Interferences

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Slides are supplementary material and are NOT a replacement for textbooks and/or lecture notes
Interference and noise

- Interferences are due to other systems which are connected (either electrically or electro-magnetically) to the system under exam.
- Noise is due to fundamental properties of matter (thermal agitation, charge quantization, ...)
- Both can degrade the signal and must be curbed in a good design/test.
Common point

From [1]
Capacitive coupling

A time-varying voltage leads to electric coupling, represented by a capacitor connecting the two circuits.
Inductive coupling

A time-varying current leads to magnetic coupling, represented by mutual inductance between the two circuits.

From [1]

From Elettronica 75513 by Alessandro Spinelli
Ground potential fluctuations

• IC is related to the circuit loop area
• If the circuit is grounded at two points, current flows beneath the surface and disturbs arise (loop area cannot be controlled)
• Earth contact resistance (typically 1-10 Ω) can also contribute to electrical interferences
General approach

- **Electrical coupling**
  - Use electrostatic shield (Faraday cage)

- **Magnetic coupling**
  - Reduce loop area, check orientation (magnetic shielding is not effective)

- **Ground fluctuations**
  - Use single ground point

- **The requirements are often conflicting!**
Cables (CC)

From [1]

Extension of the central conductor beyond the shield must be minimized

Shield must be grounded at one point
Shield grounding – 1

From [1]

Case C must be avoided as it allows shield noise current to flow into the signal path.
Shield grounding – 2

Always connect the shield to the signal reference, even if not grounded!

If signal reference is located at the amplifier side, C becomes the best choice

From [1]
Shield does not change the geometry nor the mutual inductances (even if grounded at one point) $\Rightarrow$ no effect on the induced voltage

From [1]
IC shielding

From [1]

- Shield must be grounded at two points
- Mutual inductance forces a return current which reduces the loop area
Shield connection

- Two-point connection is effective for magnetic shielding at $\omega > \omega_s = R_s/L_s$, but
- Ground fluctuations at low frequencies generate a return current via the shield, limiting the efficacy

From [2]

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Twisted pairs can also be useful but have lower bandwidth (≈100 kHz) than coaxial cables.
Amplifiers

From [3]
A good connection

From [3]
Complete scheme

Generates a differential signal $V_d = V_n \frac{R_1}{(R_1+Z)}$

Pre-amps, filters & Co. should be included in the source shield

Becomes a common-mode voltage

From [3]
A simple solution

Convert single-ended amps to differential ones

From [3]

V_n becomes a common-mode voltage
Driven shield

- For high-impedance (e.g., capacitive) sensors, the standard shield connection does not work
  - Shield-cable resistance degrades signal
  - Shield-cable capacitance limits bandwidth
- Shield must be kept at the signal potential

From [2]

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Improved solutions

Noise pick-up is reduced

A loop is formed and stability must be checked

From [2]
Reflection coefficient of metals

From [4]

Typically of the order of $10^{15}$ Hz
Absorption of electromagnetic waves

\[ I = I_0 e^{-x/\delta} \]

\[ \delta = \sqrt{\frac{2}{\omega \mu \sigma}} = \sqrt{\frac{1}{\sqrt{\pi \mu_0 \mu_r f}}} \]

(skin depth)

From [5]
Shielding effectiveness

From [1]

0.5 mm copper plate in the far-field limit
Near and far field

- It is difficult to shield low-frequency magnetic fields
- Can we find any high-permittivity material?
Mu-metal

- Only good for low frequencies
- Only works if the field is lower than the (usually low) saturation limit

From [2]
Magnetic screening

From [7]

• A magnetic shield provides a low-reluctance path
• The magnetic field flows in the screen, bypassing the area inside
Apertures

• Real shield effectiveness is limited by apertures
• The shield leakage is determined by
  – The maximum linear dimension of the aperture
  – The frequency (i.e., wavelength) of the wave
  – The wave impedance
References