EE-511
Sensors in medical instrumentation

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Objectives

- To know the techniques used to detect and convert physiological information to electrical signals.
- To be able to control the fundamental principles and methods used for physiological signal conditioning with the help of examples from existing medical instrumentation design.
- To establish a more efficient communication with the medical and clinical partners thanks to a better understanding of medical instrumentation.

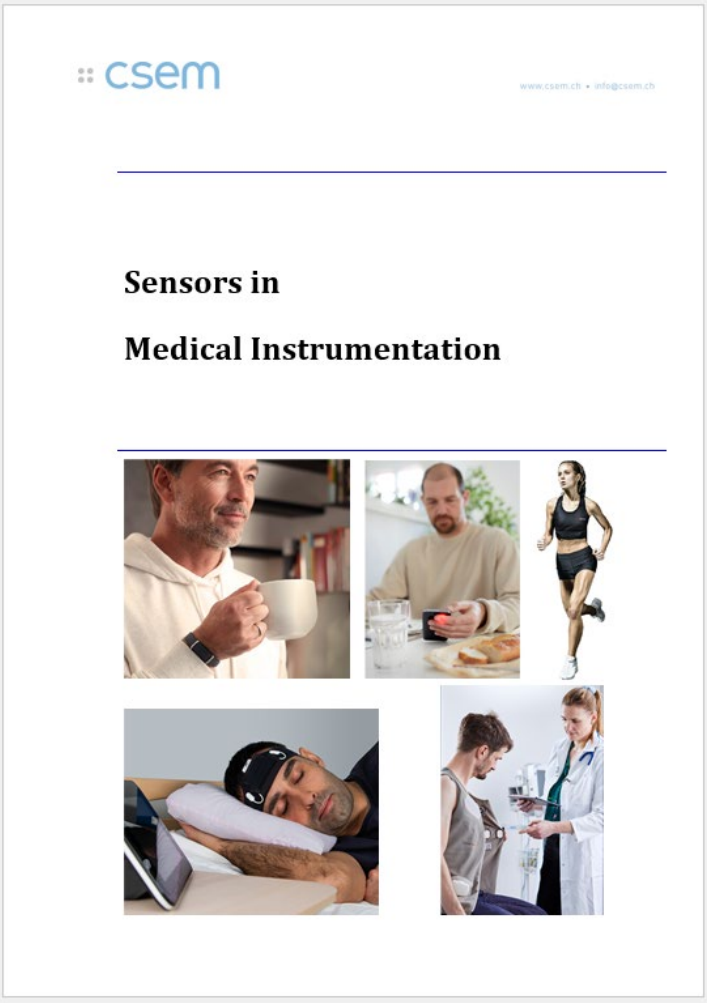
Date	Lecture (14–16 h)		Exercises (16–17 h)
20.02†	Basic safety of ME equipment		
27.02†	Biopotentials, bioimpedances, electrodes		Session 1
06.03†	Metrology of biopotentials		Session 2
13.03†	Metrology of bioimpedances		Session 3
20.03†	TEST 1	Optical sensors (PPG, oBPM)	Session 4
27.03†	Optical sensors (SpO2, NIRS)		Session 5
3.04*	Resistive sensors		Session 6
10.04*	Inductive sensors		Session 7
17.04*	TEST 2	Resistive & Inductive sensors	Session 8
24.04	Easter holiday		
1.05*	Capacitive sensors		Mock test
8.05*	Capacitive sensors		Session 9
15.05*	Piezoelectric sensors		Session 10
22.05*	TEST 3	Capacitive & Piezoelectric sensors	Session 11
29.05	Ascension holiday		

† Olivier Chételat, * Anisoara Ionescu

Evaluation

- The final grade will be a weighted sum of
    - three tests during the semester (weightage: 15%) and
    - Final Exam (weightage: 85%)
- Tests are in the form of quiz
- Final Exam is in the form of problems and quiz

