Date	Lecture (14–16 h)		Exercises (16–17 h)
20.02†	Basic safety of ME equipment		
27.02†	Biopotentials, bioimpedances		Session 1
06.03†	Electrodes, 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

Rules for TEST 1 (copied from moodle)

- 14:15–15:00, MX F1 (same place as for the class)
- scope: what has been taught until March 13 (included)
- on paper, individually
- 25 questions, single choice (only one answer is correct)
  - correct answer: 3 points
  - no or multiple answers: 0 point
  - wrong answer: −1 point
- all questions with the same weight, 5% of course grade
- with Camipro Card
- no internet, no SMS
- OK: personal notes, EE-511 documents on moodle (paper or electronic support)

Example:

The questions may be written in the form of statements. If so, **indicate which statement is true**:

Work is produced by muscles from
☒ chemical energy
☐ electrical energy
☐ thermal energy
☐ nuclear energy

In the above example, there are four statements:

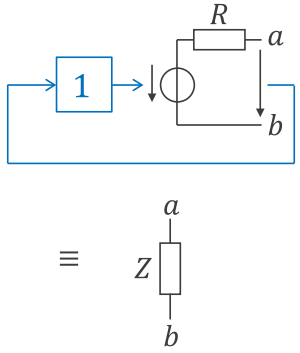
- Work is produced by muscles from chemical energy.
- Work is produced by muscles from electrical energy.
- Work is produced by muscles from thermal energy.
- Work is produced by muscles from nuclear energy.

The first one is correct; the three others are incorrect.

Quiz

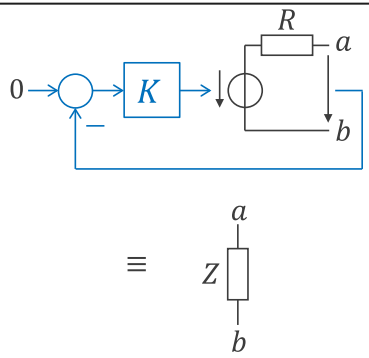
We have

- ☐ $Z = 0$
- ☐ $Z = -R$
- ☐ $Z = \infty$
- ☐ $Z = 2R$



We have

- ☐ $Z = 0$
- ☐ $Z = -R$
- ☐ $Z = \infty$
- ☐ $Z = 2R$

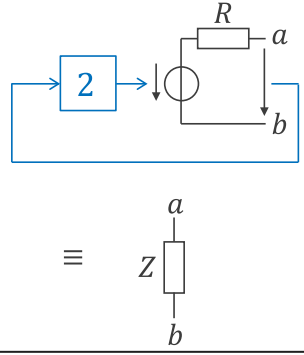


Electrodes N and RL are

- ☐ averaged for Wilson CT potential
- ☐ negative and right-lead electrodes
- ☐ white and purple electrodes
- ☐ two names for the same electrode

We have

- ☐ $Z = 0$
- ☐ $Z = -R$
- ☐ $Z = \infty$
- ☐ $Z = 2R$



EE-511 Sensors in medical instrumentation
Lesson 7 – Metrology of bioimpedances

4.6.1 Devices for bioimpedance measurement
4.6.2 Bipolar method
4.6.3 Tetrapolar method
4.6.4 Impedance signals at a given frequency
~~4.6.5 Sinewave current~~
4.6.6 Demodulator
4.6.7 Wire and cable leakages
4.6.8 Example of complete circuit

Objectives

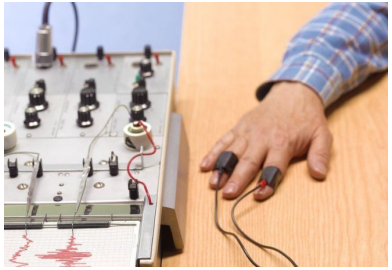
understand:

- bipolar method, tetrapolar method
- AM, IQ demodulation
- leakage, shielding

4.6.1 Devices for bioimpedance measurement

- Impedance plethysmography

- Bioimpedance analysis



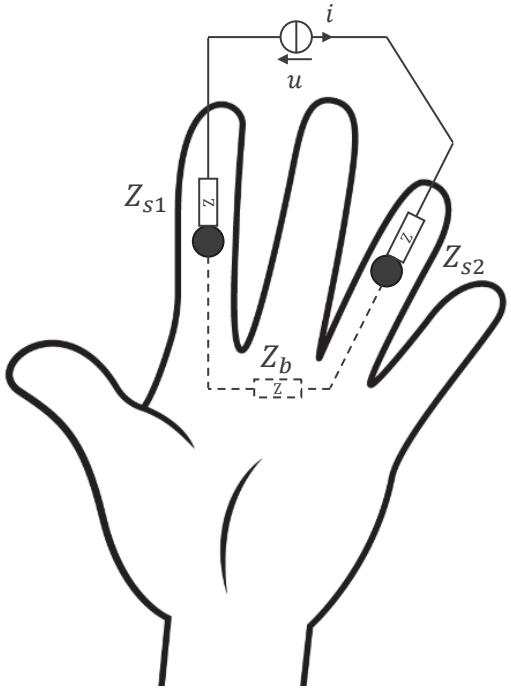
- Electrodermal activity

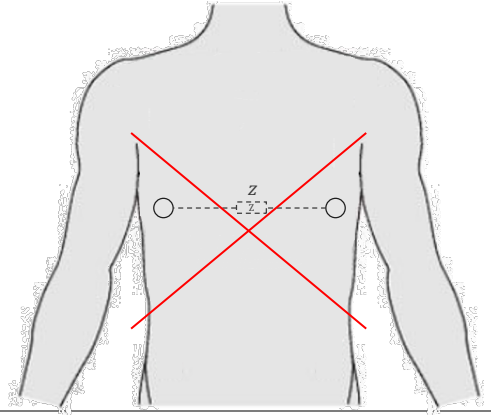
- Electrical impedance tomography

4.6.2 Bipolar method

$$u \cong (Z_{s1} + Z_{s2})i$$

- $Z_{s1}, Z_{s2} \gg Z_b$
- therefore, measured bioimpedance is $\cong Z_{s1} + Z_{s2}$
- good for EDA (electrodermal activity)

