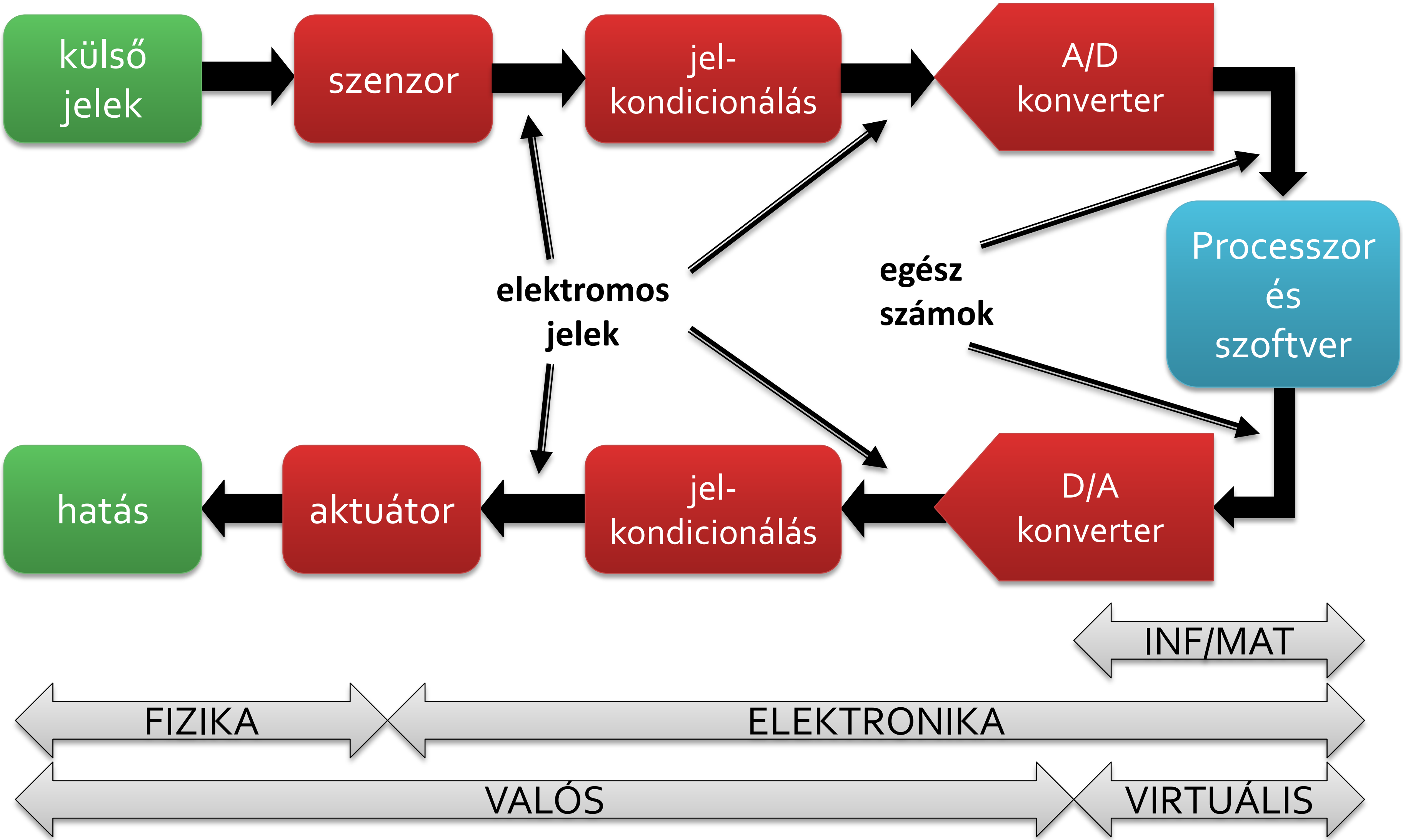
Gingl Zoltán
ITCS szeminárium 2013.09.17.

A Műszaki Informatika Tanszék kutatási témáiból

Modern műszer, gép, eszköz



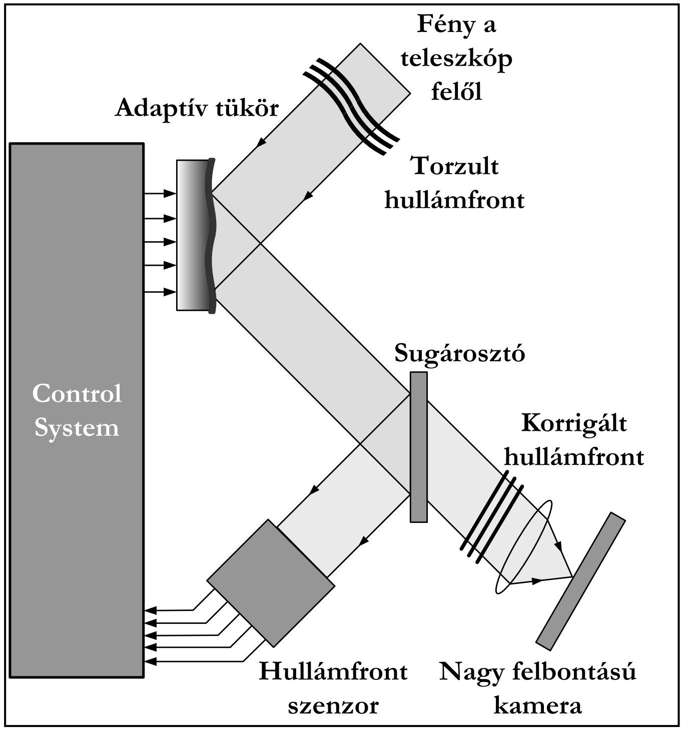
Robotika, irányítástechnika (Szépe T.)

- Mobil robotok, pályakövetés
- Pneumatikus műizmok modellezése
- Távelérésű laborok (router, szenzorinterfészek)

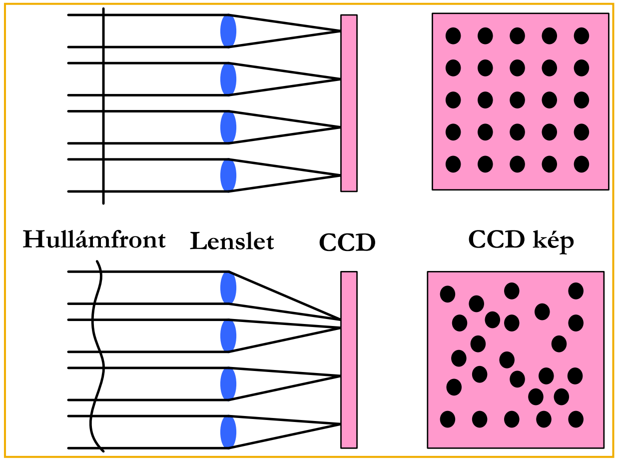
FPGA alapú adaptív optikai rendszer (Kincses Z.)

- **Feladat: Egy költséghatékony FPGA alapú hullámfront szenzor megvalósítása**
  - A hullámfront szenzor a beeső fény hullámfrontjának torzulását határozza meg,
  - A referencia és az éppen aktuális kép közötti eltolódás mérésével (SAD eljárás),
  - Ez alapján valós időben kompenzálható a beeső fény hullám frontja,
  - Jelentősen javul a képfeldolgozó rendszer teljesítménye

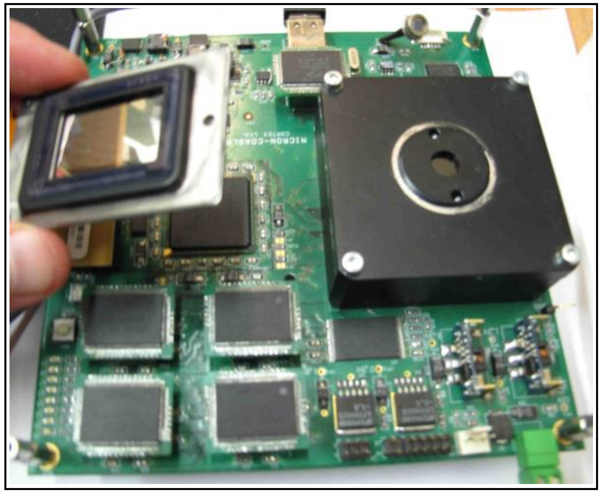
- Adaptív optika rendszer



- Hullámfront szenzor



- FPGA alapú adaptív optikai rendszer



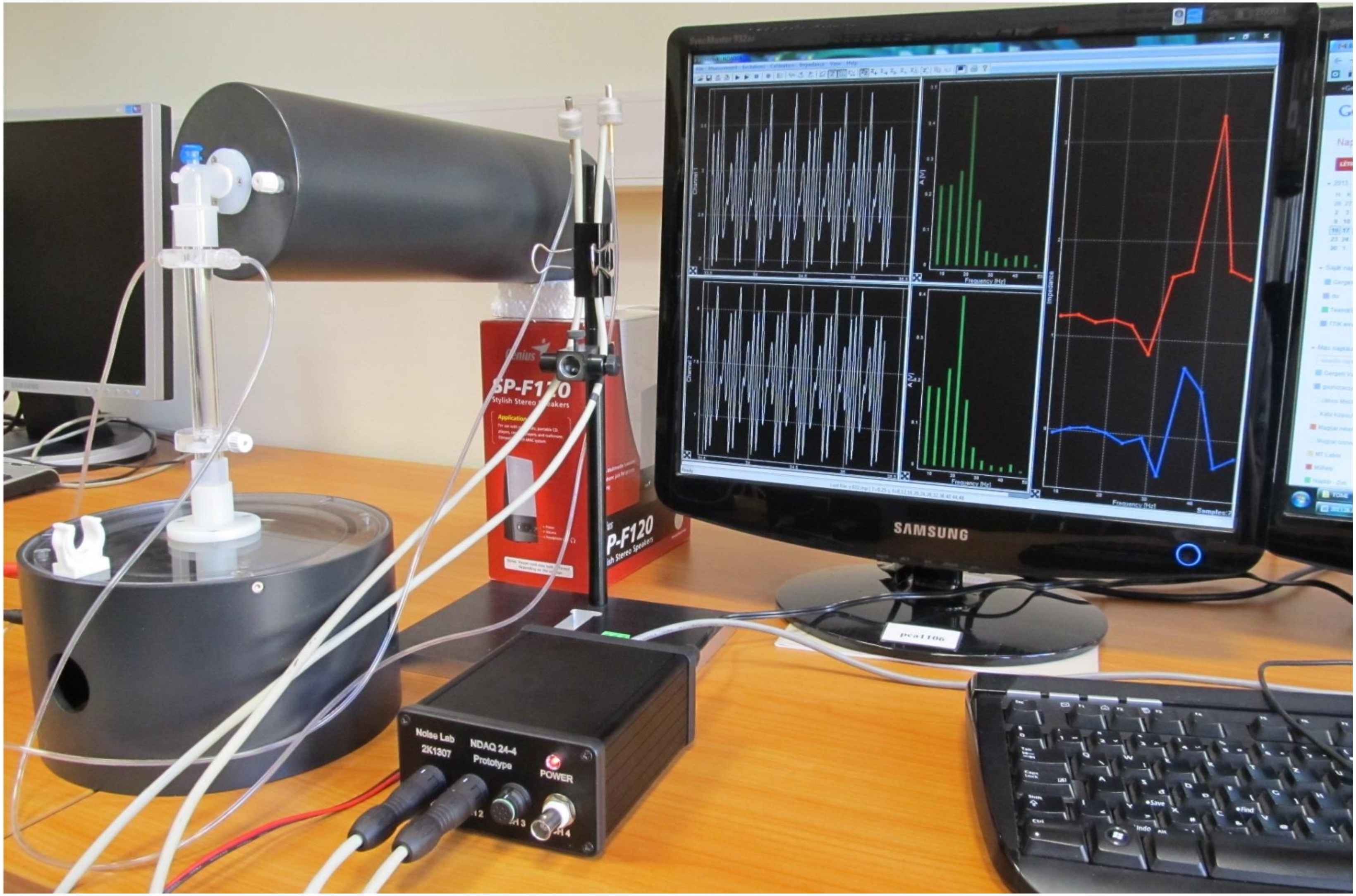
Hardware-in-the-loop eszközök (Csikós S.)

Szabályozó, PLC (feladat)

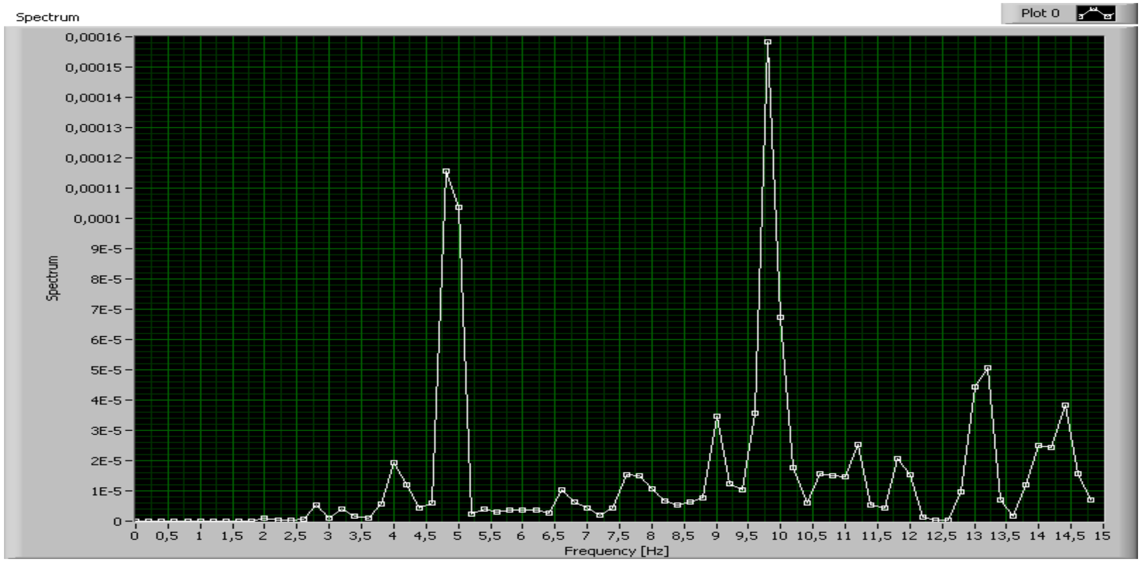
A szabályozott rendszer elektronikai ekvivalense: A/D, D/A, mikrovezérlő

Számítógép megjelenítés, szoftver

Légzésmechanikai vizsgálatok (Makan G., Mellár J., Hantos Z.)

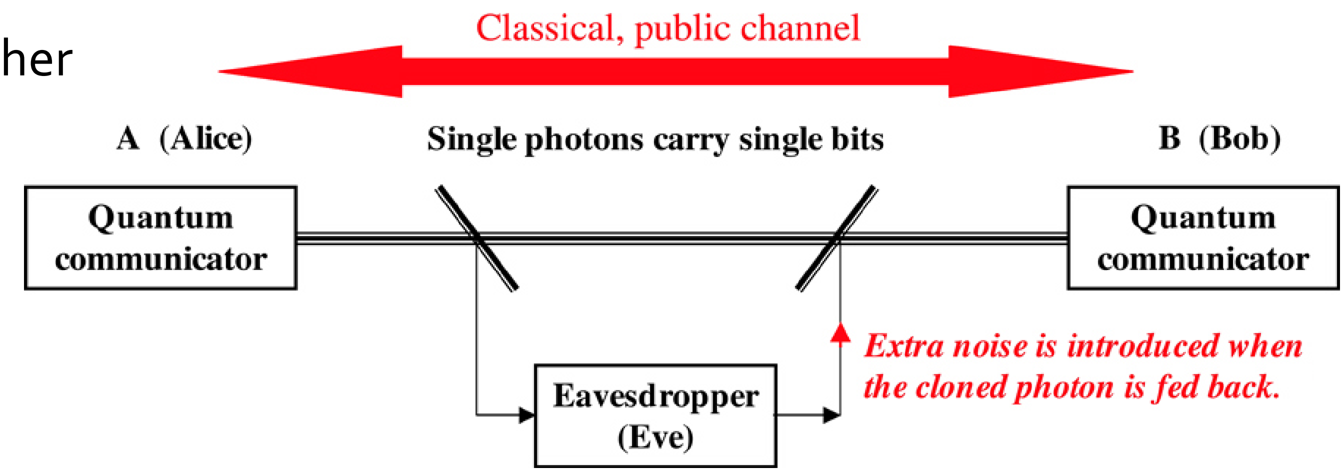


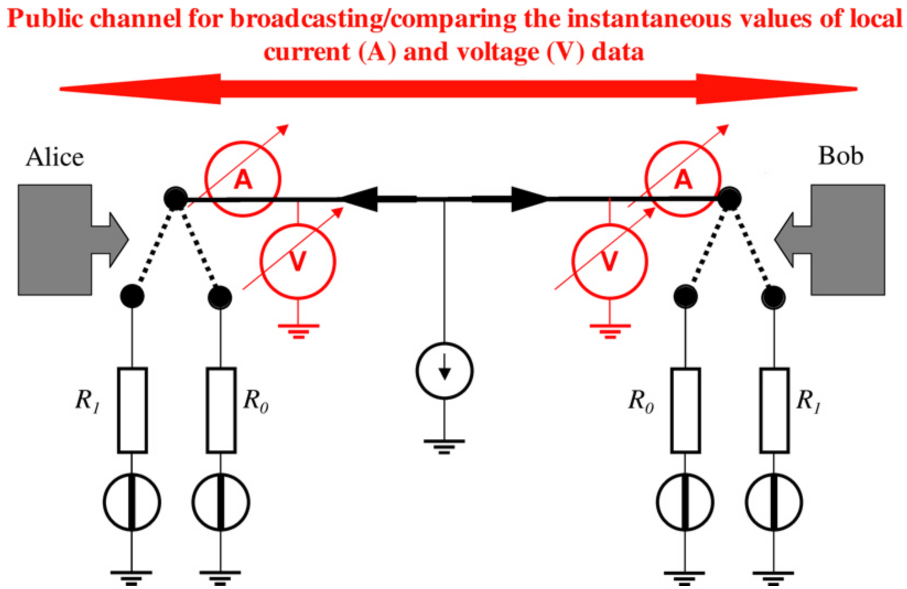
Pitvarfibrillációs EKG jelek spektrális analízise (Szénási R.)

