ELEC 207
Instrumentation and Control

12 – Noise and Interference

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Signal processing
Analog and digital processing

A measurement signal is often processed to extract relevant information or to “clean” it by removing noise and other disturbances.

There are two types of signal processing:

- **Analog signal processing**:
  - Applied to an analog signal (e.g. before the ADC);
  - A typical example is **filtering** to remove noise;
- **Digital signal processing**:
  - Applied to a digital signal (e.g. after the ADC);
  - Typical examples are the **calculation** of the signal RMS value or the **transformation** of the signal into the frequency domain, etc.

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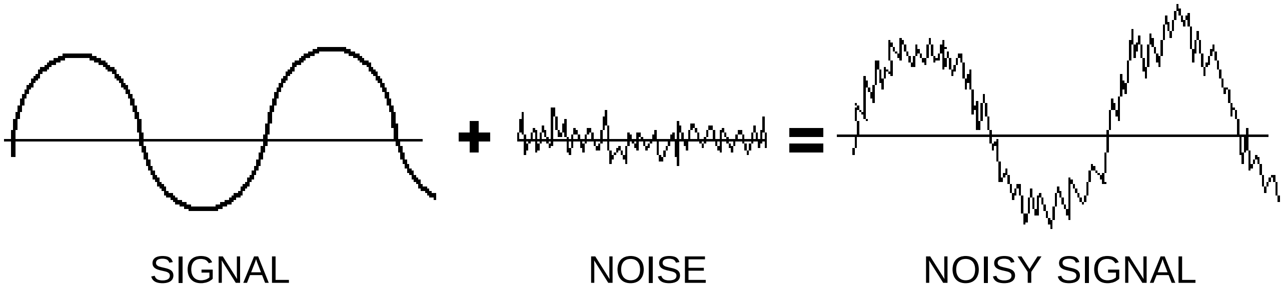
Signal and noise

Internal noise and external interference

Noise is an undesired disturbance, superimposed to the measurement signal, which affects the quality (and therefore the accuracy) of the signal:



- The quality of the signal can be measured by the **signal-to-noise ratio (SNR)**, which is the ratio between the signal power and the noise power.

Noise in a measurement system can arise from two sources:

- **Internal** (e.g. thermal noise);
- **External** (interference from other circuits).

Electromagnetic interference

Overview and general solutions

Electromagnetic interference from external (power) circuits is quite common, particularly in industrial environments:

- It is caused by **inductive and/or capacitive coupling** between the measurement circuit and other (power) circuits near it;
- It typically produces **noise at high frequency** because the coupling is more effective at higher frequencies;
- The coupling (and therefore the noise) can be decreased by separating the measurement circuit from the other circuits, but this is not always possible:
  - E.g. when the measurand is a quantity in the power circuit itself;
  - Therefore other solutions are required.

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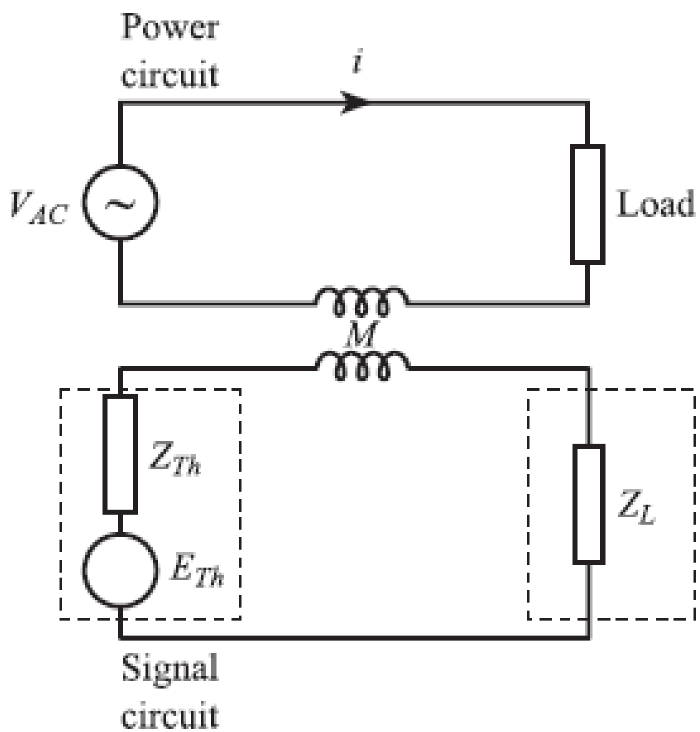
Inductive coupling