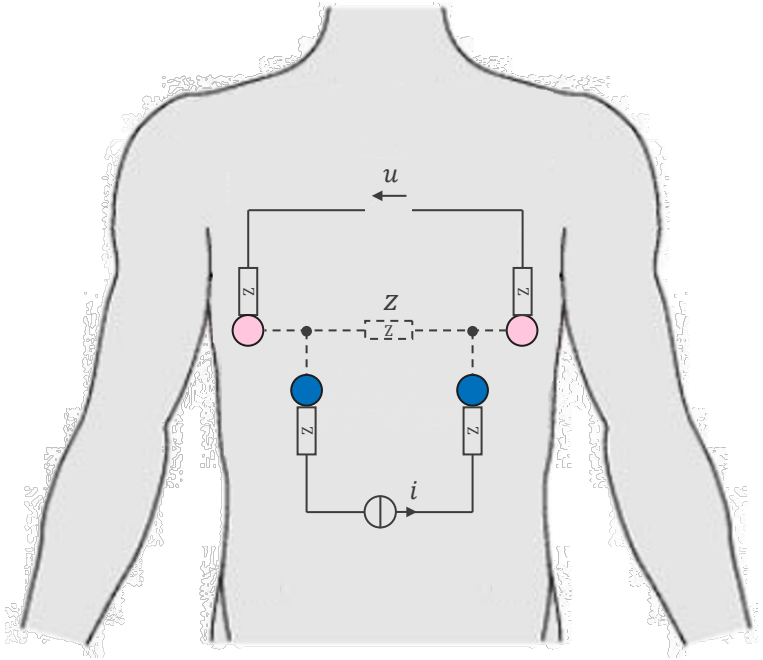




4.6.3 Tetrapolar method

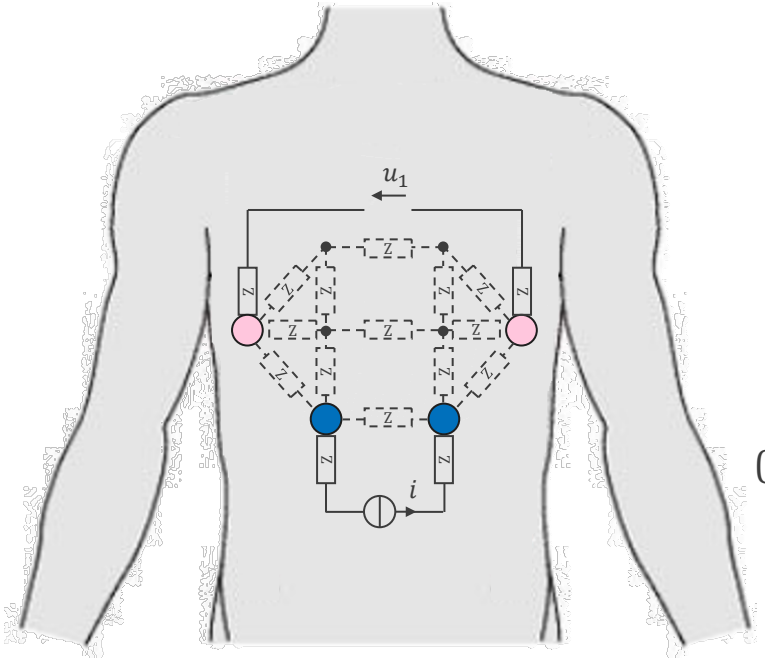
- different pair of electrodes
  - one as potential electrodes
  - one as current electrodes
- independent of skin impedance

$$u = Zi$$



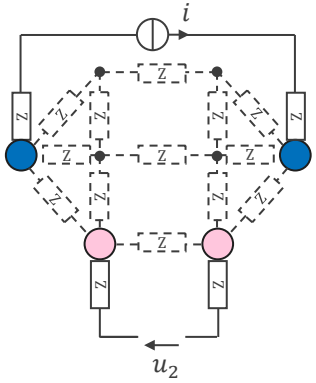
4.6.3 Tetrapolar method (continued)

- in reality, bioimpedance is a distributed network



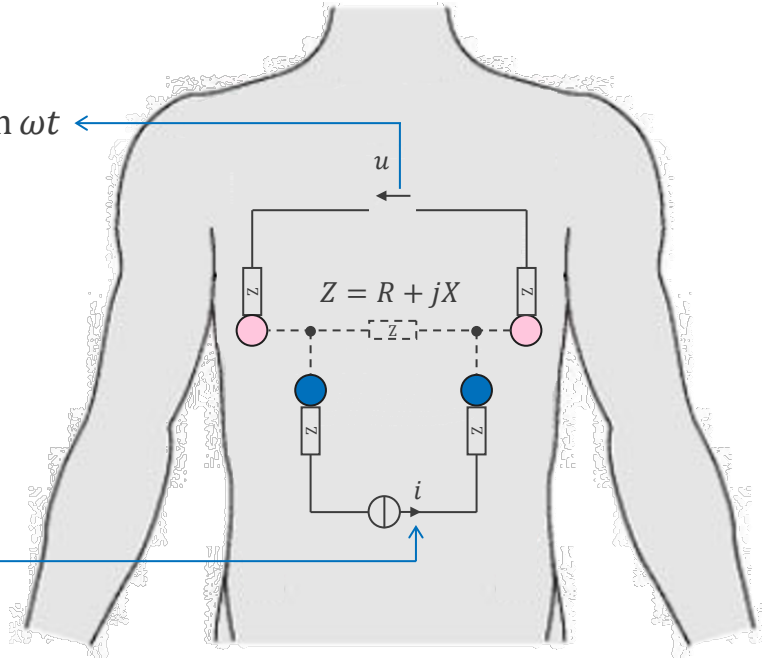
$$u_1 \overset{?}{=} u_2$$

(yes: reciprocity theorem)



