

Støy

Stoff fra

- Fraden kap 5.13 (Støy)
- Fraden kap 5.11 (Brokoblinger)
- Fraden kap 3 (Induktans, kapasitans, Seebeck effekt, piezoelektrisitet, (triboelektrisitet)).
- Keithley: Low level measurements handbook
- Labøving 3

Geofon (for oljeleting)

Specifications

INPUT/OUTPUT, INC.

Frequency

Natural frequency (f_n)	1 Hz
Tolerance	$\pm 15\%$
Maximum tilt angle for specified f_n	20° (vertical) or 5° (horizontal)

Distortion

Distortion with 0.7 in/s _{r.m.s.} coil-to-case velocity	<0.15%
Distortion measurement frequency	12 Hz

Damping

Open-circuit damping (typical)	100%
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Sensitivity

Sensitivity	15 V/m/s
Tolerance	$\pm 10\%$
Spurious frequency	240 Hz

Equivalent Input Noise

300 nm/(s.sqrt(Hz)) above 10 Hz

Power Supply Voltage

$\pm 5 V_{dc}$ to $\pm 15 V_{dc}$ (symmetrical)

Supply Current

± 1 mA (at rest)

Physical Characteristics

Diameter	34 mm (1.34 in)
Height	65 mm (2.56 in)
Weight	170 g (6 oz)
Operating temperature range	-20°C to +60°C (-4°F to +140°F)
Storage temperature range	-40°C to +70°C (-40°F to +158°F)

Mounting Thread

M8



Egenskaper ved støy

- Middelerdien av støysignalet er null

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

- Ser på middelerdien av kvadratet

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

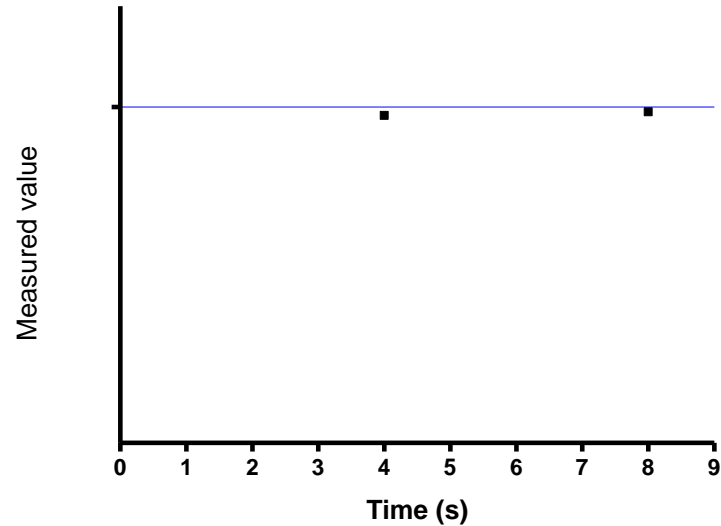
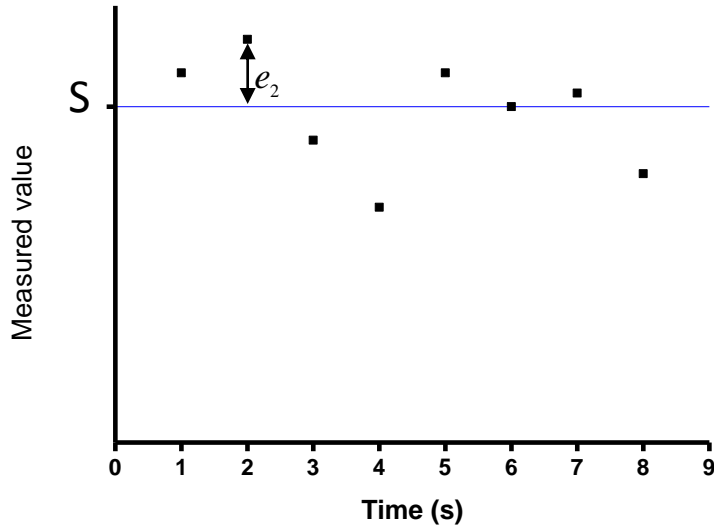
- Eller Root-Mean-Square

