

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
<b>Hours</b>	<b>3 weekly</b>
Lecture	2 weekly
Exercises	1 weekly
<b>Number of positions</b>	

**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, SpO<sub>2</sub>

- **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:

- Choose techniques detecting and convert physiological information's to electrical signals
- Exploit fundamental principles and methods used for physiological signal conditioning
- Design measuring devices
- Interpret error, noise in biomedical measuring systems
- Work out / Determine what sensors to choose and how to place them to measure a given physiological signal.
- Work out / Determine what electronic circuits to use.
- Dimension the electronic circuit.
- Analyze the sources of noise.

### Transversal skills

- Use a work methodology appropriate to the task.
- Communicate effectively with professionals from other disciplines.
- 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

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>

**Prerequisite for**

Semester project and Master project