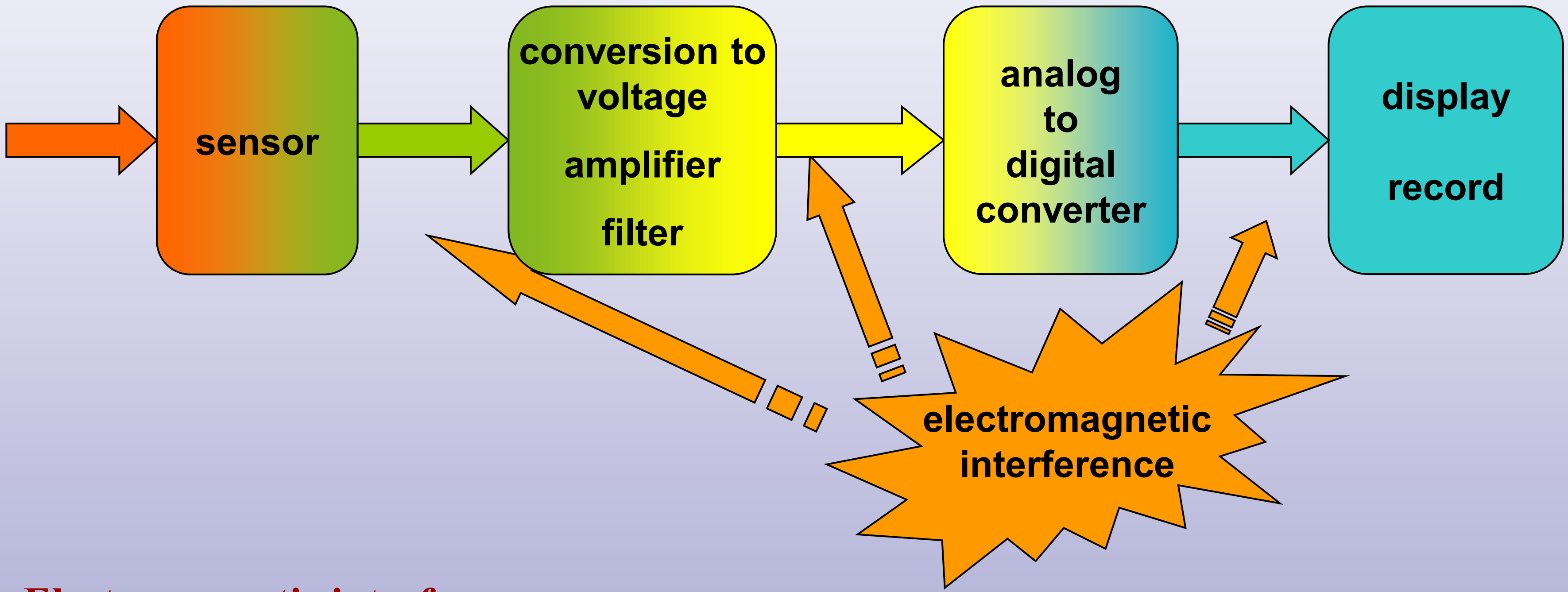
MEASUREMENT DEVICE
AND
ELECTROMAGNETIC INTERFERENCE

1. PRINCIPAL OF ELECTROMAGNETIC INTERFERENCE



Electromagnetic interference:

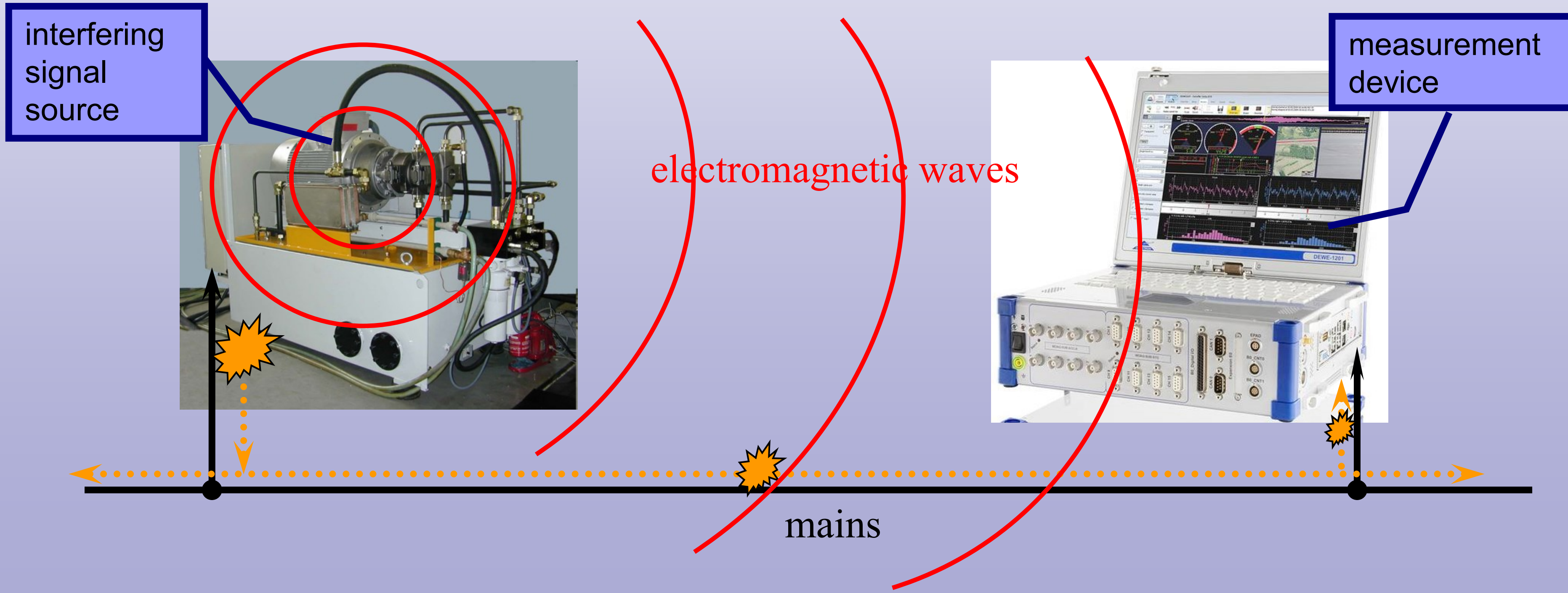
- the signal generated by the interference source is transmitted via galvanic or electromagnetic coupling into the measurement device
- electromagnetic interference causes distortion of the measured signal, there is noise on the signal

1. PRINCIPAL OF ELECTROMAGNETIC INTERFERENCE

- **electromagnetic interference classification**
  - **according to the interfering signal source**
    - **natural:** lightning, solar activity
    - **artificial:** created by human activity
      - **functional:** signal production is the meaning of their existence, but for other devices their signal is disruptive **-** transmitters, radars
      - **parasitic:** interfering signal creates as a by-product of its activity **-** motors, frequency converters, switching power supplies, contactors
  - **according to the type of interfering signal**
    - **continuous:** motors, transmitters
    - **impulse:** relays, contactors
  - **according to the interfering signal frequency**
    - **narrowband interference:** network frequency 50Hz
    - **broadband interference:** frequency converters, switching power supplies

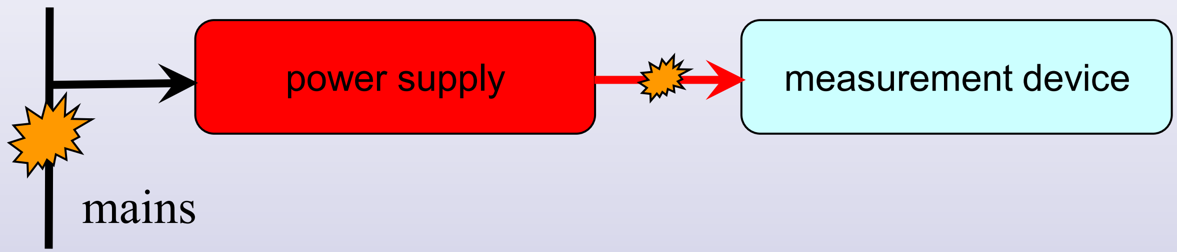
2. TRANSMISSION PATHS OF THE INTERFERING SIGNAL

- **coupling mechanisms**
- **galvanic**
  - **coupling path via electrical network**
- **non galvanic**
  - **capacitive** coupling path via electrical field
  - **inductive** coupling path via magnetic field
  - **electromagnetic field** coupling path via electromagnetic waves