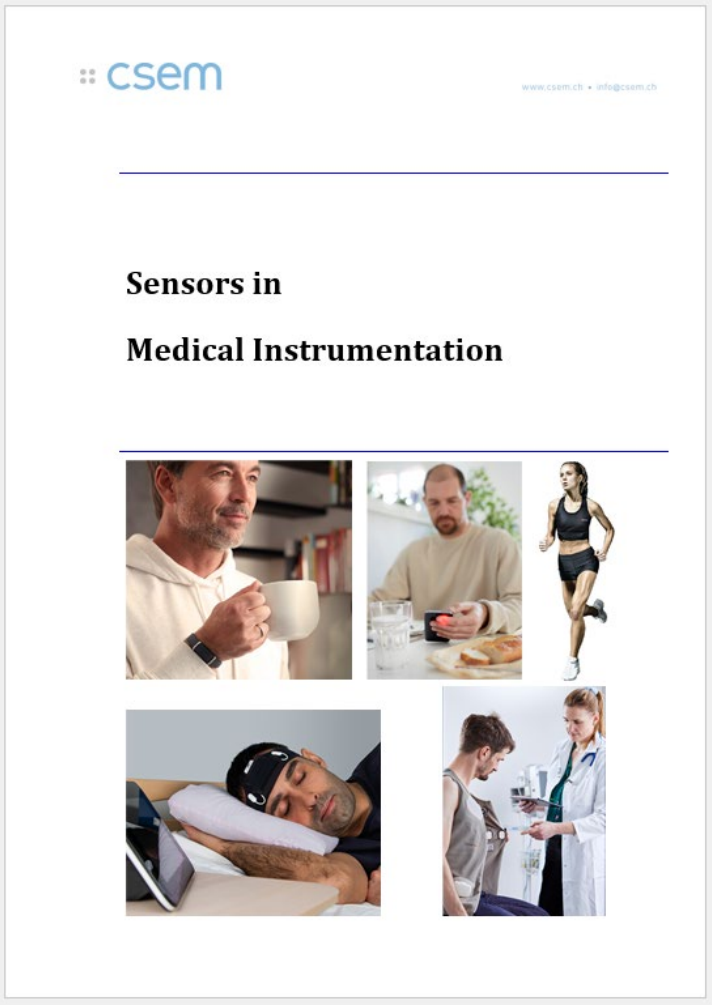
Textbook



Additional reference:

- **Medical Instrumentation—Application and Design, John G. Webster (Editor),** Fourth Edition (2010), John Wiley & Sons, ISBN-13 978-0471-67600.

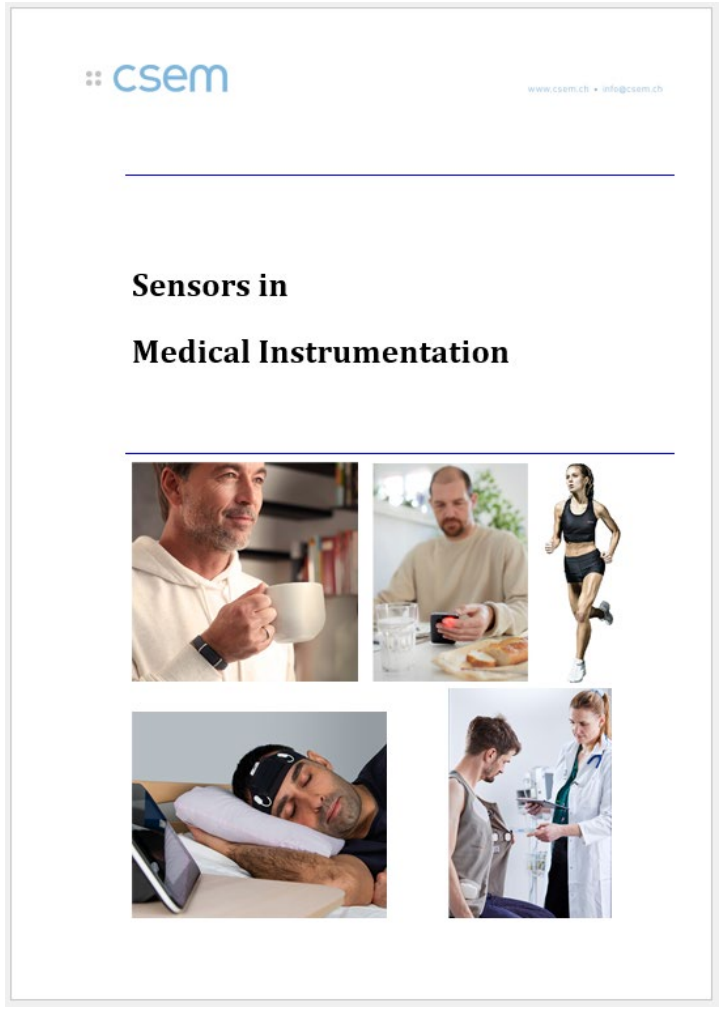
Textbook



Chapters 1 and 2 not explicitly taught
(reference or refresher)