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

- Mange støykilder er ukorrelerte

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

Midling



$$M_i = S + e_i$$

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

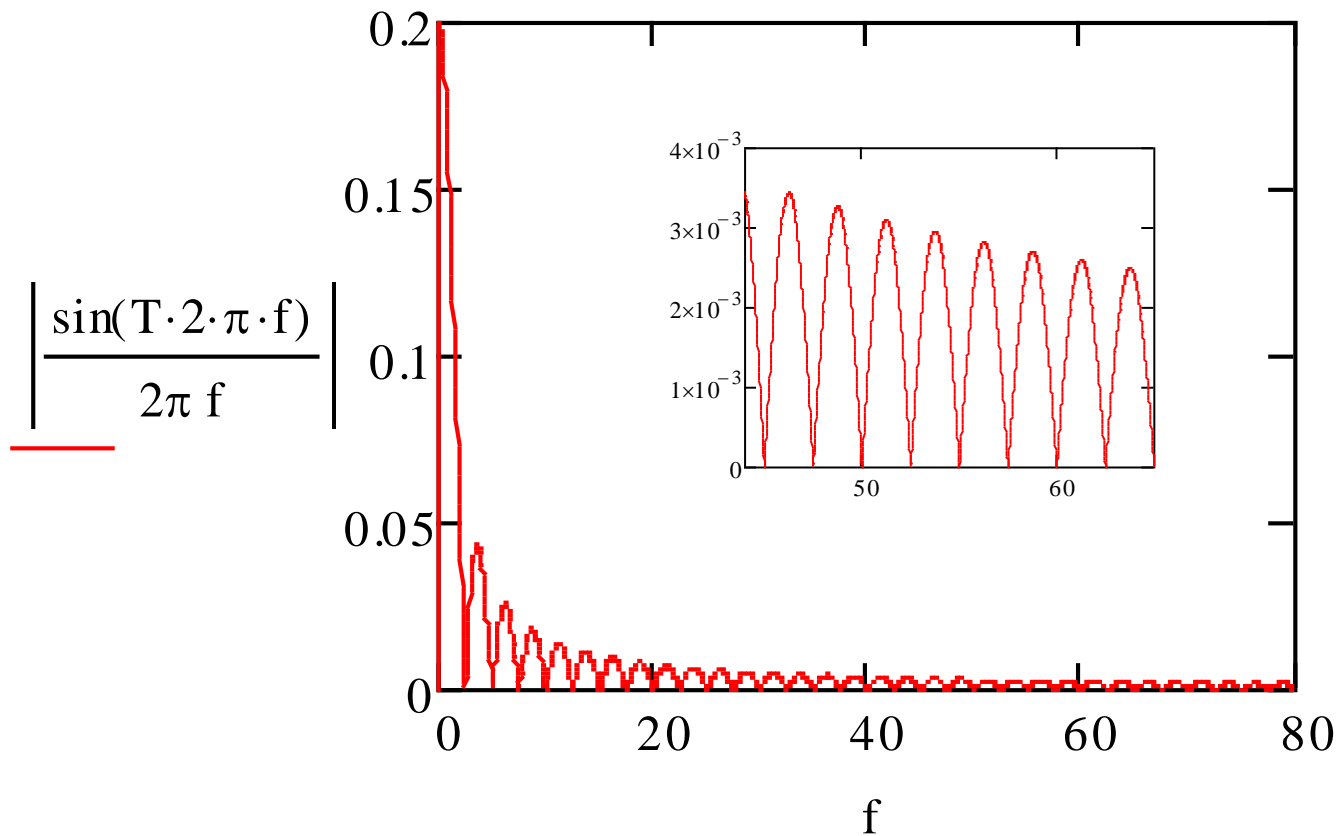
$$M = \frac{1}{4} \sum_{i=1}^4 M_i = \frac{1}{4} \sum_{i=1}^4 S + e_i$$

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

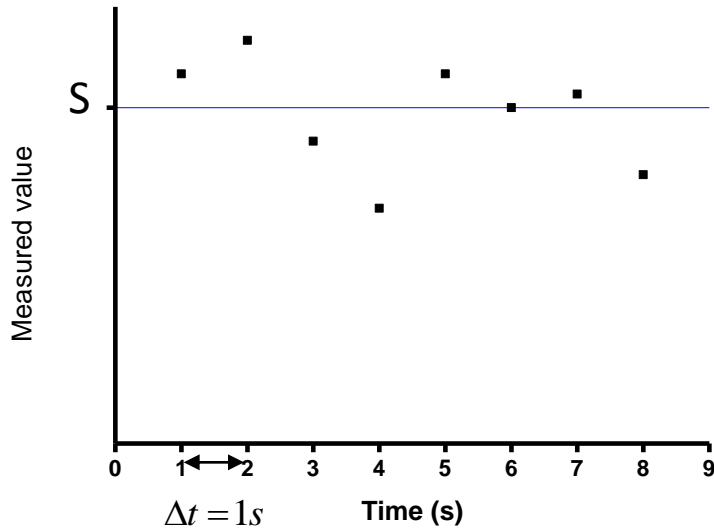
Midling over 4 punkter reduserer **standard avviket** med en faktor 2

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

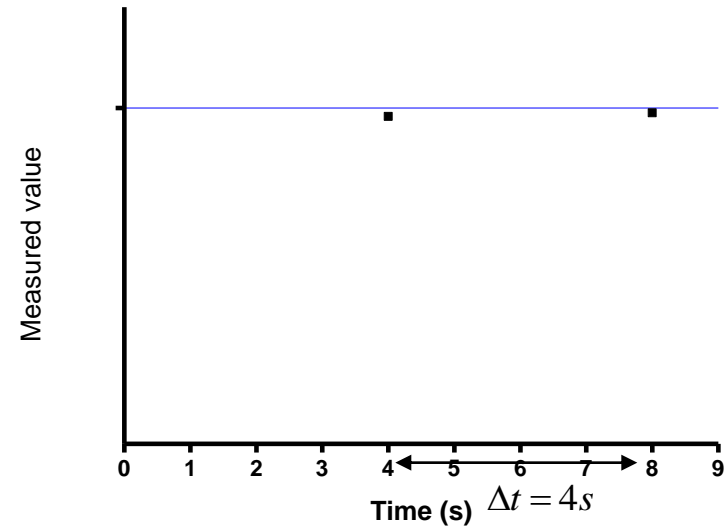
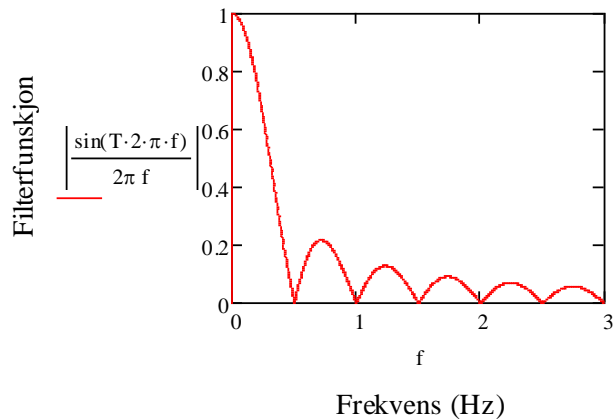
Filteregenskaper for midling over en periode T



