

Støy

Stoff fra

- Fraden kap 5.13
- Fraden kap 3 (Induktans, kapasitans, Seebeck effekt, piezoelektrisitet (triboelektrisitet)).
- Keithley: Low level measurements handbook

Egenskaper ved støy

- Middelerdien av støysignalet er null

$$\langle V_{noise} \rangle = 0$$

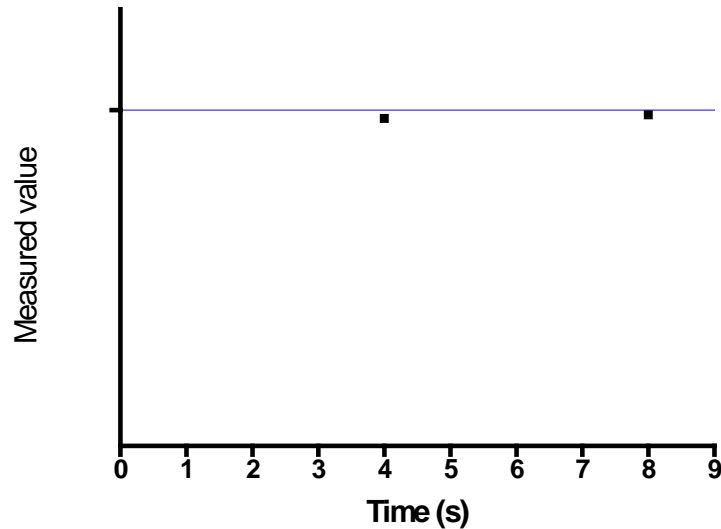
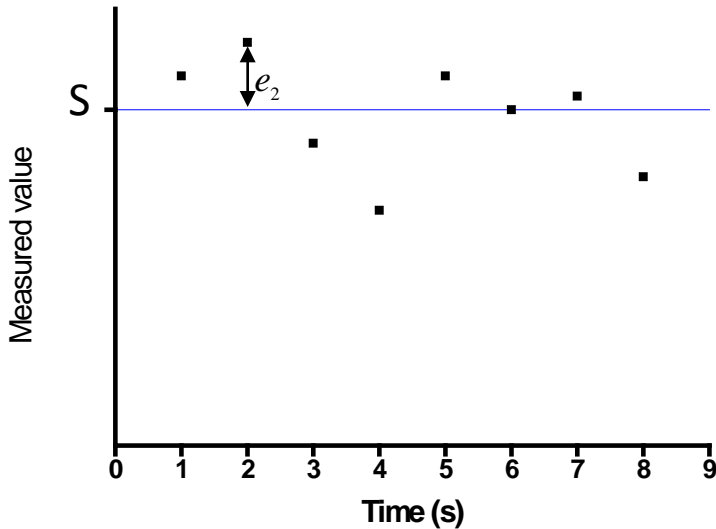
- Ser på middelerdien av kvadratet