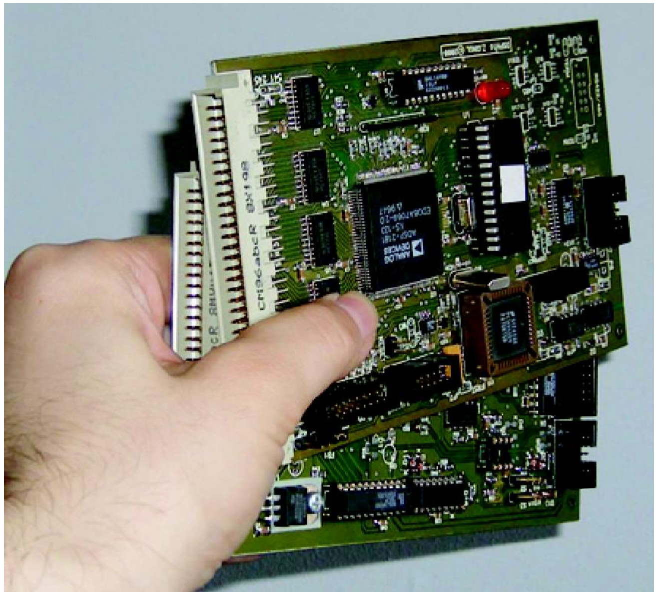


Abszolút biztonságos kommunikáció (Mingesz R.)

Kvantum cipher



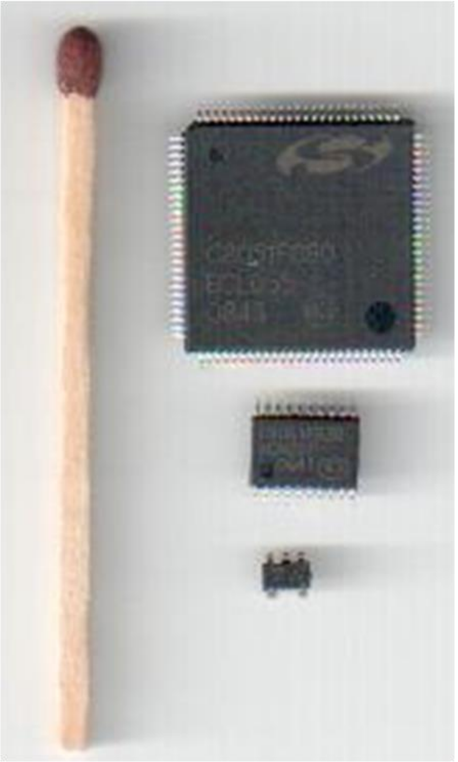




Random noise as information source
Multidisciplinary applications

Low power, small devices

- Tablets, smartphones
- Small PCs
  - „credit-card sized" computers
  - Raspberry PI
  - BeagleBone
- Single-chip computers
  - microcontrollers (8051, ARM)
  - digital signal controllers
- Industrial? Temperature? Accuracy? Reliability?



Miniature, efficient devices

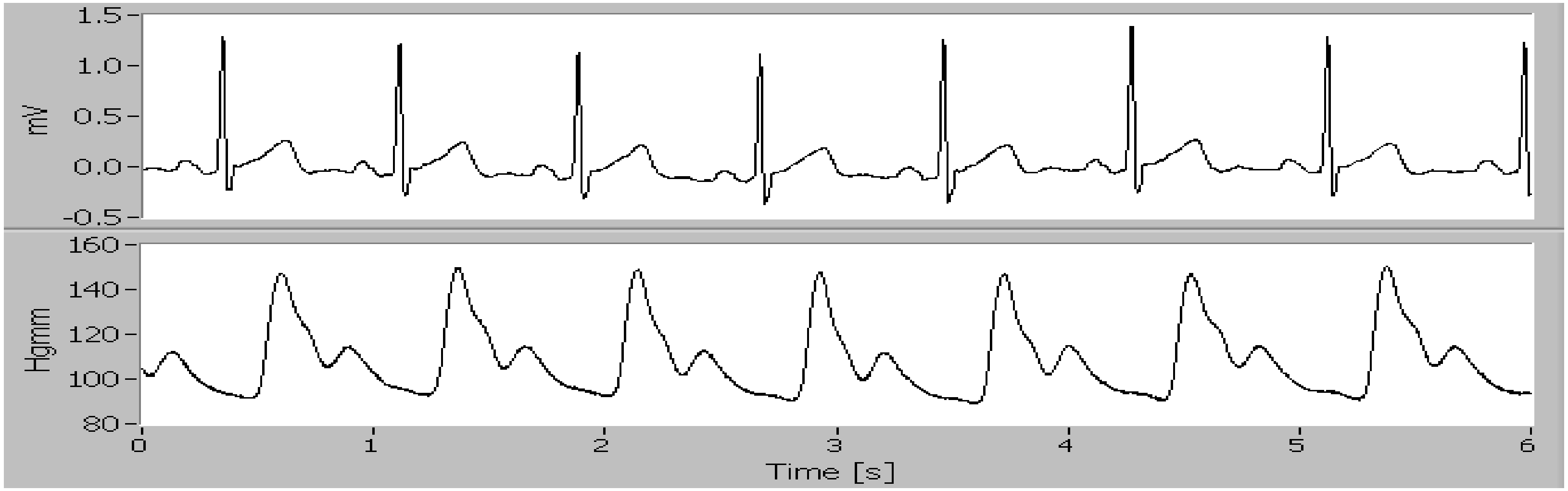
- Intelligent systems (chips) integrate
  - Sensors
  - Analog signal conditioning
  - Digital signal porcessing
  - Networking/storage
- System-on-a-chip
- Lab-on-a-chip

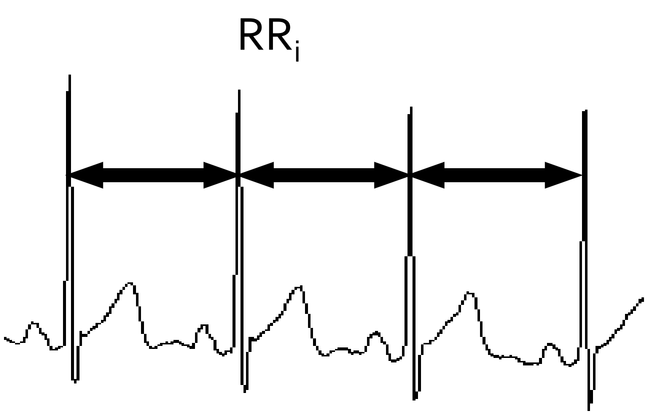
Noisy signal proecessing

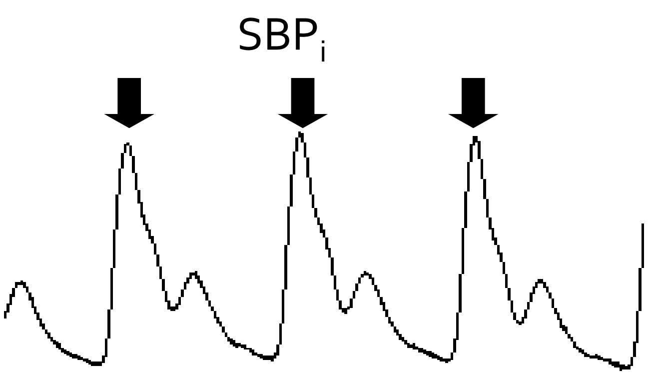
- **Noise is the signal**
- Signal processing is rather complex
- Electronic support:
  - Mixed-signal devices
    - Analog: noise signal conditioning
    - Digital: information extraction (software)

Heart rate variability

ECG, blood pressure



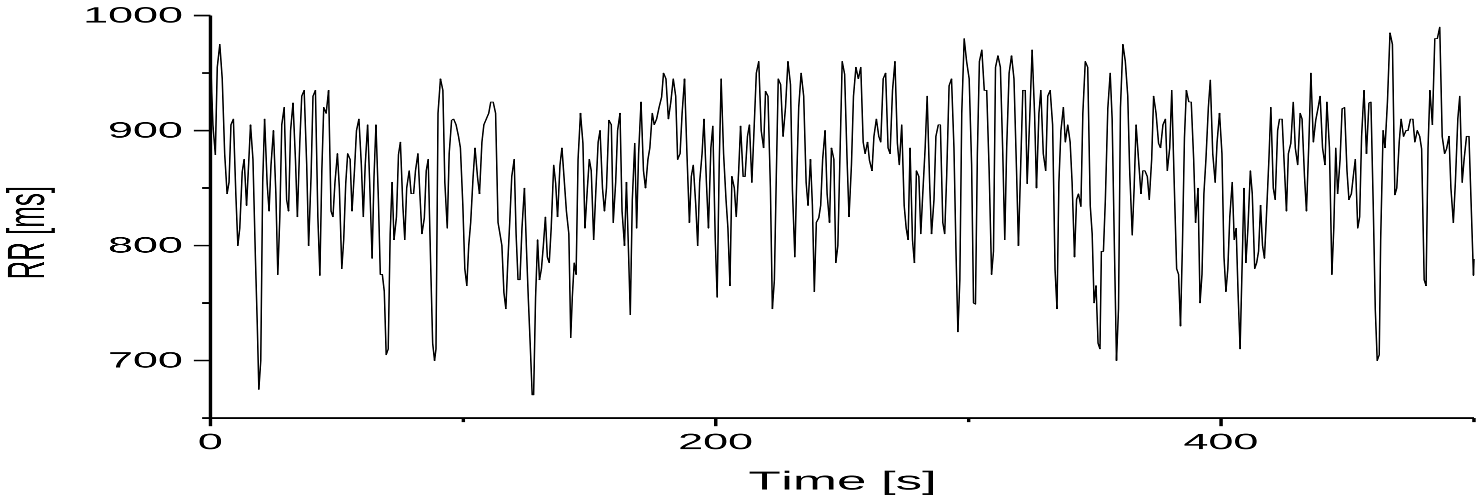


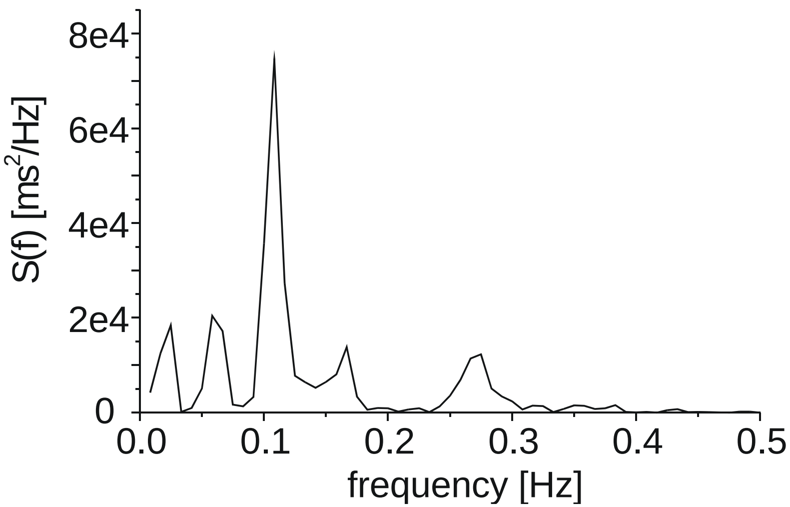


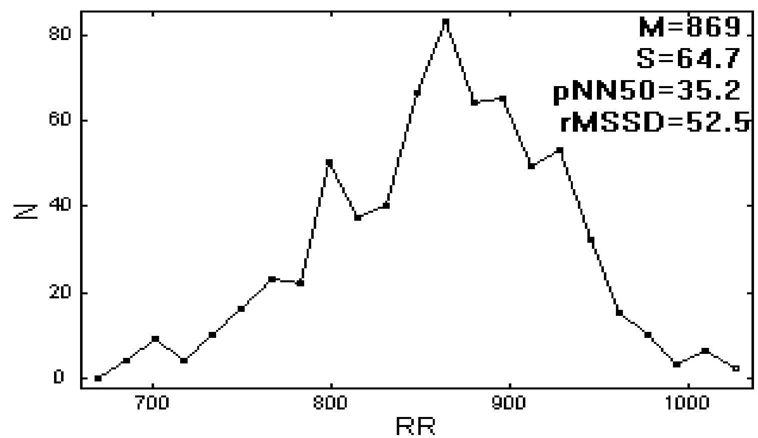
RR processing

- mean
- standard deviation (sdRR)
- pNN50
- variance of variance
- power spectra