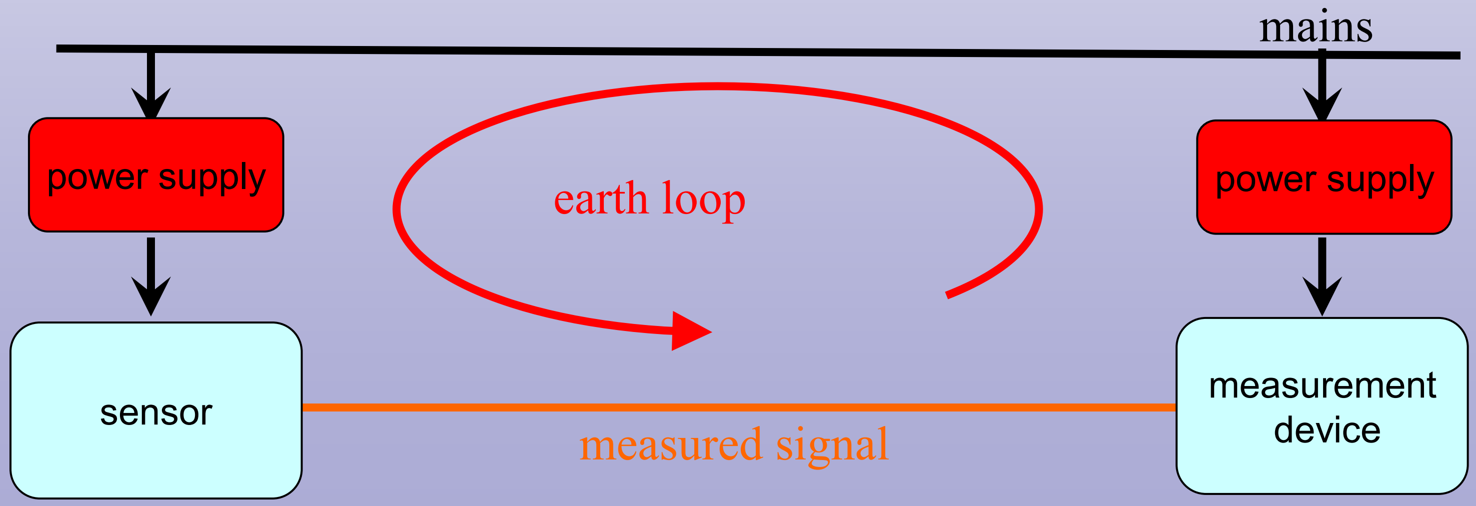


2. TRANSMISSION PATHS OF THE INTERFERING SIGNAL

- **galvanic path**
  - The interference propagates from the sources through the electrical network and from there it penetrates into the measuring device via its power supply.

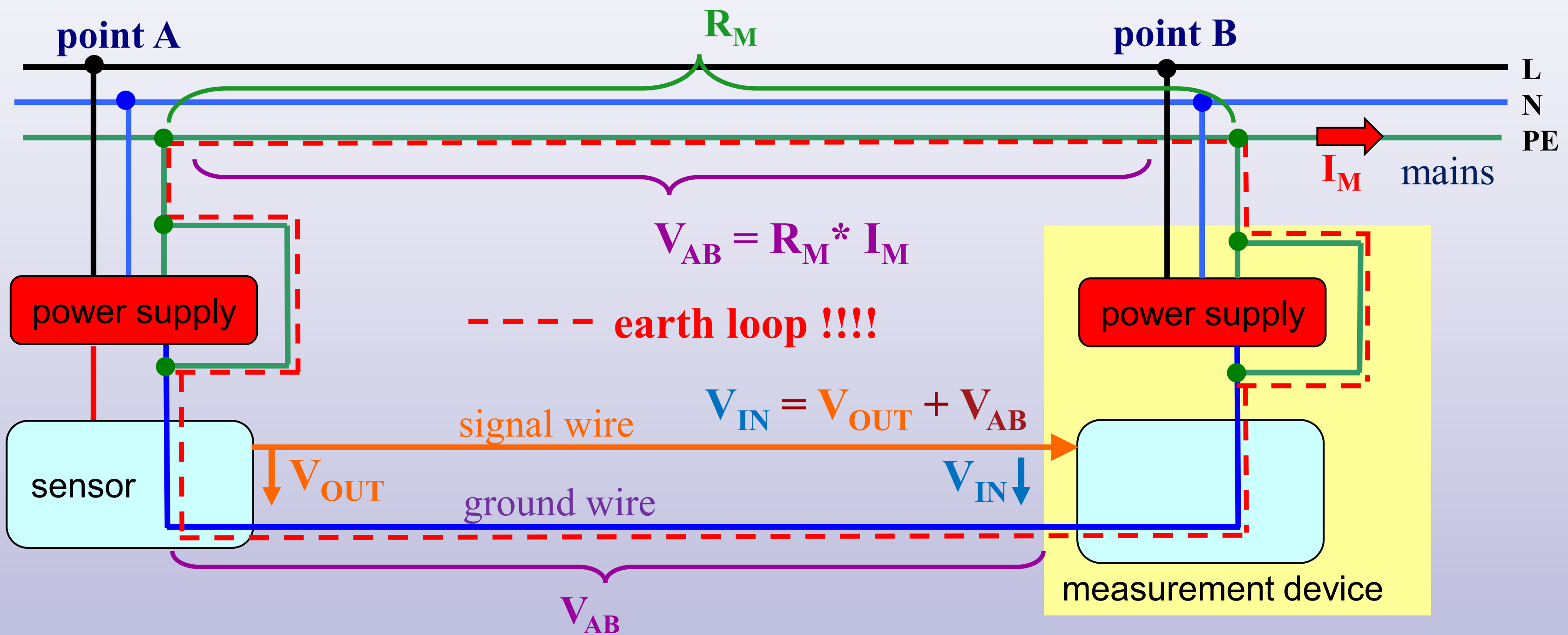


- If the distributed measurement device has multiple power supplies, **the earth loop** will occur if the power supplies are not connected properly. This is very dangerous, the measured signal can be completely destroyed in this case.



2. TRANSMISSION PATHS OF THE INTERFERING SIGNAL

- **the earth loop principle**

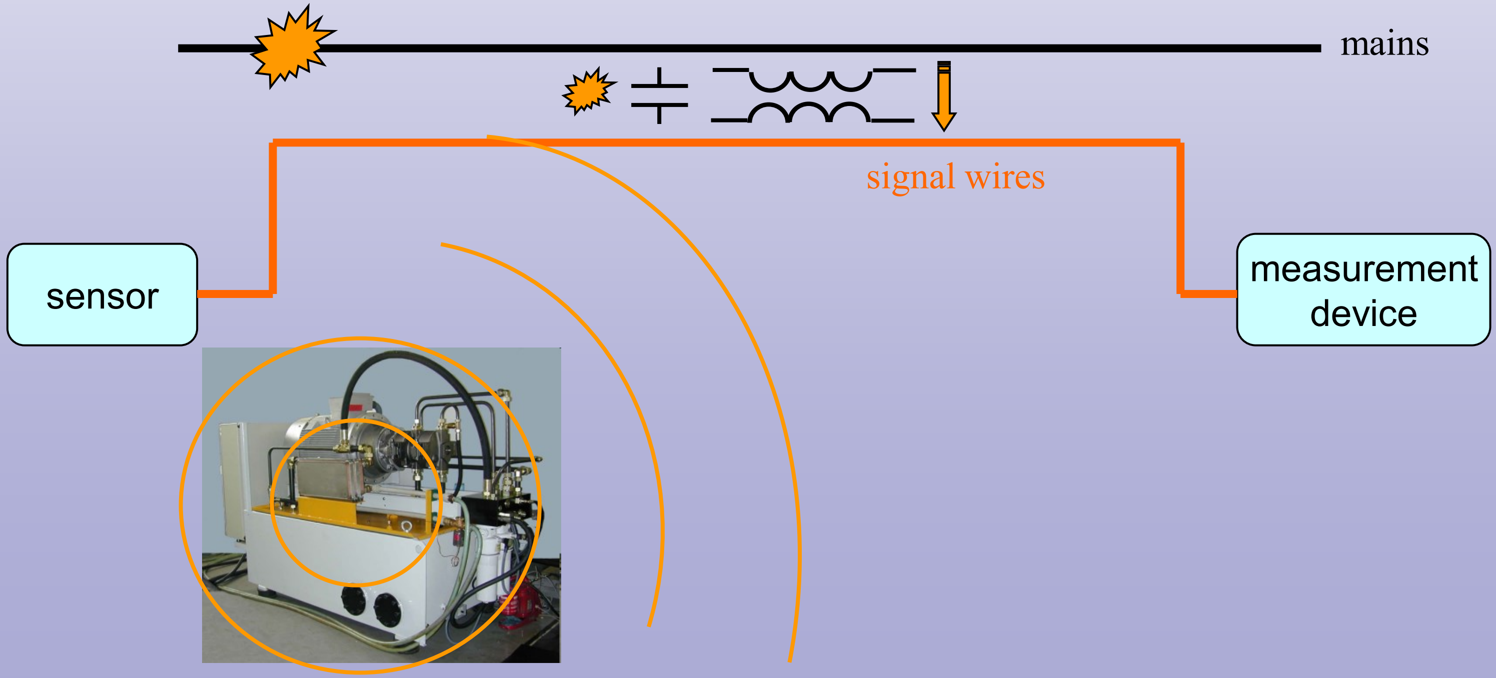


- two power supplies of the measurement device are connected to the mains at points A and B
- both parts of the measurement device are connected by the signal wire and the ground wire and the ground wire is earthed to the mains in both parts - safety rule against electric shock
- electric current I_M flows through the mains
- the mains wires have a resistance R_M, the V_{AB} voltage is generated between points A and B (ohm's law)
- the voltage V_{AB} is added to the output signal of the sensor V_{OUT} (Kirchhoff's circuit laws), the input signal to the measuring device V_{IN} is different than the output of the sensor V_{OUT}
- many different appliances are connected to the mains, the I_M and V_{AB} are very variable over time, so the parasitic variable voltage V_{AB} is reflected in the measured signal as noise, which can be very strong