$$\langle V_{noise}^2 \rangle \neq 0$$

- Mange støykilder er ukorrelerete

$$\langle V_{A+B}^2 \rangle = \langle V_A^2 \rangle + \langle V_B^2 \rangle$$

Midling



$$M_i = S + e_i$$

$$\langle (M - \langle M \rangle)^2 \rangle = \langle e^2 \rangle$$

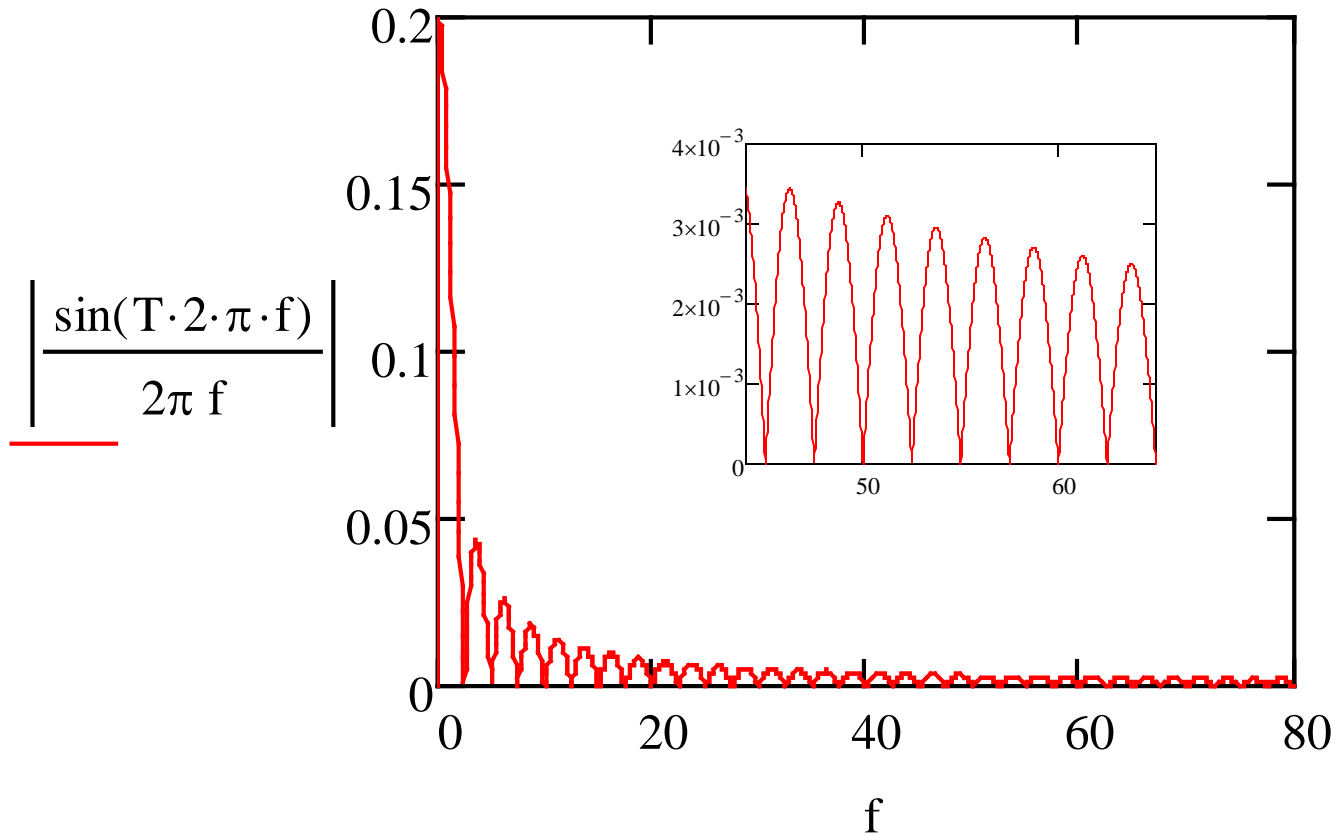
$$M = \frac{1}{4} \sum_{i=1}^4 M_i = \frac{1}{4} \sum_{i=1}^4 S + e_i$$

$$\langle (M - \langle M \rangle)^2 \rangle = \underline{\underline{\frac{1}{4} \langle e^2 \rangle}}$$

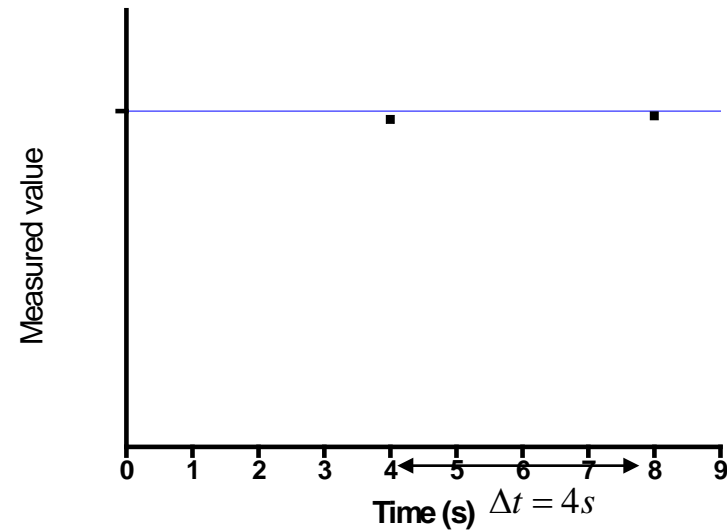
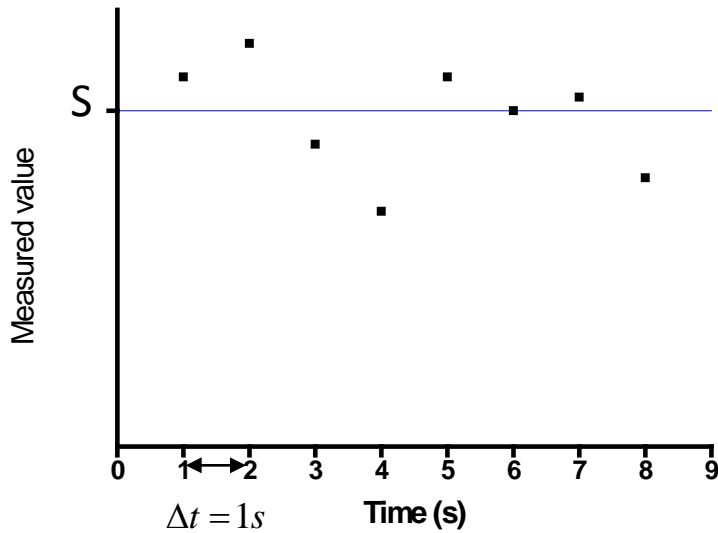
Midling over 4 punkter reduserer **standard avviket** med en faktor 2

Lett å se at midling over n punkter reduserer **standard avviket** med en faktor \sqrt{n}