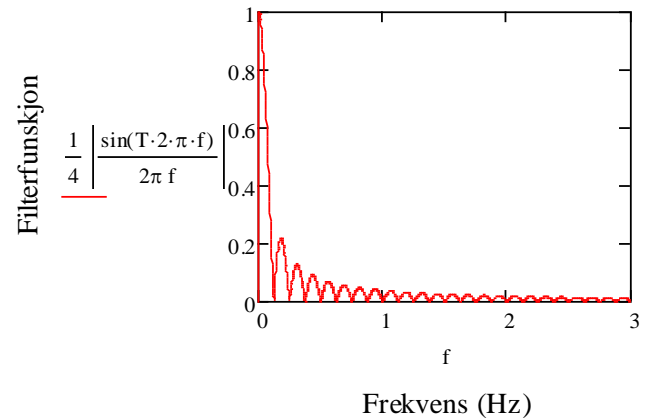
Hva med båndbredden?



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



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



Altså

Midling over n perioder:

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

Forutsatt:

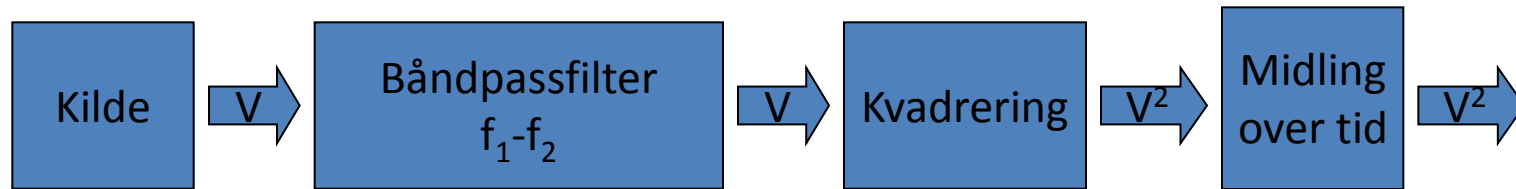
- Målingene er ukorrelerte i tid
- Støyen er hvit

Har forsøkt å sannsynliggjøre:

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

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

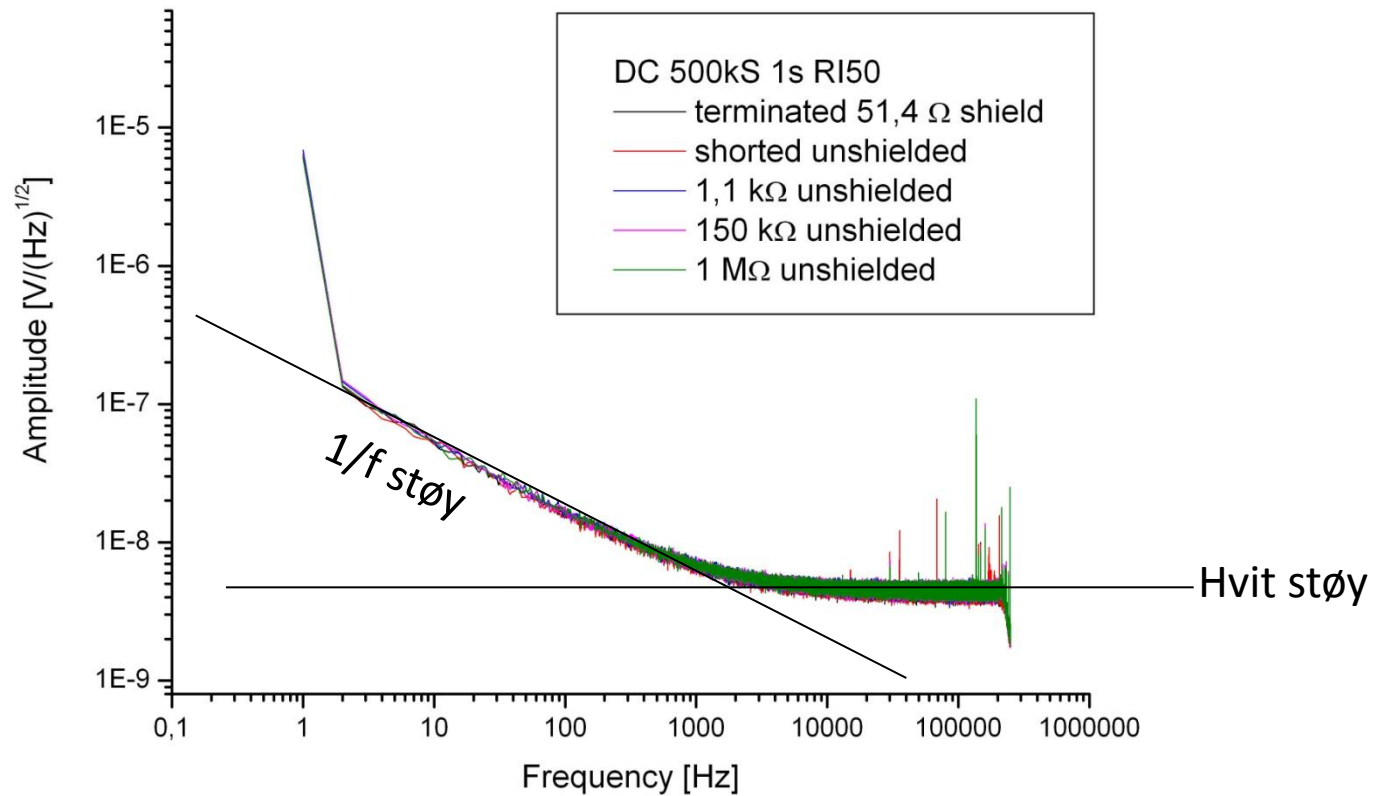


$$\sqrt{\langle V_{noise}^2 \rangle} = e(f) \sqrt{\Delta f}$$

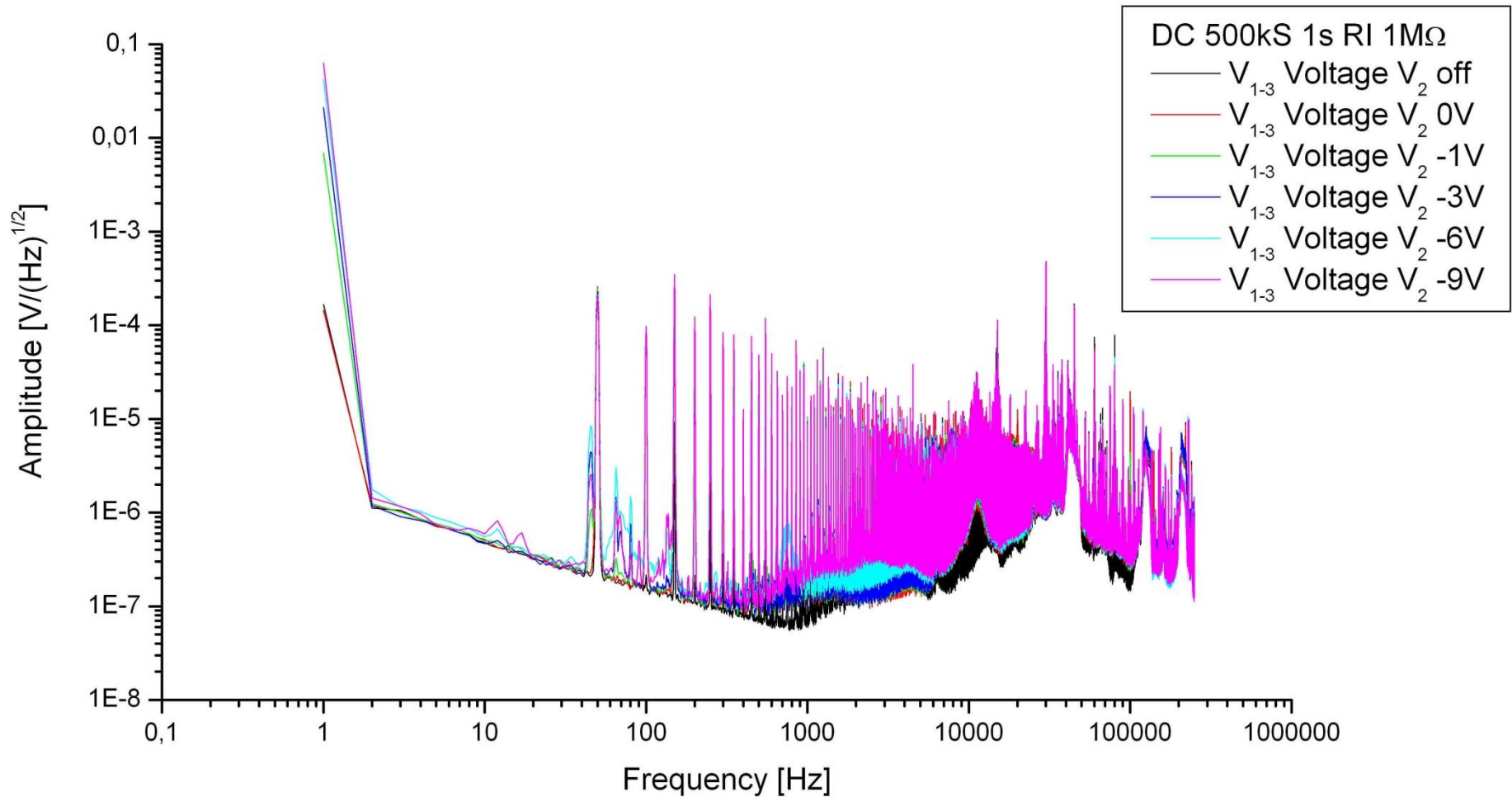
↓
v

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

Eksempel 1

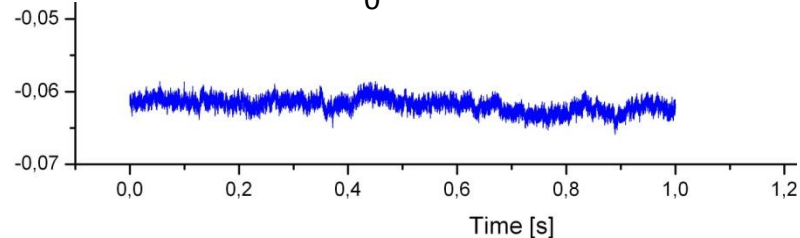


Eksempel 2: Dårlig skjermet

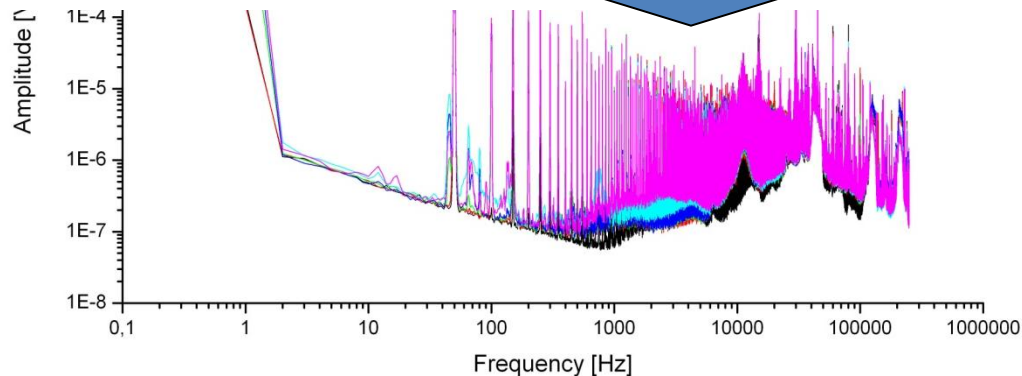


Praktisk støymåling

Måler over tid t_0 med intervall Δt



