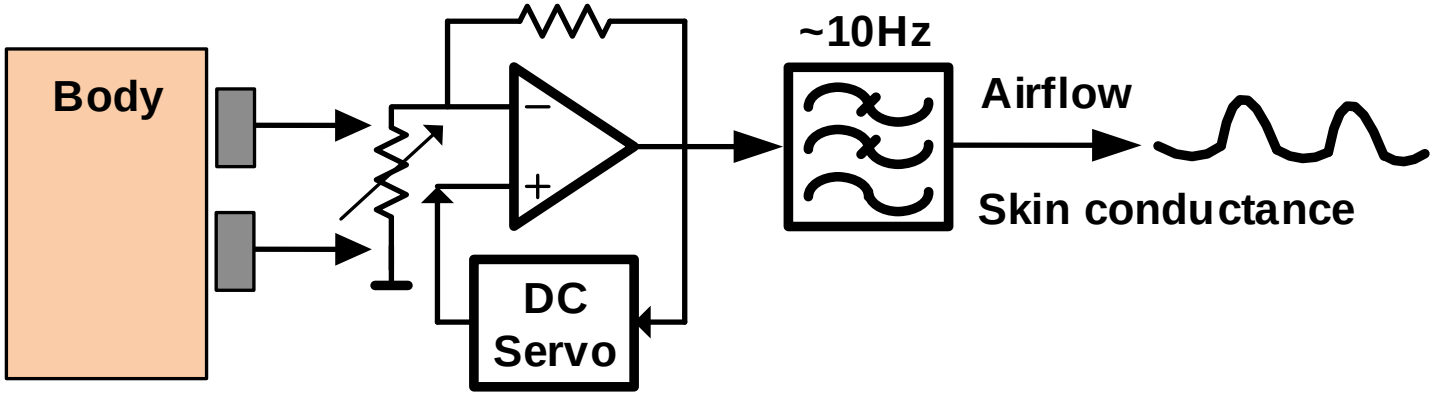




- **Bio-impedance [3] is adopted**
- **Measuring impedance of the abdomen**
  - **Respiration ➔ Impedance variation**
- **IA, Envelope detector, BPF, and VGA**

[3] M.-C. Cho, J.-Y. Kim, and S.-H. Cho, "A bio-impedance measurement system for portable monitoring of heart rate and pulse wave velocity using small body area," *ISCAS '09*

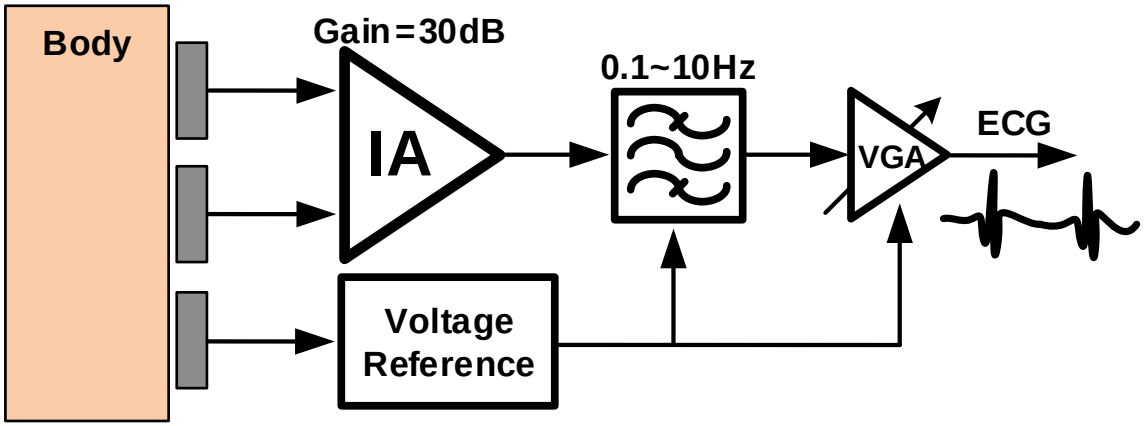
Airflow and Skin Conductance



- **Thermistor (Airflow)**
- **DC resistance middle and index finger (SC [4])**
- **DC servo loop ➔ baseline fluctuation**