1 Signal theory 7
1.1 Functional block diagrams 7
1.2 Properties of transfer functions 11
1.3 Control theory 17
1.4 Amplitude modulation (AM) 23
1.5 Digital signals 26
2 Components and circuits 30
2.1 Basic components 30
2.2 Circuit theory 36
2.3 Semiconductor components 40
2.4 Power supplies 44
2.5 Operational amplifier (OPA) 49
2.6 Voltage amplifiers (controlled voltage sources) 52
2.7 Impedance converters 62
2.8 Transconductance amplifiers (controlled current sources) 65

Textbook

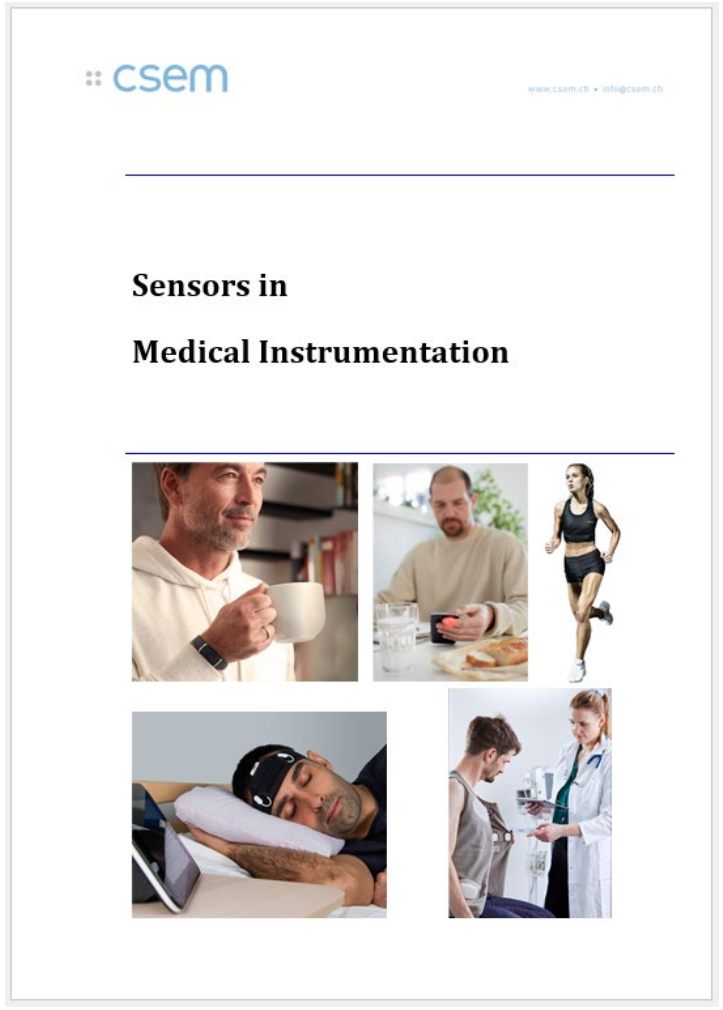


Chapter 3 (today)

3 BASIC SAFETY of ME EQUIPMENT 70
3.1 Safety assurance 70
3.2 MEANS OF PROTECTION (against electric shock) 78
3.3 Leakage current protection 84
3.4 Defibrillation-proof protection 90