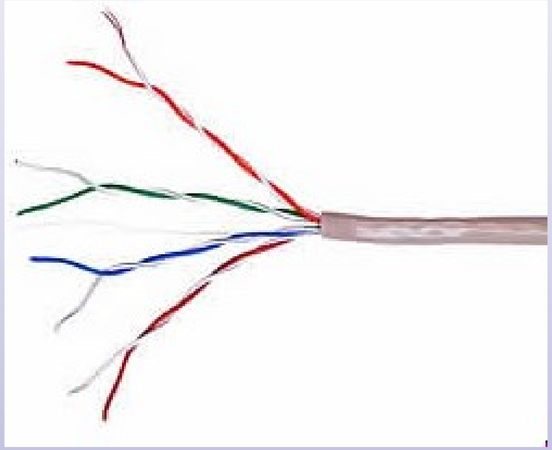
2. TRANSMISSION PATHS OF THE INTERFERING SIGNAL

- **non galvanic path**

- **capacitive** coupling path via electrical field
- **inductive** coupling path via magnetic field
  - every two parallel wires have capacitive and inductive coupling between them
  - electromagnetic interference is transmitted from the mains to the signal wires by this path
- **electromagnetic field** coupling path via electromagnetic waves
  - the sources of interference emit an electromagnetic field and the signal wires are like the antenna that receives it



3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE



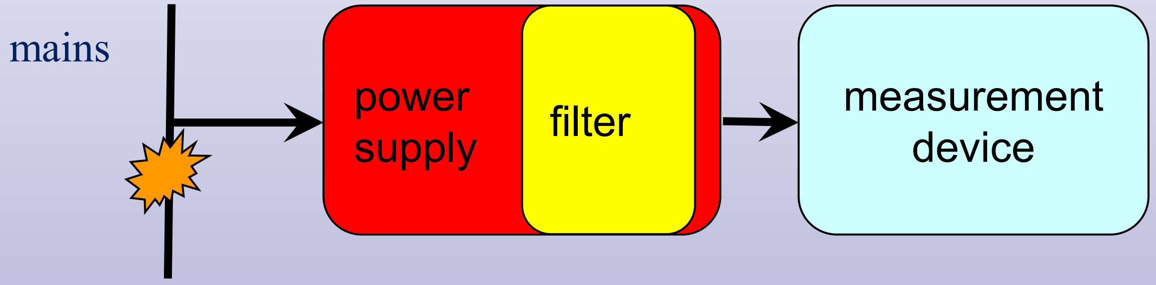
- 3.1. galvanic path
- 3.2. earth loop
- 3.3. capacitive and inductive path
- 3.4. electromagnetic field

3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

3.1. galvanic path

- Interference protection is provided by:
  - power supply with anti-interference filter
  - cables with interference suppressor

    the permanent magnet (ferrite ring) on the cable is „a trap“ for interfering electromagnetic fields



Special power supplies with filter are used to power measuring devices.

Do not replace them with cheap power supplies in case of their failure. Cheap sources usually do not have anti-interference filters and the interference from the mains will then penetrate into the measurement device!

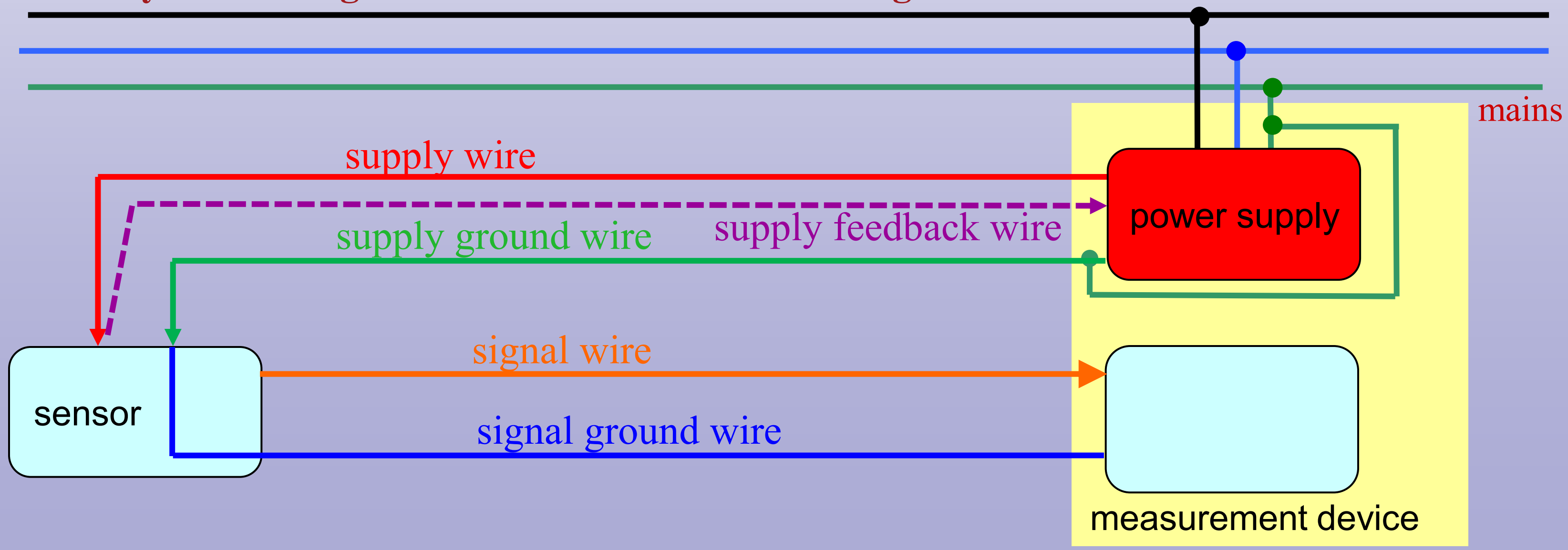
3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

3.2. earth loop

In any case, a earth loop should be avoided!!! Here are the sulutions:

1) using only one power supply

- all separate parts of the measurement device are supplied from a single source which is earthed
  - the supply ground and the signal ground must be separated so that the signal ground is not loaded by the supply current
  - the voltage drops on the long supply line. For long lines, it is necessary to use an additional feedback wire so that the separate part has the correct supply voltage
- **many connecting wires are the main disadvantage of this solution**

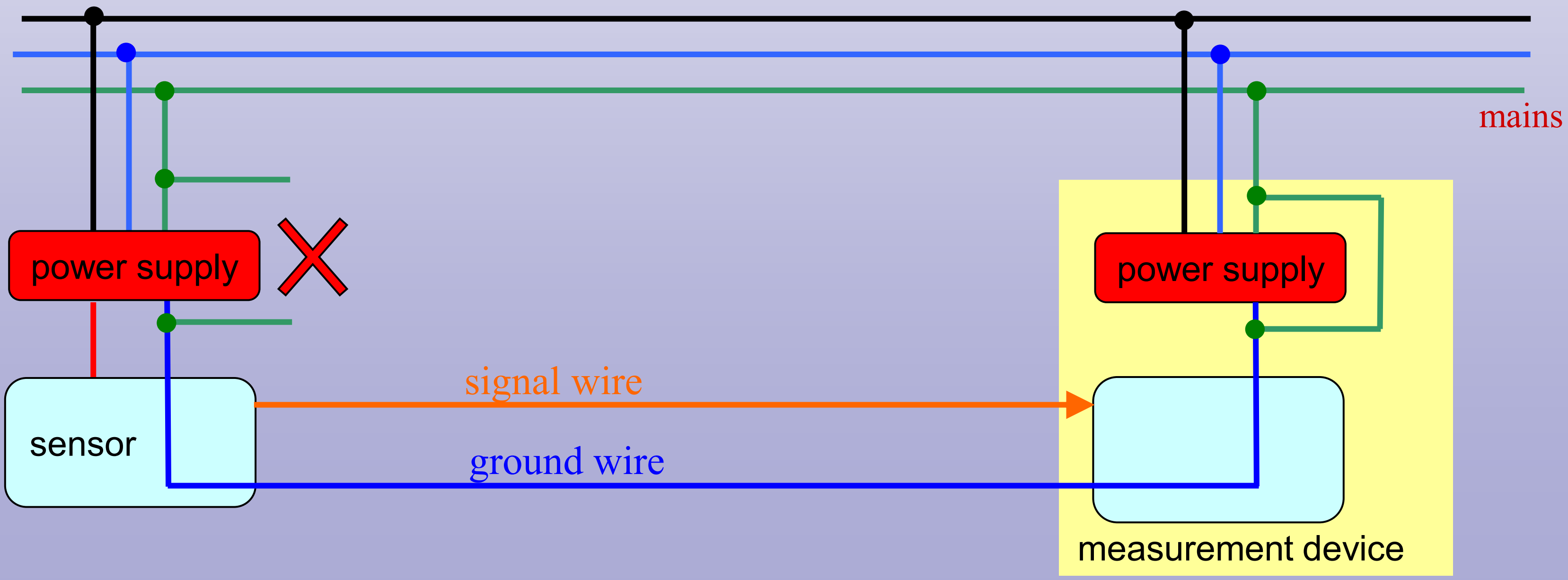


3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

3.2. earth loop

2) disconnecting of the earth in the separated parts of the measurement device

- the measurement device is earthed at only one power supply
  - only theoretical possibility
  - very often impracticable solution, earthing is realized inside the power supply and it cannot be disconnected
- **it is a violation of safety regulations, do not do it !!**