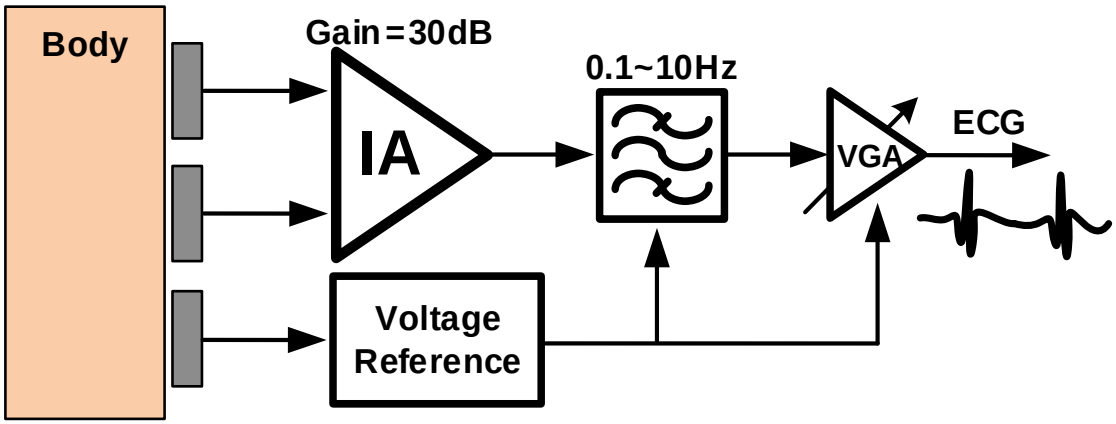
[4] M. Poh, N. Swenson, and R. Picard, "A Wearable Sensor for Unobtrusive, Long-Term Assessment of Electrodermal Activity," *TBME '10*

ECG Analog-front-end

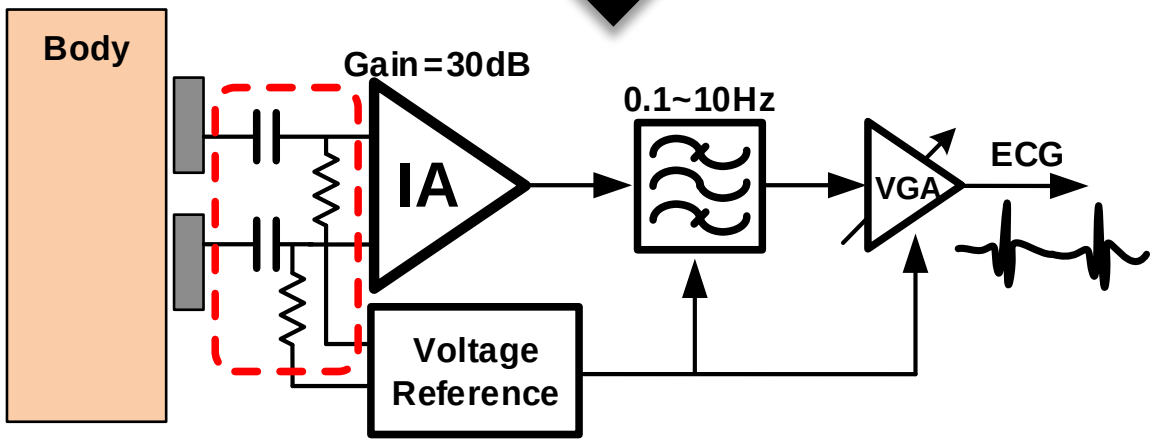


- IA, BPF, VGA, and Voltage reference
- Voltage references
  - Bias voltage of the body ➔ Half V_{dd}
  - It can interfere with SC measurement
    - Problematic!