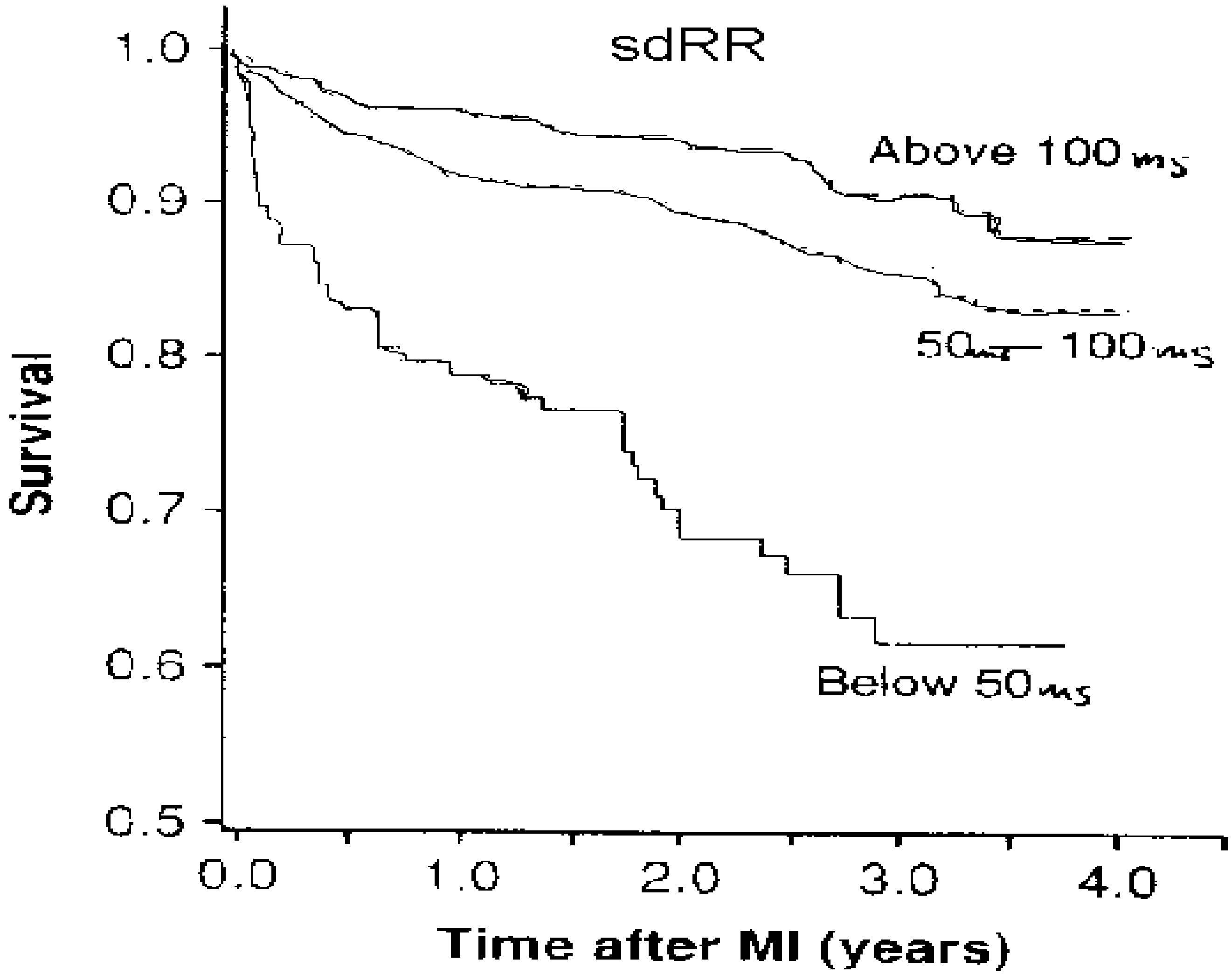
RR trend and spectrum



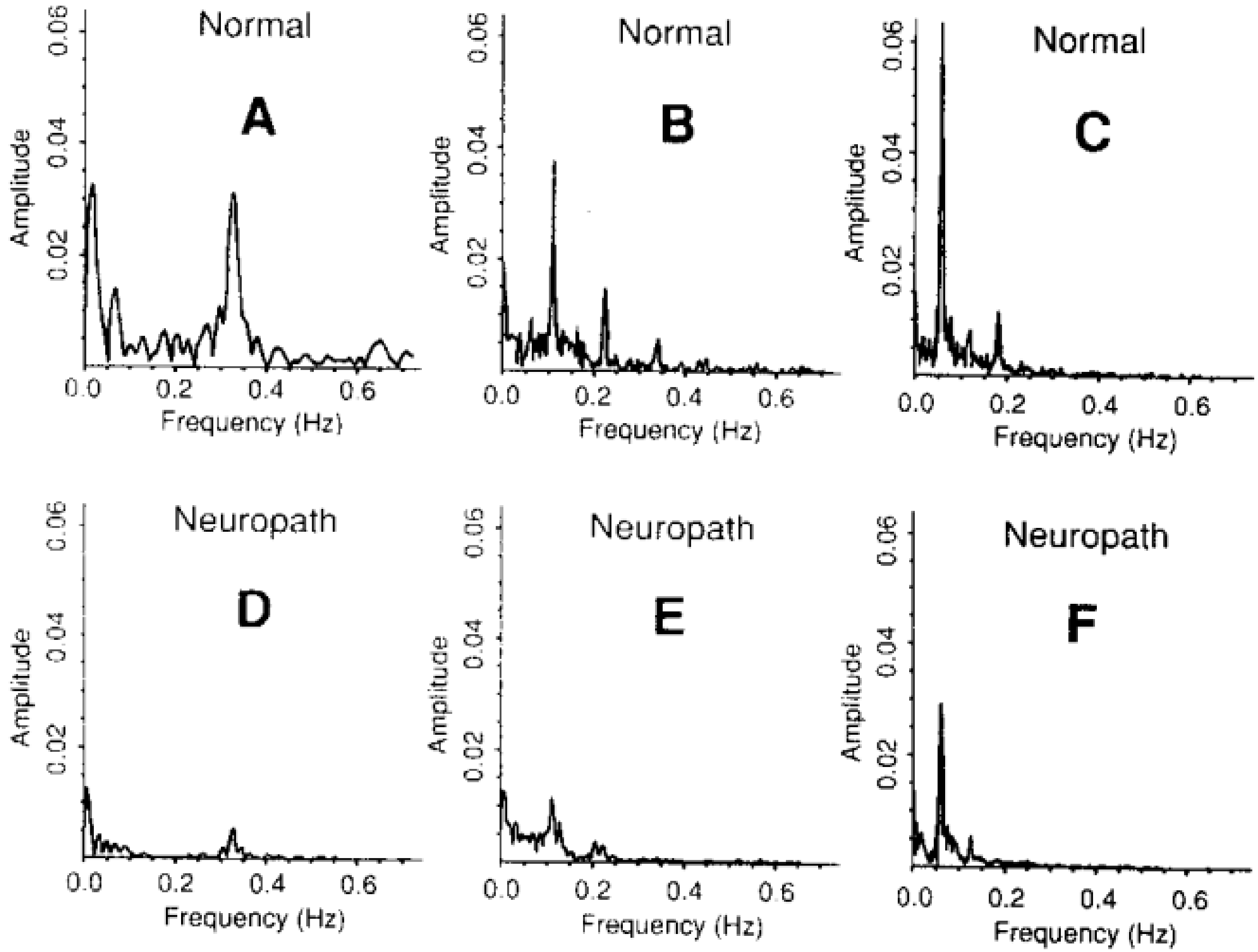




sdRR is an indicator

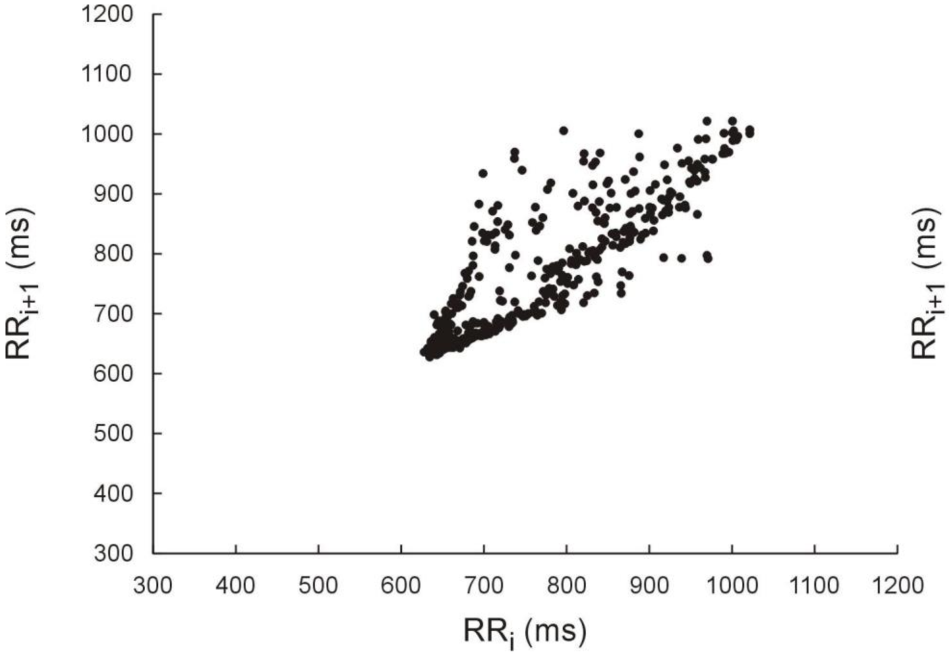


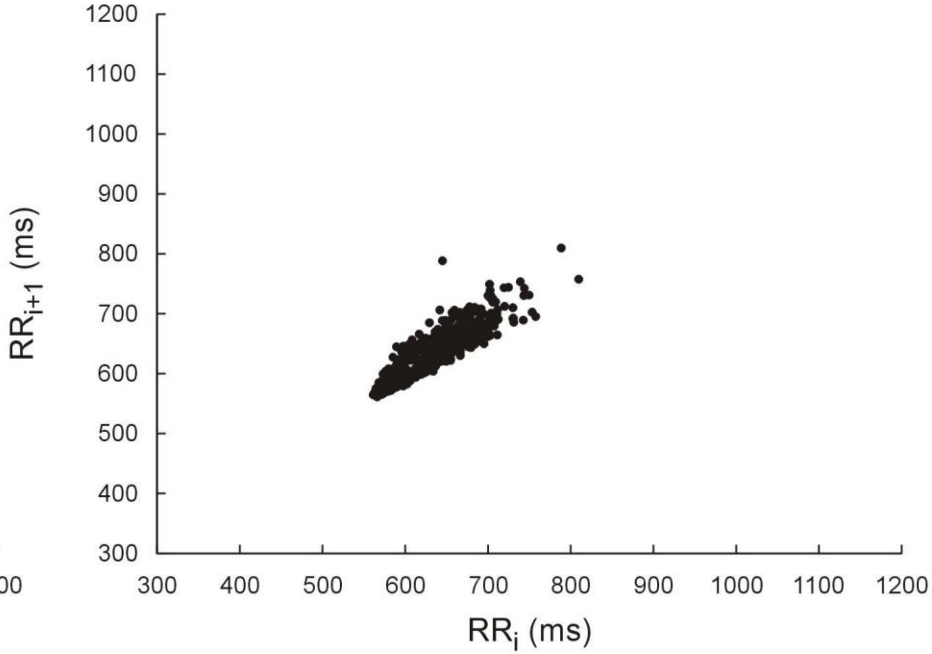
Spektrumok betegség esetén

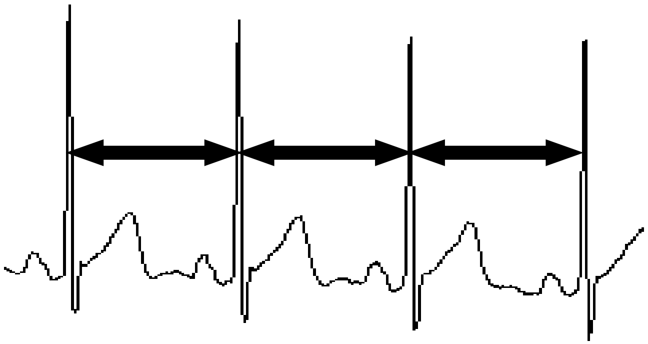


Poincare plot

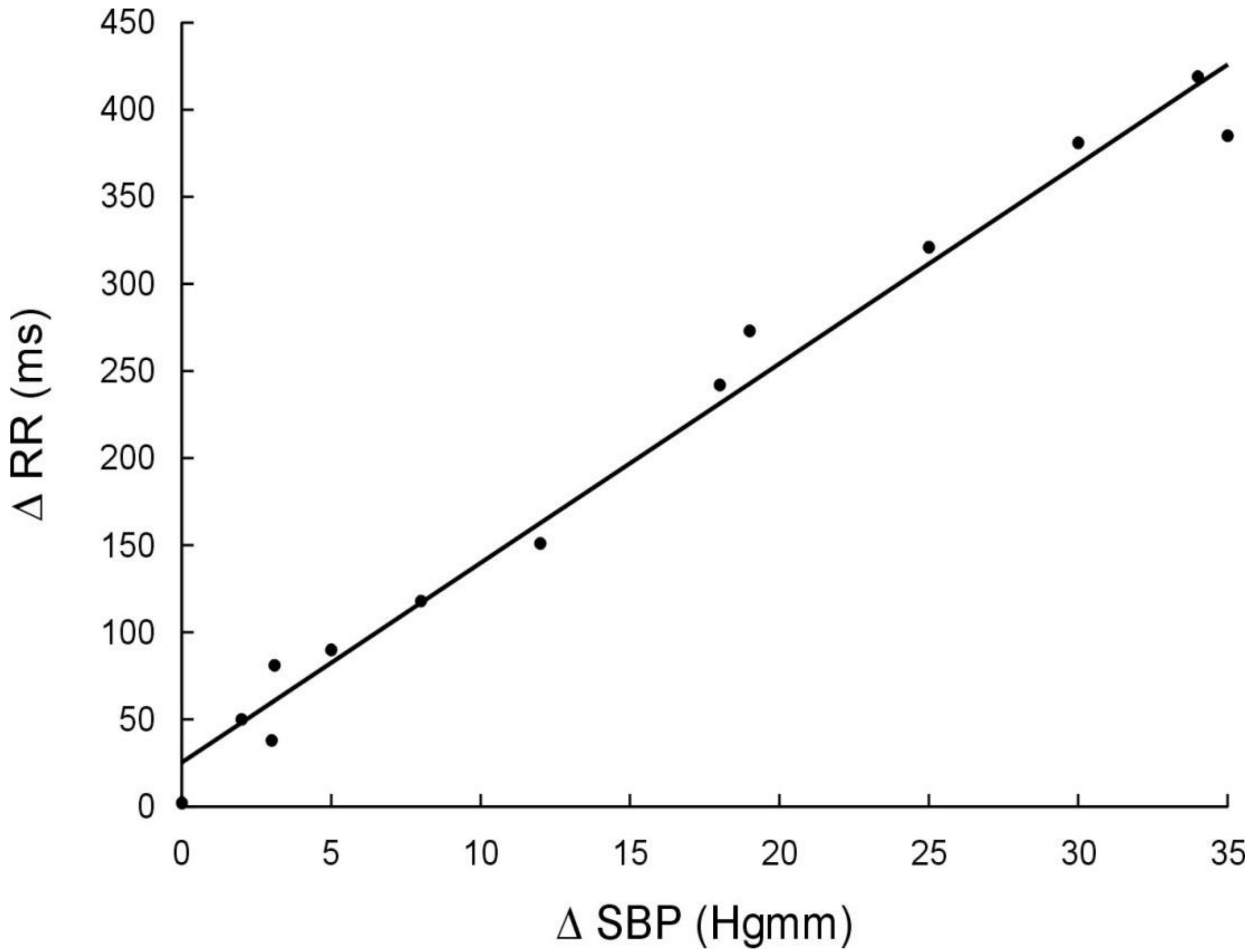
(to smoke or not to smoke, that is the question…)



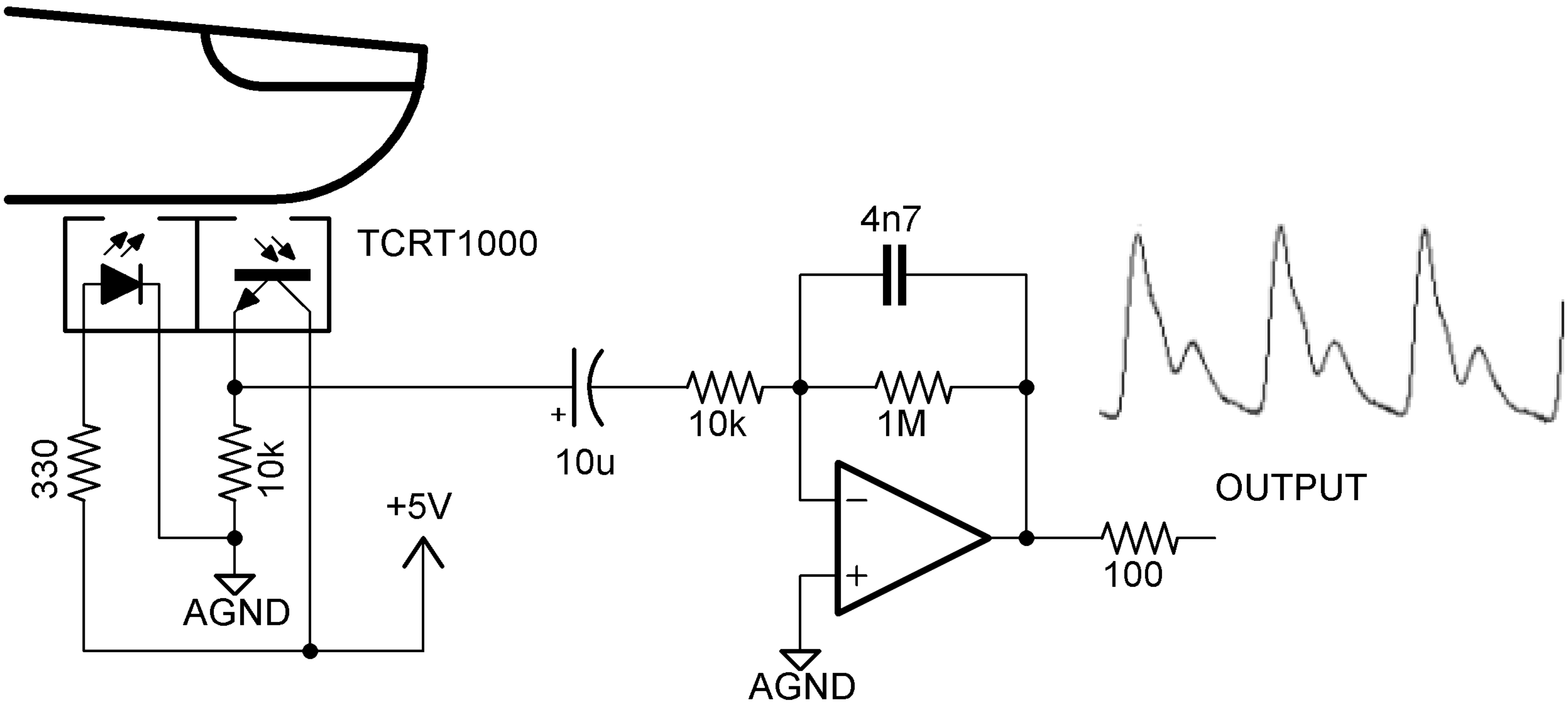




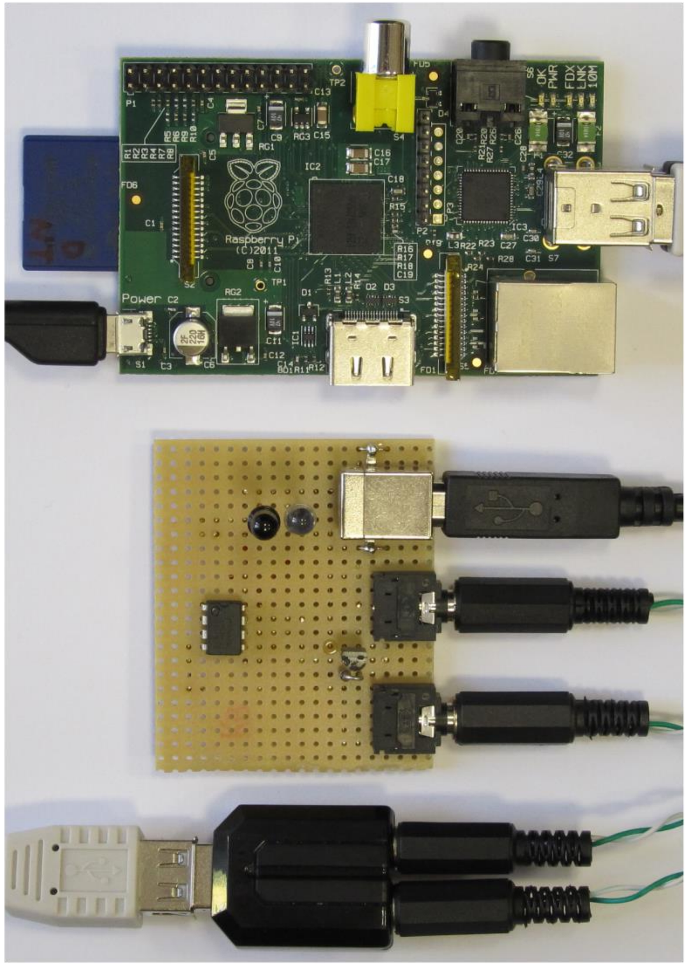
Baroreflex sensitivity (spontaneous)