February 20

Textbook



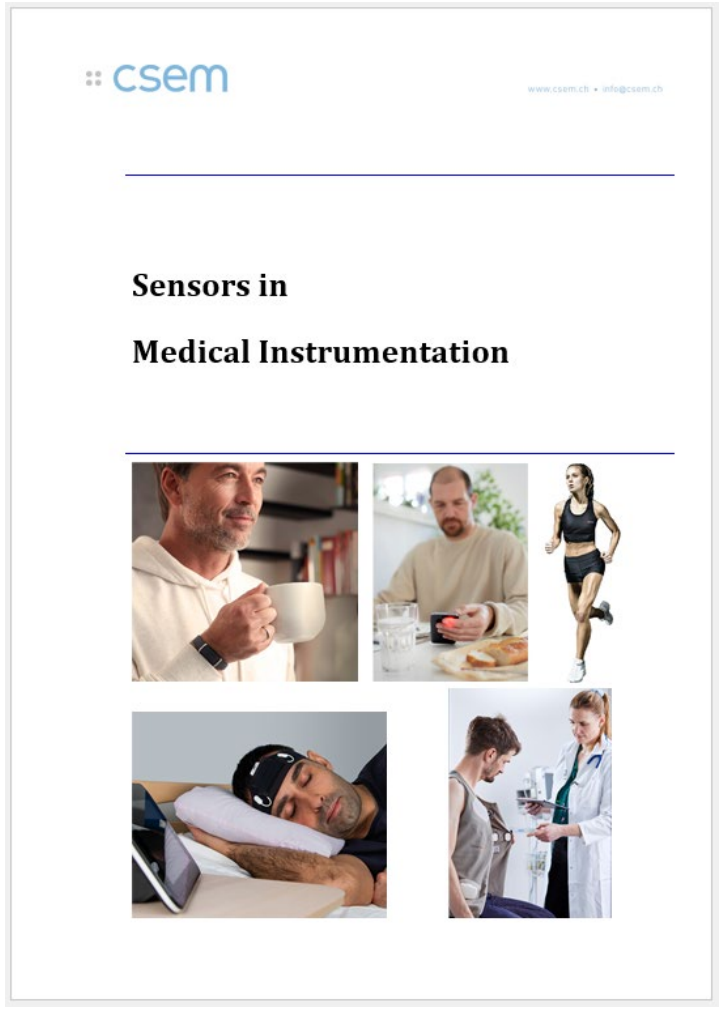
Chapter 4

4 Electrode sensors 93
4.1 Action potential 93
4.2 Biopotentials 101
4.3 Bioimpedances 111
4.4 Electrodes 120
4.5 Metrology of biopotentials 128
4.6 Metrology of bioimpedances 153
4.7 Active electrodes 165
4.8 Bi-electrodes 171

February 27

March 6
March 13

Textbook



Chapter 5

5 Optical sensors 179

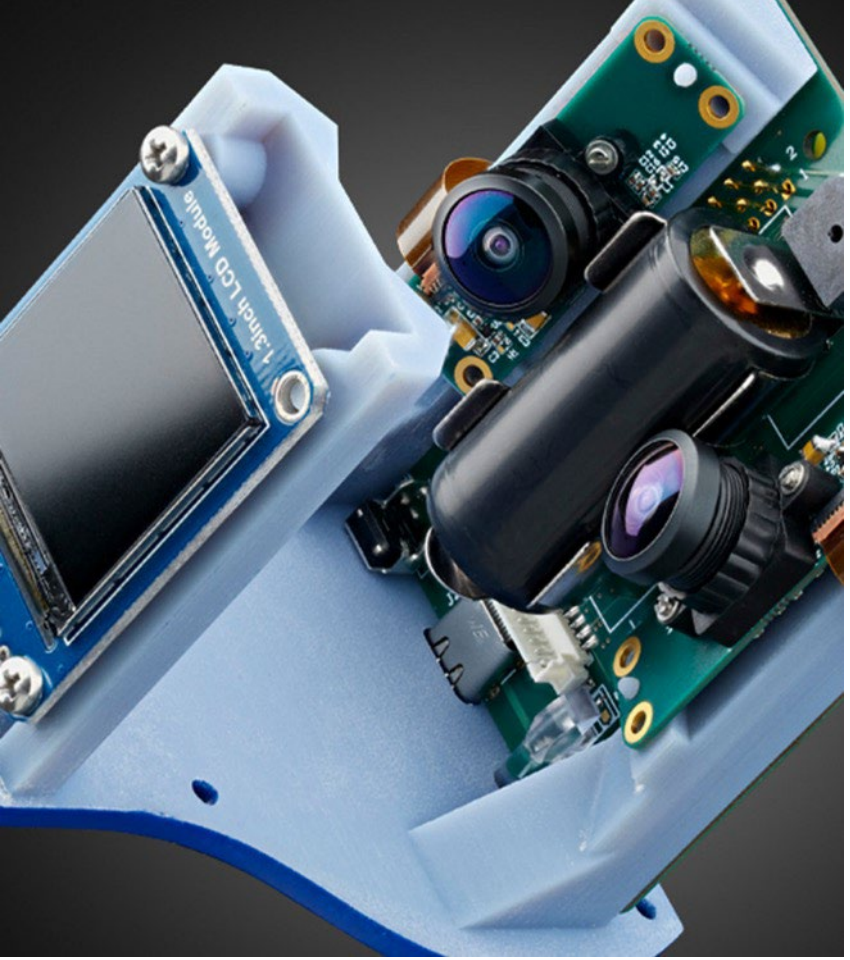
5.1 Photoplethysmography 179
5.1.1 PPG signal 179
5.1.2 Optical heart rate monitoring (oHRM) 182
5.1.3 Ambient light 184
5.1.4 Volume clamp blood pressure 185
5.1.5 Optical blood pressure monitoring (oBPM®) 186