ECG Analog-front-end

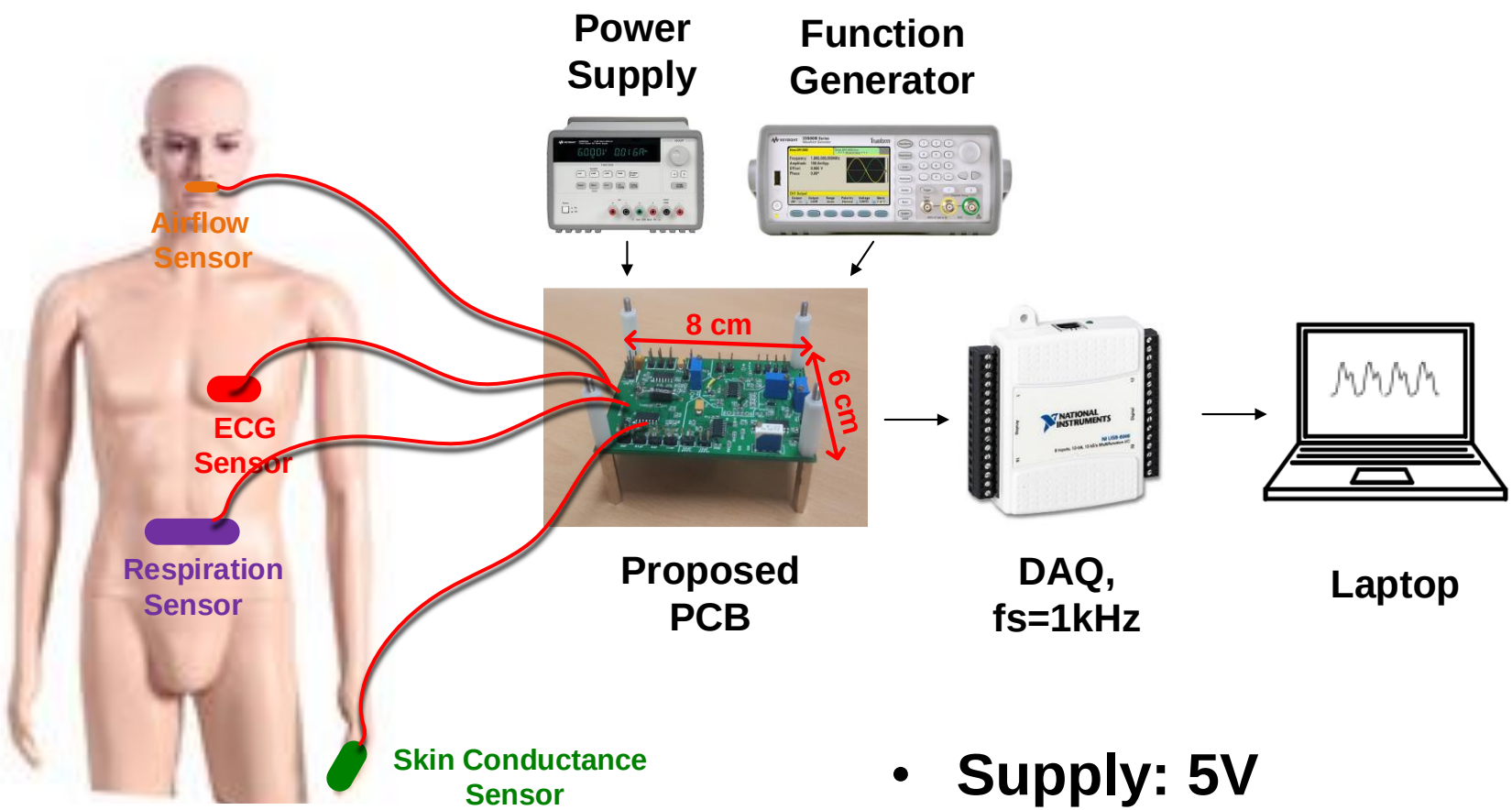


[Conventional]