Filteregenskaper for midling over en periode T

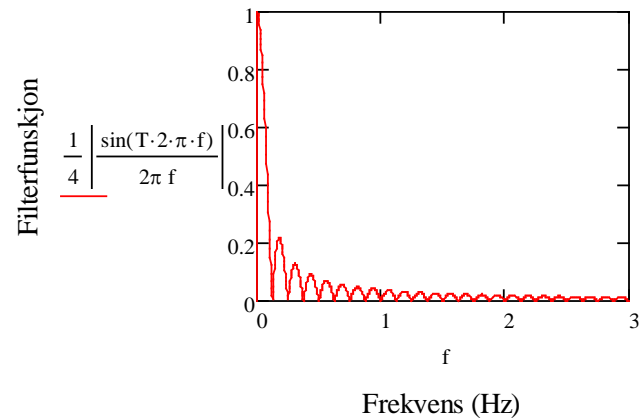
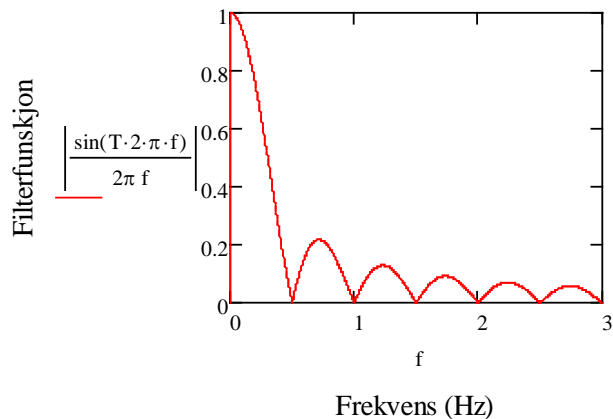


Hva med båndbredden?



Båndbredde: $\Delta f = \frac{1}{2\Delta t} = \frac{1}{2} Hz$

$\Delta f = \frac{1}{2\Delta t} = \frac{1}{8} Hz$



Altså

Midling over n perioder:

- Reduserer RMS støyen med en faktor $1/\sqrt{n}$
- Reduserer samtidig båndbredden med en faktor $1/n$

Forutsatt:

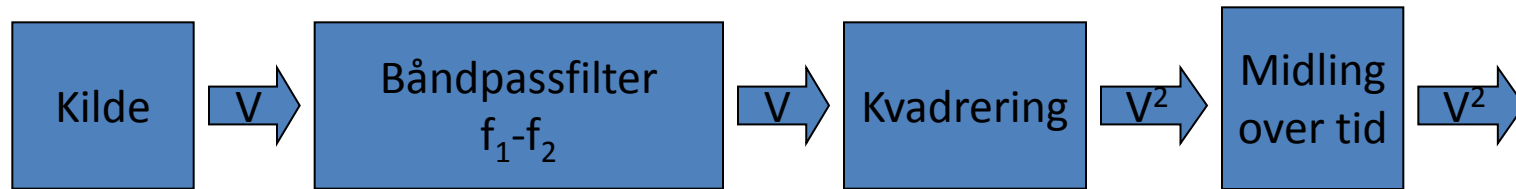
- Målingene er ukorrelerte i tid
- Støyen er hvit

Har forsøkt å sannsynliggjøre:

$$e_{rms} = \sqrt{\Delta f}$$

Støymåling

Kan tenke oss:



Resultatet:

- Avhenger av frekvensen vi måler ved $f = \frac{1}{2}(f_1 + f_2)$
- og av båndbredden vi måler med $\Delta f = (f_2 - f_1)$