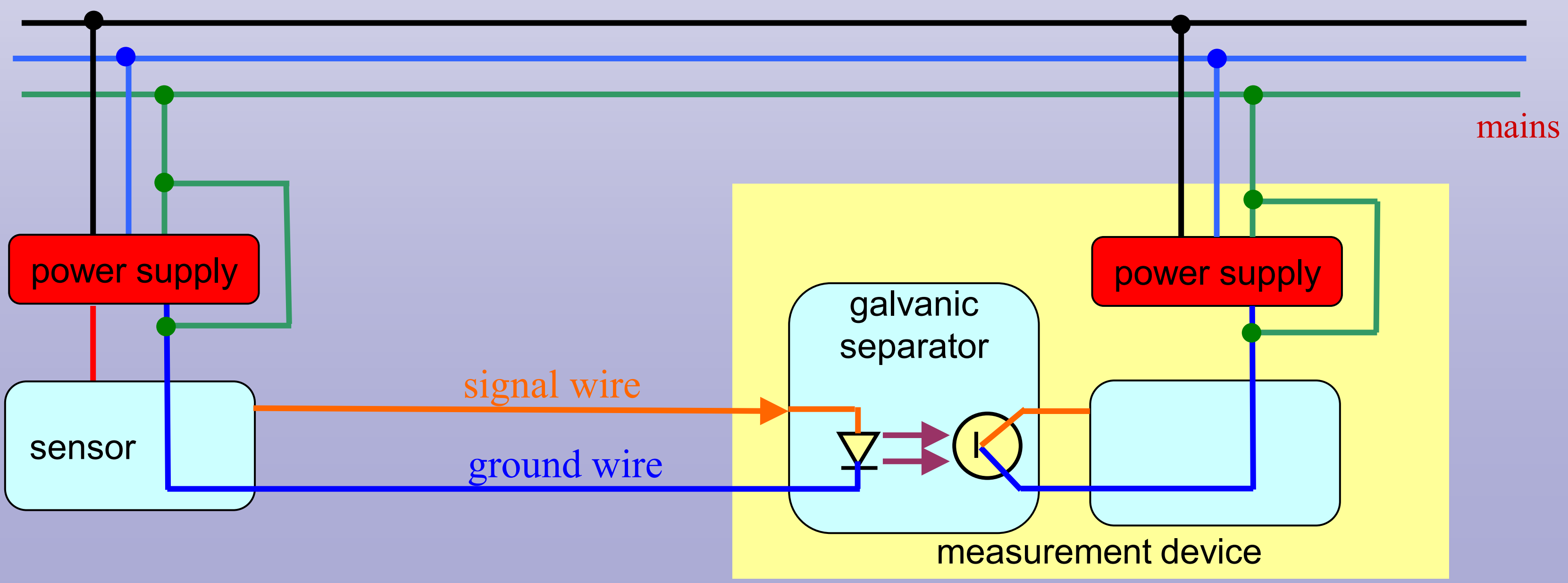


3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

3.2. earth loop

3) using of galvanic separator of the measurement signal

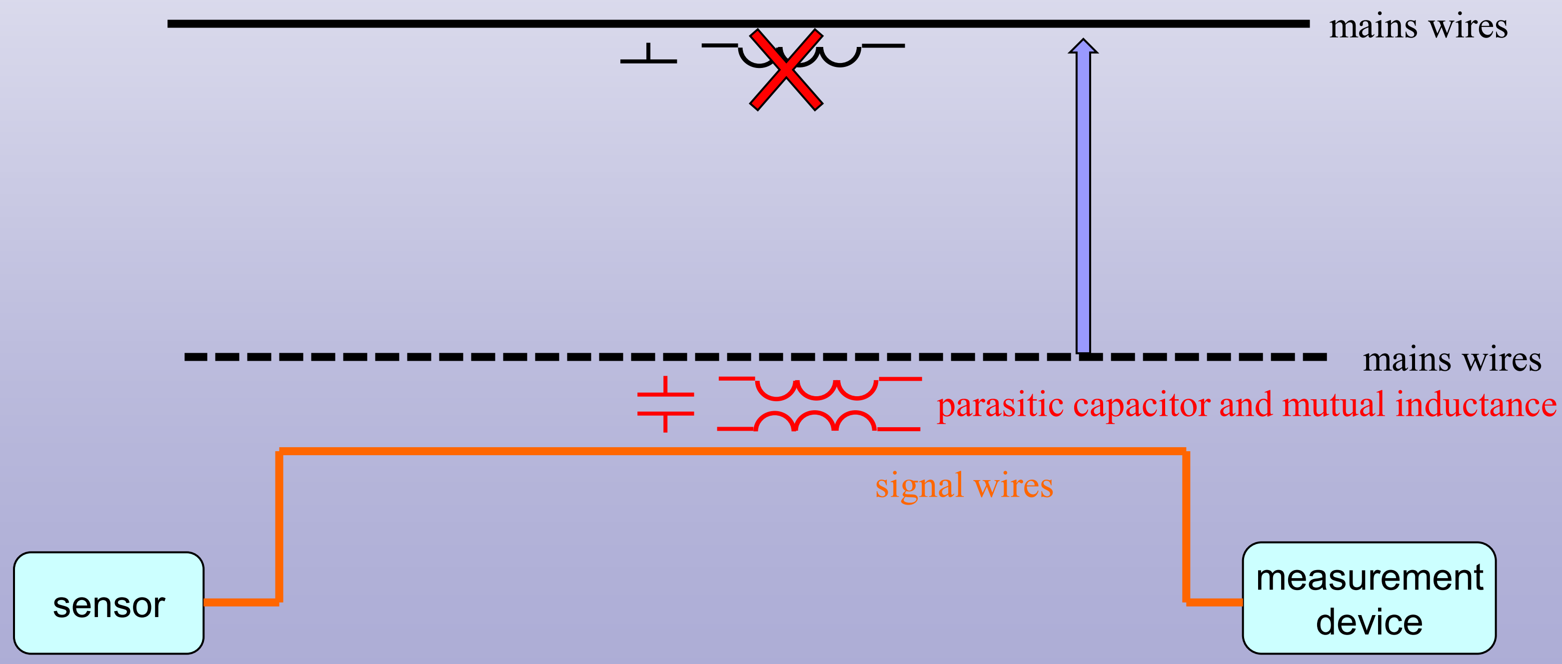
- both signal wires are interrupted in the galvanic separator and thus the earth loop is interrupted too
  - the galvanic separator is based on the optical (optocoupler) or electromagnetic (transformer) principle
- **this is the best and most versatile solution against the earth loop**
  - if you are considering using separate parts with their own power supplies for the measurement, get a measuring device with galvanically separated inputs