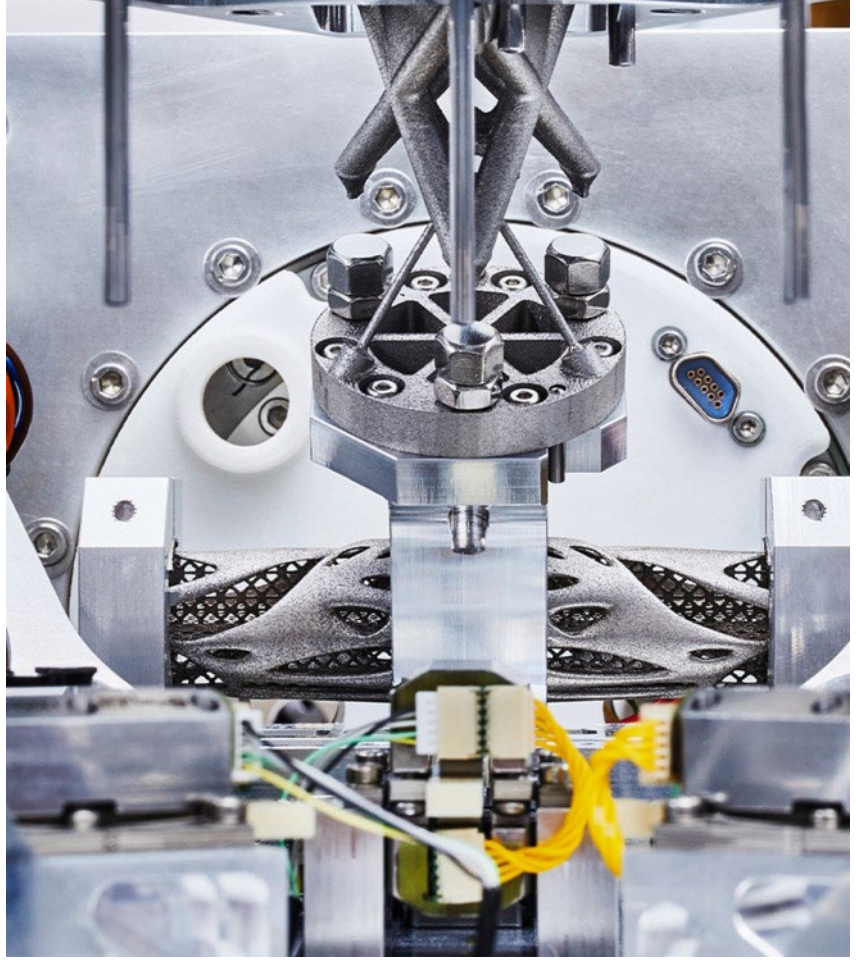
5.1.6 Pulse oximetry (SpO2) 188

5.2 Near infrared spectroscopy (NIRS) 193
5.2.1 Basic NIRS 193
5.2.2 Differential NIRS 196

March 20

March 27





COMPANY PRESENTATION

csem

Centre Suisse d’Électronique et de Microtechnique

CSEM AT A GLANCE

We are a public-private, non-profit Swiss **technology innovation center**

We enable competitiveness by **developing and transferring world-class technologies to the industrial sector**