$$\langle V_{noise}^2 \rangle = g(f) \Delta f$$

Tar ofte kvadratroten for å finne RMS verdien

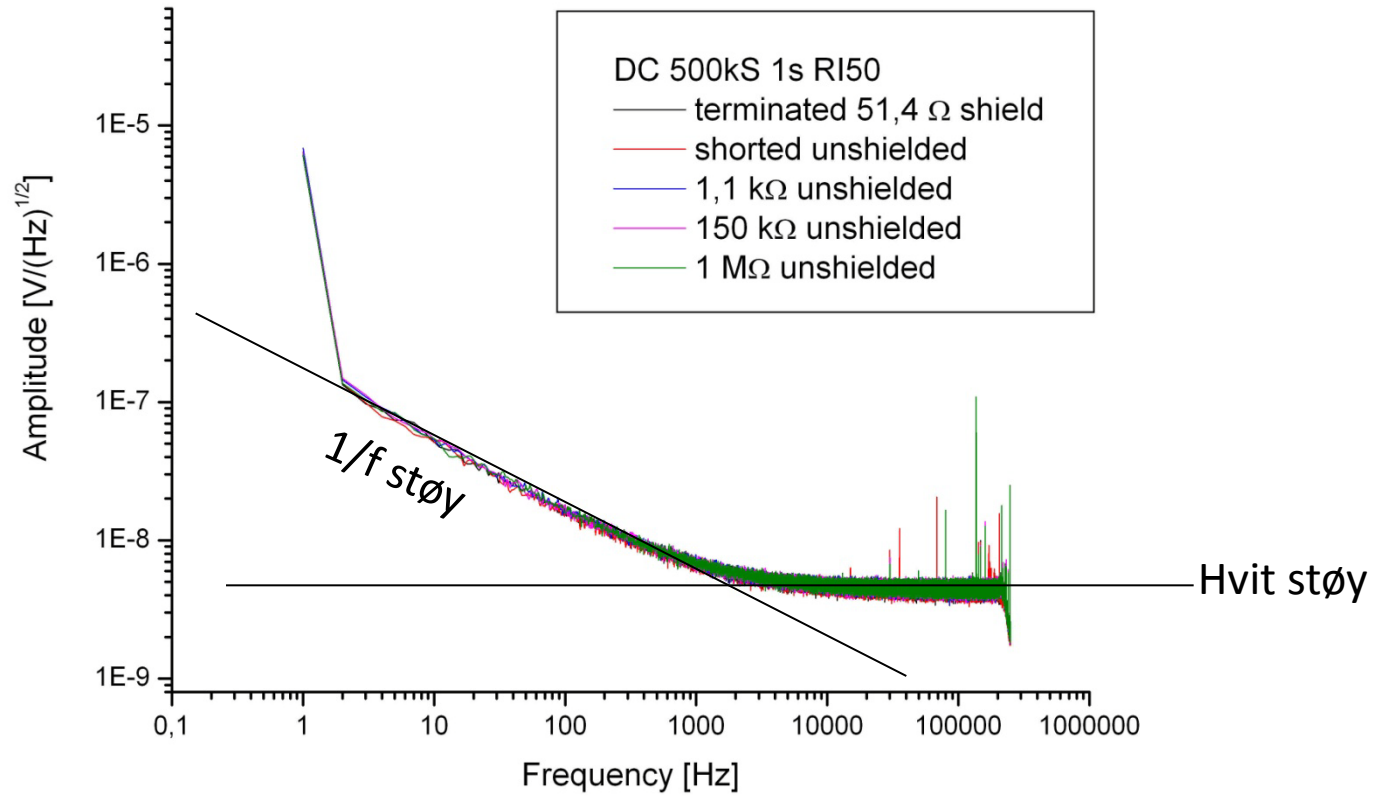


$$\sqrt{\langle V_{noise}^2 \rangle} = e(f) \sqrt{\Delta f}$$

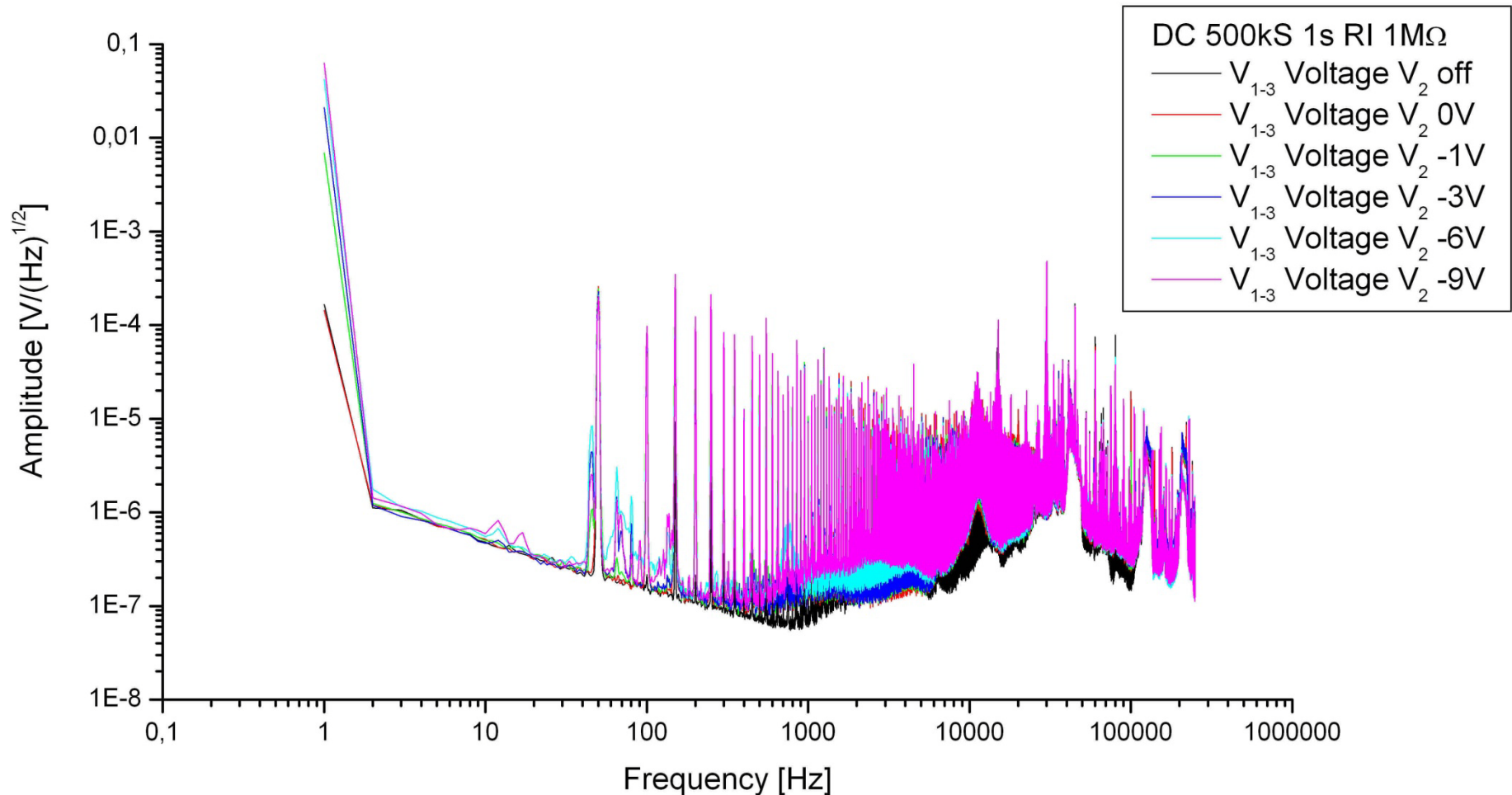
↓
V

Enhet: $\frac{V}{\sqrt{Hz}}$

Eksempel 1

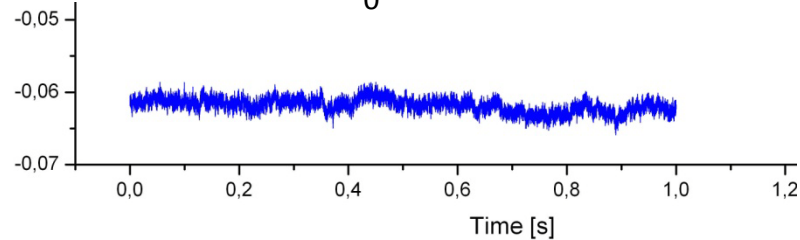


Eksempel 2: Dårlig skjjermet

