BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

11.04.2017

# MEASUREMENT ELECTRONICS AND ELECTROMAGNETIC COMPATIBILITY (EMC)

Julius Oeff

www.bam.de

# Outline

# 1. Introduction to Measurement Electronics

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Key components

1. transducers / sensor
2. data acquisition systems (DAQ)
3. signal conditioners

# 1. Introduction to Measurement Electronics

1. Difference of Sensors and Transducers

**Sensors**:
Responds to some type of input from the physical environment

**Transducers**:
converts one form of energy to another (temperature, pressure, light, radiation, sound)

*all sensors are transducers, but not all transducers are sensors

# 1. Introduction to Measurement Electronics

2. Importance of measurement systems in electronics

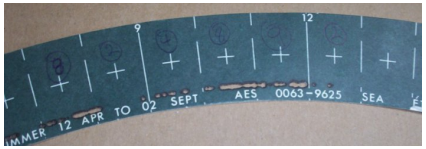
-**D**ata **Acq**uisition (DAQ)

Analog non electric

Analog electric

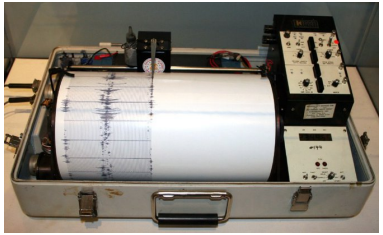
Digital electric

Source:
Copilot/GPT




Source:
wikipedia.org/wiki/Campbell–Stokes_recorder

Source:
Copilot/GPT

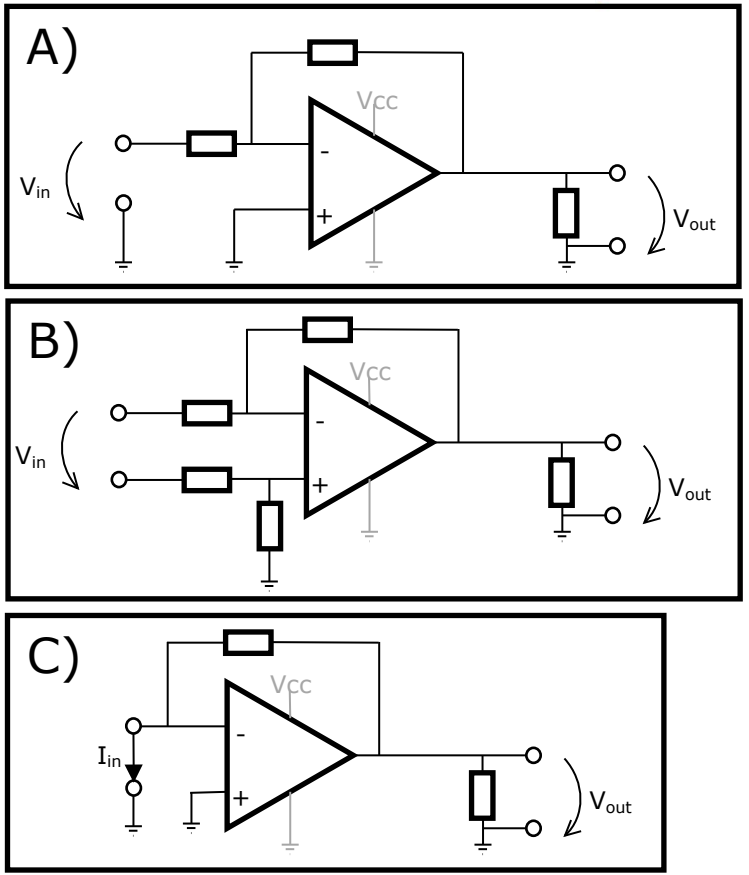


Source:
wikiwand.com/en/articles/Seismometer

# 1. Introduction to Measurement Electronics

3. signal conditioners

- Operation Amplifier
  A) Single ended Op-Amp
  B) Differential Op-Amp
  C) Transimpedance Op-Amp



# 2. Understanding Multimeters, Oscilloscopes, and ADC‘s

Source:
Copilot/GPT

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Copilot/GPT

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Copilot/GPT

# 2. Understanding Multimeters, Oscilloscopes, and ADC‘s

1. Multimeters
   -Convert electrical values into readable numbers

   -Essential for troubleshooting

   -slow (~ one reading per second)

   -no display of a signal form

   -no storage

Source:
Copilot/GPT

Source:
Copilot/GPT

# 2. Understanding Multimeters, Oscilloscopes, and ADC‘s

2. Oscilloscopes

- Acquire **fast** signal forms at high frequencies
- take a snapshot
- no long-term data acquisition*

Source:
Copilot/GPT

# 2. Understanding Multimeters, Oscilloscopes, and ADC's

3. ADC

Converting analog to digital values, Sampling-rate, bit-depth

-Sampling-rate: Samples per second
-Input voltage range
-bit-depth

Example: 12-bit ADC with 0 to 5 V input range

Resolution of one bit = $\frac{5V}{212}$ = 1,22 mV/bit

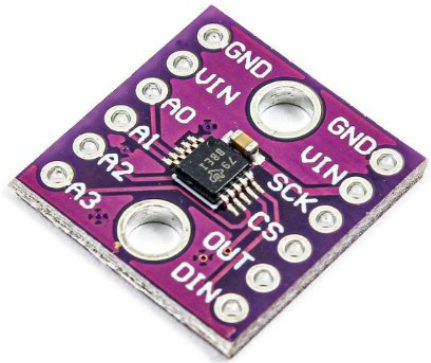
# 2. Understanding Multimeters, Oscilloscopes, and ADC's