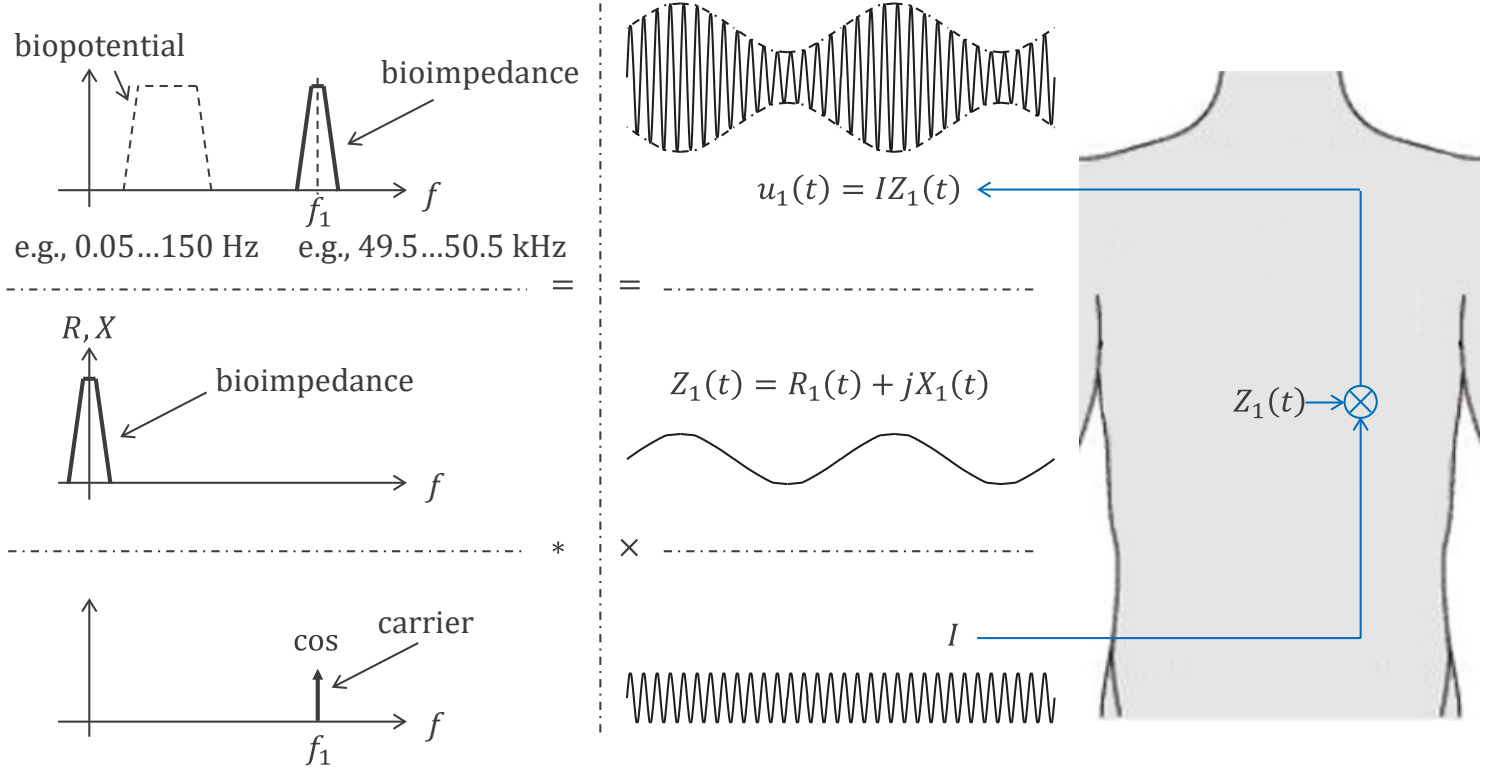
4.6.4 Impedance signals at a given frequency