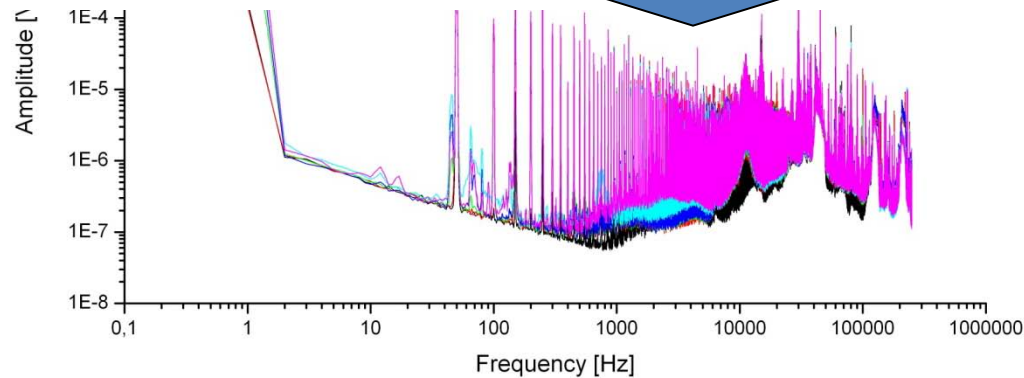


Praktisk støymåling

Måler over tid t_0 med intervall Δt



Fouriertransform



Spekter:

Båndbredde/inkrement $1/t_0$

Høyeste meningsfulle frekvens $1/(2 \Delta t)$

Typer støy

Indre støy (inherent noise)

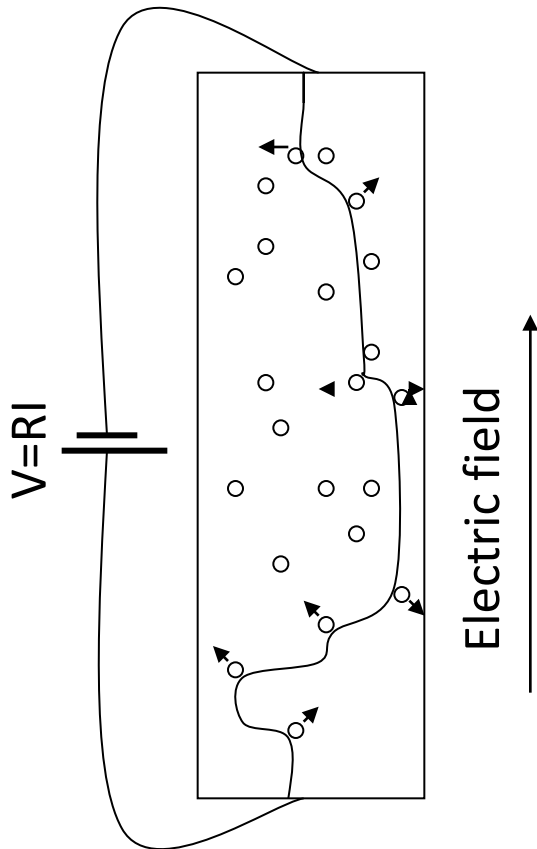
- Termisk støy (Johnson noise)
- Schottky noise
- $1/f$ støy