3. ADC

Max. Frequency: $\frac{860\ Samples/s}{2}$ = 430 Hz

Example: ADS 1118

Input range: 0 – 2 V to 5.5 V
Input channels: 1-4
Speed(max): 860 Samples per second
Bit-depth: 16 bit ($2^{16}$)

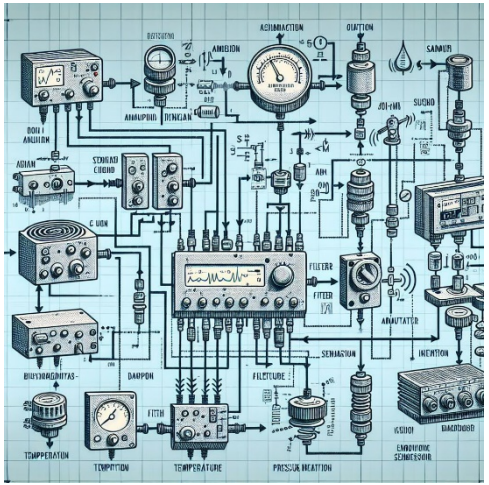



Source: electropeak.com

Interface: SPI

Resolution(max. input 2 V): $\frac{2V}{216}$= 30 µV / bit
Resolution(max. input 5,5 V): $\frac{5{,}5V}{216}$= 84 µV / bit

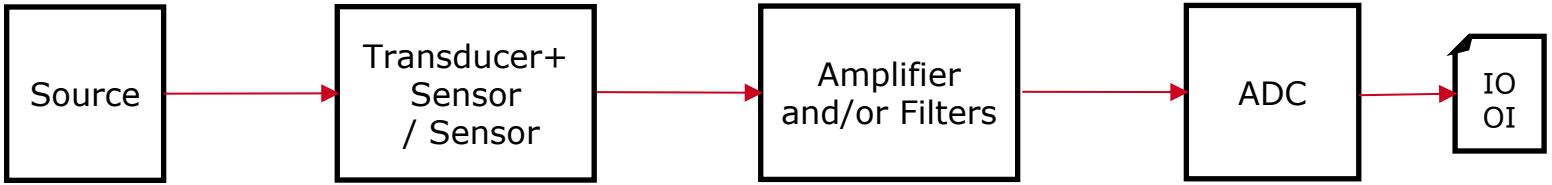
# 3. Signal Chains in Measurement Electronics



Source: Copilot / GPT4

# 3. Signal Chains in Measurement Electronics

Main components in a signal chain:



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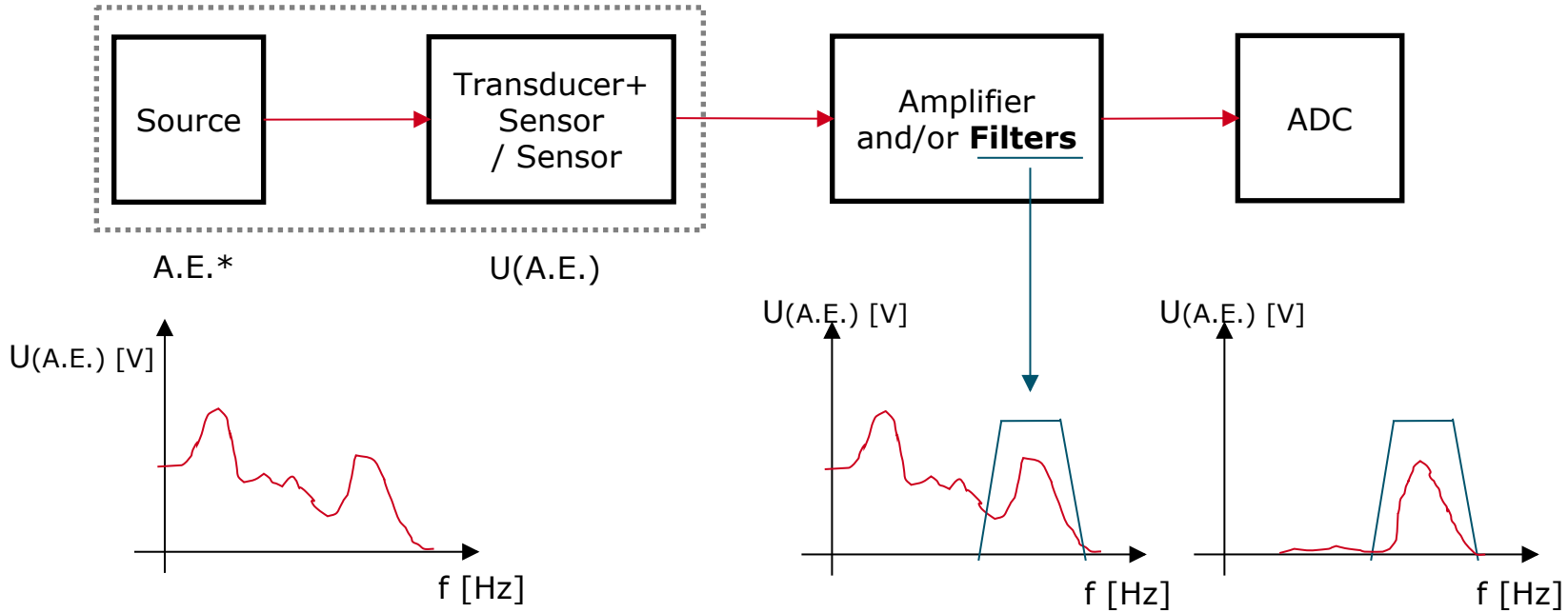