Fouriertransform



Spekter:

Båndbredde/inkrement $1/t_0$

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

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

Typer støy

Indre støy (inherent noise)

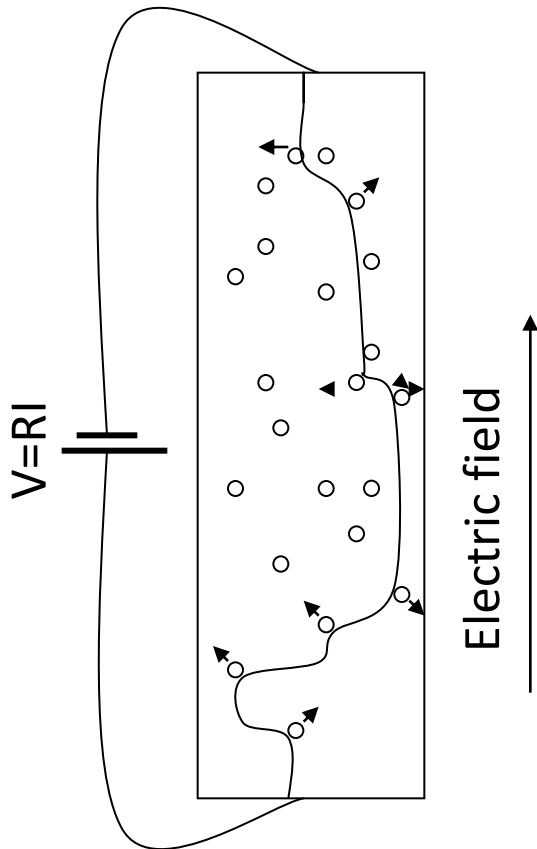
- Termisk støy (Johnson noise)
- Schottky noise
- $1/f$ støy

Ytre støy (transmitted noise):

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

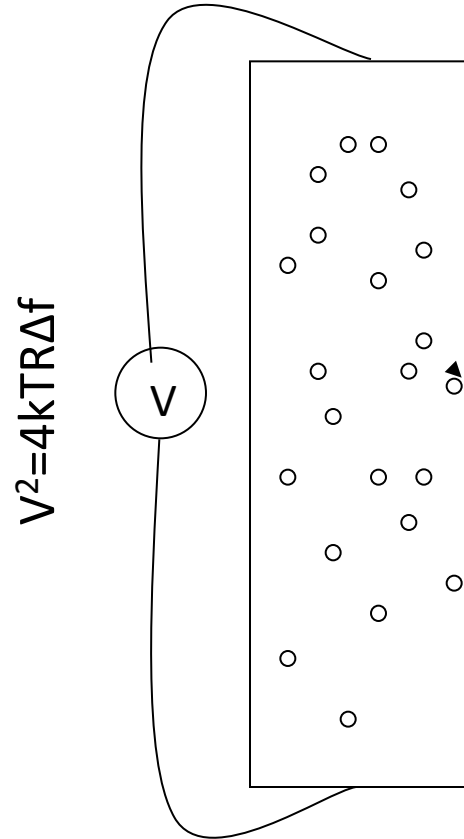
Termisk støy

Resistivity/dissipation:



Electric energy -> Heat

Noise:



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

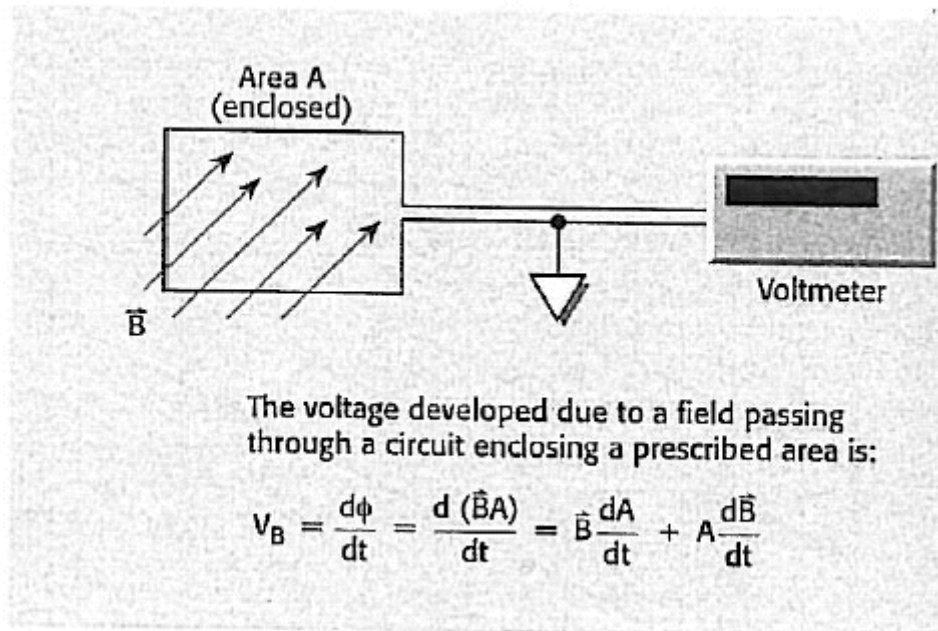
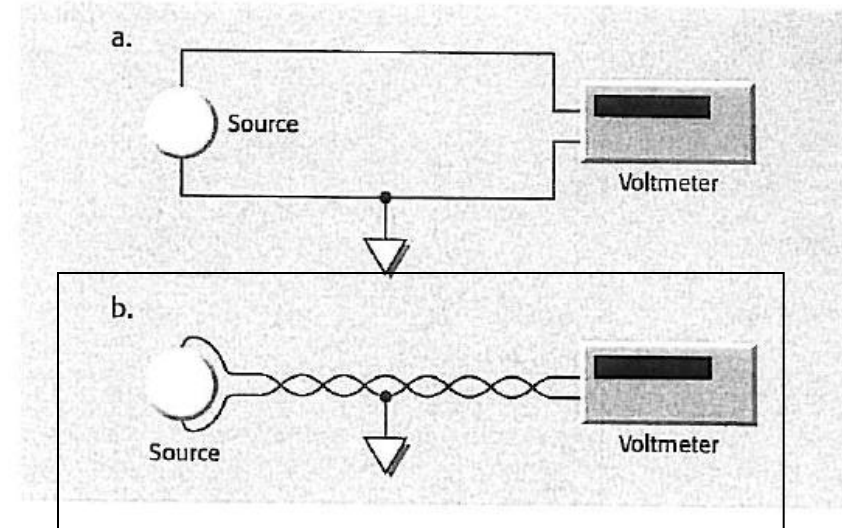


FIGURE 3-10: Minimizing Interference from Magnetic Fields



Elektromagnetisk skjerming
Eller magnetisk skjerming (vanskelig)