Photoplethysmography



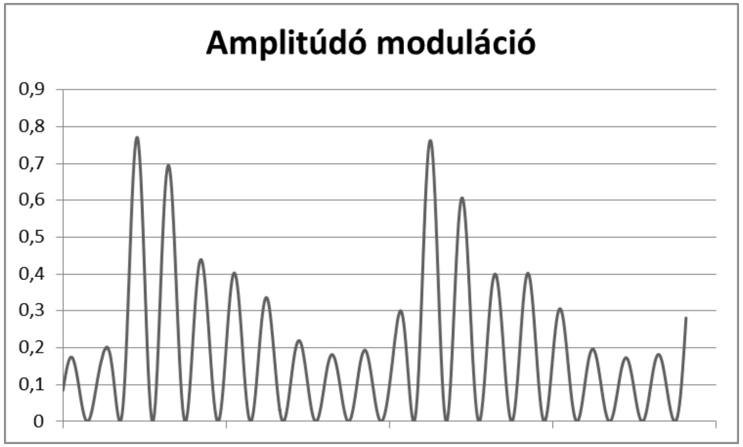
Using a Raspberry Pi (Tamás Nagy)

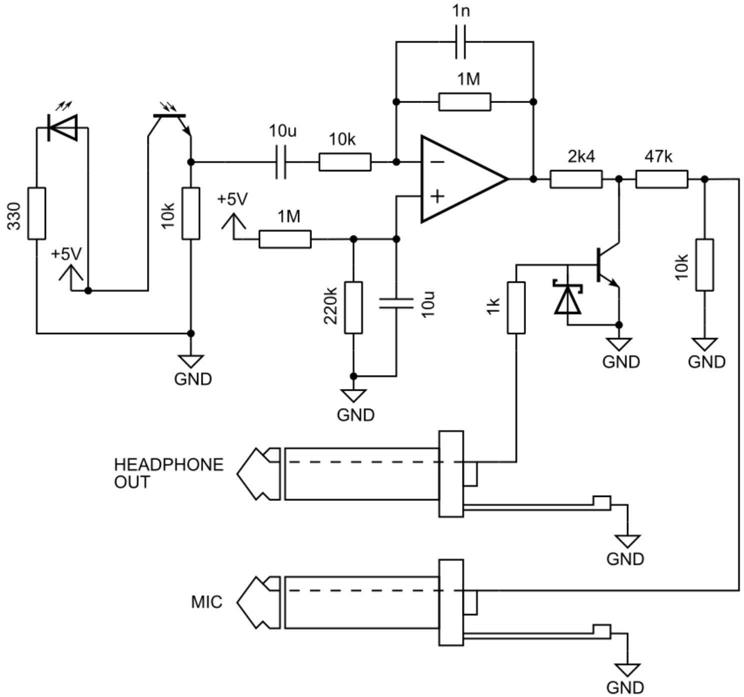


- Sound card interface
- Java + JavaFX software
- peak detection (RR)
- mean RR, sd RR, spectrum
- Portable to other platfomrs

Amplitude modulation

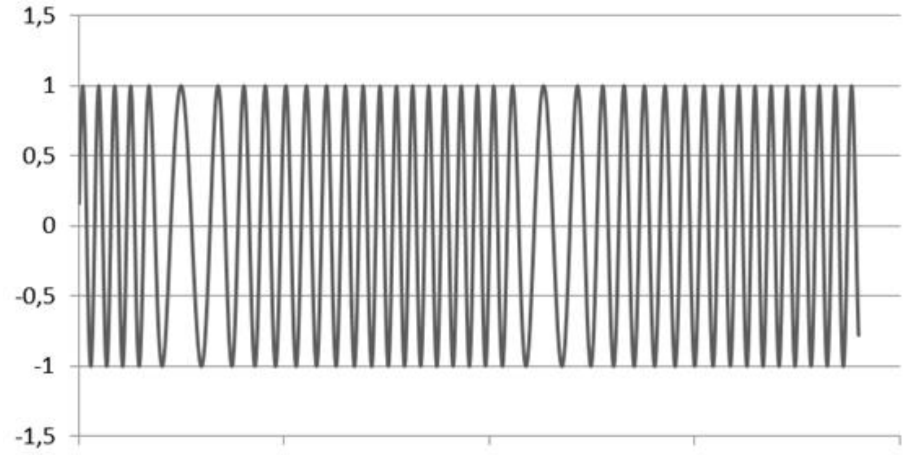
- Amplitude: information
- Headphone out: 1kHz sine
- Transistor „chopping”
- Microphone input

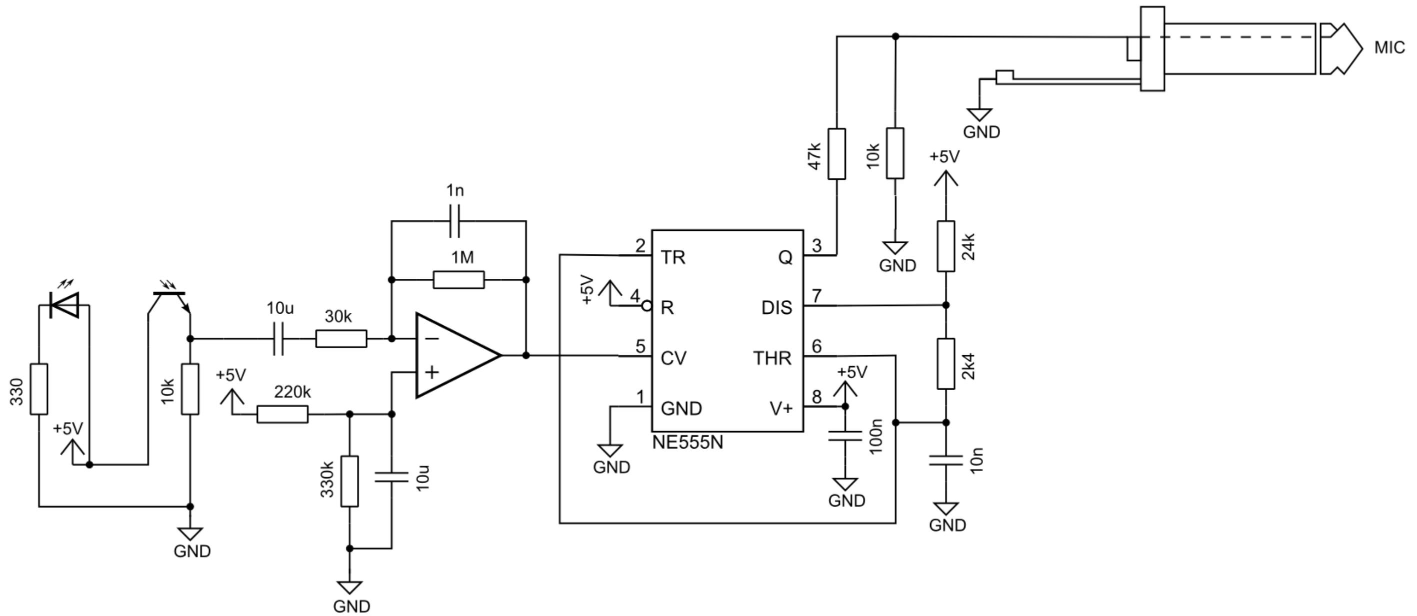




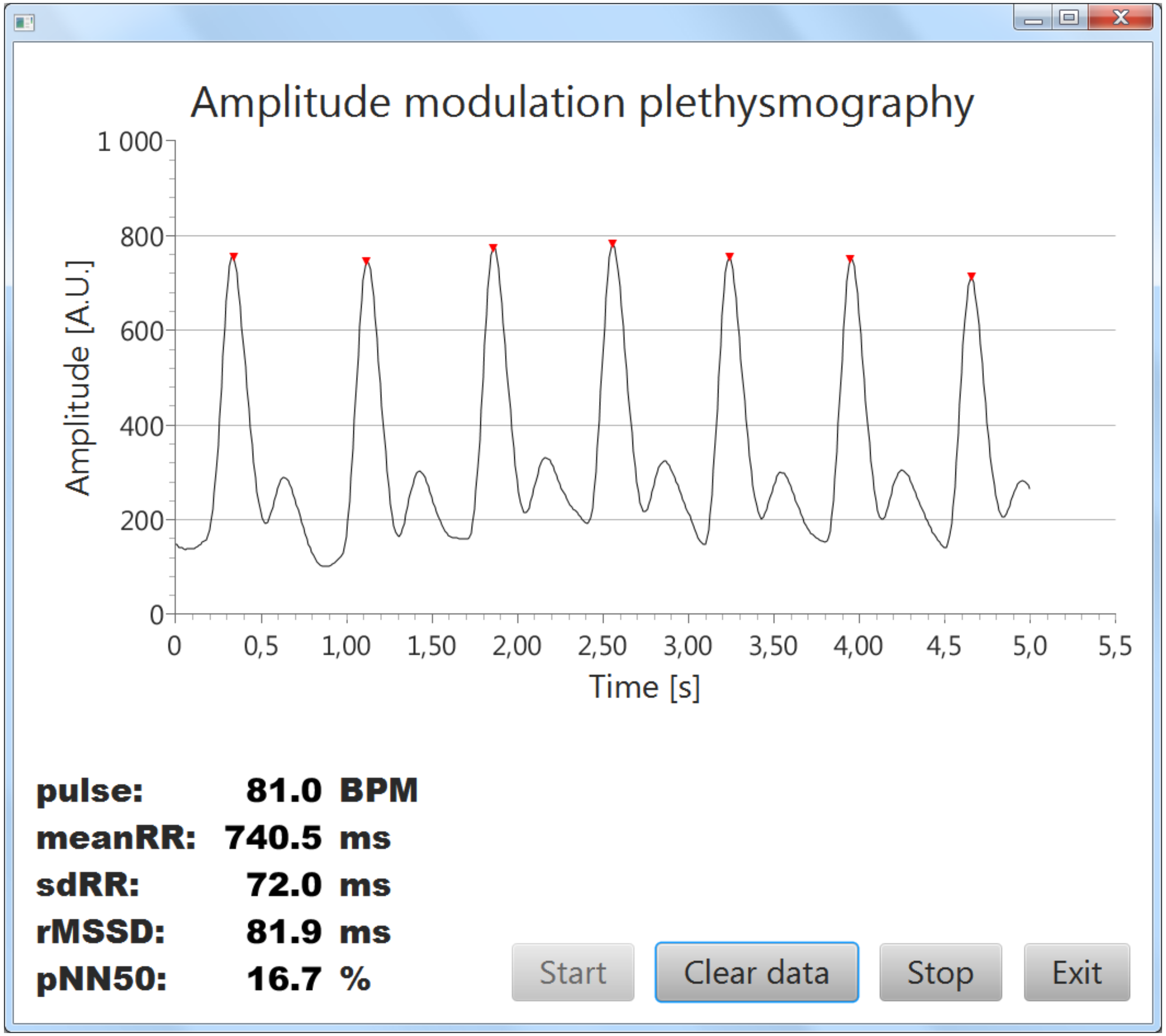
Frequency modulation

- Frequency: information
- V-F converter circuit
- Microphone input



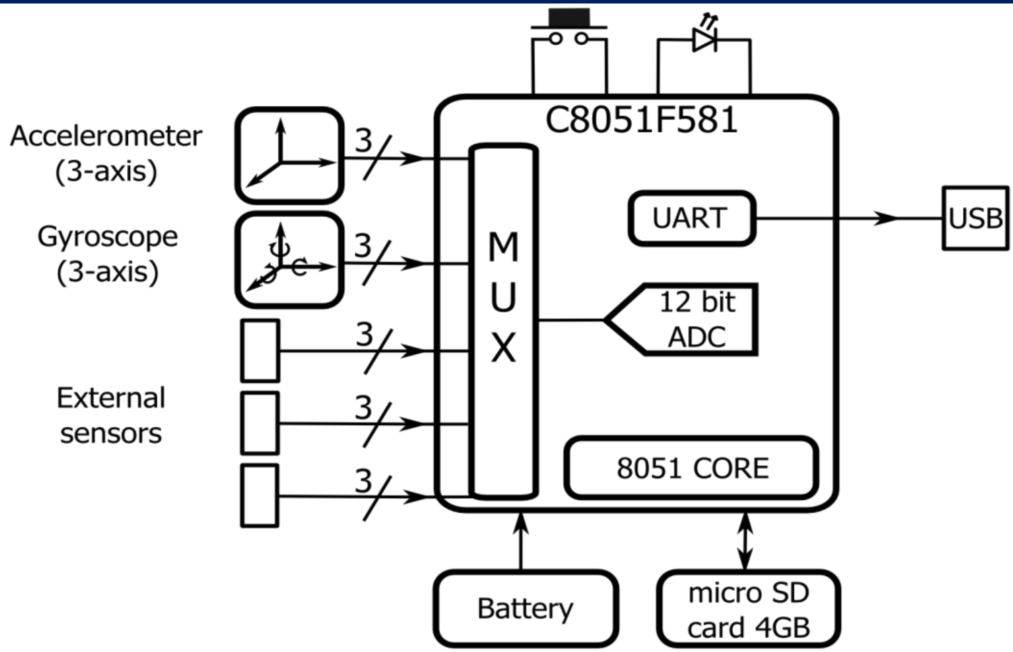


Signal processing



Performance estimation of kayak paddlers by fluctuation analysis

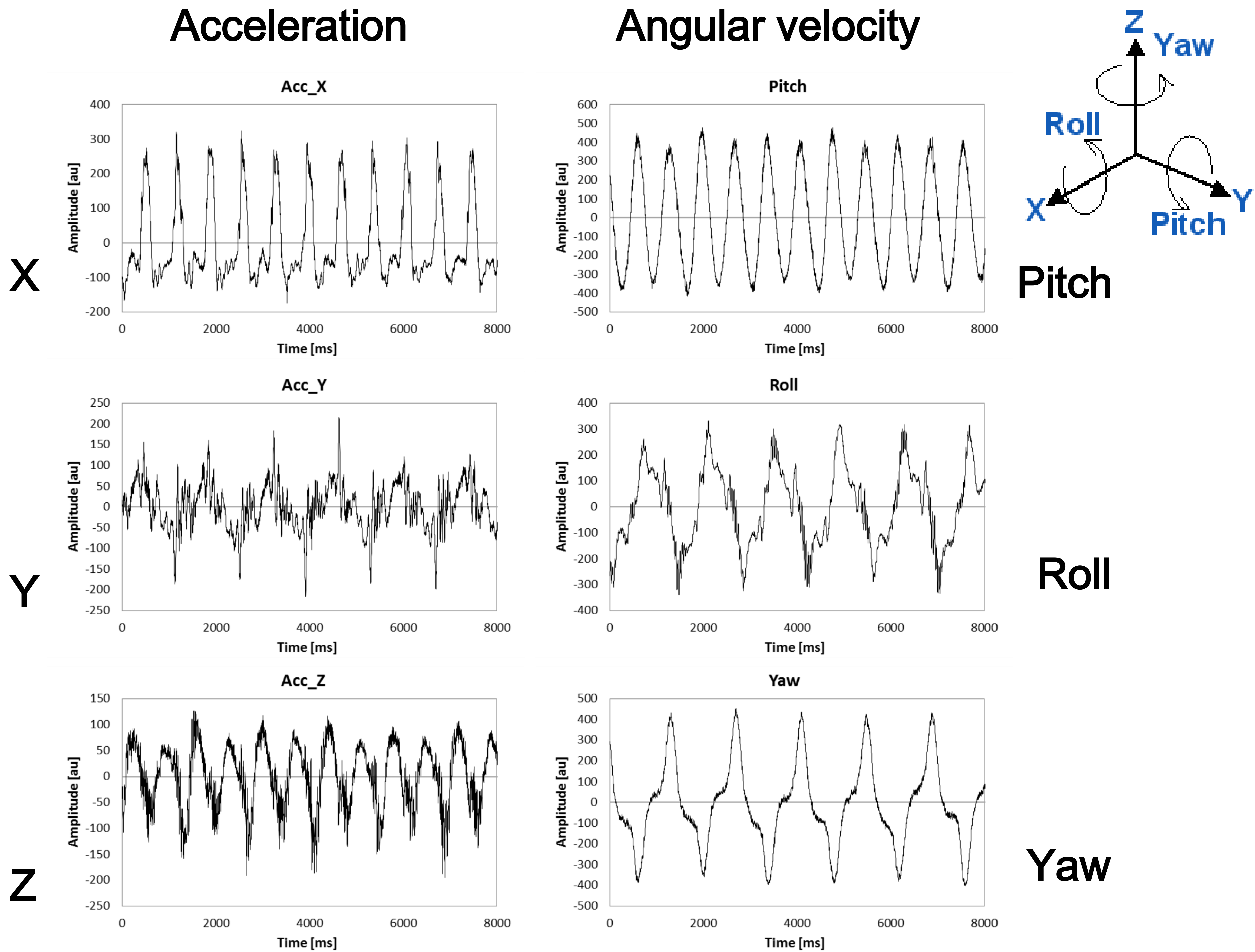
Measurement system



- optimal dynamic range
- sample rate:
  1000 Hz per channel
- aliasing and noise reduction
  - passive filters
- further digital signal analysis