A.E. = Abitraian units

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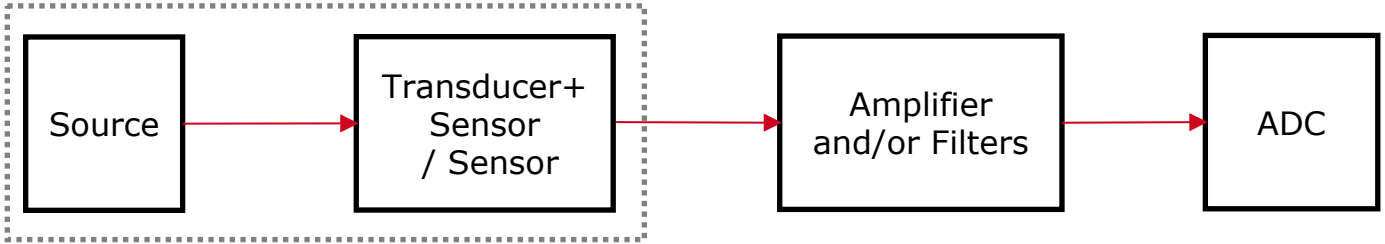



-Dose my signal need an amplification?
-Dose it need to be filtered?
-Is my measurement a) time or b) frequency sensitive?
  a) When dose my signal apprear?
  b) In what freqency range dose my signal appear?
-Do I capture correct? (Sample-rate, dynamic/range)

# 4. Sources and Mitigation of Electrical Noise

# 4. Sources and Mitigation of Electrical Noise

We want: High signal to noise ratio (SNR)

If we have a high noise level:
- is it static?
- dose it have a shape?
- is it periodic?

--> What is the cause?

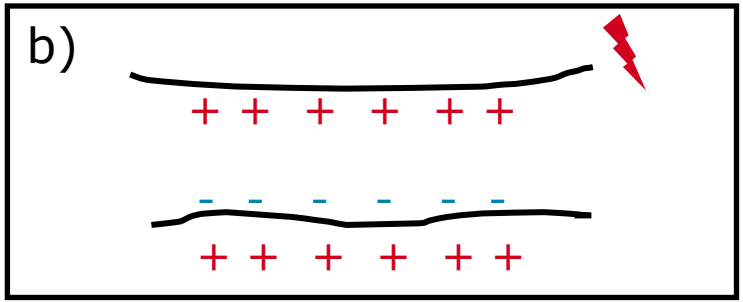
# 4. Sources and Mitigation of Electrical Noise

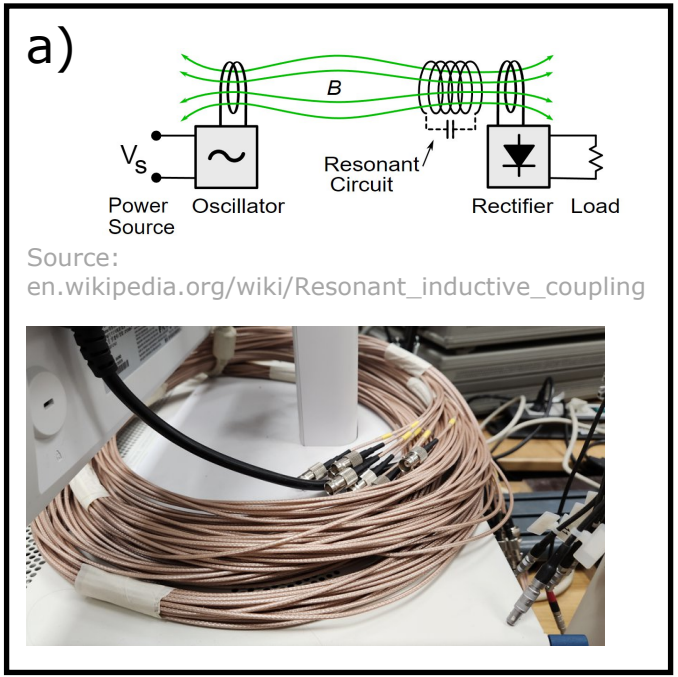
Sources unwanted noise are mostly acquired through

-a) inductive (B-Field)

or

-b) capacitive (E-Field) coupling




Source: en.wikipedia.org/wiki/Resonant_inductive_coupling

# 4. Sources and Mitigation of Electrical Noise

2. signal conditioners

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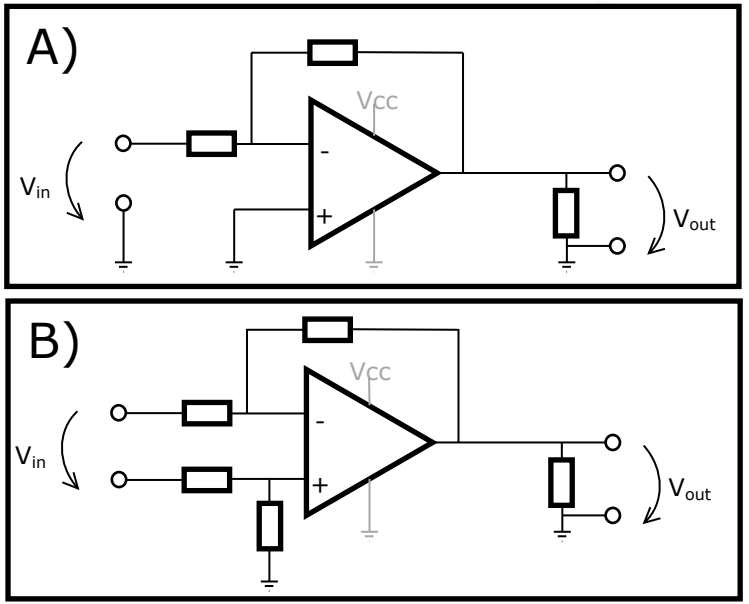