3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

3.3. capacitive and inductive path

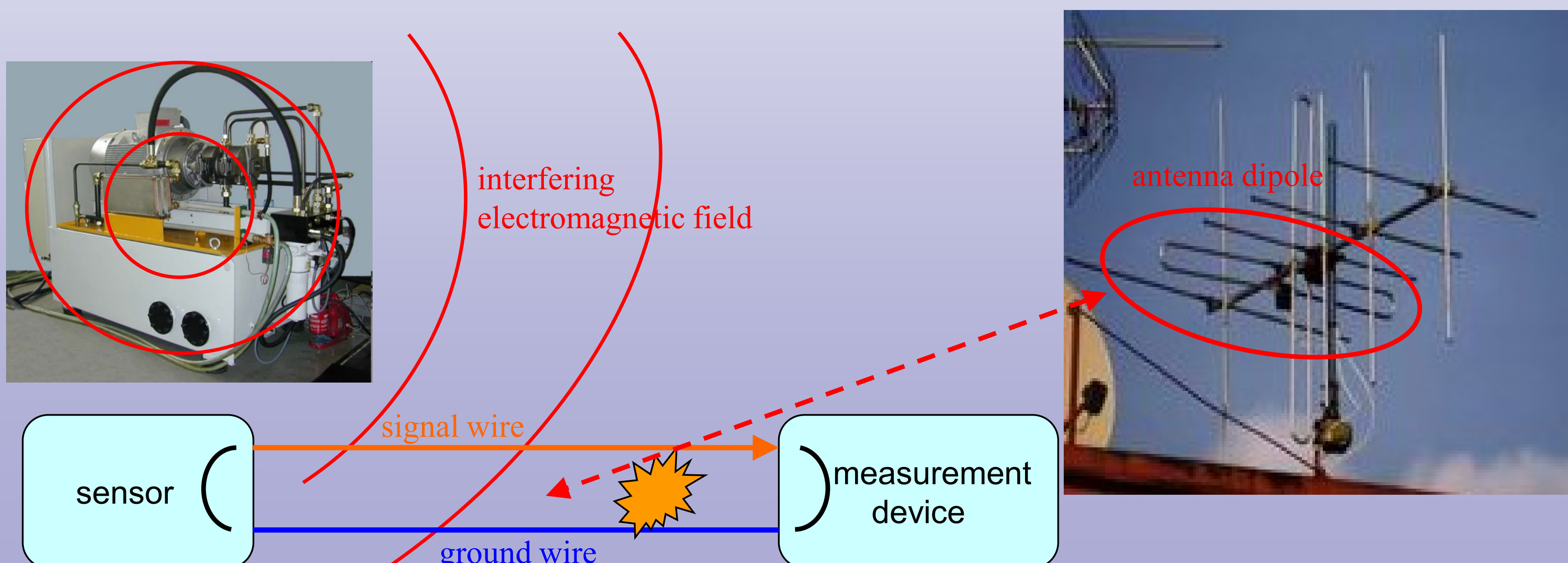
- the **capacity** of the parasitic capacitor or parasitic **mutual inductance** between the mains wires and the measurement device signal wires
  are inversely proportional to their distance
  - **the solution is simple - spatially separate mains wires and signal wires**
  - the greater the distance, the less interference penetrates through the capacitive and inductive path



3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

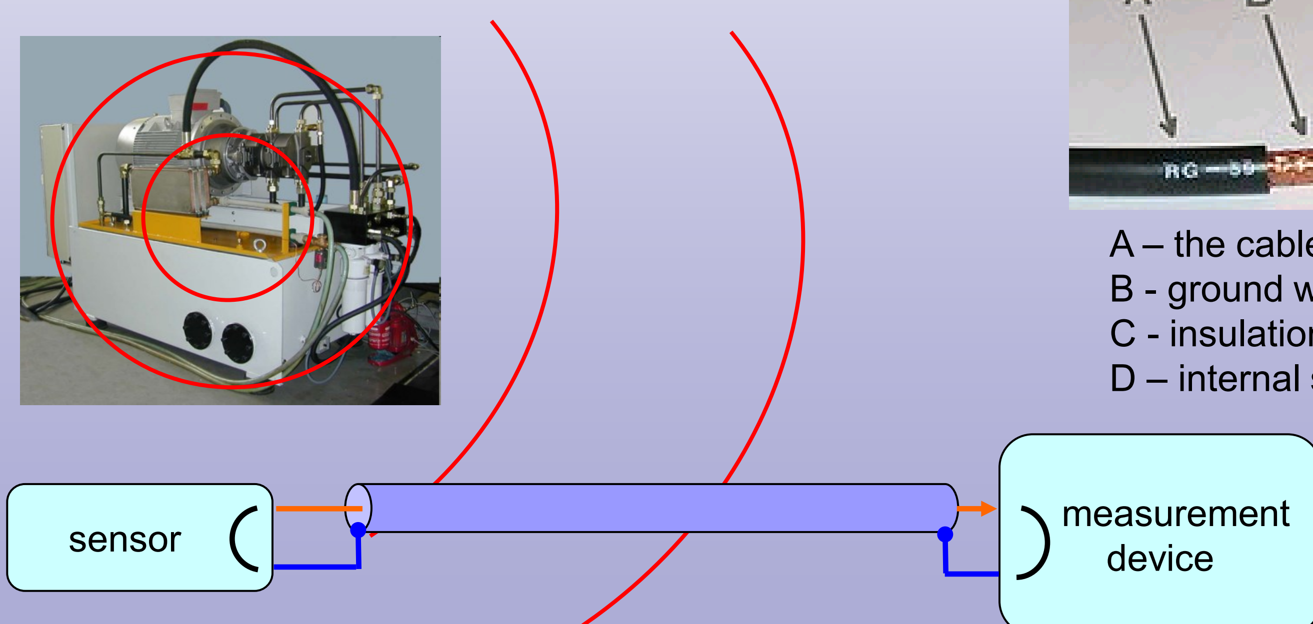
3.4. electromagnetic field

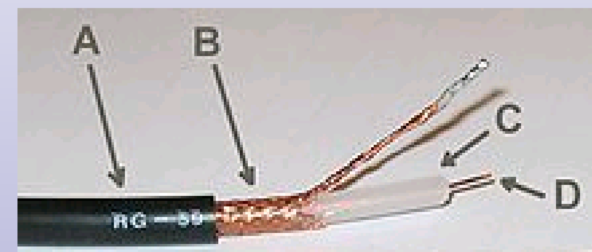
- **separate components of the measurement device are always connected by two wires - signal and ground**
  - if this wires are parallel, it is an ideal antenna for receiving an interfering electromagnetic field
- **protection options:**
  - do not use parallel wires, ie use a **coaxial cable** or **twisted pair**
  - prevent the access of the electromagnetic field to the wires, ie use **shield**



3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE
3.4. electromagnetic field

- **the coaxial cable**
  - the ground wire is in the shape of a tube and the signal wire is inside
  - the wires do not form an antenna dipole
- **this is the best solution,** but it has disadvantages:
  - expensive solutions - difficult cable production and a lot of expensive copper
  - the coaxial cable cannot be multi-wire, a separate cable must be used for each signal and another for power supply if required

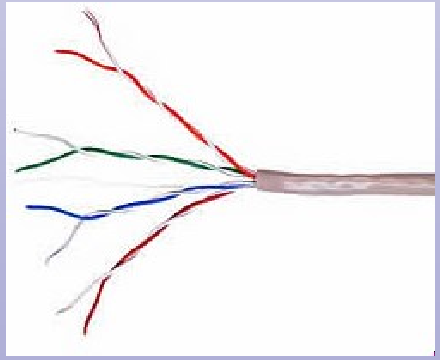


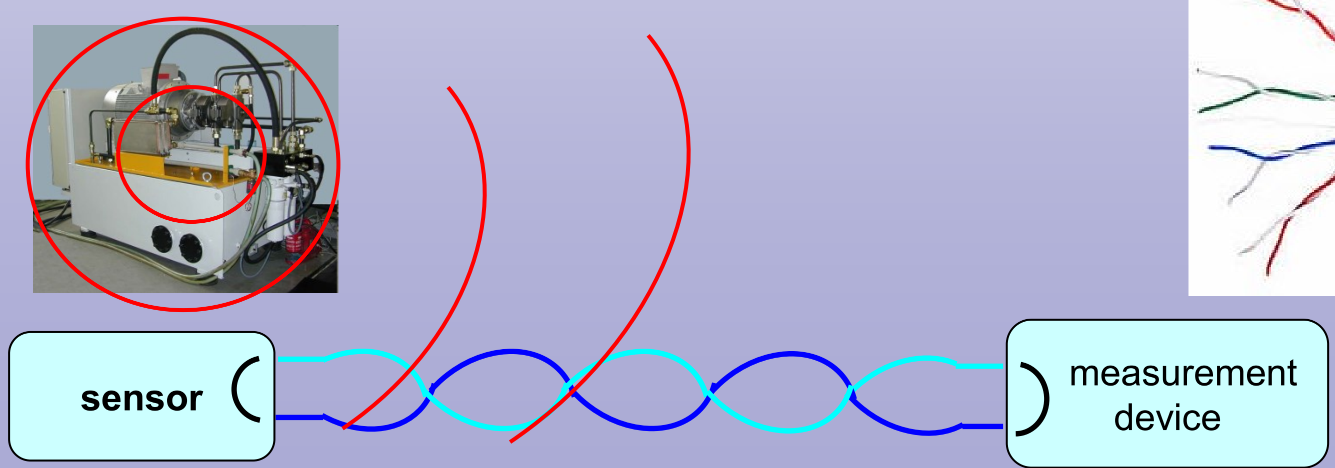


A – the cable sheathing
B - ground wire in the shape of a tube
C - insulation material
D – internal signal wire

3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE
3.4. electromagnetic field

- **the twisted pair**
  - the signal wire and ground wire are twisted into a pair
  - a series of small antenna dipoles rotated 180° relative to each other is created
  - the polarity of the induced interference is given by the direction of passage of the elmag. Field through the dipole
  - the rotation of the loops by 180 ° has the effect that the interference, which is added in one loop, is subtracted in the next
- **this the cheapest and most used solution,** but it has disadvantages:
  - the interfering field is not homogeneous, the assumption of addition and subtraction does not apply 100%, so the twisted pair is less resistant to interference than coaxial cable
- **big advantage** - there can be many twisted pairs in one cable = many signals including power supply can be led by one cable