$$u(t) = RI\cos\omega t + XI\sin\omega t$$
$$u = RI + jXI$$

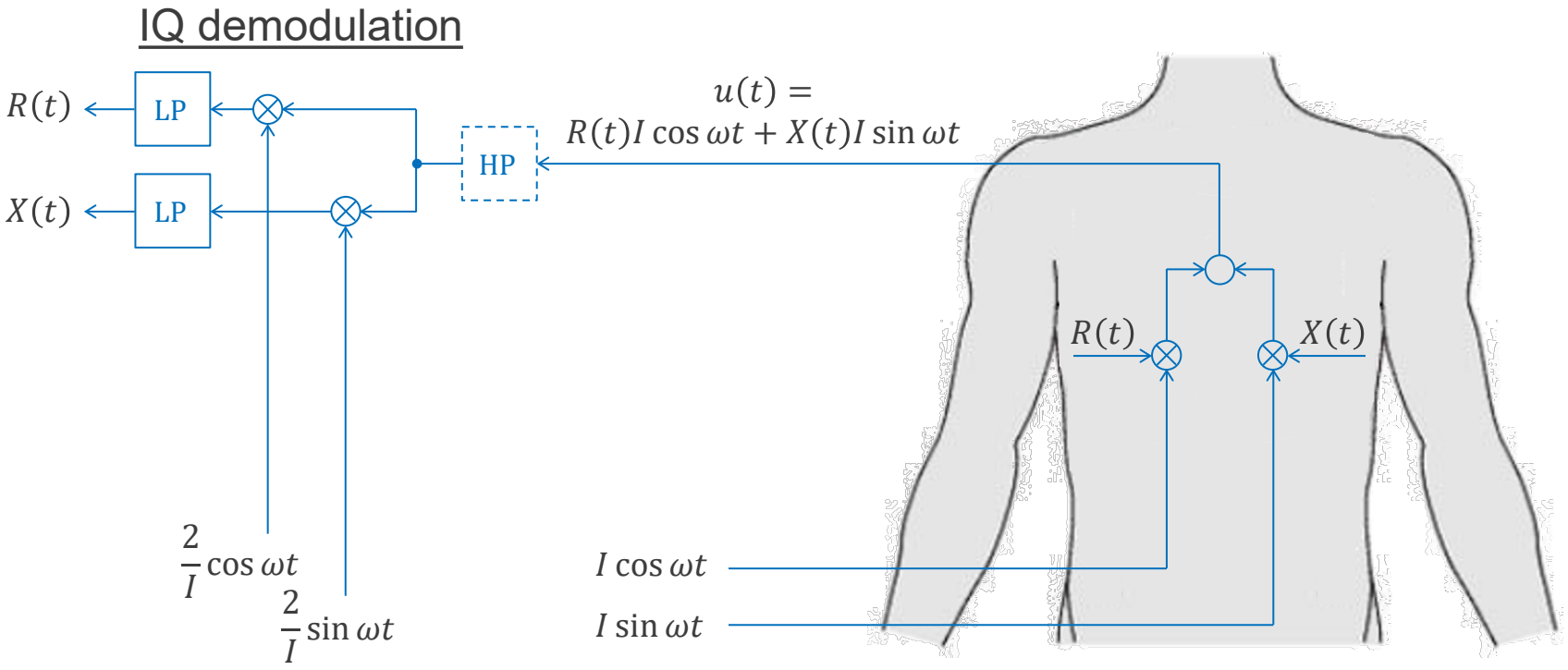


$$i(t) = I\cos\omega t$$
$$i = I$$

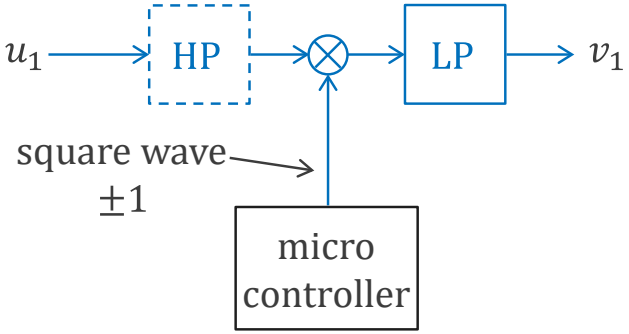
4.6.4 Impedance signals at a given frequency (continued)

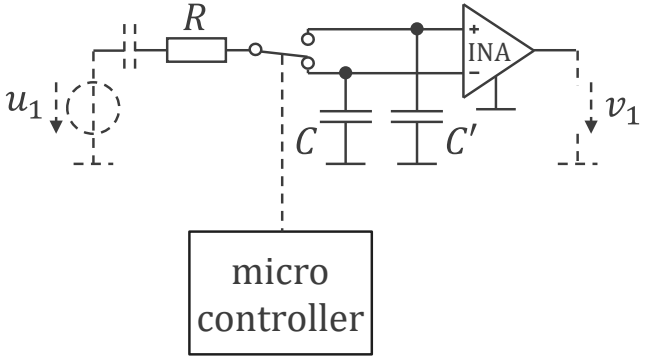


4.6.6 Demodulator



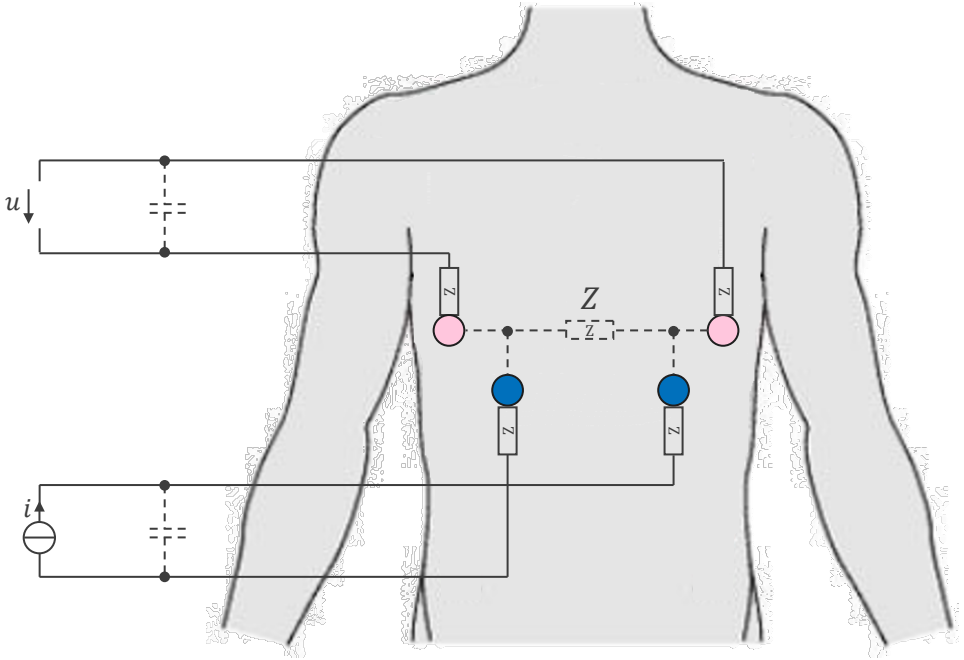
4.6.6 Demodulator (continued)