Ytre støy (transmitted noise):

- Magnetisk
- Elektrisk
- Elektromagnetisk (RF)
- Termisk
- Vibrasjoner
- Fuktighet/kjemikalier

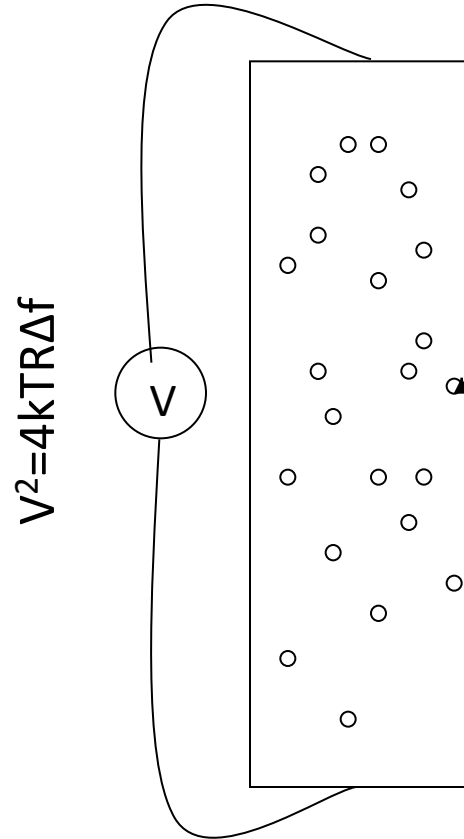
Termisk støy

Resistivity/dissipation:



Electric energy -> Heat

Noise:



$$V^2 = 4kTR\Delta f$$

Heat -> Electric energy

1/f støy

- Mange mekanismer
 - For eksempel ”fanging” av ladningsbærere
- Avhenger av kvalitet og størrelse på komponenter
- Kan reduseres
- Umulig å bli kvitt

Induksjon i sløyfer

FIGURE 3-9: Low Voltages Generated by Magnetic Fields

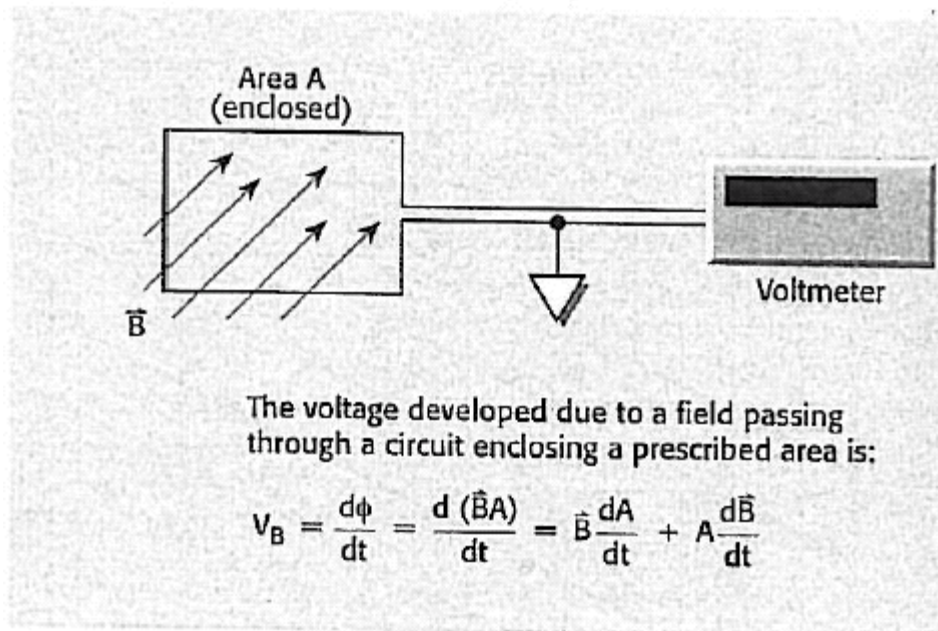
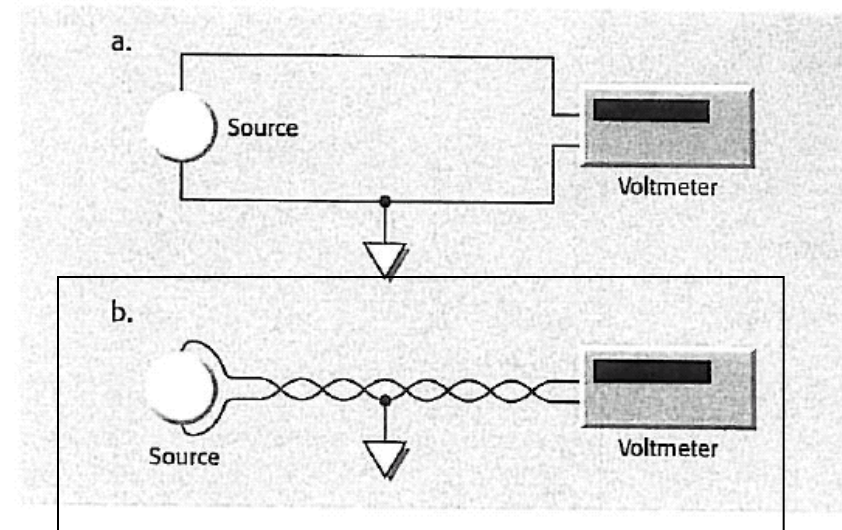