# 4. Sources and Mitigation of Electrical Noise

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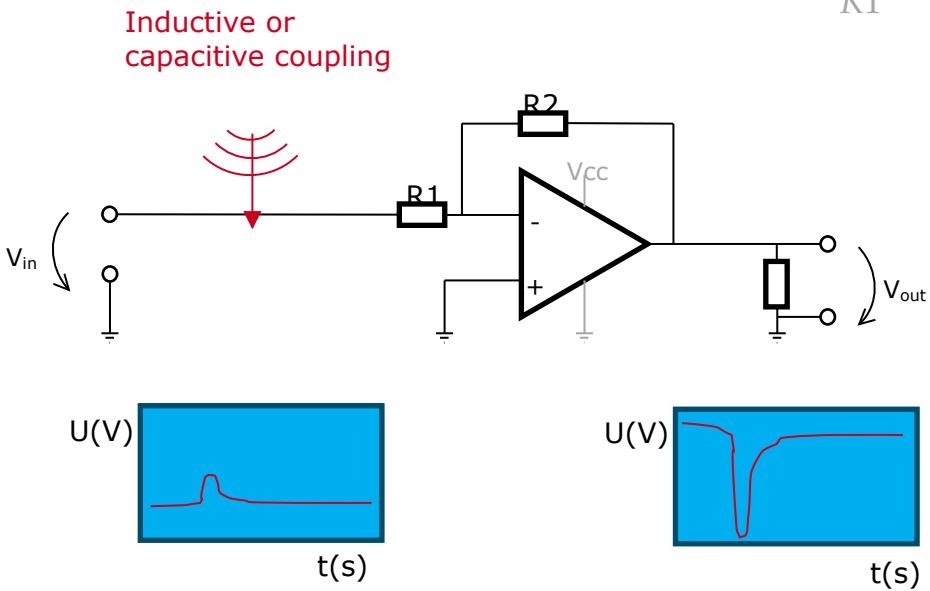
  A) Single ended Op-Amp

$$V_{out} = -V_{in} \left(\frac{R2}{R1}\right)$$



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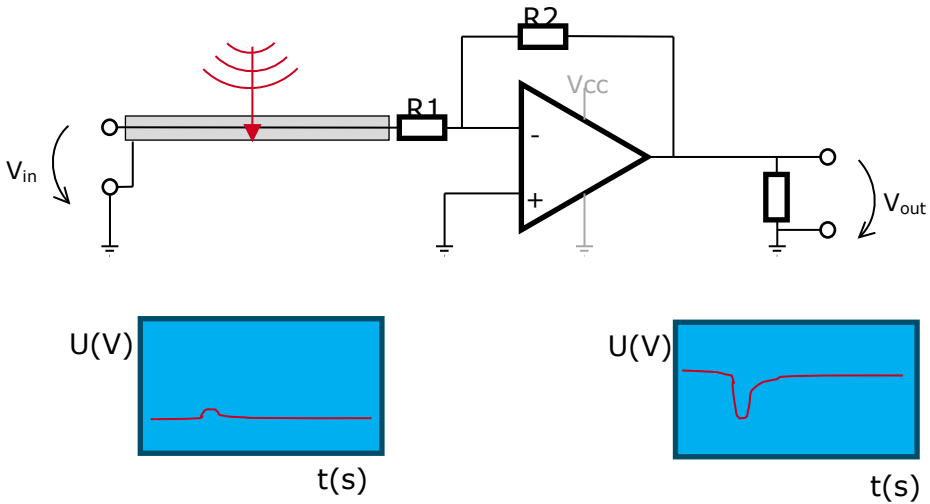
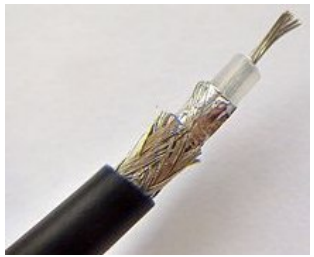



-shielded cable (coax)



Source:
de.wikipedia.org/wiki/Koaxialkabel

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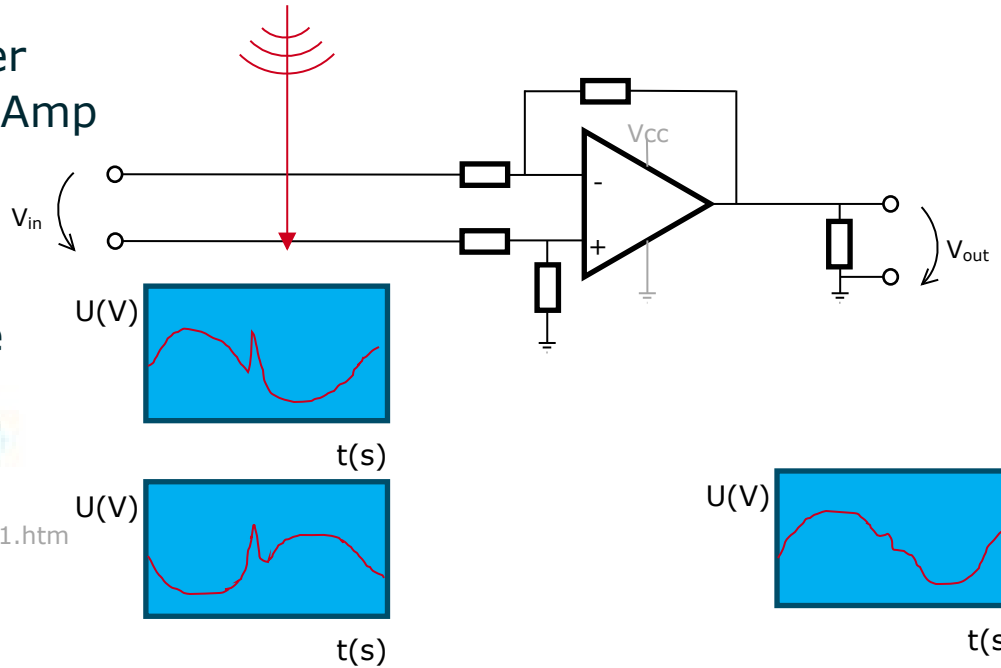