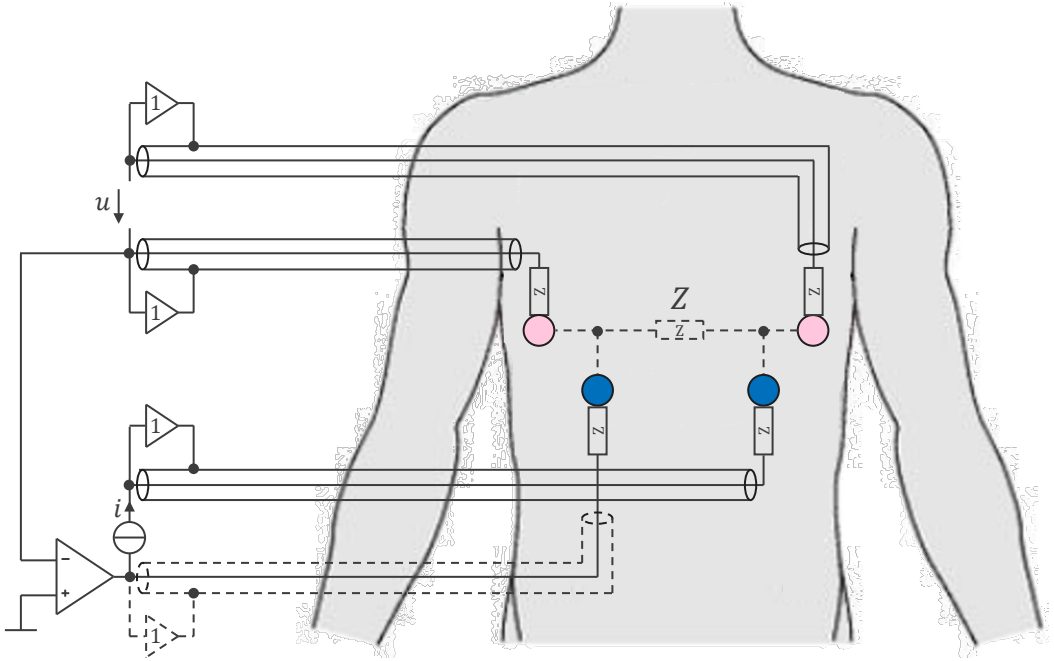
4.6.7 Wire and cable leakages

- stray capacitance between wires



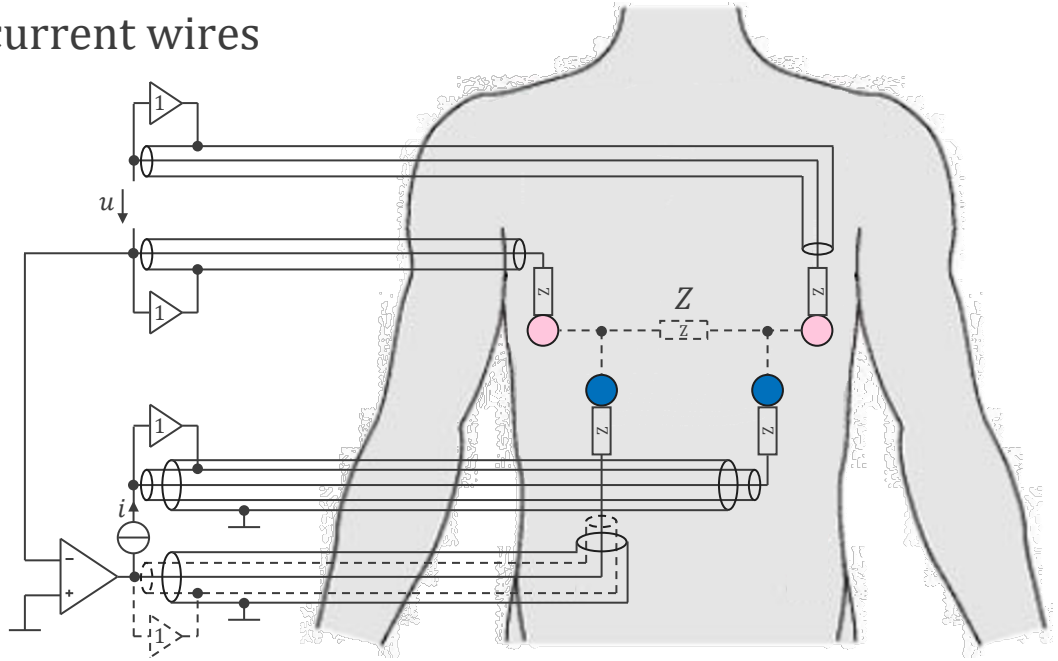
4.6.7 Wire and cable leakages (continued)

