EE-511

# Sensors in medical instrumentation

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| Cursus | Sem. | Type |
|---|---|---|
| Biomedical technologies minor | E | Opt. |
| Electrical and Electronical Engineering | MA2, MA4 | Opt. |
| Life Sciences Engineering | MA2, MA4 | Opt. |
| Mechanical engineering | MA2, MA4 | Opt. |
| Microtechnics | MA2, MA4 | Opt. |
| Neuro-X minor | E | Opt. |
| Neuro-X | MA2, MA4 | Opt. |
| Robotics, Control and Intelligent Systems | | Opt. |
| Robotics | MA2, MA4 | Opt. |

| | |
|---|---|
| Language of teaching | English |
| Credits | 3 |
| Session | Summer |
| Semester | Spring |
| Exam | Written |
| Workload | 90h |
| Weeks | 14 |
| **Hours** | **3 weekly** |
| Lecture | 2 weekly |
| Exercises | 1 weekly |
| **Number of positions** | |

## Summary

Fundamental principles and methods used for physiological signal conditioning. Electrode, optical, resistive, capacitive, inductive, and piezoelectric sensor techniques used to detect and convert physiological information to electrical signals. Medical devices for physiological signal monitoring.

## Content

**1. Electrode sensors**

- **Action potentials**
  Nernst equation, Hodgkin-Huxley model, action potential, voltage clamp
- **Biopotentials**
  ECG (electrocardiogram), EEG (electroencephalogram), ExG (other electrogram), ECGi (ECG imaging)
- **Bioimpedances**
  Impedance model, impedance plethysmography, impedance spectroscopy, EIT (electrical impedance tomography), PAP (pulmonary artery pressure)
- **Basic safety of ME equipment**
  Regulations, 60601-1, MOP, applied part and patient connections, leakage and auxiliary currents, defibrillator-proof
- **Electrodes**
  Electrode model, motion artefacts, noise, dry electrodes, potential and current electrodes
- **Metrology of biopotentials**
  EM interferences, shielding, neutral electrode, common mode, defibrillation and ESD protections
- **Metrology of bioimpedances**
  Bipolar and tetrapolar methods, bi-electrodes, AM, IQ demodulation, leakage, shielding

**2. Optical sensors**

- **Photo-plethysmography**
  PPG, oHRM, ambient light, volume clamp blood pressure, optical blood pressure, SpO2
- **NIRS (near infrared spectroscopy)**
  Basic NIRS, differential NIRS

**3. Resistive sensors**
Thermistor and its biomedical applications; strain gage for the measurement of blood pressure; force and accelerations of the body
**4. Inductive sensors**
Simple and mutual inductance and its medical applications
**5. Capacitive sensors**
Respiratory flow measurement by the gradient of pressure
**6. Piezoelectric sensors**
Force platform, accelerometer, angular rate sensor for the measurement of tremors and body movements, ultrasound

transducer : measurement of pressure and flow rate

### Keywords

Sensors, instrumentation, medical devices, physiological signals, electronic circuits, metrology, monitoring

### Learning Prerequisites

#### Required courses

basic signal and control theory, basic electronics (Kirchhoff, OPA, INA)

#### Recommended courses

systems, sensors, electronics

#### Important concepts to start the course

basic electronics, basic physics

### Learning Outcomes

By the end of the course, the student must be able to:

- Work out / Determine what sensors to choose and how to place them to measure a given physiologica signal.
- Work out / Determine what electronic circuits to use.
- Dimension the electronic circuit.
- Analyze the sources of noise.

### Transversal skills

- Take account of the social and human dimensions of the engineering profession.

### Teaching methods

Ex cathedra (including examples) with textbook and exercises

### Expected student activities

read textbook, exercises, quizzes and problems

### Assessment methods

three quizzes/problems sessions during semester (each worth 5%)
final written exam (worth 85%)

### Supervision

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|---|---|
| Office hours | Yes |
| Assistants | Yes |
| Forum | Yes |

### Resources

#### Virtual desktop infrastructure (VDI)

No

#### Bibliography

Medical Instrumentation, application and design, Webster, 4th edition

### Ressources en bibliothèque

- Medical Instrumentation, application and design, Webster, 5th edition

### Notes/Handbook

Sensors in medical instrumentation (textbook)
Slides

### Moodle Link

- https://go.epfl.ch/EE-511