-twisted pair cable

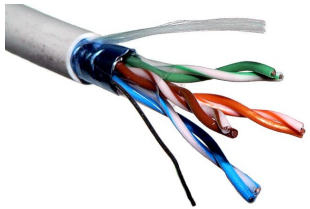
Source:
elektronik-kompendium.de/sites/net/0603191.htm

# 4. Sources and Mitigation of Electrical Noise

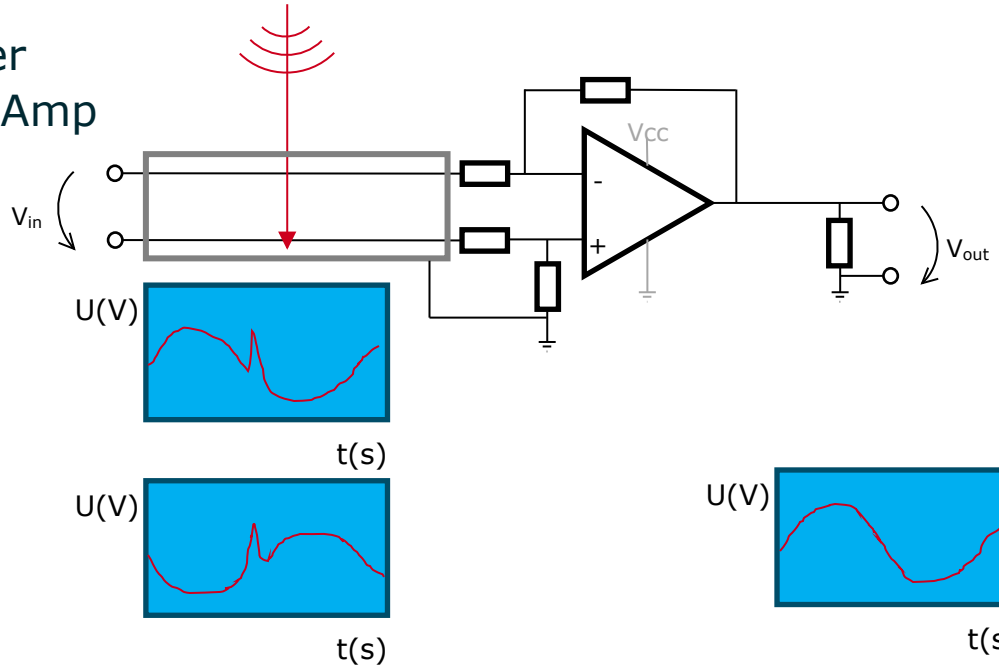
2. signal conditioners

- Operation Amplifier
  B) Differential Op-Amp

-shielded
twisted pair cable



Source:
en.wikipedia.org/wiki/Twisted_pair



# 5. Fundamentals of Electromegnetic Complatibility (EMC)

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1. Emission Control

   **Definition**: Limiting the amount of EM energy that a device emits.

2. Immunity

   **Definition**: A device‘s ability to operate correctly in the presence of EM interference (EMI).

3. Grounding and Shielding

   **Definition**: Proper grounding provides a reference point for circuits and helps to dissipating unwanted EM energy. Shielding involving conductive or magnetic materials to block EMI.

# 5. Fundamentals of Electromegnetic Complatibility (EMC)

1. Emission Control

**Definition**: Limiting the amount of EM energy that a device emits.

**Importance**:
Reducing emissions helps prevent interference with other electronic devices and ensures that the device comlies with regulatory standarts.

# 5. Fundamentals of Electromegnetic Complatibility (EMC)

2. Immunity

**Definition**: A device‘s ability to operate correctly in the presence of EM interference (EMI).

**Importance**:
Ensuring immunity is cruisial for the reliable operation of electronic devices in enviornments with various sources of EMI.

# 5. Fundamentals of Electromegnetic Complatibility (EMC)

## 3. Grounding and Shielding

**Definition**: Grounding provides a reference point for circuits and helps to dissipating unwanted EM energy. Shielding involving conductive or magnetic materials to block EMI.

**Importance**:
Proper grounding and shielding are essential for protecting sensitive electronic components from external and internal sources of interference.

# 6. Designing Measurement Setup / Electronics for EMC Compliance

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1. Minimize Loop Areas
   **Rule**: Keep the loop areas of signal and power circuits as small as possible.

2. Use proper shielding and grounding
   **Rule**: Implement effective shielding and grounding techniques.

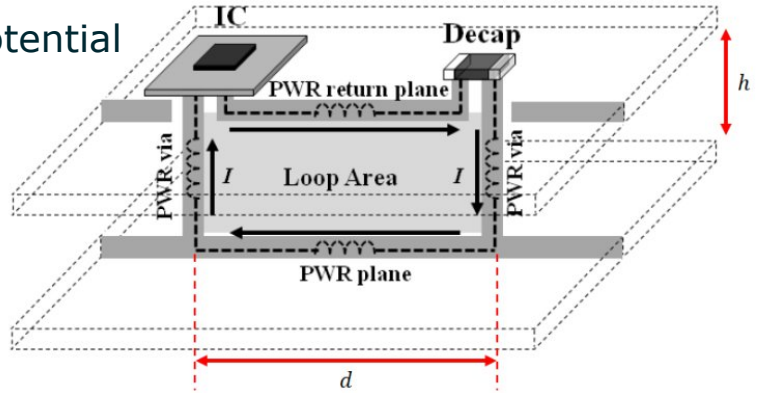
3. Filter power and signal lines
   **Rule**: Use filters on power and signal lines to suppress unwanted frequencies.