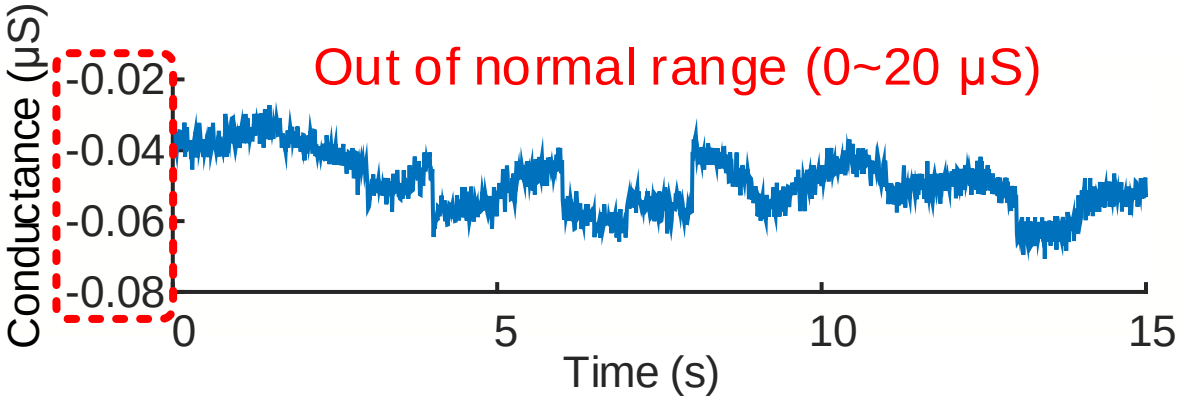
[Proposed]

Measurement Set-up

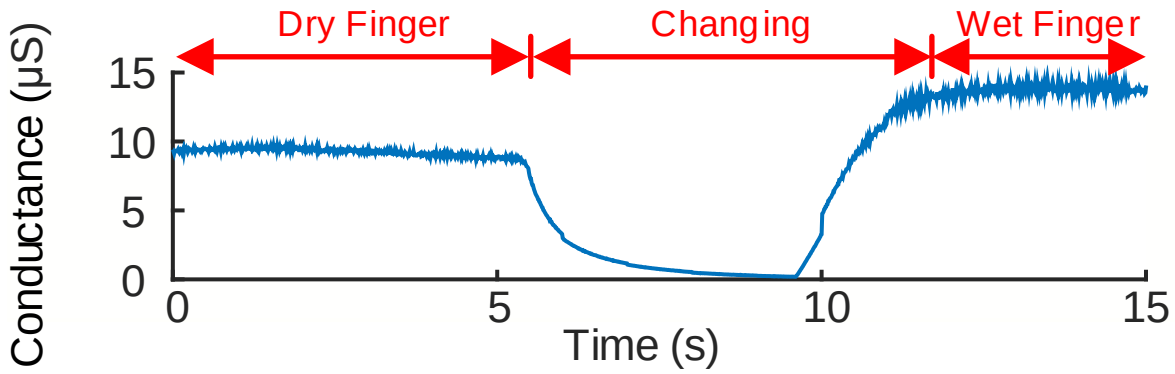


- **Supply: 5V**
- **Power: 50mW**

Measurement Results (Skin Conductance)