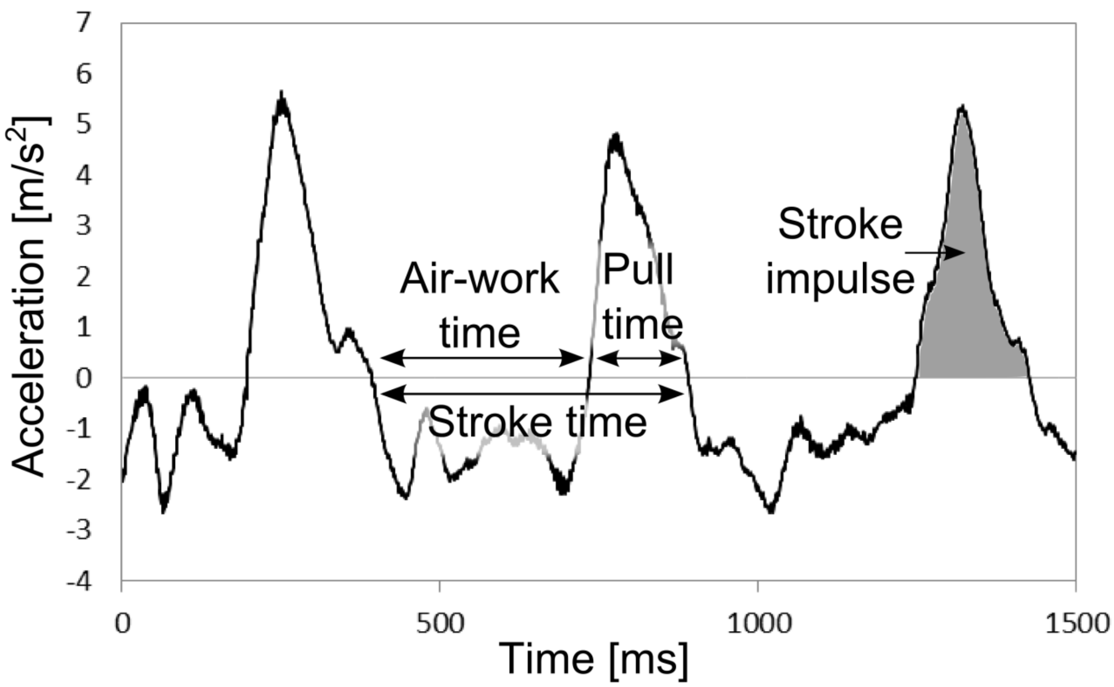
Further external sensors can be connected:

- physiological signals (e.g.: heart rate)
- forces in the paddle
- velocity
- more inertial signals…


Acceleration
Angular velocity
Z
Yaw
Roll
X
Y
Pitch
X
Pitch
Y
Roll
Z
Yaw
Acc_X
Pitch
Acc_Y
Roll
Acc_Z
Yaw
Amplitude [au]
Time [ms]

Classical parameters

- Detecting the parameters in **x-axis acceleration** using:
  - Peak search and level-crossing algorithms
  - Yaw axis gyroscope signal

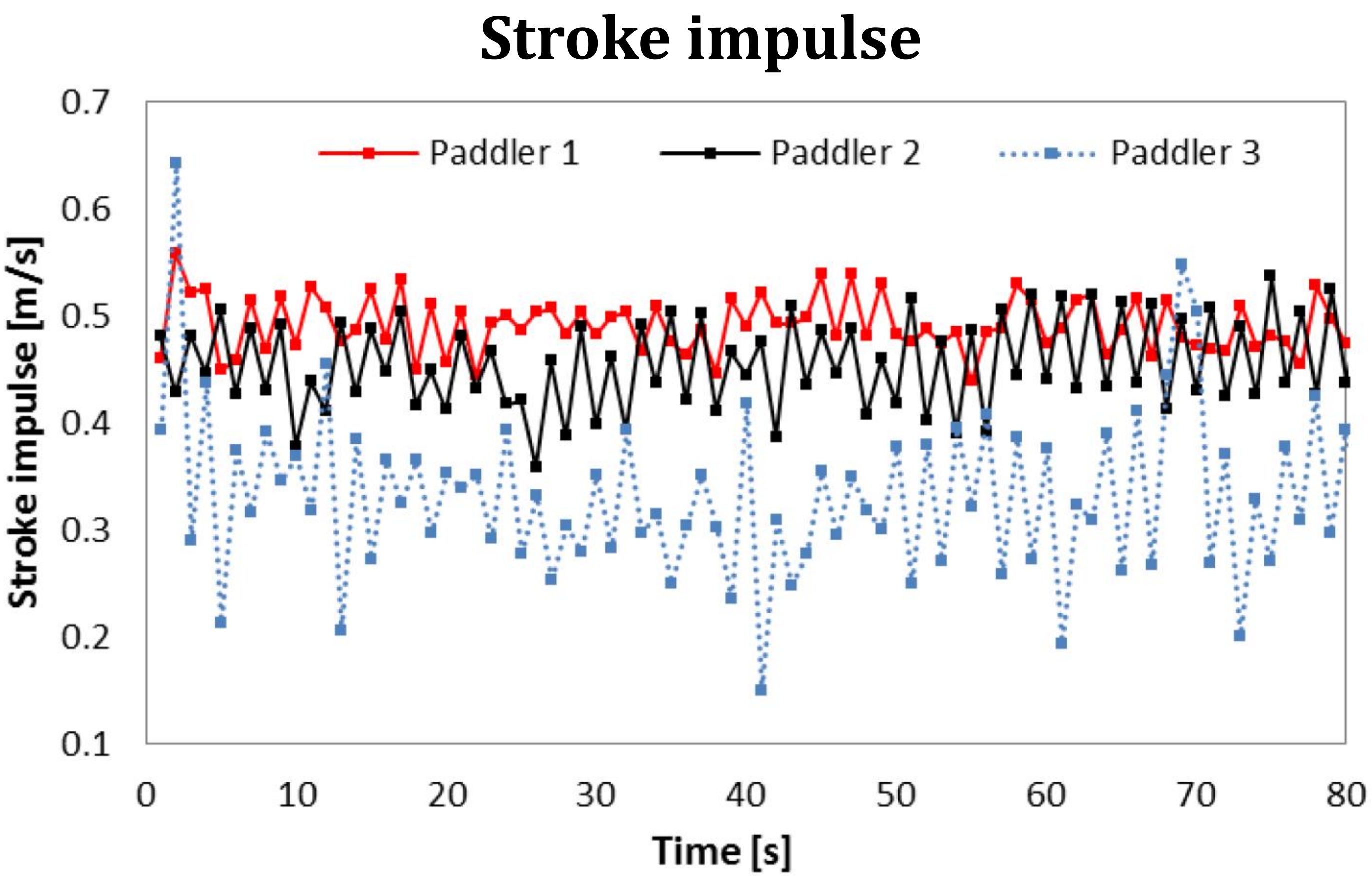


Paddler 2
(Professional)
Training

- **Alternative parameters:**
  Stroke rate; Mechanical impulse [kg*m/s]; Symmetry factor

Fluctuation analysis (Vadai G.)

- Very difficult for the coaches to analyze the shape of raw signals
- Simple indicators are needed
- Using the temporal fluctuation of regular parameters

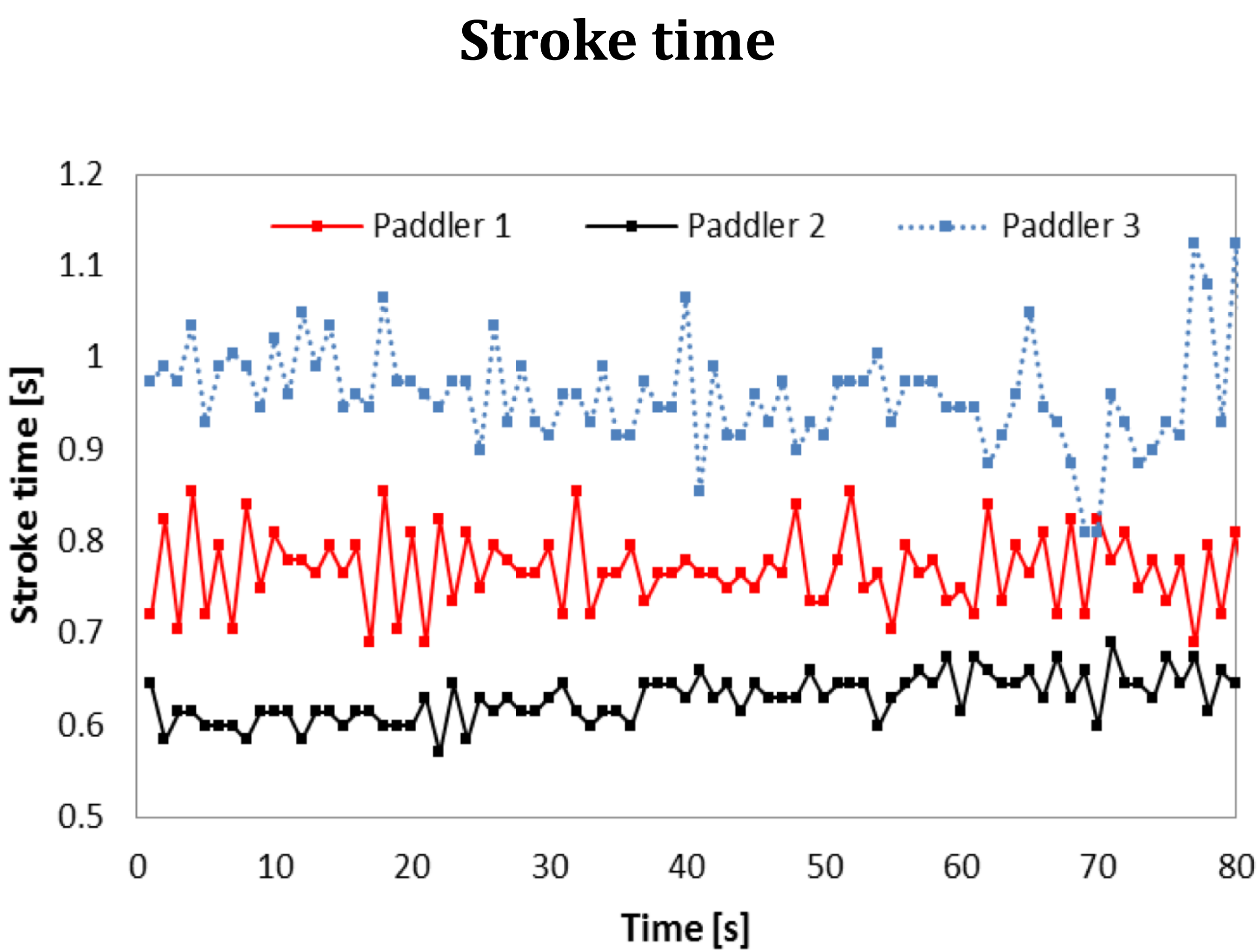


World Champion

Professional athlete (assymetric style)

Beginner (13 years old)

Fluctuation analysis



World Champion

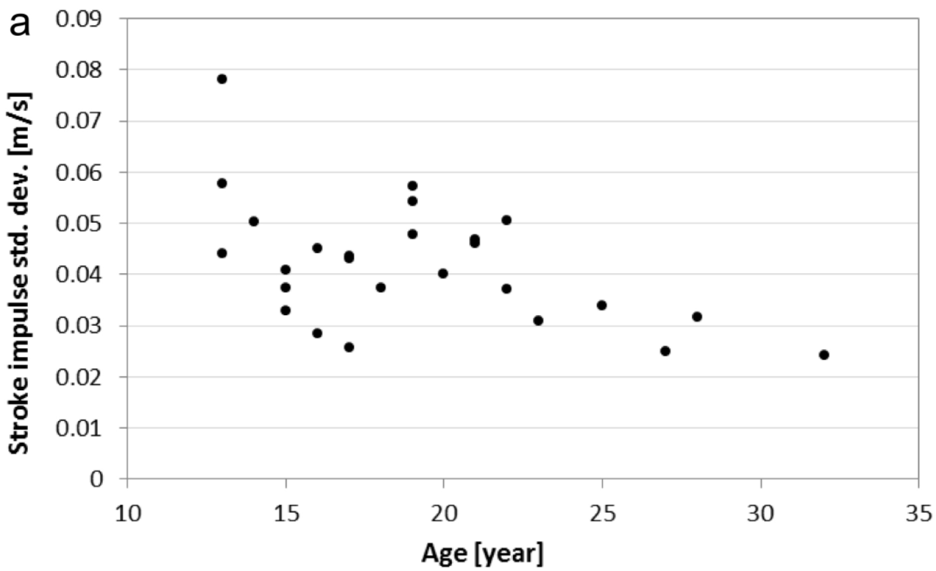
Professional athlete
(assymetric style)

Beginner
(13 years old)

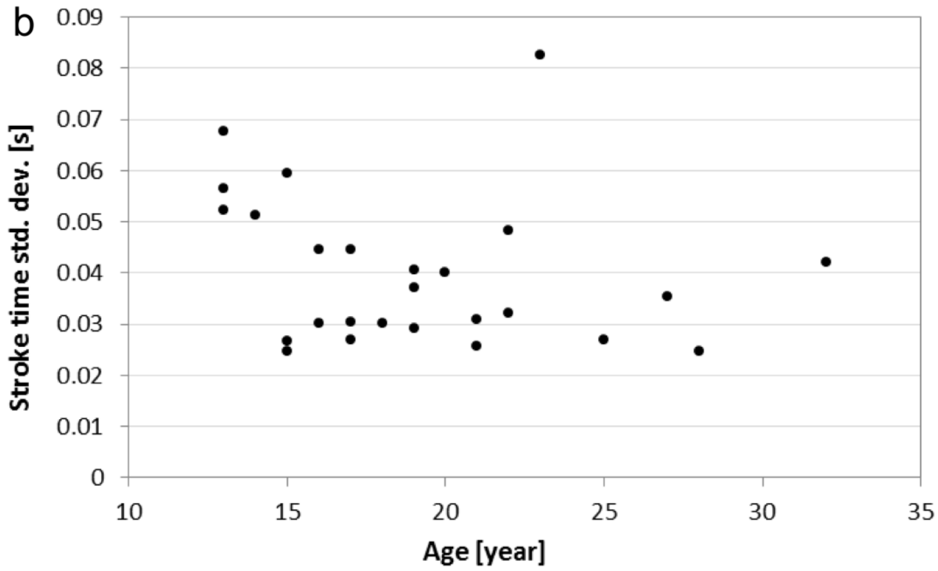
Standard deviations

- **Standard deviation** (SD) of stroke impulse decreases with age significantly
- Useful indicator of technical skills!

Stroke impulse SD



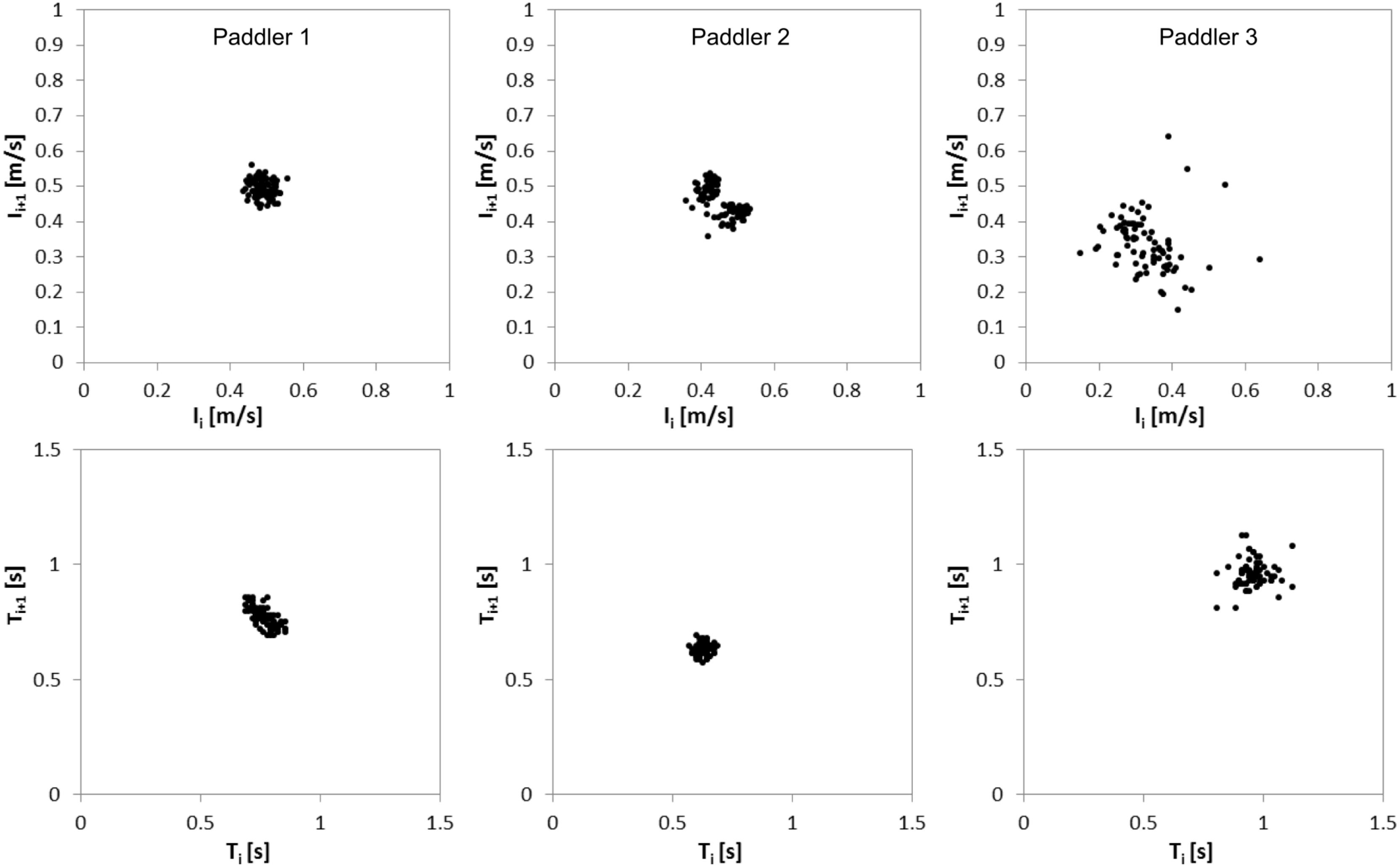
Stroke time SD



- Relationship between age and technical skills?