# 6. Designing Measurement Setup / Electronics for EMC Compliance

1. Minimize Loop Areas

   **Rule**: Keep the loop areas of signal and power circuits as small as possible.

   **Because**:
   Large loop areas act as antennas, increasing the potential for both emitting and recieving EMI's




Source:
resources.altium.com/de/p/what-spreading-inductance

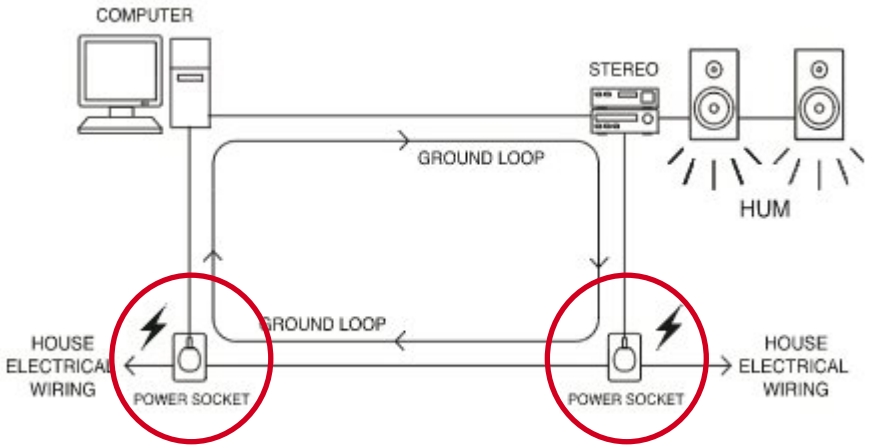
# 6. Designing Measurement Setup / Electronics for EMC Compliance

1. Minimize Loop Areas

   **Rule**: Try to use one power socket for one setup.

   **Because**:

   Large loop areas act as antennas.




Source:
elektronauts.com/t/ground-loop-in-setup

# 6. Designing Measurement Setup / Electronics for EMC Compliance

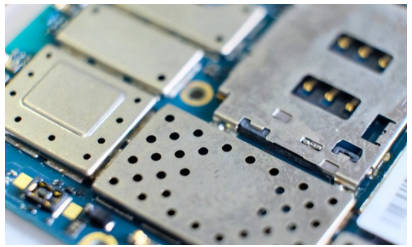
2. Use proper shielding and grounding

   **Rule**: Implement effective shielding and grounding techniques.

   **Because**:

   Shielding helps to block external from affecting your circuits, while proper grounding provides a stable reference point for signals and helps to dissipate unwanted EM energy. This is cruical for maintaining signal integrity and reducing noise.


Source:
digikey.de



Source:
pcbbuy.com

# 6. Designing Measurement Setup / Electronics for EMC Compliance

3. Filter power and signal lines

   **Rule**: Use filters on power and signal lines to suppress unwanted frequencies.

   **Because**:

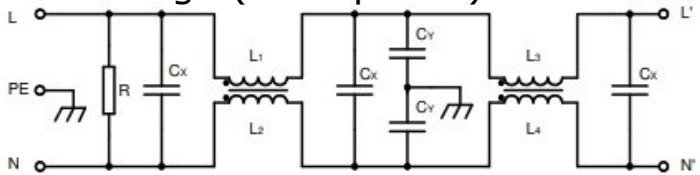
   Filters, such as capacitors and inductors, can block high-frequenciy noise from entering or leaving your circuit.