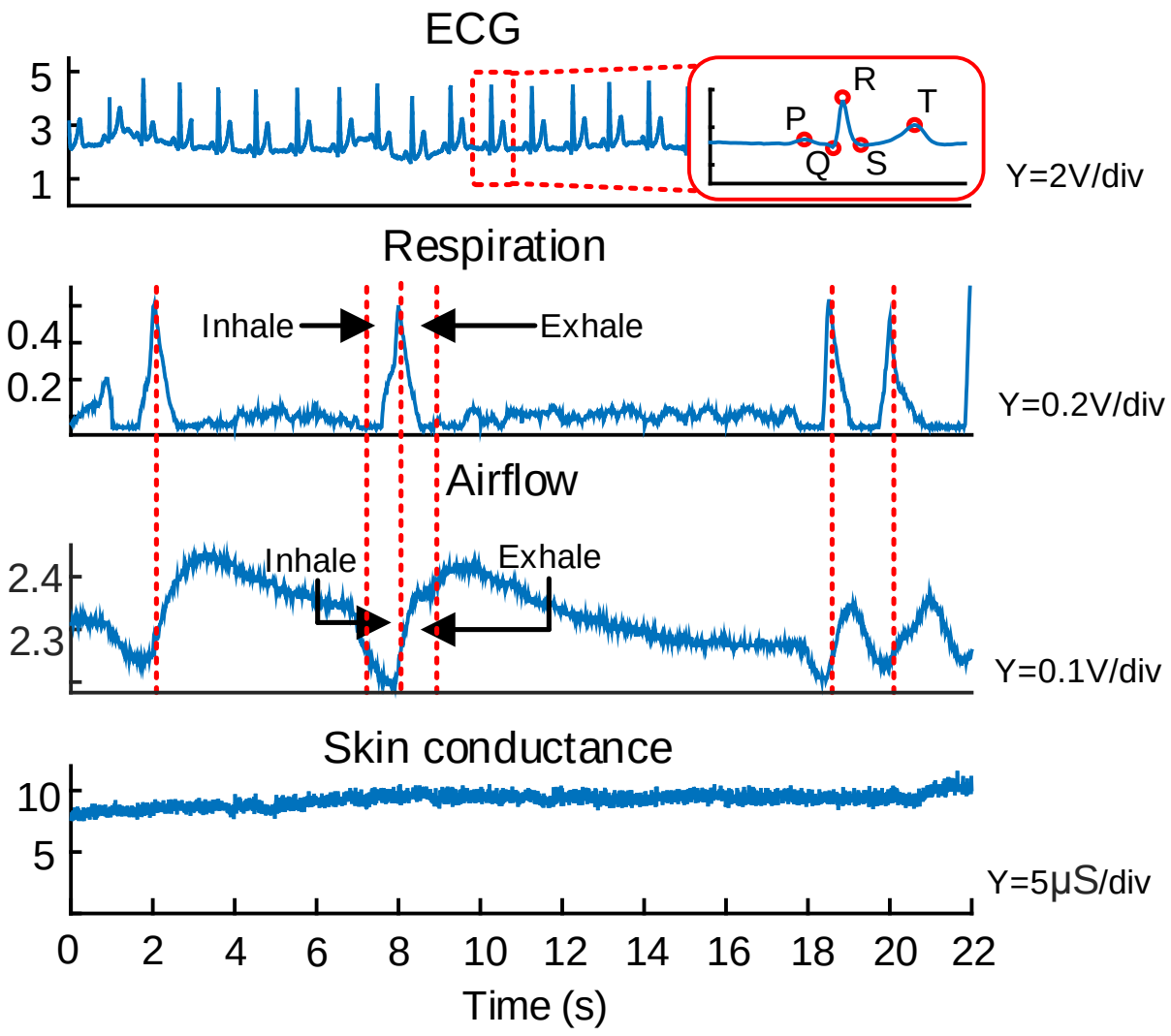


[With inteference]



[Without inteference]

Measurement Results(All signals)



- **ECG**
  - **PQRST waveform**
- **Respiration & Airflow**
  - **Synchronized**
- **Skin conductance**
  - **Within normal physiological range**

Comparison Table

	[5] Bang BioCAS'09	[6] Altini EMBC'11	This Work
Functionality	ECG, BI, PWV	Respiration, ECG, EMG	ECG, BI, Airflow, Skin Conductance
Additional Sensor	No	Yes (Accelerometer)	No
Supply Voltage	10V	3.7V	5V
Power	1,077mW	9mW	50mW

- **All electrical method**
- **The largest number of bio-signals**

[5] S. Bang, J. Park, M.-C. Cho, and S.-H. Cho, "A Pulse Transit Time Measurement Method Based on Electrocardiography and Bio-impedance," *BioCAS '09*

[6] M. Altini, et al., "A Low-power Multi-modal Sensor Network with application to Epileptic Seizure Monitoring," *EMBC '11*

Conclusions

- **Interference-free multiple physiological parameter monitoring system**
  - **ECG, Respiration, Airflow, Skin Conductance**
- **All electrical implementation**
  - **Cost-effective solution**
- **It achieves the monitoring of the largest number of the bio-signal among the recently published systems implemented on PCB**