FIGURE 3-10: Minimizing Interference from Magnetic Fields



Elektromagnetisk skjerming
Eller magnetisk skjerming (vanskelig)

Jordsløyfer

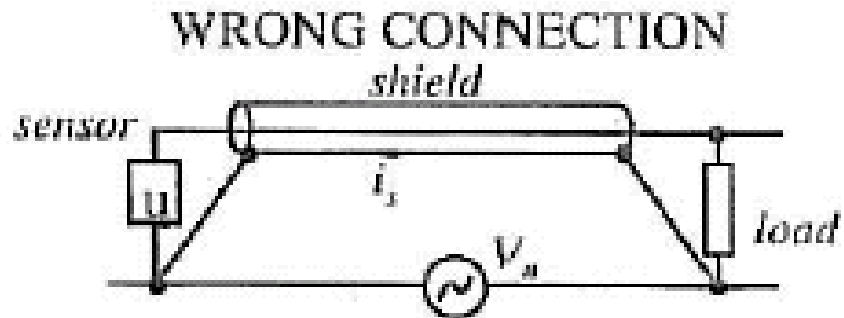
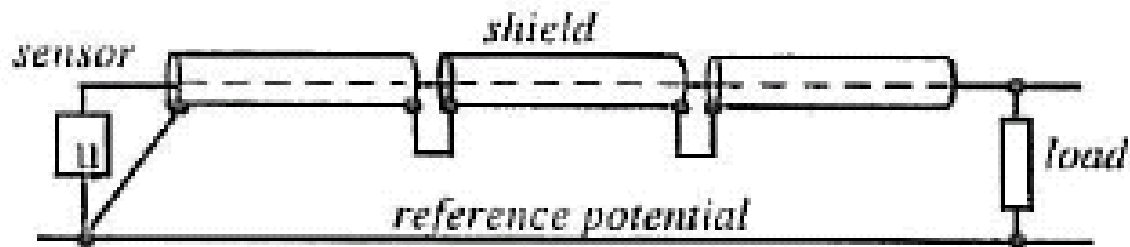


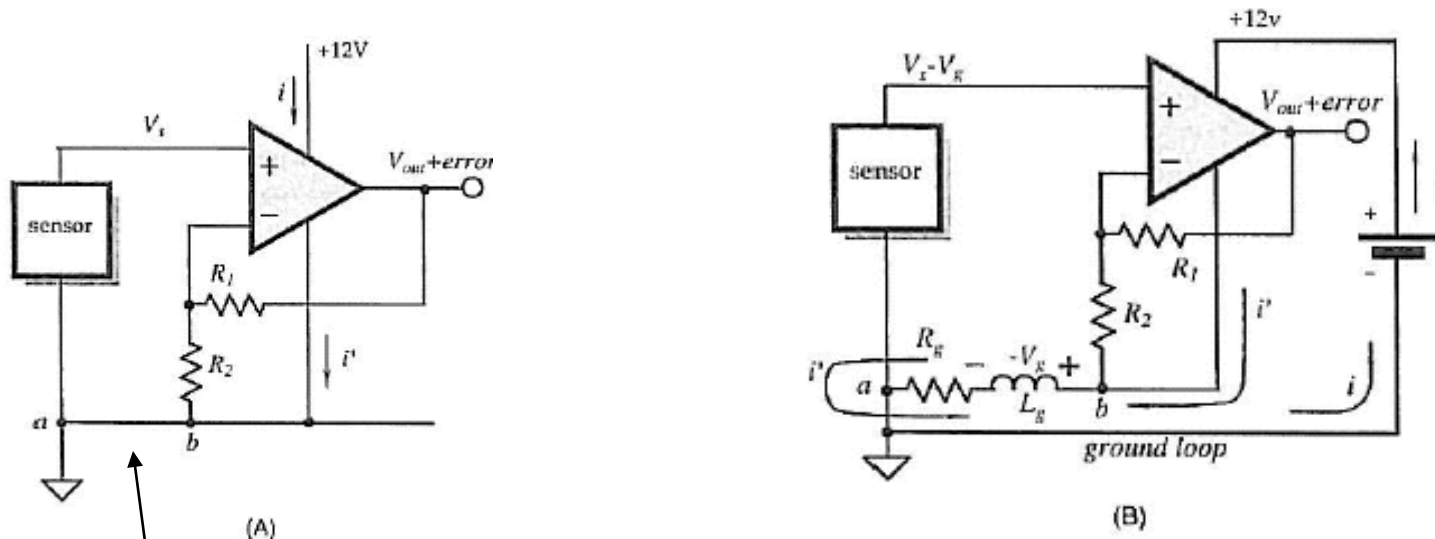
Fig. 5.50. Cable shield is erroneously grounded at both ends.