Poincaré maps

	World Champion Age: 32	Professional Age: 21	Beginner Age: 13
Stroke impulse			
Stroke time			



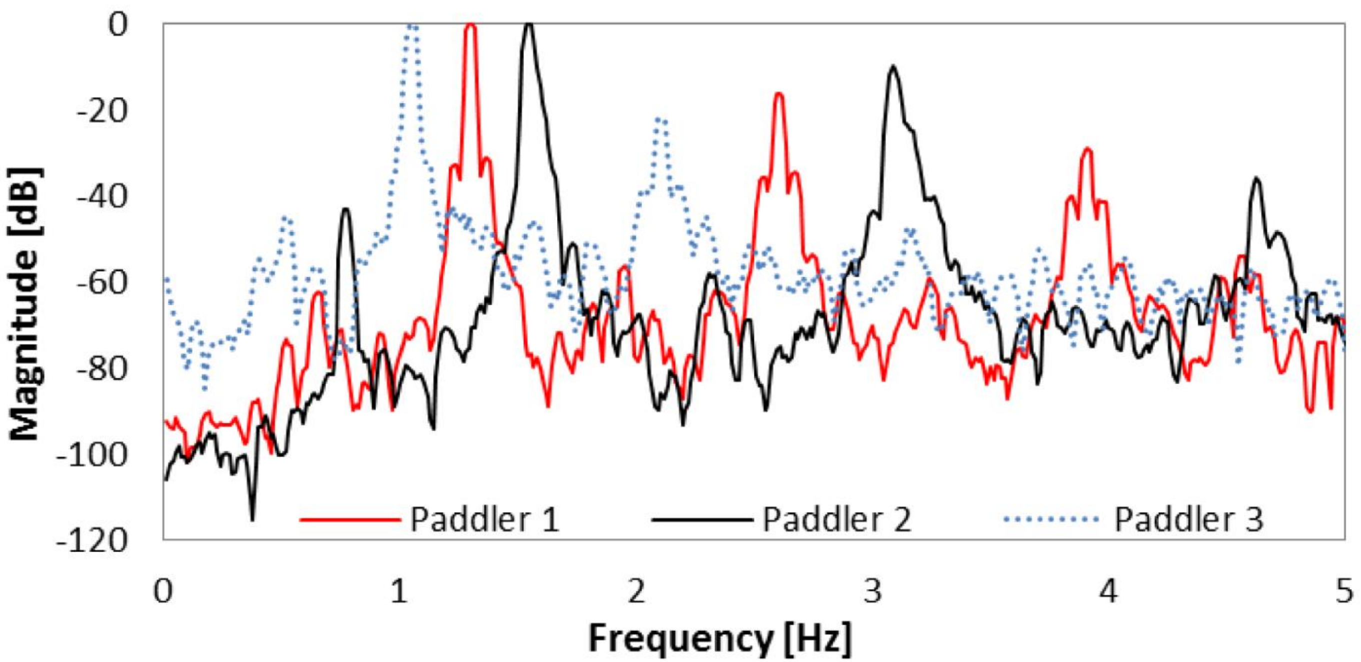
Spectral analysis of raw signals

- Many cases the signals are more complex
  - detection is more difficult
- The relationship between the parameters’ fluctuation and the technical skills could be understood:
  - steady paddling is required to avoid the suboptimal motion

- **Aim:** determining indicators from the raw movement signals
- Calculating Power spectral density (PSD) of raw movement signals
  - using Hanning window,
  - smoothed with a 10 samples long moving average,
  - normalized to the dominant frequencies.
- avoids using complex and less reliable detecting algorithms

Power spectral density

- X-axis acceleration PSD



World Champion

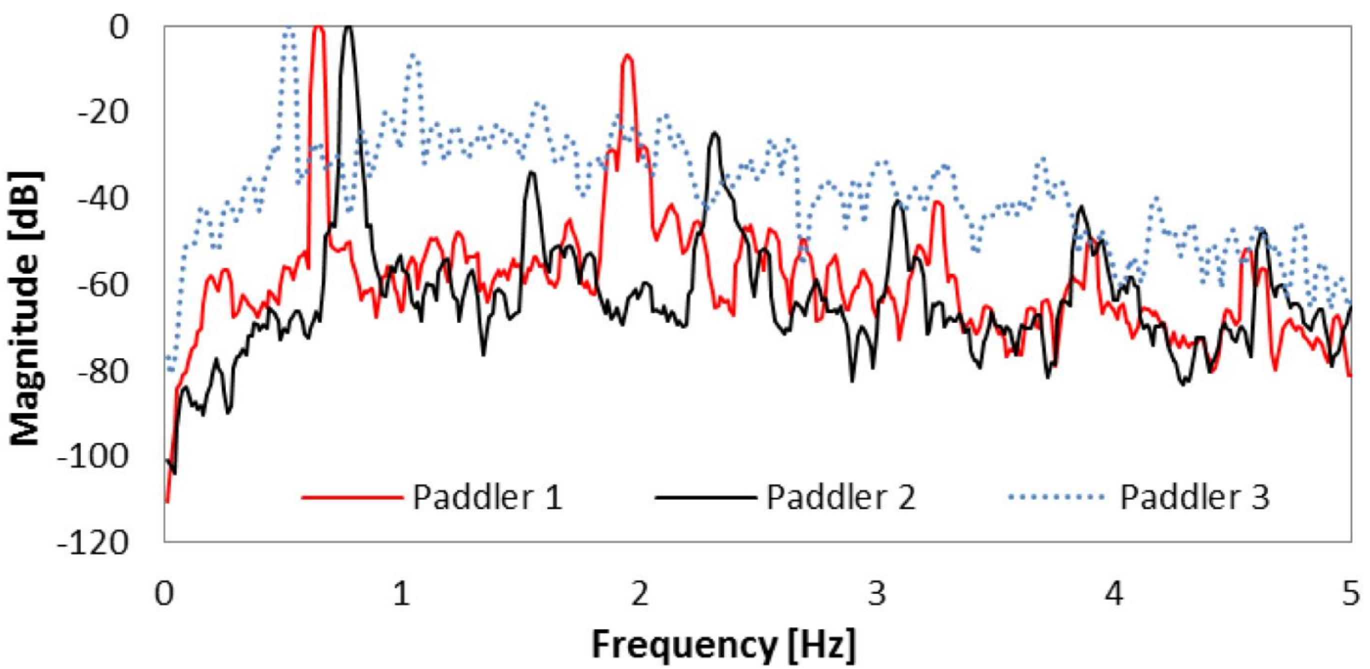
Professional athlete (assymetric style)

Beginner (13 years old)

- Dominant frequency: **first harmonic** (belongs for one stroke cycle)

Power spectral density

- Roll-axis angular velocity PSD



World Champion

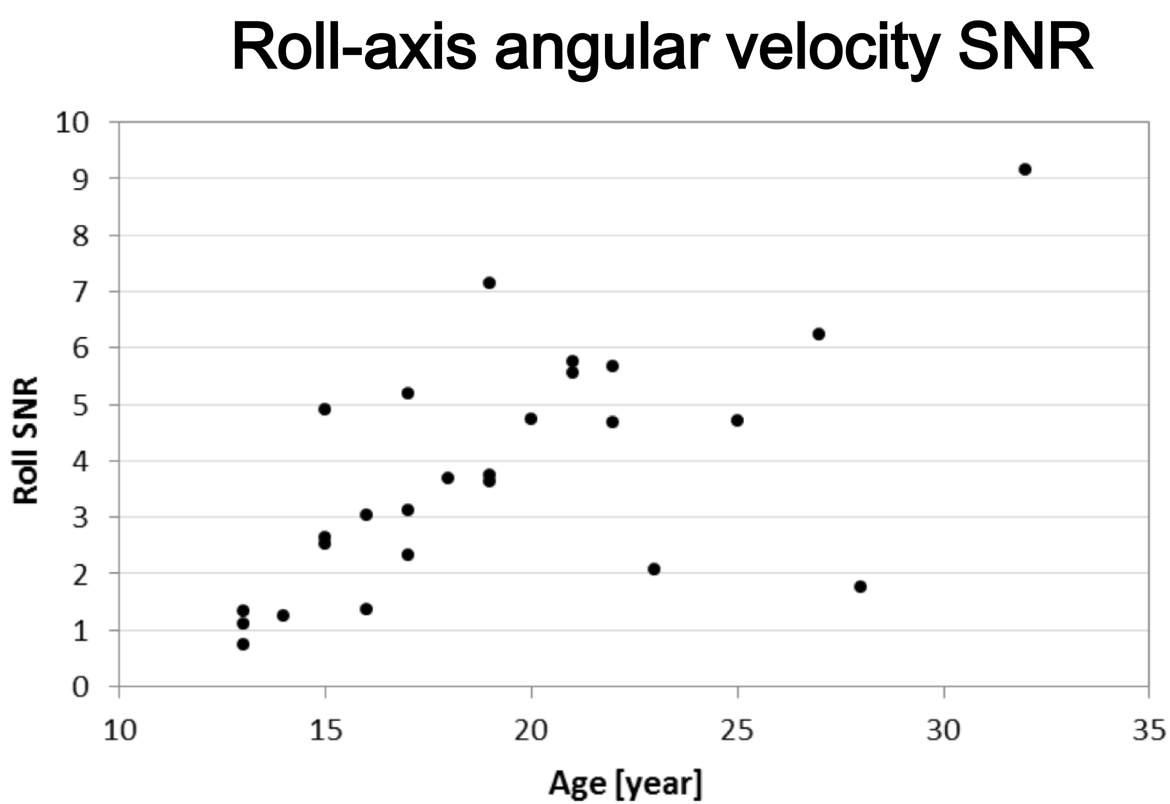
Professional athlete
(assymetric style)

Beginner
(13 years old)

- Dominant frequency: **fundamental frequency**
(belongs to the sum of a right and a left hands stroke time)

Signal-to-noise ratio (SNR)

- **deterministic part**: harmonic peaks
- **noise**: the rest of the spectrum
- (SNR) of raw movement signals indicates the quality of paddling technique, too



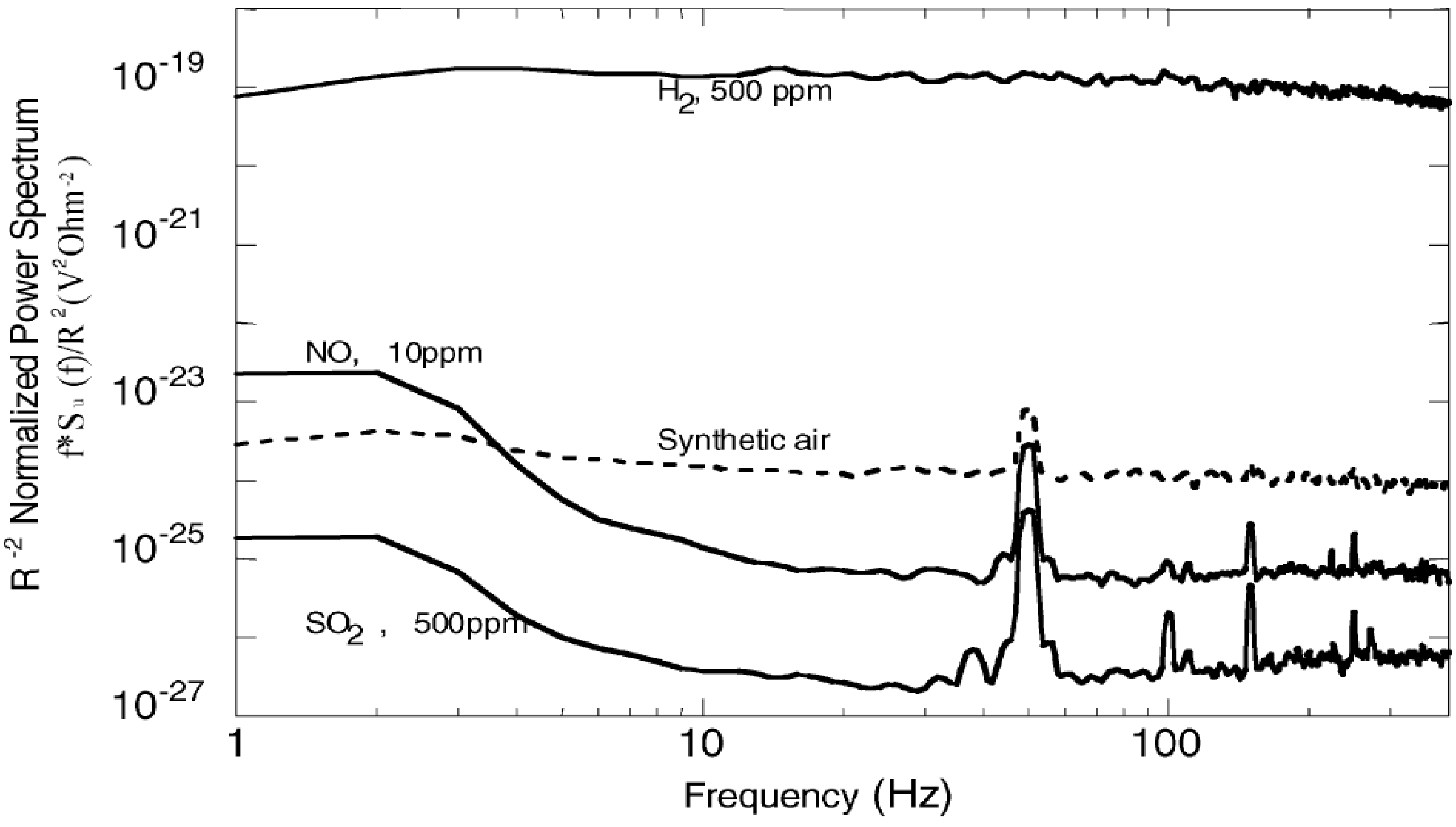
Wireless fluctuation enhanced gas sensor module

The principle of Fluctuation Enhanced Sensing

- **Resistive** gas sensors
- Multiple gases: array of sensors
- Selectivity, sensitivity problems
- More information: ***resistance fluctuations***
  - Magnitude
  - Shape (roughly 1/f)
  - Power spectrum measurement
  - Pattern recognition methods to detect small differences in PSD
  - Single sensor – multiple gases?

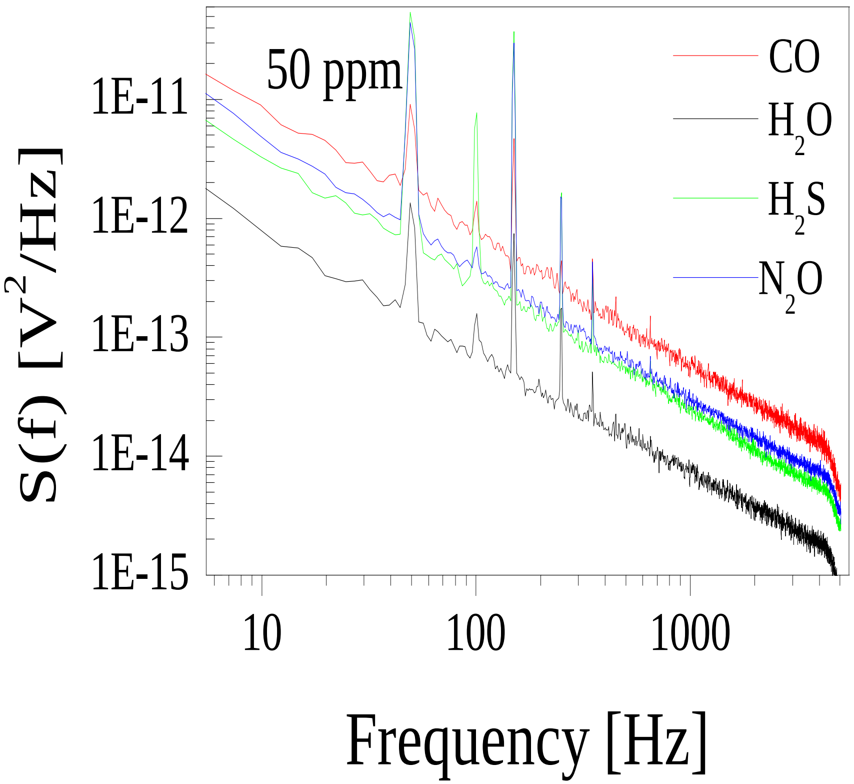
Semiconductor gas sensors

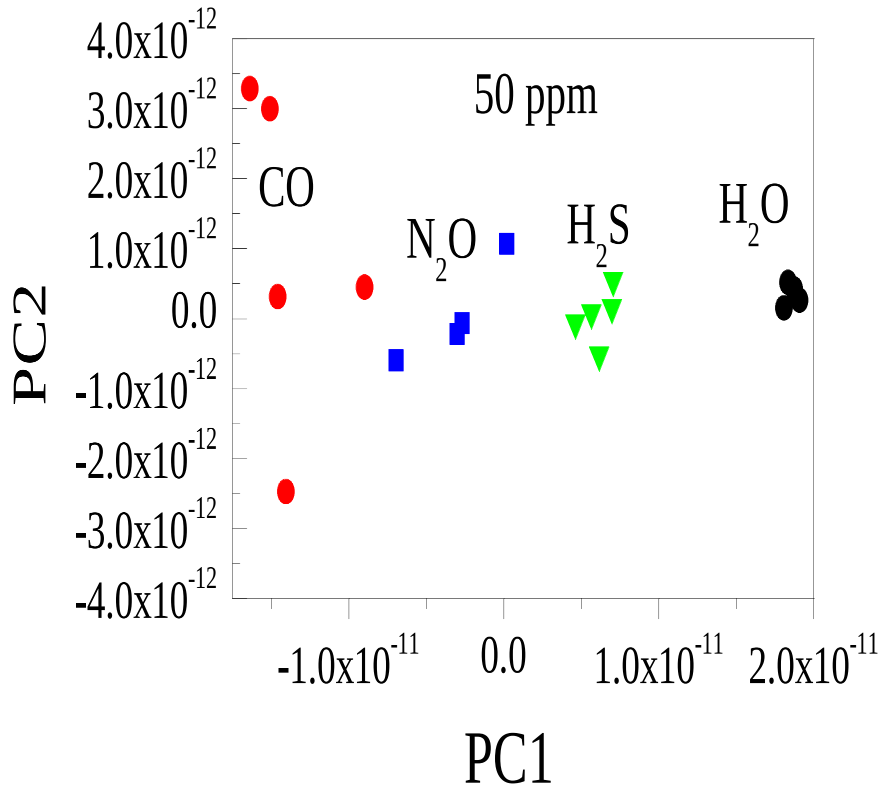
- L.B. Kish et. al.,"Detecting Harmful Gases Using Fluctuation-Enhanced Sensing With Taguchi Sensors", IEEE Sensors Journal, Vol. 5, No. 4, 2005