Cause of the problem

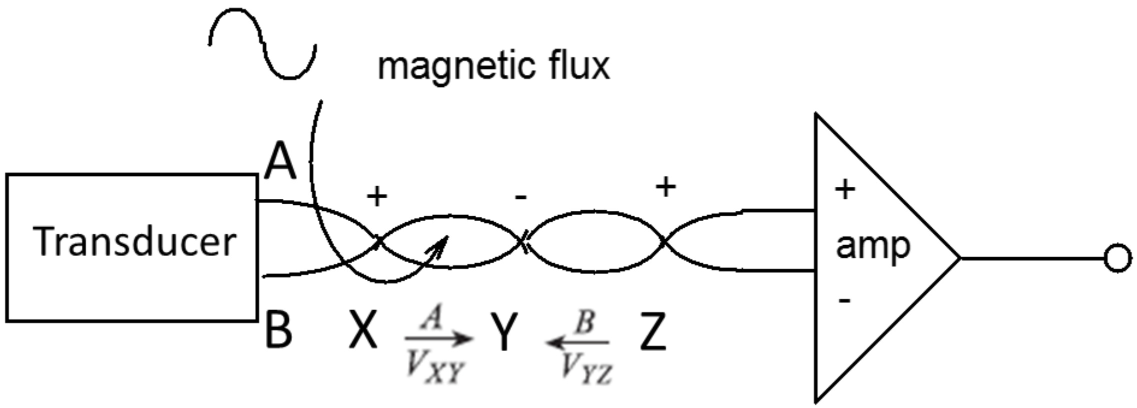
A strong time-varying magnetic field (typically originated from a power circuit) near the measurement circuit may induce a voltage in the measurement circuit due to inductive coupling:



Inductive coupling

Possible solution

A possible way to decrease the induced voltage in the measurement circuit is to **twist the wires** in the measurement circuit:

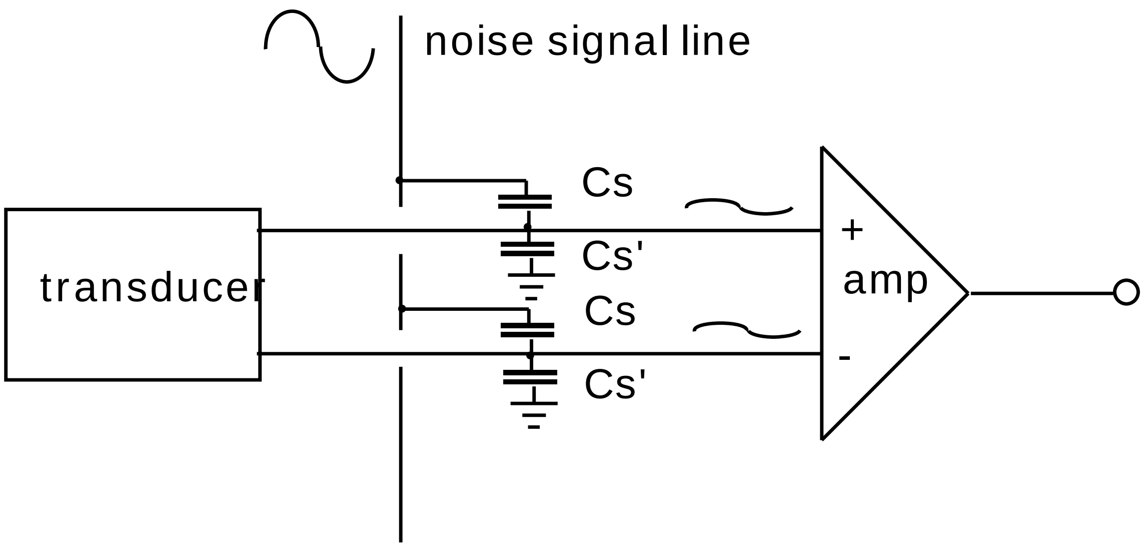


- This has two positive effects:
  - The loop area is reduced to a minimum value;
  - The voltages induced in adjacent loops are opposite, so they balance out and (ideally) the overall induced voltage is zero.

Capacitive coupling
Cause of the problem

Wires are conductors, so there is always a capacitance between wires in different circuits (e.g. the measurement circuit and a power circuit near it):

- This capacitive coupling may induce voltages in the measurement circuit.



Capacitive coupling

Possible solutions (1)

The induced voltage due to capacitive coupling is usually a **common-mode voltage**, i.e. it is the same on the two wires of the measurement circuit:

- Therefore it can be easily removed by a **differential amplifier**, which amplifies only the difference between the voltages at the two terminals;

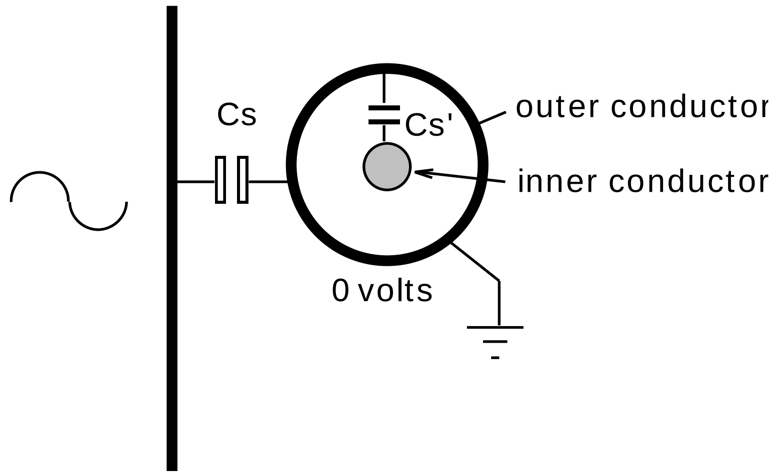
- The effectiveness in removing the capacitive coupling is measured by the **common-mode rejection ratio (CMRR)** of the amplifier, which is the ratio between the differential voltage amplification and the common-mode voltage amplification:

  - The higher the CMRR the better;

  - **Instrumentation amplifiers** have a very high CMRR (above 100 dB) and are particularly suitable for measurement applications.