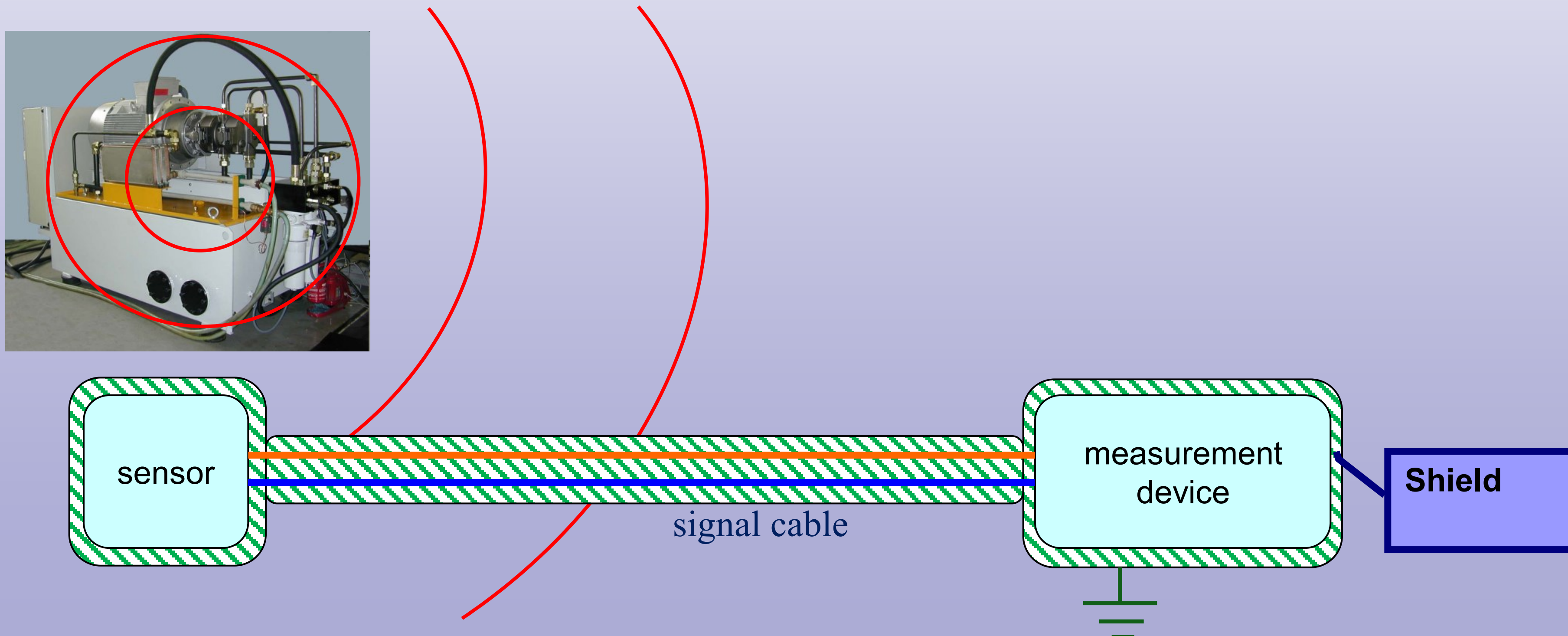




3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

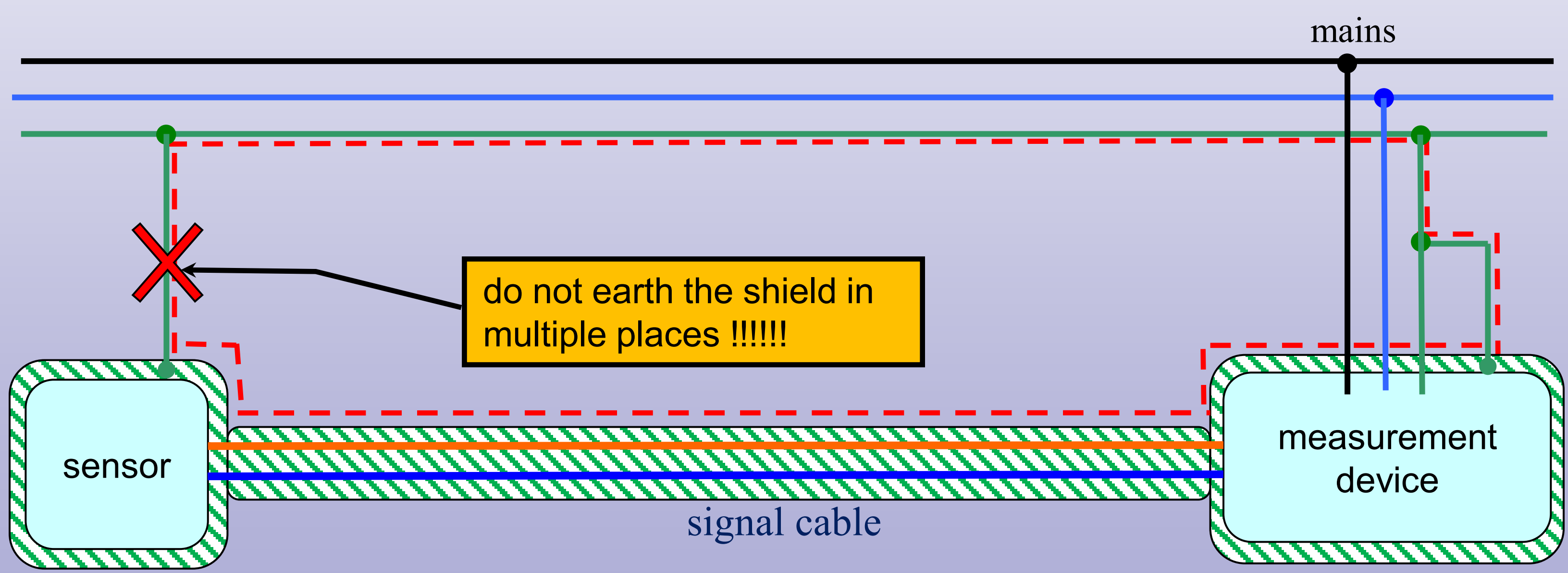
3.4. electromagnetic field

- **the shield**
  - the principle of **Faraday's cage**, the principle is based on the fact that the electric charge is concentrated only on the surface of the conductor, not in its volume
  - all measurement device components and cables are covered by conductive material = **shield**
  - the induced interference remains in the conductive layer of the shield and does not penetrate inside
  - the shield must be earthed so that the electric charge induced by the interfering field is removed



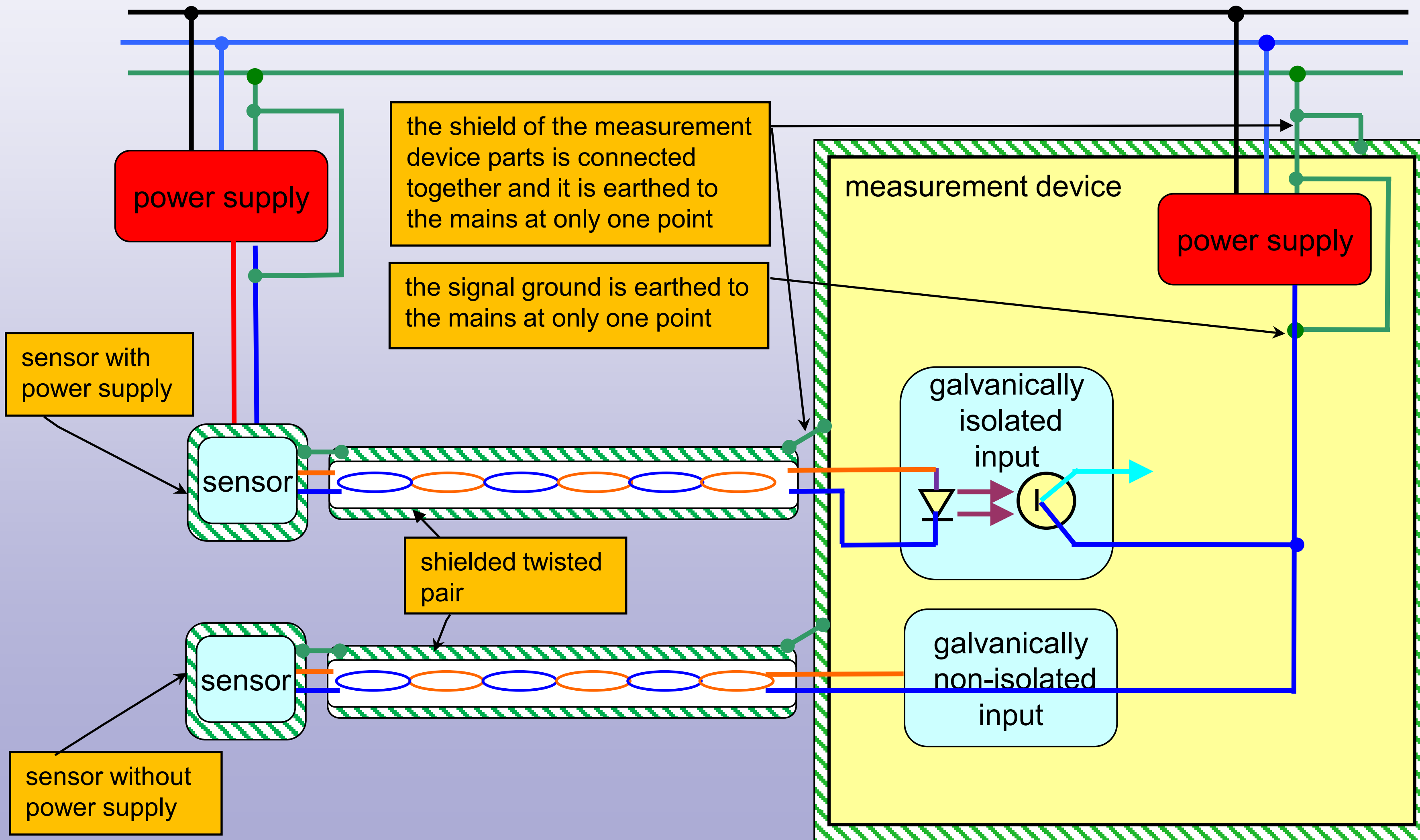
3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE
3.4. electromagnetic field