Riktig:



(B)

Jordsløyfe 2



Delt leder

Fig. 5.54. Wrong connection of a ground terminal to a circuit (A); path of a supply current through the ground conductors (B).

Seebeck støy

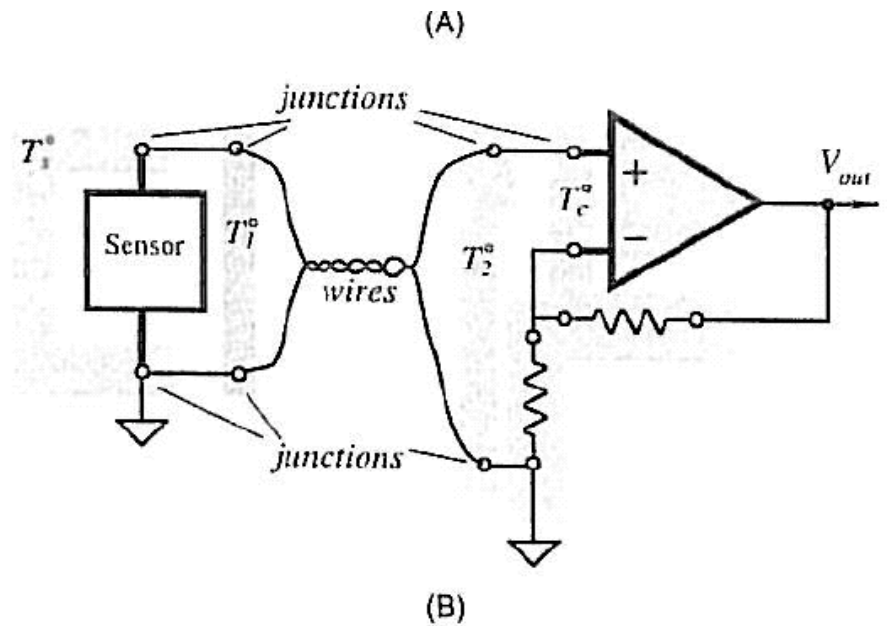
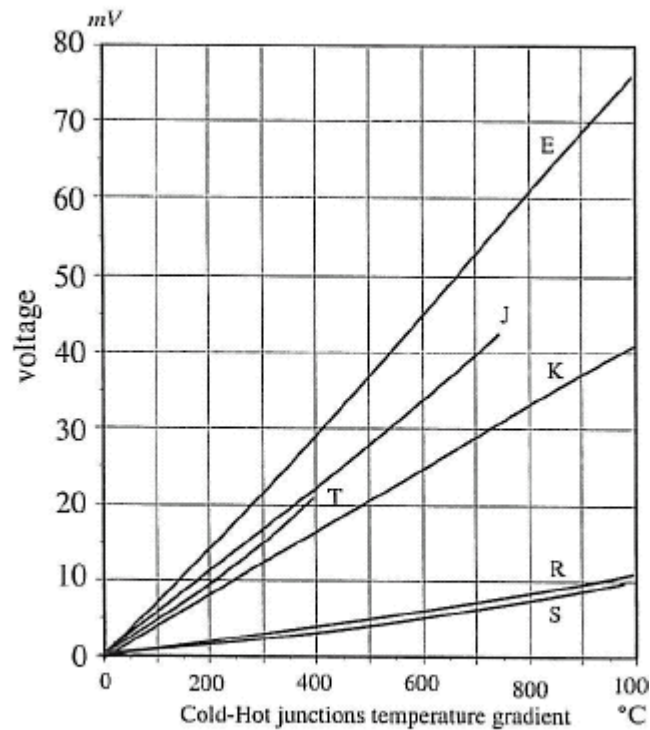


Fig. 3.36. Output voltage from standard thermocouples as functions of a cold-hot temperature gradient.

Støy i ledningsføring

- (Elektro) magnetisk induksjon
- Piezoelektrisk effekt
- Triboelektrisk effekt
- Lekkasjestrømmer (på kort)

Frekvensinnhold (Fraden)

Table 5.4. Typical Sources of Transmitted Noise

External Source	Typical Magnitude	Typical Cure
60/50 Hz power	100 pA	Shielding; attention to ground loops; isolated power supply
120/100 Hz supply ripple	3 μ V	Supply filtering
180/150 Hz magnetic pickup from saturated 60/50-Hz transformers	0.5 μ V	Reorientation of components
Radio broadcast stations	1 mV	Shielding
Switch arcing	1 mV	Filtering of 5–100-MHz components; attention to ground loops and shielding
Vibration	10 pA (10–100 Hz)	Proper attention to mechanical coupling; elimination of leads with large voltages near input terminals and sensors
Cable vibration	100 pA	Use a low-noise (carbon-coated dielectric) cable
Circuit boards	0.01–10 pA/Hz below 10 Hz	Clean board thoroughly; use Teflon insulation where needed and guard well

Source: Adapted from Ref. [13].