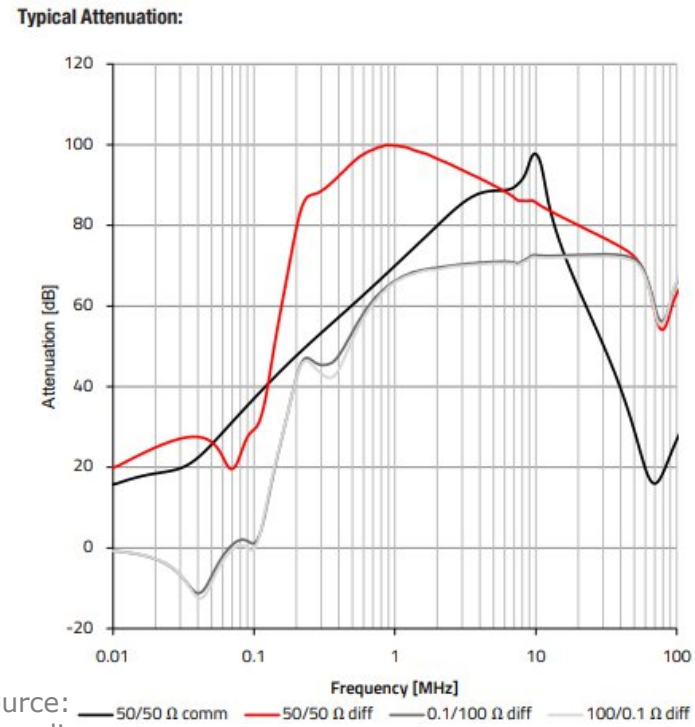
Source:
we-online.com

# 6. Designing Measurement Setup / Electronics for EMC Compliance

3. Filter **power** and signal lines

Two-Stage (main power) line filter



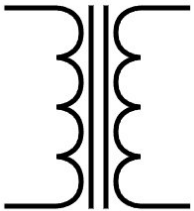

Source: we-online.com

# 6. Designing Measurement Setup / Electronics for EMC Compliance

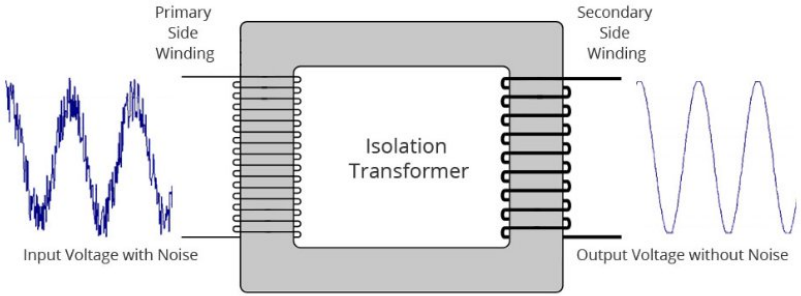
3. Filter **power** and signal lines

Isolation transformator (1:1)

-Galvanic isolation
-reduction of electrical noise
-eliminate ground loops



Source:wikipedia



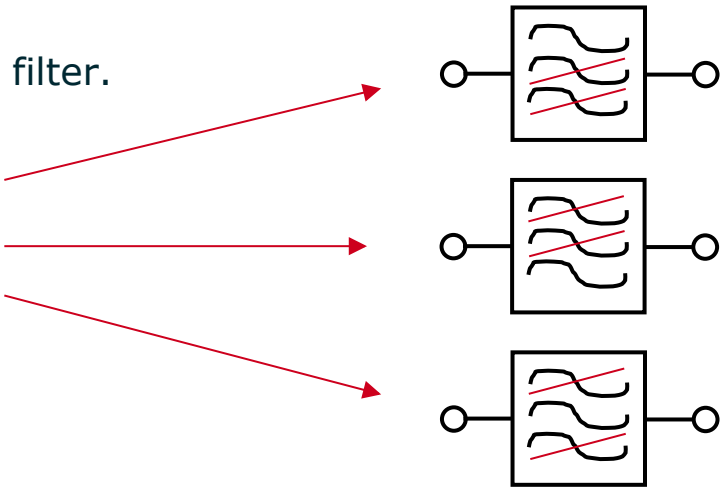

Source: voltronics.co.in

# 6. Designing Measurement Setup / Electronics for EMC Compliance

3. Filter power and **signal** lines

Noisy signal ? Try to filter.

- High-pass filter
- Low-pass filter
- Band-pass filter



# 7. EMC Testing and Troubleshooting Techniques

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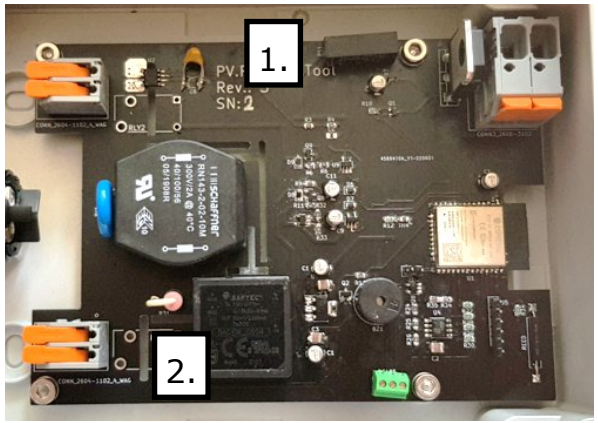
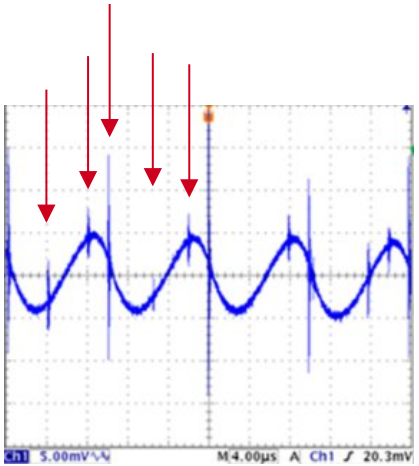
Example:

Switching noise showed up on a signal lane.

- Two components used a internal switches. 1. Step-up Converter, 2. Power Supply Unit