1984
FOUNDED

600
SPECIALISTS in 2023

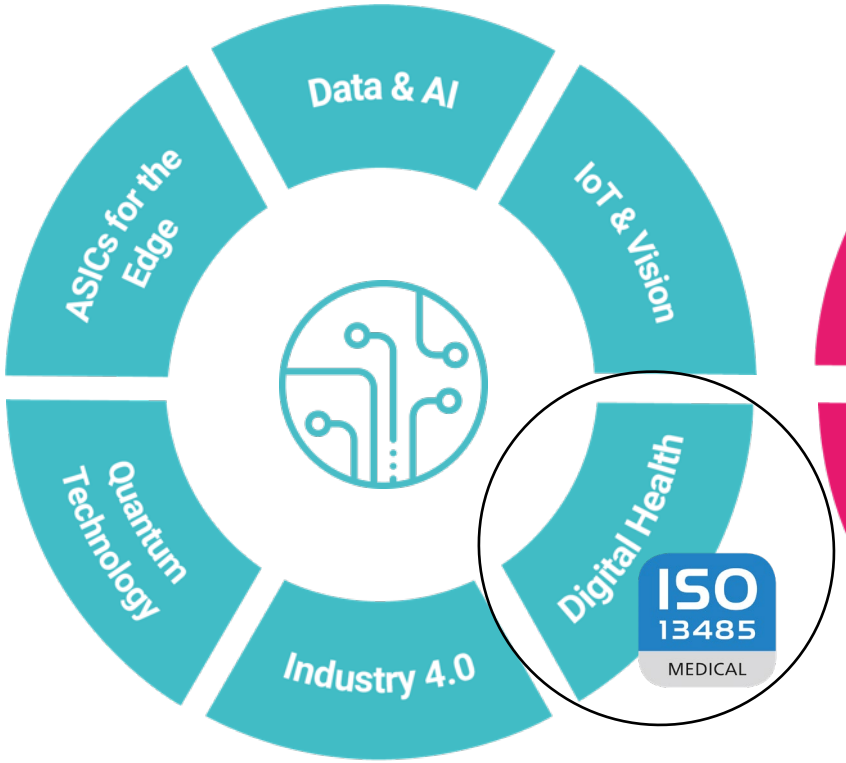
100.4
MIO TURNOVER in 2022

> 50
VENTURES since 1984

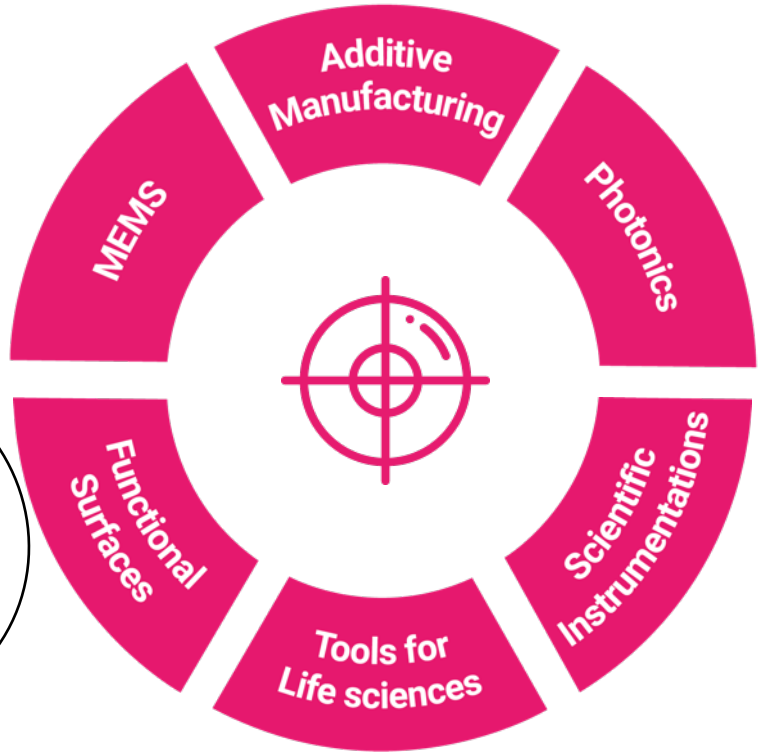
csem

WE FOCUS ON THREE CLEAR PRIORITIES

Digital Technologies



Precision Manufacturing



Sustainable Energy

csem

DIGITAL HEALTH @ CSEM

About 60 people divided in 5 groups