Capacitive coupling
Possible solutions (2)

Another possible solution to decrease the interference arising from capacitive coupling is to use a **shielded (or screened) cable** for the measurement circuit, with the shield grounded:



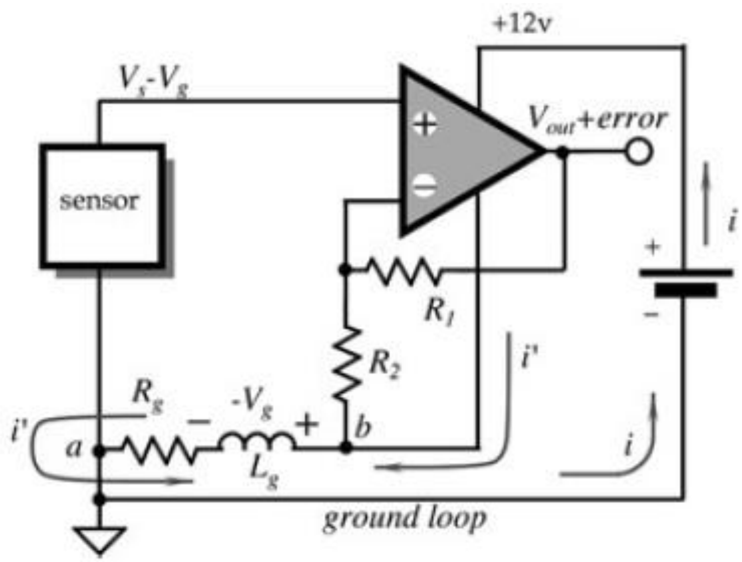
- The shield could be either the negative (reference) terminal in the measurement circuit or a third conductor.

Ground loops

Cause of the problem

Another source of possible noise is represented by **multiple ground points** in the circuit:

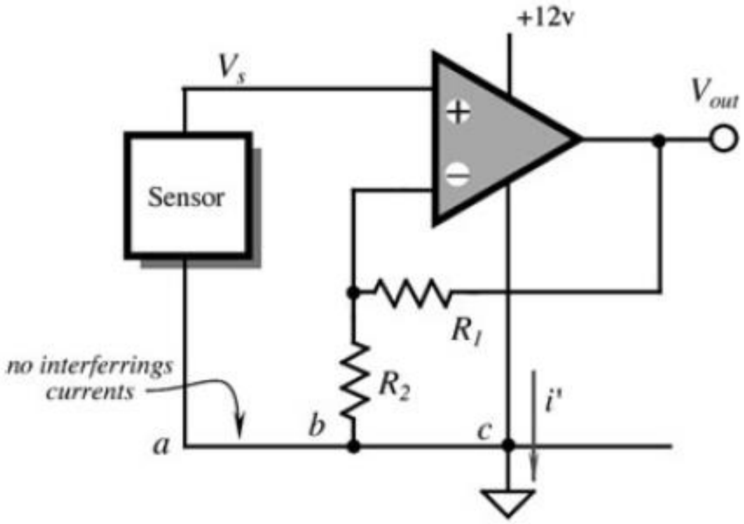
- The ground resistance and inductance are not zero as in an ideal circuit:
  - Therefore current flowing through a ground path creates a voltage drop, which means that two reference points in the circuit (two 'grounds') may actually be at different potentials;
  - Also, a **ground loop** in the circuit is a source of noise.



Ground loops

Possible solution

To avoid ground loops, the whole circuit should be **connected to ground only in one point**, and all elements in the circuit (transducer, amplifier, etc.) should be referenced to this common point:



- When connecting an additional element to the circuit (e.g. an oscilloscope to acquire a voltage signal), it is very important to know whether it adds another ground connection and therefore a possible ground loop.

References

Textbook: Principles of Measurement Systems, 4th ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Bentley** textbook:

- Chapter 6, Sec. 6.3: **Effects of noise and interference on measurement circuits**;
- Chapter 6, Sec. 6.4: **Noise sources and coupling mechanisms**;
- Chapter 6, Sec. 6.5: **Methods of reducing effects of noise and interference**.

NOTE: Topics not covered in the lecture are not required for the exam.

References

Textbook: Measurement and Instrumentation, 2nd ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Morris-Langari** textbook:

- Chapter 3, Sec. 3.6: **Induced measurement noise**;
- Chapter 3, Sec. 3.7: **Techniques for reducing induced measurement noise**.

NOTE: Topics not covered in the lecture are not required for the exam.