Carbon nanotube gas sensors

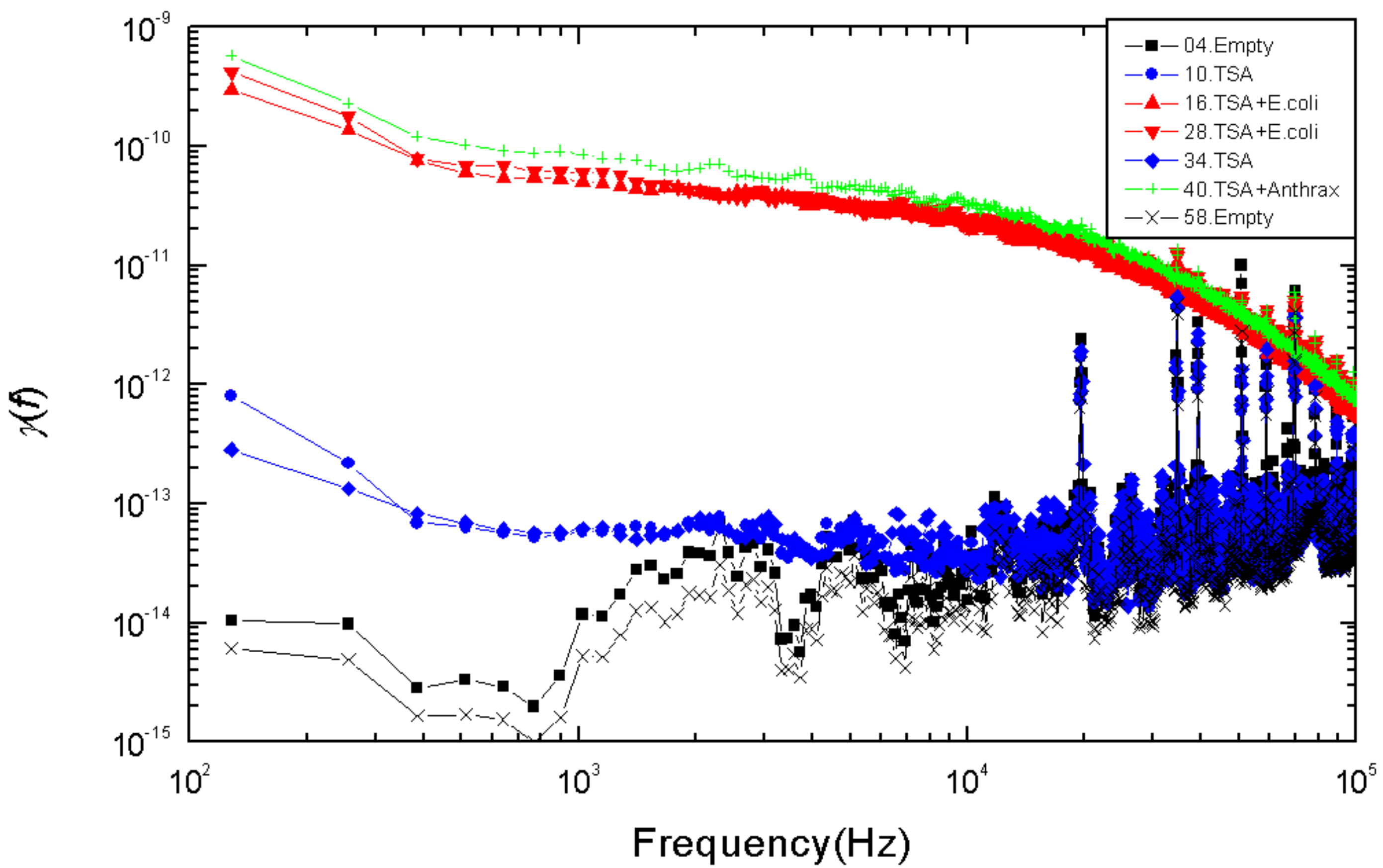
- Á. Kukovecz, D. Molnár, K. Kordás, Z. Gingl et al, “Carbon nanotube based sensors and fluctuation enhanced sensing,” Phys. Status Solidi C, vol. 7, no. 3-4, pp. 1217–1221, 2010



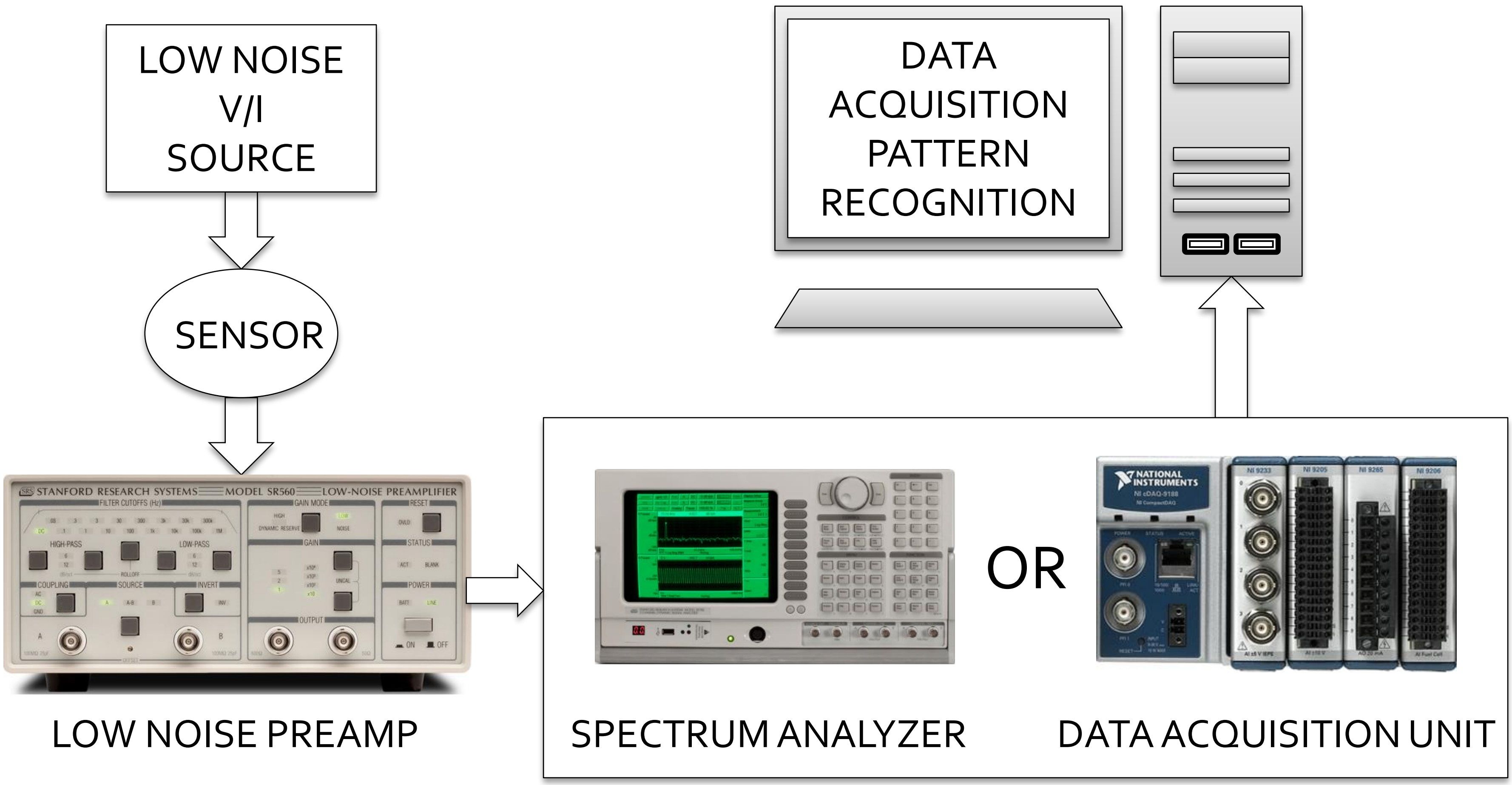


Bacterial odor sensing

- Chang H-C, Kish LB, King MD, Kwan C, Fluctuation-enhanced sensing of bacterium odors. SENSORS AND ACTUATORS, B: CHEMICAL 142:(2), pp. 429-434. (2009)



Typical FES measurement setup

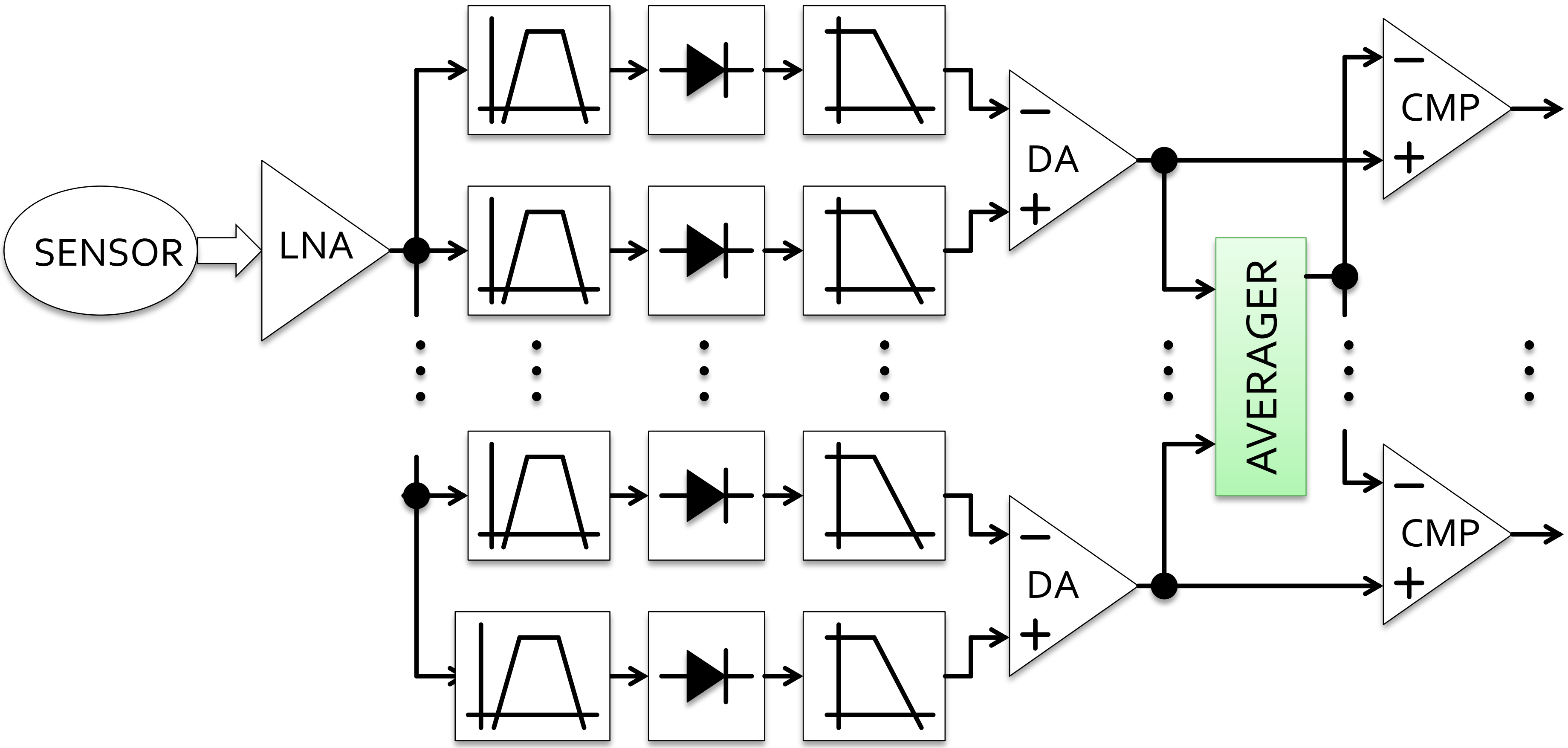


Low power FES questions

- Hardware?
- Signal processing?
- Power consumption?
  - Battery powered?
  - Energy harvesting?
- Accuracy?
- Cost, high volume applicatons?

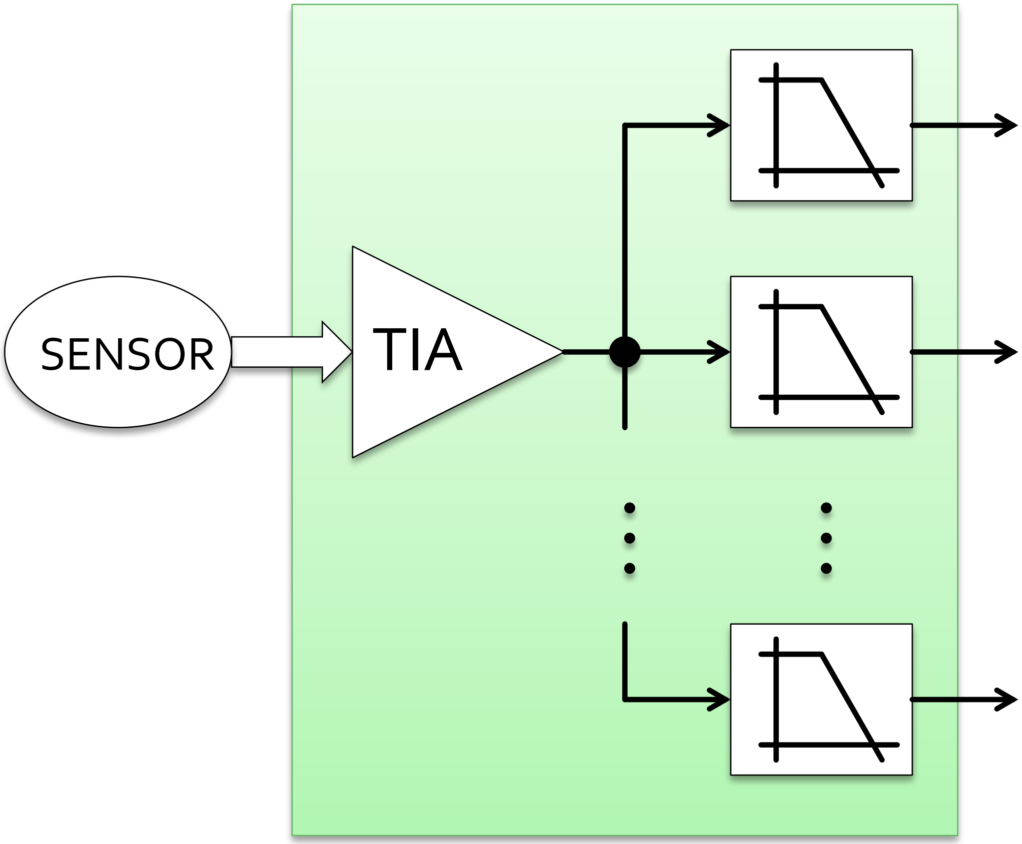
Bandpass filters, „binary fingerprints”

- Chang H-C, Kish LB, King MD, Kwan C, Binary fingerprints at fluctuation-enhanced sensing. SENSORS 10:(1), pp. 361-373. (2010)