Skjerming

5.13 Noise in Sensors and Circuits

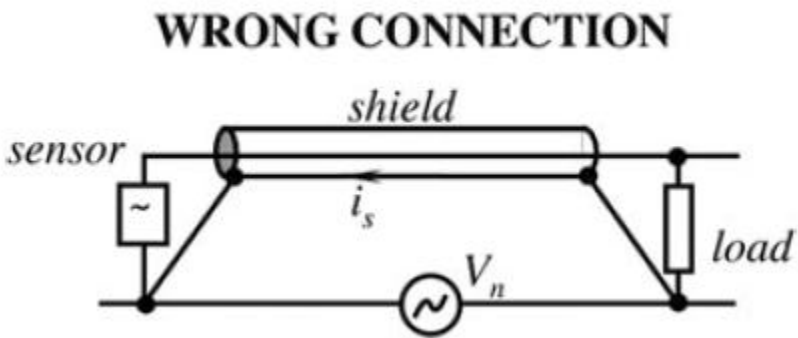
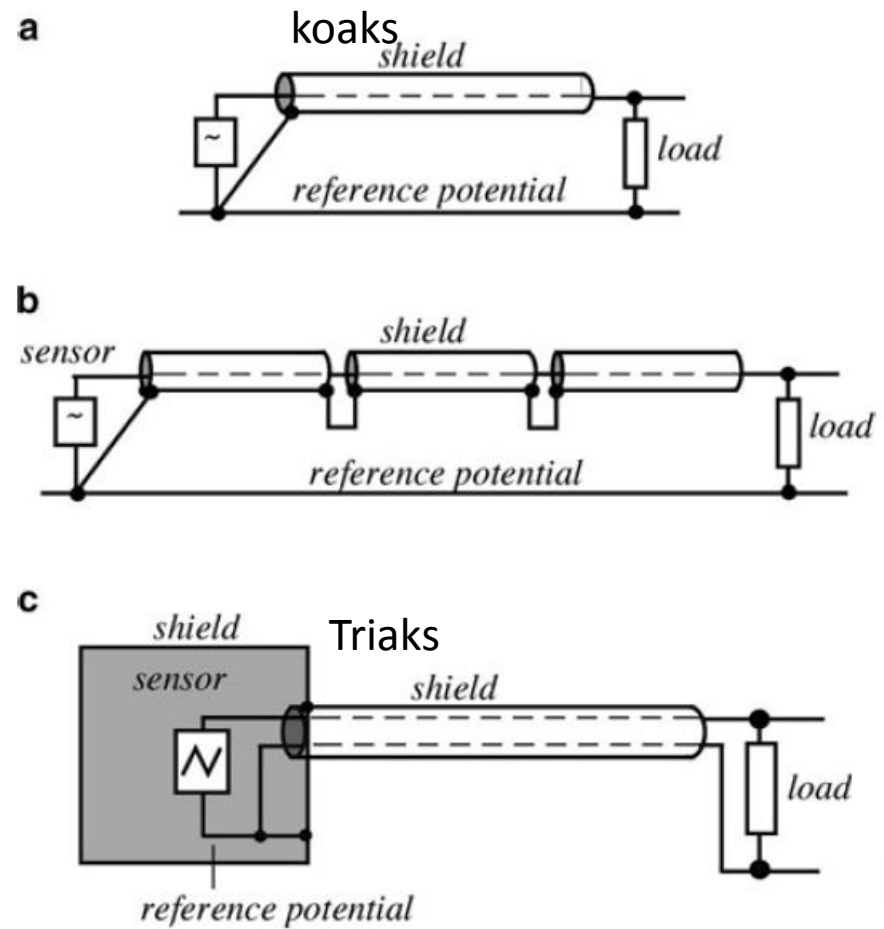
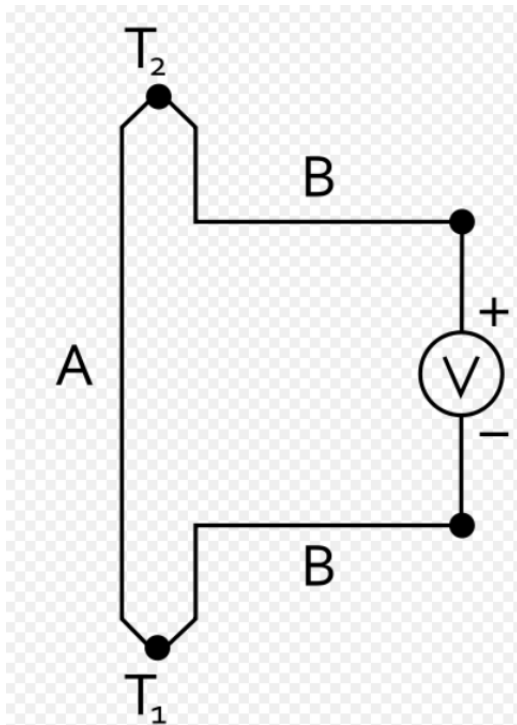