Medical systems

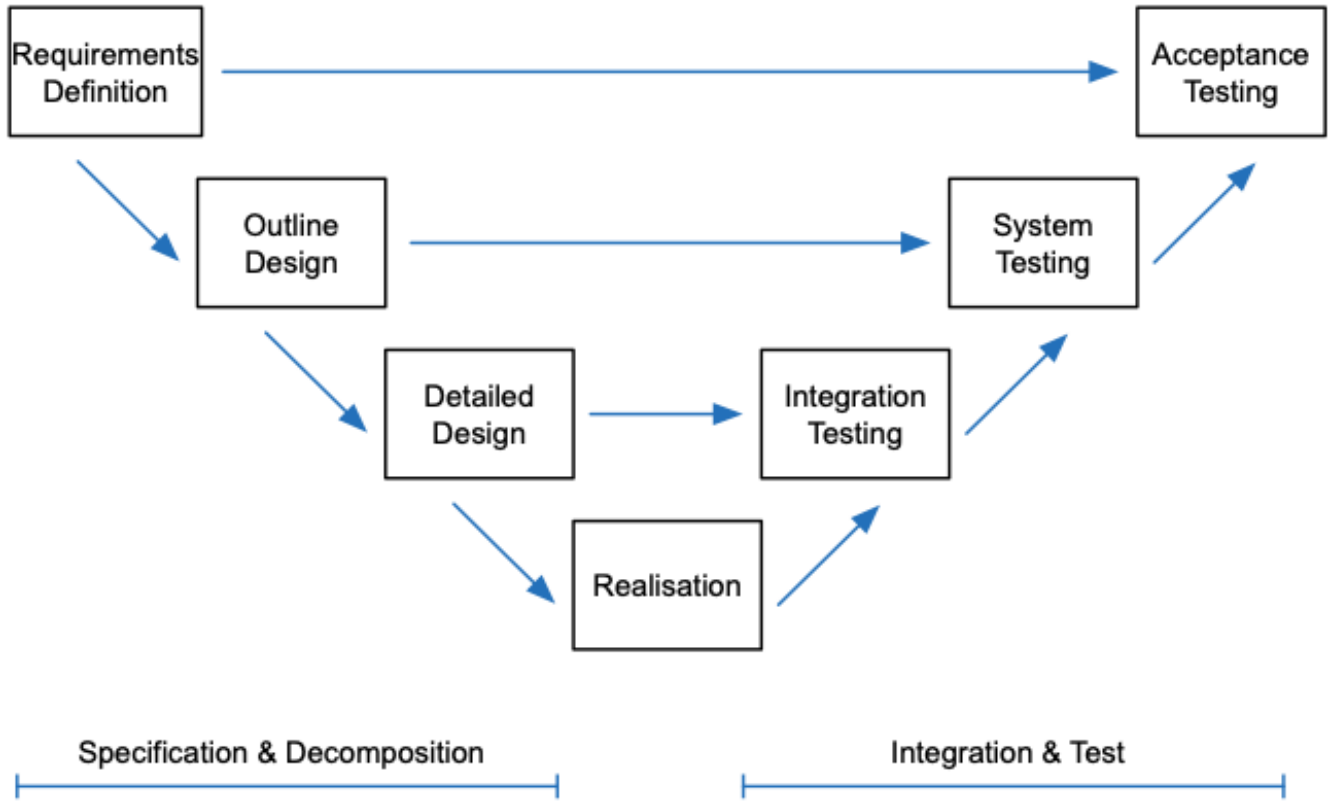
Signal processing

Edge & cloud software

Electronics & sensing

Prototyping

V diagram



EXAMPLE #1:
CUFFLESS BLOOD PRESSURE

Unmet need,
Issue to solve

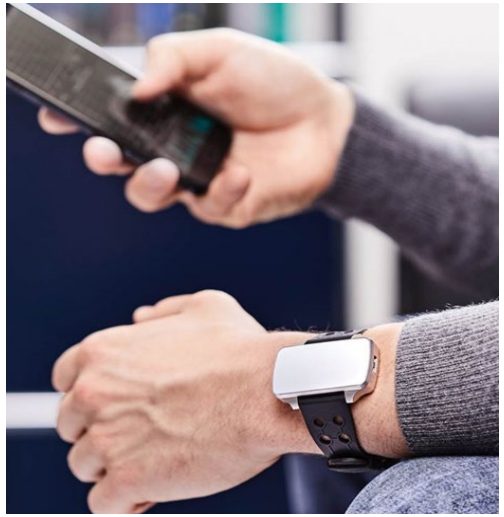
CSEM's solution,
Technology platform
(hardware + signal processing)