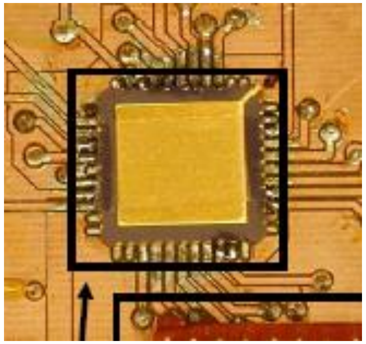


Low pass filter IC

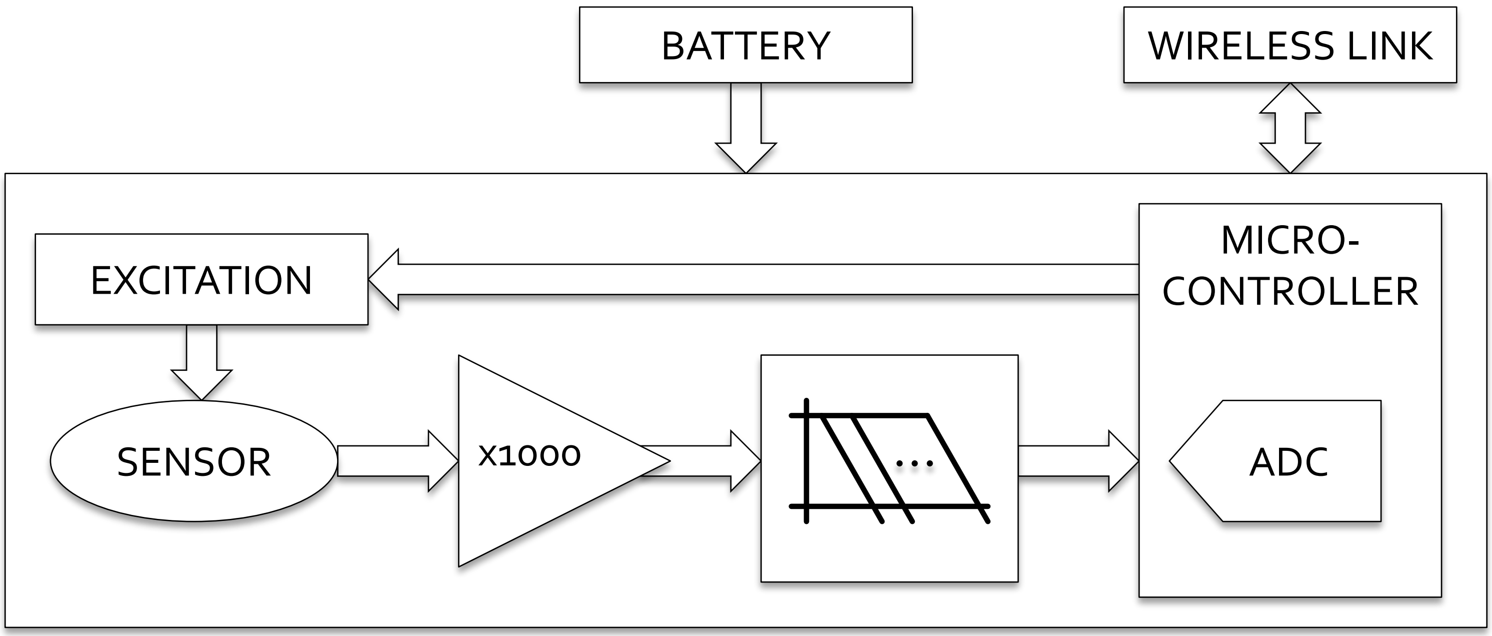
- S. Sonkusale, Y. Kim and A. Agarwal, A CMOS front-end IC for fluctuation enhanced sensing, IEEE Sensors, 2005, pp. 1213-1216

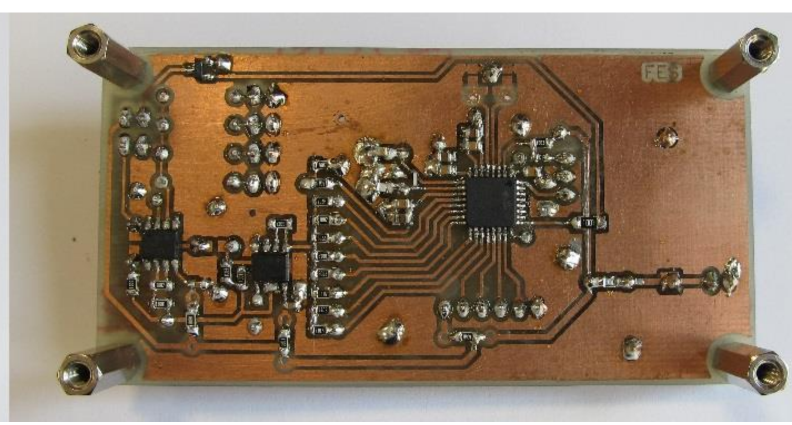


- 1,1mW-4,2mW analog front end
- preamplifier
- low pass filters
- 5pA/Hz½ (1kOhm)

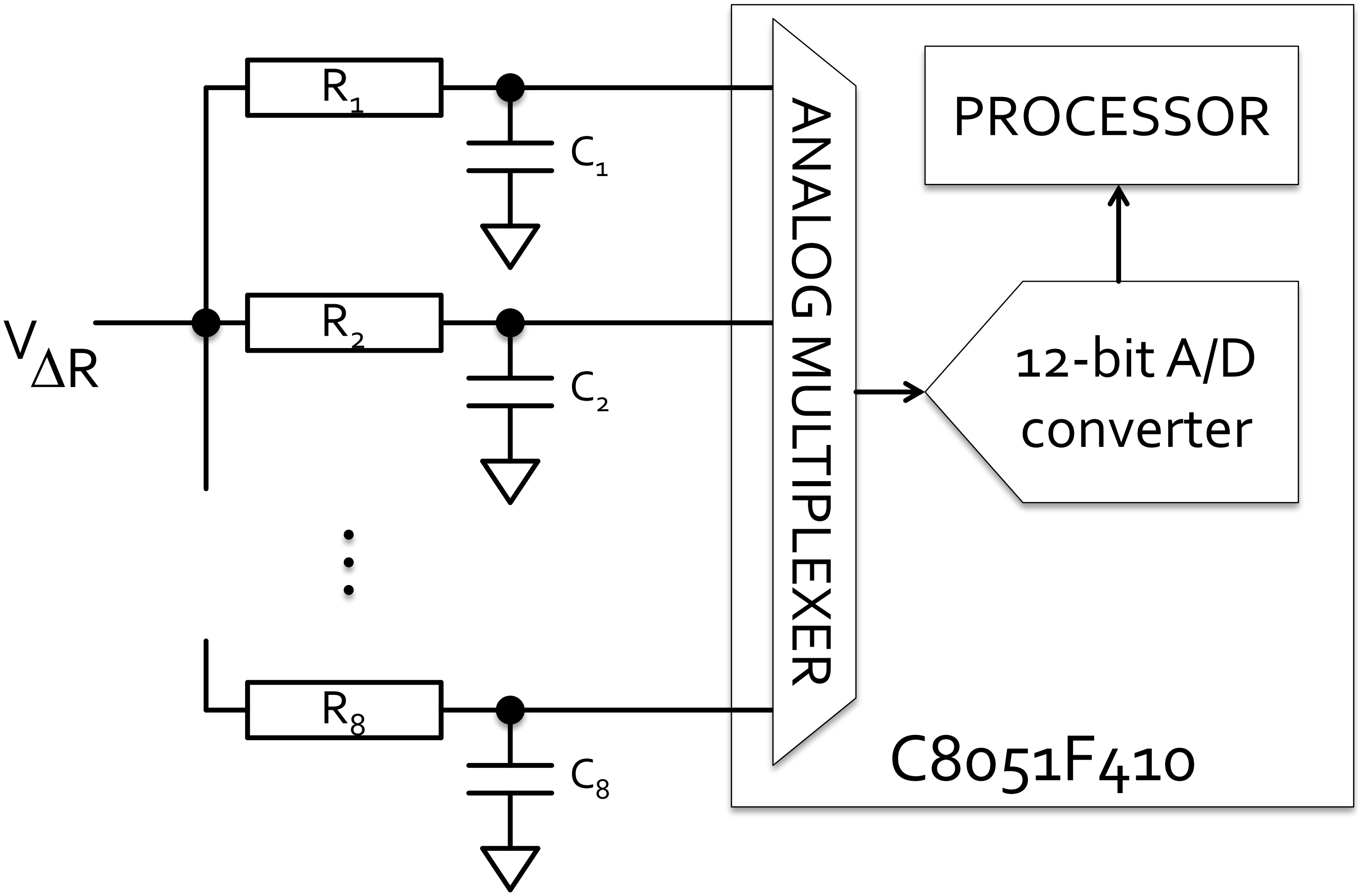


Very low power FES unit (ICNF2013)





Signal sampling and digitization



Signal processing

- Measure the variance at the output of each filter
- 8 k samples per second for all channels
- 1k samples per second on each channel
- no aliasing problems – variance/mean estimation
- recording time: 10 s

$$< x >= \frac{1}{N} \sum_{i=0}^{N-1} x_i$$

$$< x^2 >= \frac{1}{N} \sum_{i=0}^{N-1} x_i^2$$

$$\sigma^2 =< x^2 > - < x >^2$$

Accuracy ‣ A/D converter resolution

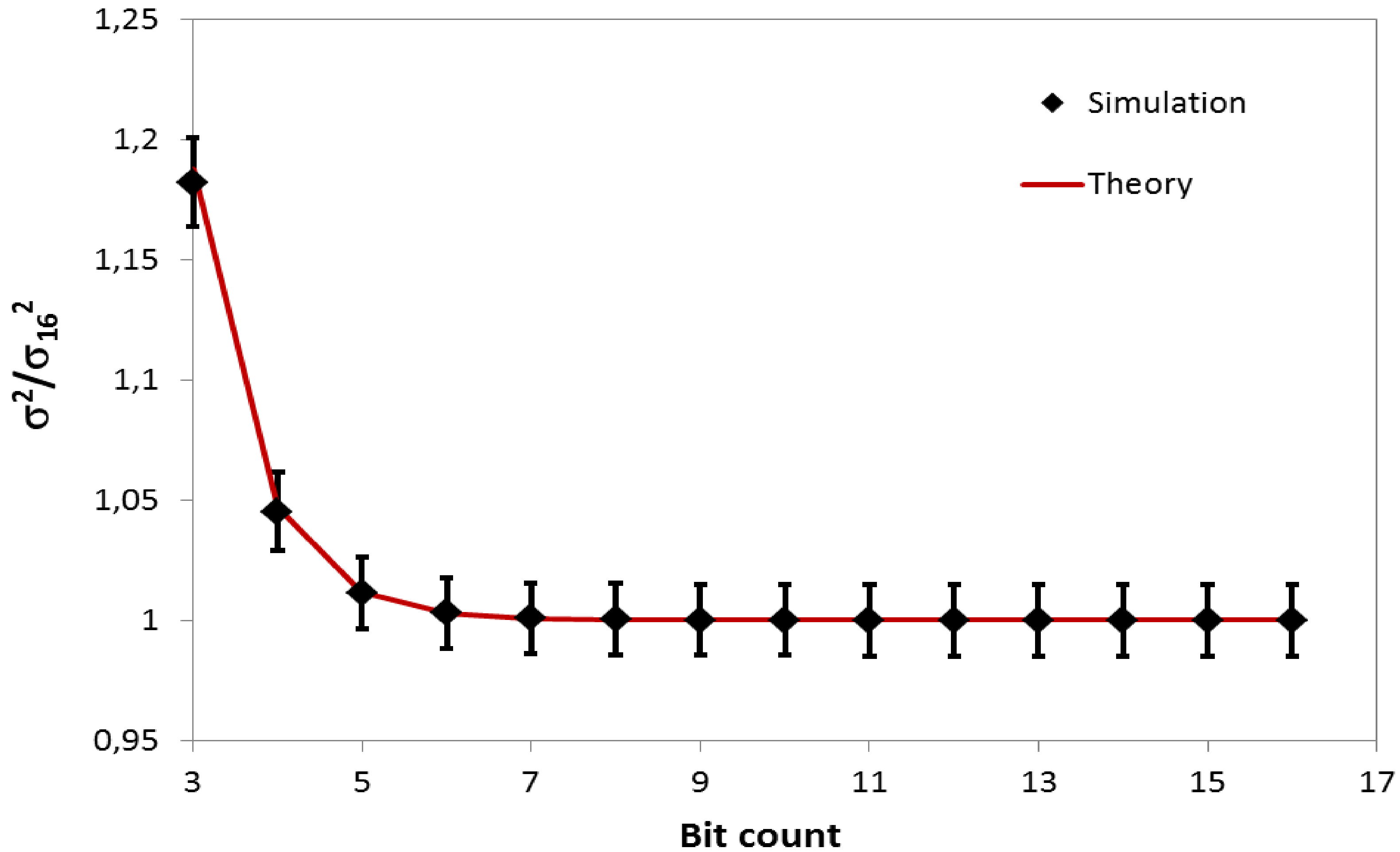
- How many bits are enough?
- Peak-to-peak noise: $6 \cdot \sigma_n = 6 \cdot c \cdot V_{ref}$ (e.g.: c=1/12)
- Quantization noise $\sigma_n = V_{LSB}/\sqrt{12}$

$$\sigma^2 = \sigma_n^2 + \sigma_q^2 = \left(c \cdot V_{ref}\right)^2 + \left(\frac{V_{ref}}{2^b \sqrt{12}}\right)$$

$$\frac{\sigma^2}{\sigma_n^2} = 1 + \frac{\dfrac{V_{ref}^2}{4^b \cdot 12}}{c^2 \cdot V_{ref}^2} = 1 + \frac{1}{c^2 \cdot 4^b \cdot 12}$$

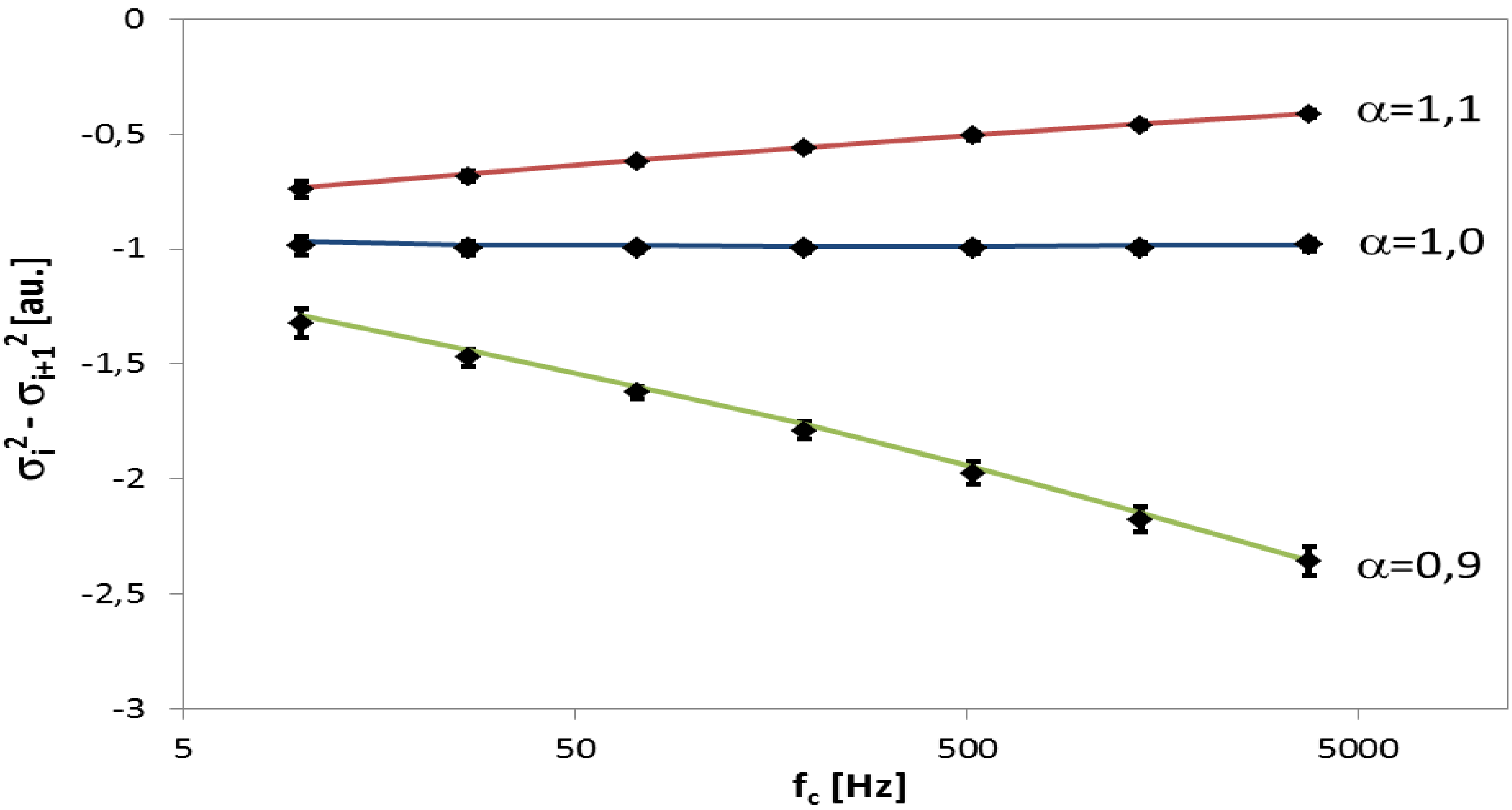
Accuracy ▸ A/D converter resolution

c=1/12: peak-to-peak noise is ½ of the measurement range



Selectivity (PSD)

- $1/f^{\alpha}$, 10s, 1kSPS



Measured power consumption

- Sample rate: 7,4 kHz
- 8 channels
- mean and variance

Circuit	current [µA]	power [mW]
Sensor excitation	220	0,66
Preamplifier	370	1,11
Low pass filters	30	0,09
Microcontroller (oscillator, ADC, processor)	710	2,13
Total	**1330**	**3,99**

Applications

- FES gas sensing
  - gas detecting
  - bacterial odor sensing
  - replacement of bulky and expensive setups
- Supports using noise as a diagnostic tool
  - electronic device degradation
- General purpose power spectrum estimation
- Wireless sensor networks

Complete FES gas sensing solution

- General purpose applications
- Very low power – 1,3mA @ 3V single supply
- Continuous active operation
  - 7 days using a CR2032 button battery
  - 48 days using two AA alkaline batteries
- 10 s active time / 10 minute gas sampling
  - 390 days using a CR2032 coin cell battery
  - 2300 days using two AA alkaline batteries
- Very low cost: $30 component cost
- Open source hardware and software

Summary

- Small, low power, low cost intelligent devices
- Efficient noisy signal processing
- Prototype, end product