- **do not earth the shield in multiple places !!!**
  - the earth loop is created
  - parasitic electric current can flow through the shield
  - the interference from this current penetrates to the signal wires by capacitive and inductive coupling between the shield and the wires inside



3. PROTECTION AGAINST ELECTROMAGNETIC INTERFERENCE

- **Example of the measurement device correct connection**



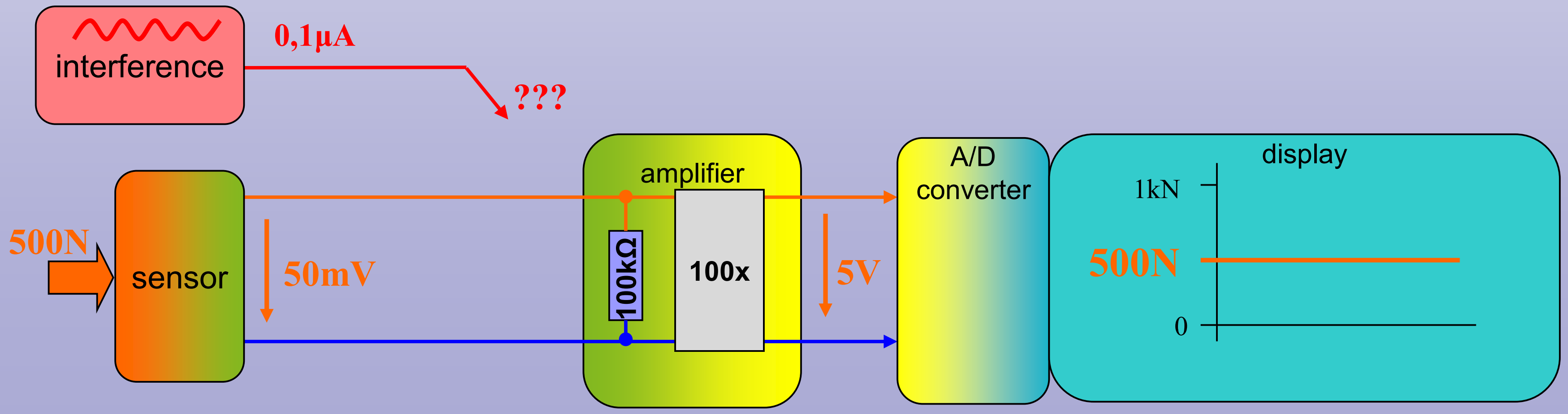
4. EXAMPLE OF SIGNAL INTERFERENCE FOR DIFFERENT VARIANTS OF THE DISTRIBUTED MEASUREMENT DEVICE

identical input assumption for all variants:

all of the values below are just an example!

- the force sensor has an input range of 0-1kN and the output signal 0-100mV corresponds to this
- A/D converter has input range 0-10V, so the sensor signal has to be amplified 100x to take full advantage of the converter range
- the amplifier has input resistance 100kΩ

- the sensor is loaded with a force of 500N, so its **output signal is 50mV**
- interference enters into the connecting cable
  - we can imagine it as a parasitic source of AC current which is added to the current of sensor output signal, the parasitic current amplitude is 0.1 μA

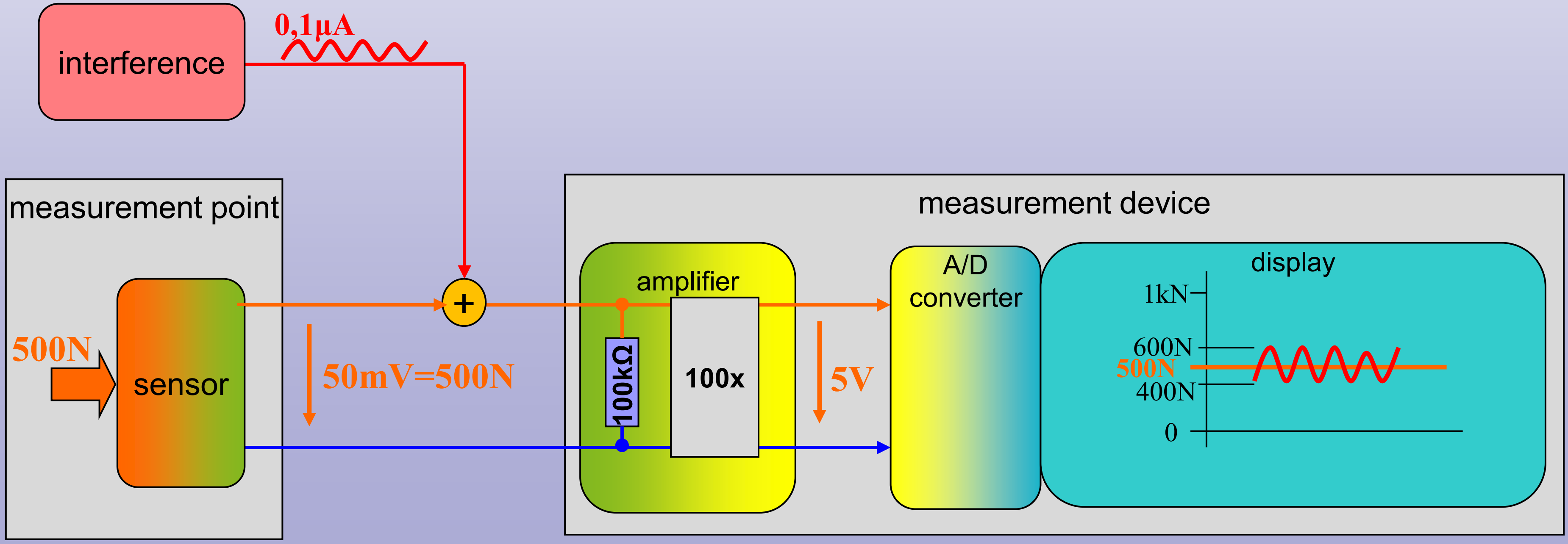


4. EXAMPLE OF SIGNAL INTERFERENCE FOR DIFFERENT VARIANTS OF THE DISTRIBUTED MEASUREMENT DEVICE

separate sensor:

the worst variant, because the interfering signal is amplified 100x in the amplifier together with the sensor signal

- parasitic AC current with amplitude 0.1µA on input resistor 100kΩ generates AC voltage with amplitude 0.01V (R x I)
- after 100x amplification, the noise amplitude is **1V**
- that is 10% of the range, ie 100N
- instead of 500N, the display shows an oscillating curve from 400N to 600N !!