Clinical trials,
Validation

Technology transfer,
Innovative product
(companies / startups)

cuffless blood pressure

wrist sensor with oBPM®



in collaboration with hospitals, e.g.,

INSELSPITAL
UNIVERSITÄTSSPITAL BERN
HOPITAL UNIVERSITAIRE DE BERNE
BERN UNIVERSITY HOSPITAL

CHUV Centre hospitalier universitaire vaudois

Hôpital neuchâtelois

medical product commercialized by

csem

EXAMPLE #2:
NON-INVASIVE PULMONARY ARTERY PRESSURE

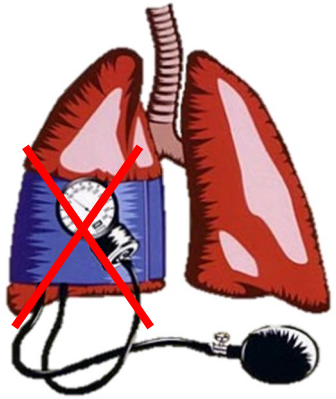
Unmet need,
Issue to solve

CSEM's solution,
Technology platform
(hardware + signal processing)

Clinical trials,
Validation

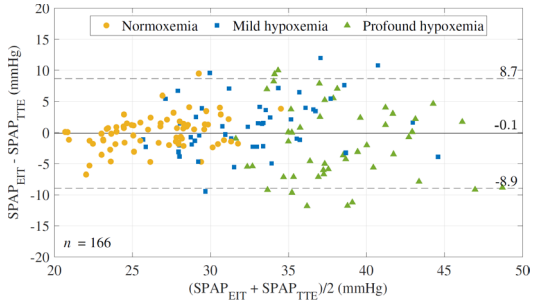
Technology transfer,
Innovative product
(companies / startups)

pulmonary artery pressure



EIT / ECG multi-electrode vest

accuracy analysis



(technology
not yet transferred)

csem

EXAMPLE #3:
COOPERATIVE SENSORS FOR IMAGING WEARABLES

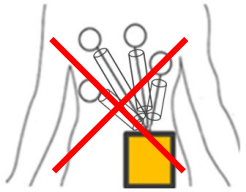
Unmet need,
Issue to solve

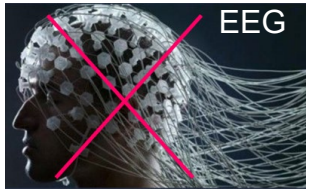
CSEM's solution,
Technology platform
(hardware + signal processing)

Clinical trials,
Validation

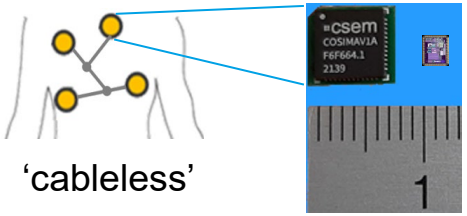
Technology transfer,
Innovative product
(companies / startups)

cables in metrology of
biopotential / impedance





cooperative sensors,
ASIC



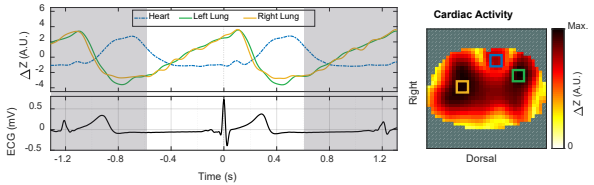
'cableless'

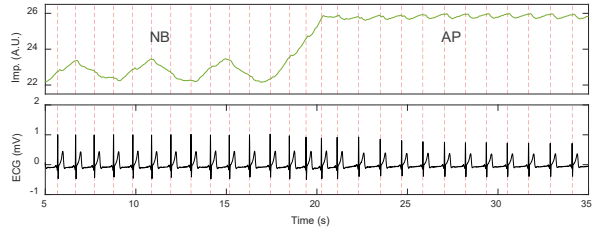
ECG

EEG

up to 250 electrodes

signal and image processing





(technology
not yet transferred)

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