- solution: driven shield

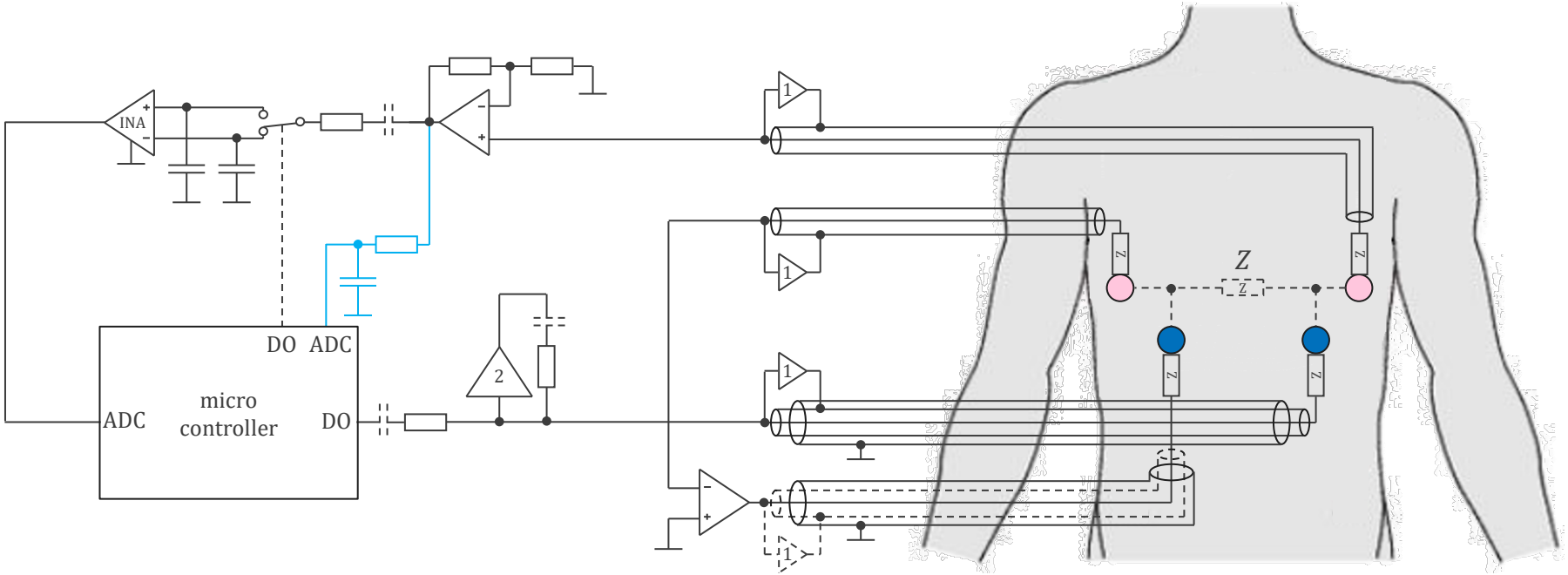


4.6.7 Wire and cable leakages (continued)

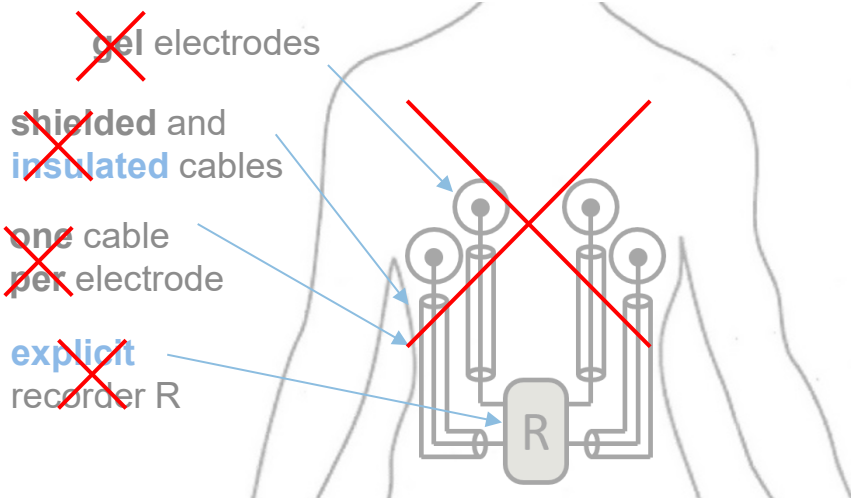
- solution: double shielding of current wires