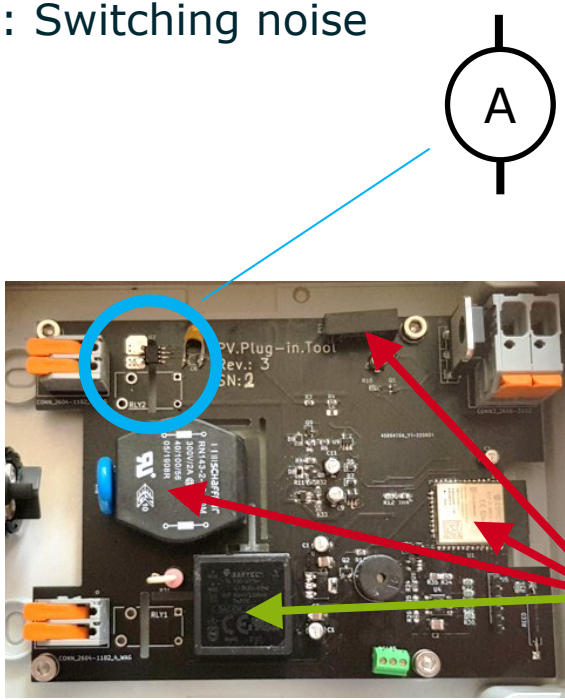


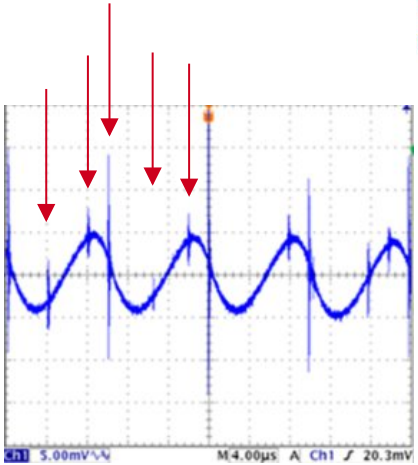

Source: 4niev.com/switching-power-supply-noise/

# 7. EMC Testing and Troubleshooting Techniques

Example: Switching noise




U(A)=



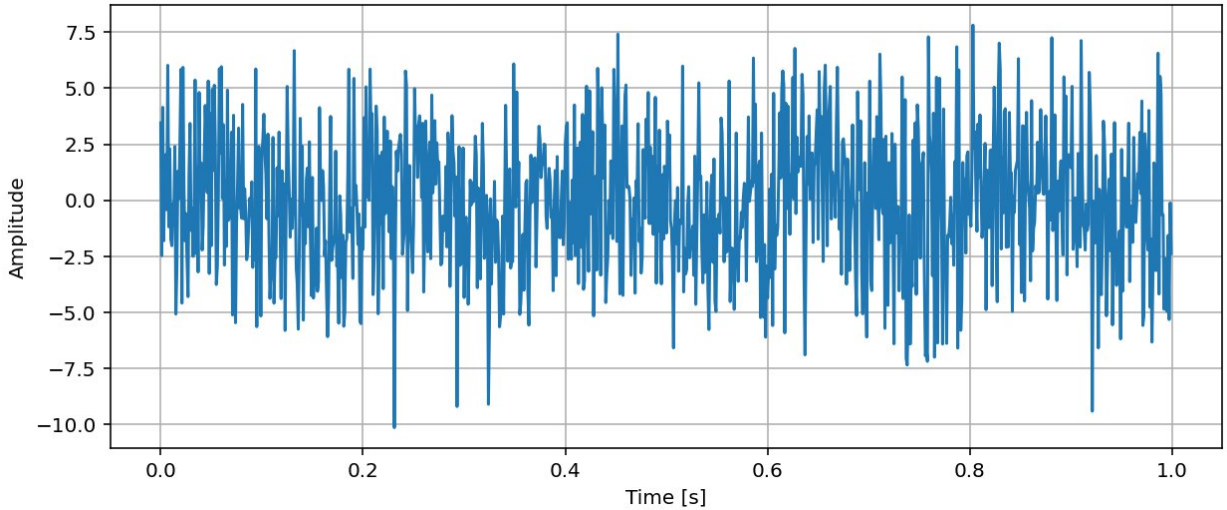

Source:
4niev.com/switching-power-supply-noise/

EMI-Probe

(Air coupled inductive probe)

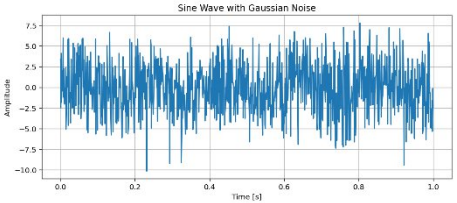
# 7. EMC Testing and Troubleshooting Techniques

Example: **Noisy Periodic signal**



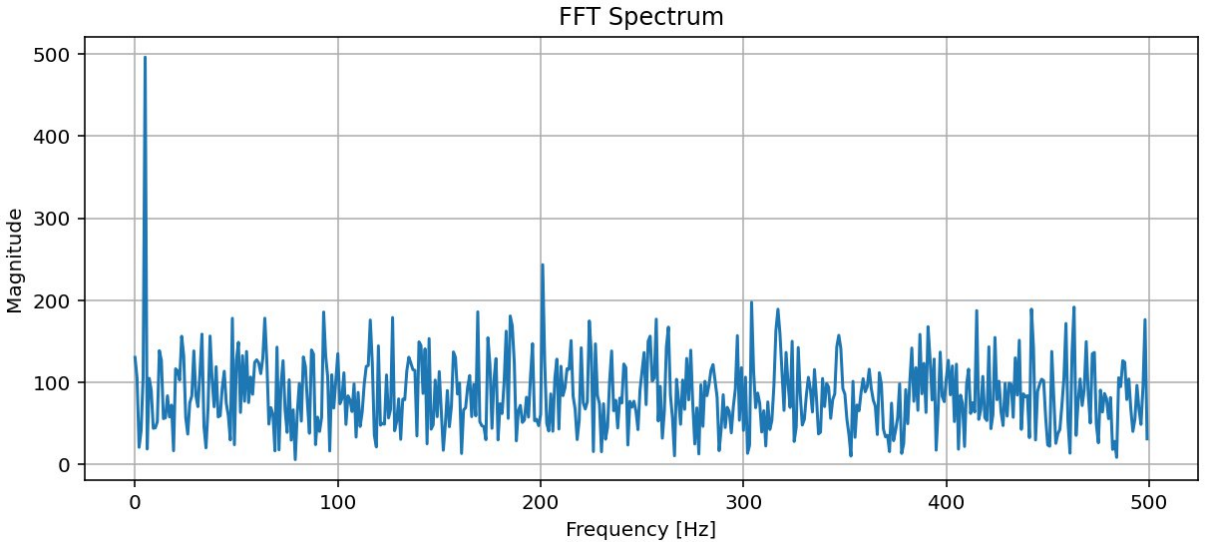
# 7. EMC Testing and Troubleshooting Techniques

Example: **Noisy Periodic signal**




**FFT:**

**f(t)-> F(w)**



# Thank you for your attention!