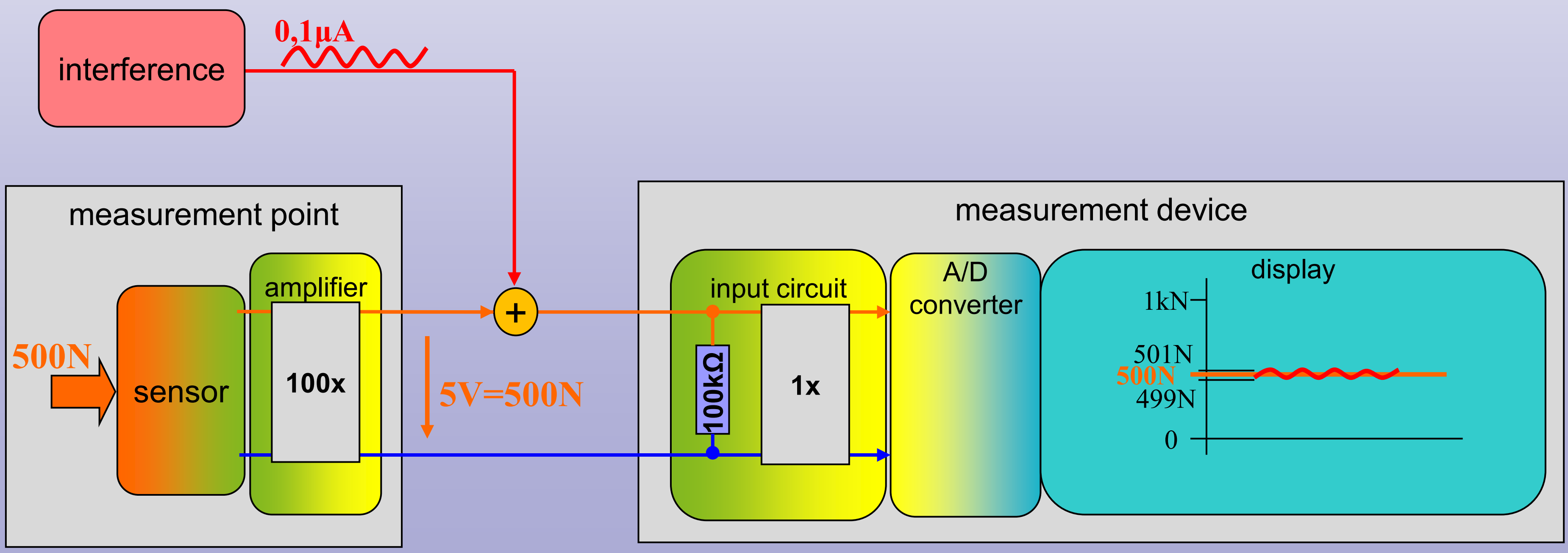


4. EXAMPLE OF SIGNAL INTERFERENCE FOR DIFFERENT VARIANTS OF THE DISTRIBUTED MEASUREMENT DEVICE

separate sensor and amplifier, laboratory version – signal 0-10V**:**

better variant because the interfering signal is not amplified

- the input circuit is placed in front of the A/D converter to keep the 100kΩ input resistance
- parasitic AC current with amplitude 0.1μA on input resistor 100kΩ generates AC voltage with amplitude 0.01V (R x I), it is not amplified
- that is only 0.1% of the range, ie 1N
- the display practically shows the value 500N, the noise is only ±1N

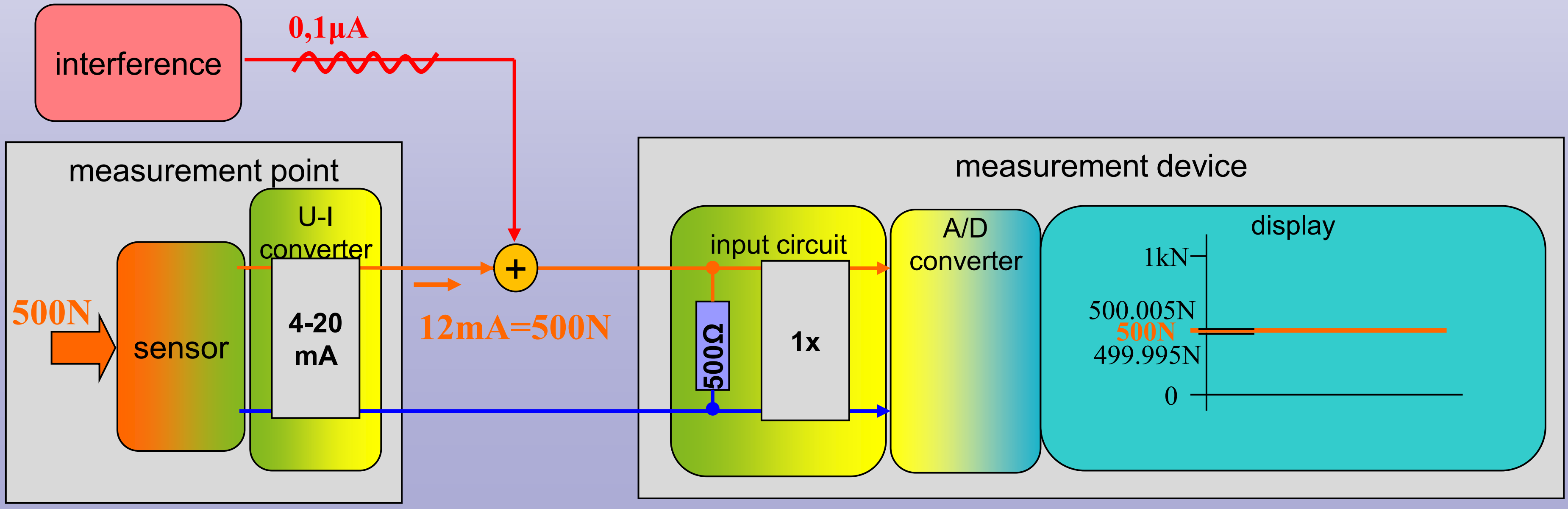


4. EXAMPLE OF SIGNAL INTERFERENCE FOR DIFFERENT VARIANTS OF THE DISTRIBUTED MEASUREMENT DEVICE

separate sensor and amplifier, industrial version – signal 4-20V**:**

the first best variant because the interfering signal is not amplified and is further suppressed by a small input resistance

- the input circuit is placed in front of the A/D converter, **input resistor is only 500Ω** for converting 4-20mA to 2-10V (R x I)
- parasitic AC current with amplitude 0.1µA on input resistor 500Ω generates parasitic AC voltage with amplitude only 0.00005V (R x I), it is not amplified
- that is only 0.0005% of the range, ie 0.005N
- the display practically shows the value 500N, without noise (only ±0.005N)

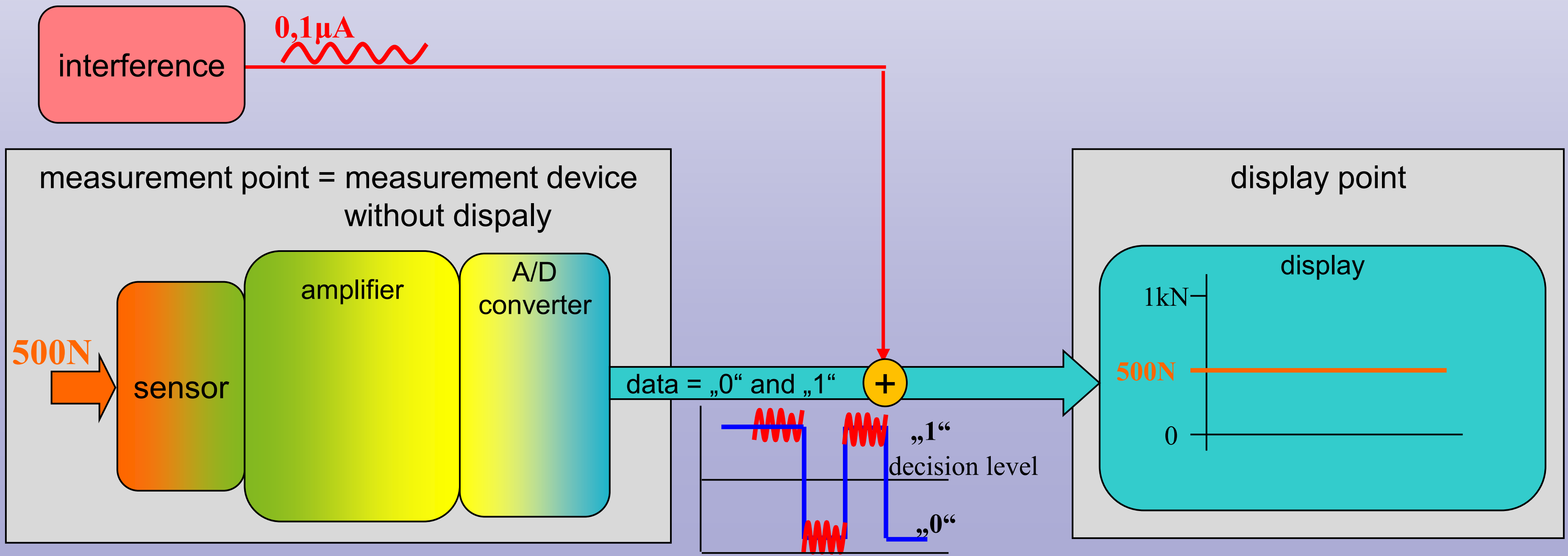


4. EXAMPLE OF SIGNAL INTERFERENCE FOR DIFFERENT VARIANTS OF THE DISTRIBUTED MEASUREMENT DEVICE

separate display:

the second best variant because the interfering signal is added to digital line

- the digital line transmits logical "0" and "1". "0" is expressed as 0V and "1" is 5V. The decision level is 2.5V, everything above it is as "1", everything below it is as "0".
- **if the parasitic noise does not exceed the decision level, the transmitted signal is not affected, display shows 500N.**
- if the parasitic noise exceeds the decision level, there will be a total loss of information, the display will not display anything!!



Exam questions

- electromagnetic interference
  - classification according to source, type an frequency (p. 3)
  - coupling mechanisms (p. 4)
  - galvanic path, earth loop (p. 5, 6)
  - non galvanic path (p.7)
- protection against electromagnetic interference
  - protection against galvanic path by power supply (p. 9)
  - protection against earth loop (p. 10, 11, 12)
  - protection against capacitive and inductive path (str.13)
  - protection against electromagnetic field – coaxial cable, twisted pair (p. 14,15,16)
  - protection against electromagnetic field – shield (p. 17, 18)