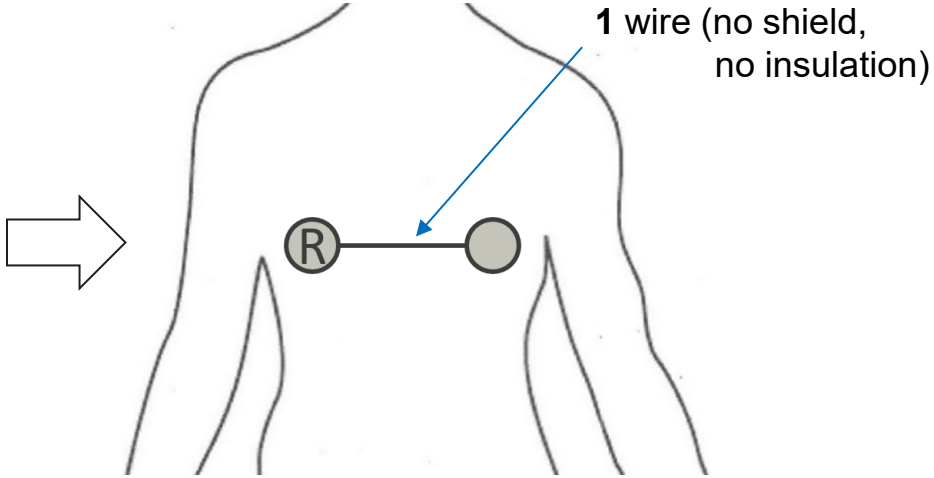
4.6.8 Example of complete circuit



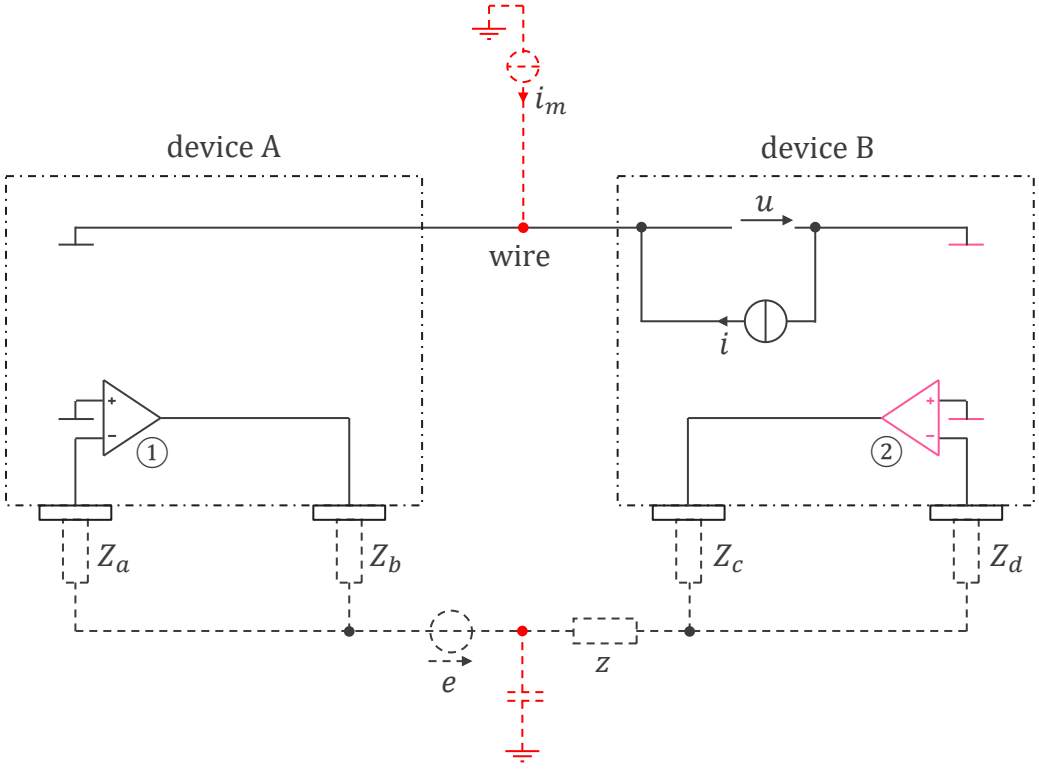
Example

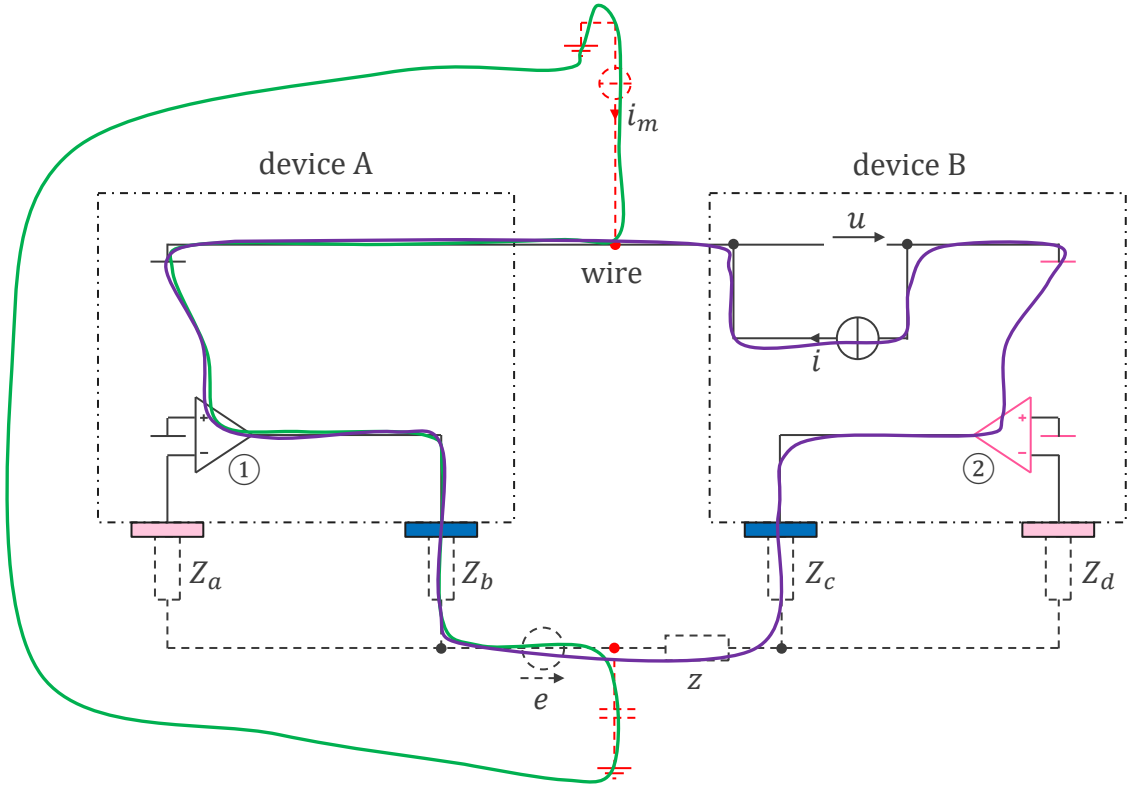


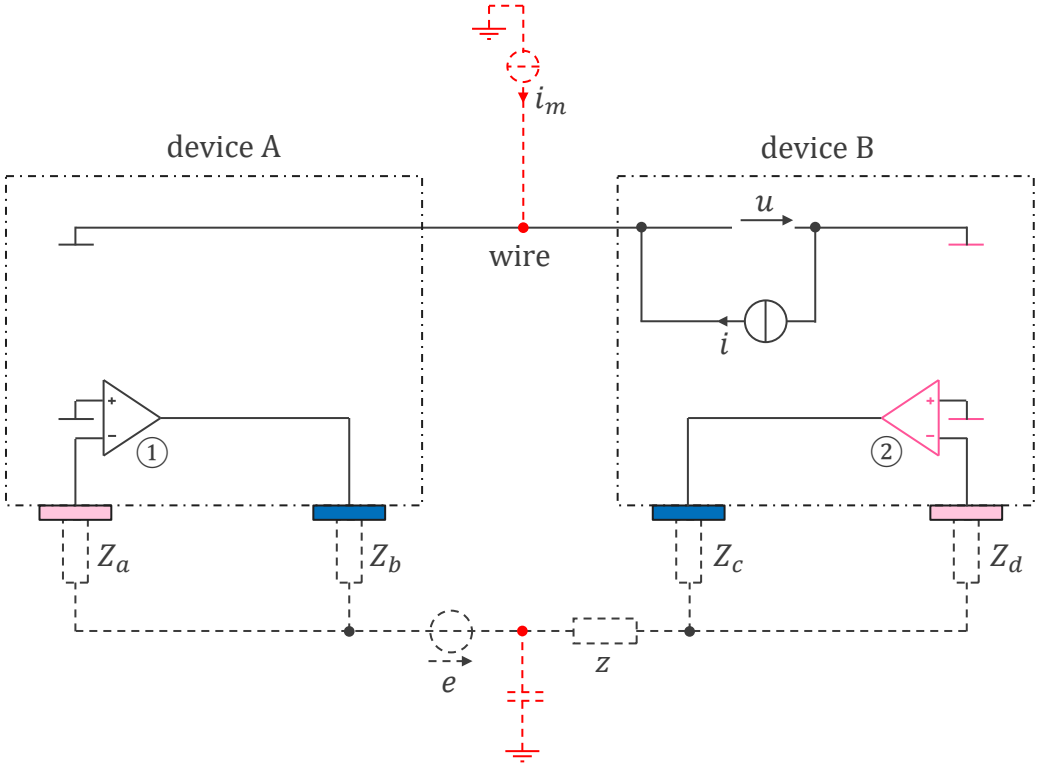
existing technology

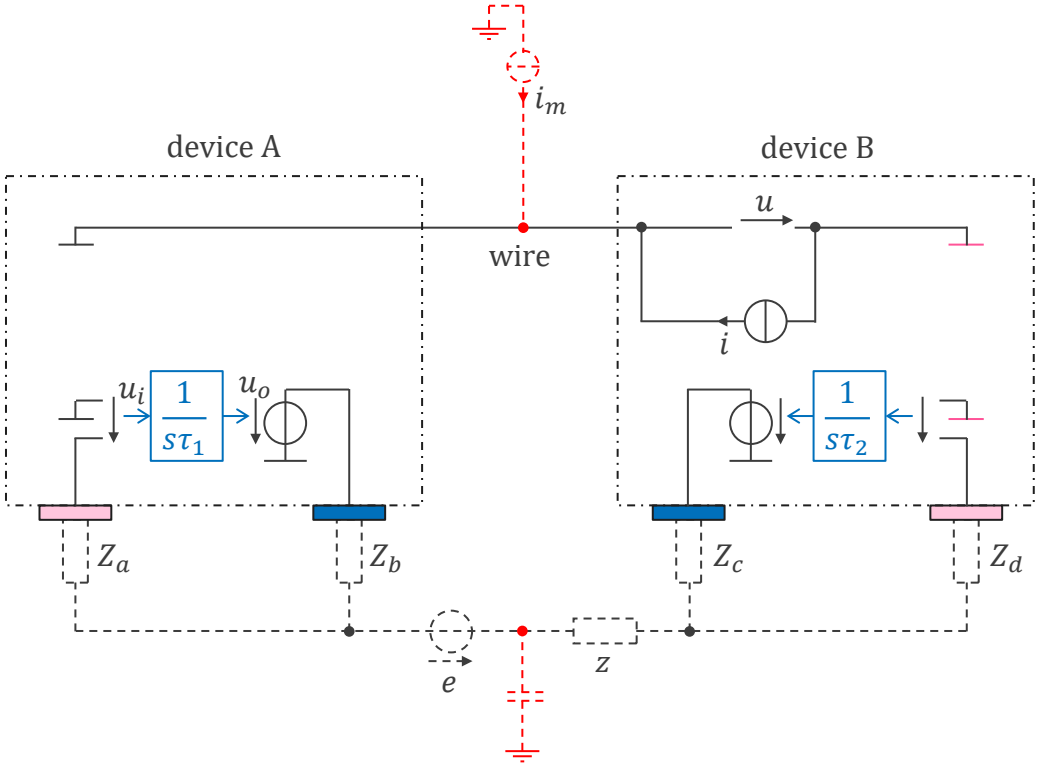


cooperative sensors


i_m
device A
device B
wire
u
i
①
②
Z_a
Z_b
Z_c
Z_d
e
z


i_m
device A
device B
wire
u
i
①
②
Z_a
Z_b
Z_c
Z_d
e
z


i_m
device A
device B
wire
u
i
①
②
Z_a
Z_b
Z_c
Z_d
e
z


i_m
device A
device B
wire
u
i
u_i
$\frac{1}{s\tau_1}$
u_o
$\frac{1}{s\tau_2}$
Z_a
Z_b
Z_c
Z_d
e
z