Fig. 5.48 Connections of an input cable to a reference potential

Termoelektrisk Seebeck effekt

Seebeck effekt



$$V = (S_B - S_A) \cdot (T_2 - T_1).$$

90 3 Physical Principles of Sensing

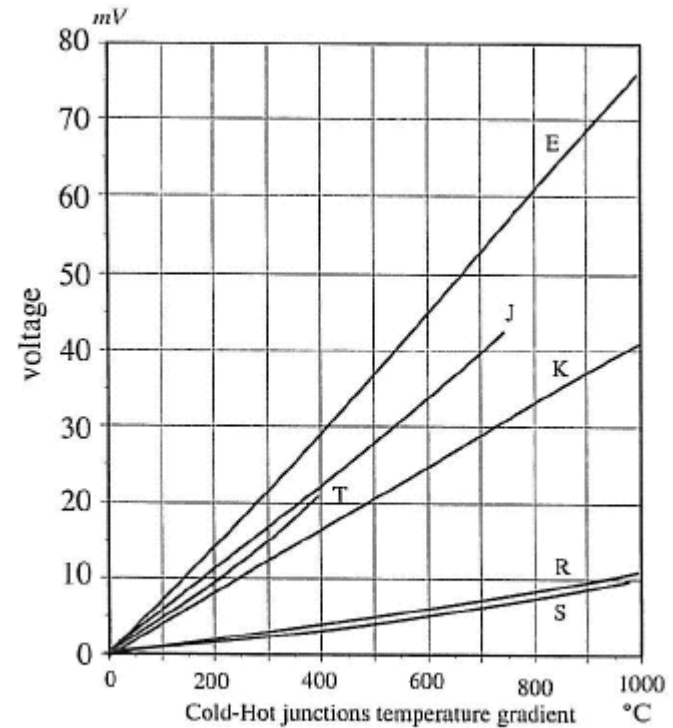
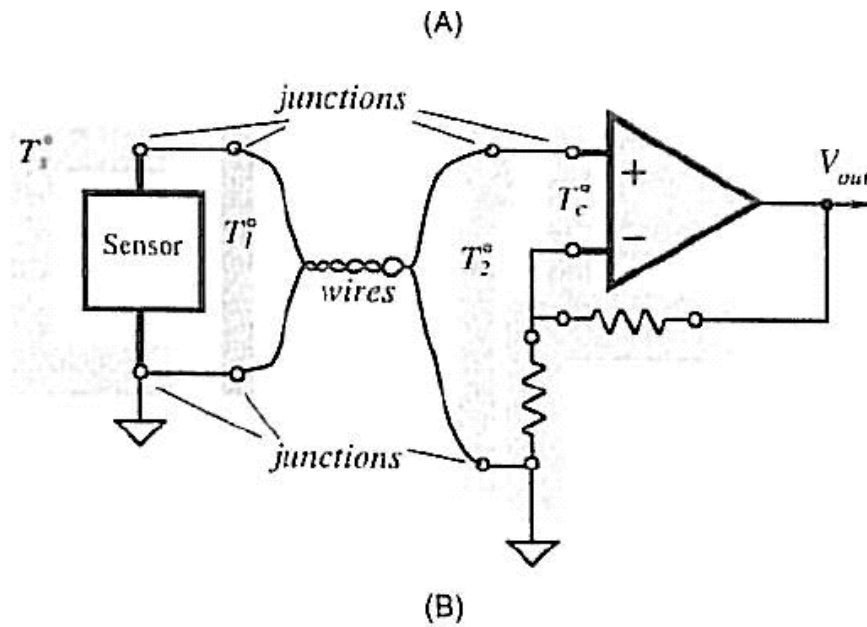


Fig. 3.36. Output voltage from standard thermocouples as functions of a cold-hot temperature gradient.

Seebeck støy



Støy i ledningsføring

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

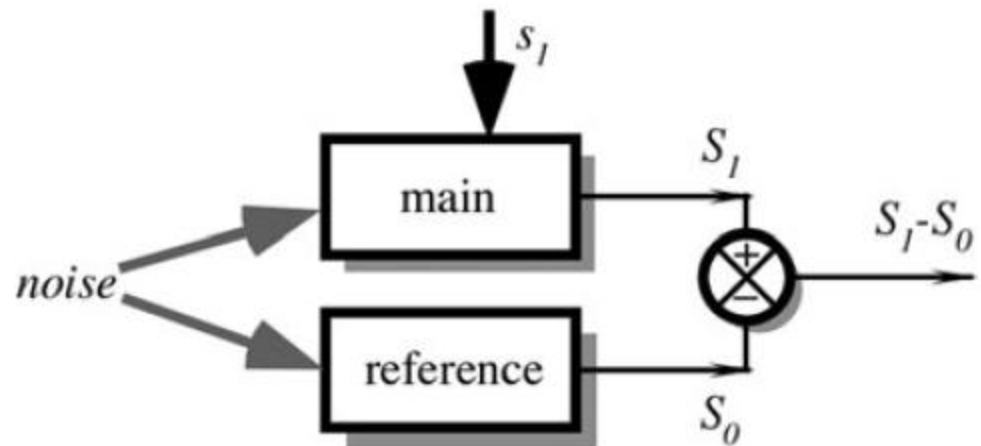
Frekvensinnhold og størrelse

Table 5.4 Typical sources of transmitted noise (adapted from [13])

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 to 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/ $\sqrt{\text{Hz}}$ below 10 Hz	Clean board thoroughly; use Teflon insulation where needed and guard well

Subtraksjon av støy

Fig. 5.46 Differential technique



Brokobling - subtraksjon

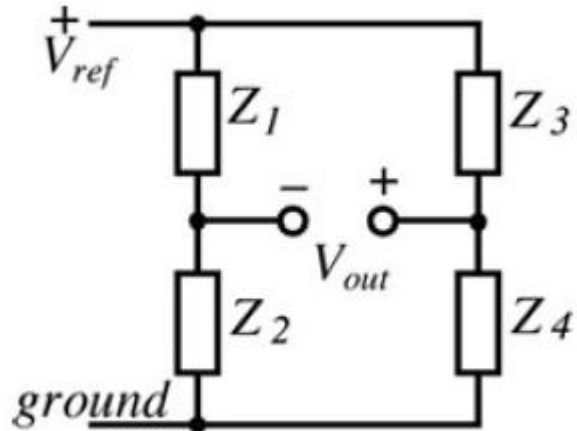
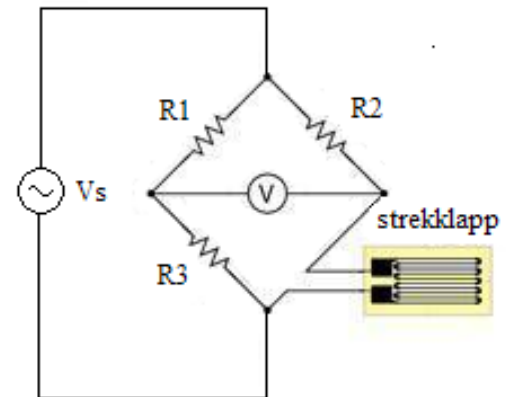


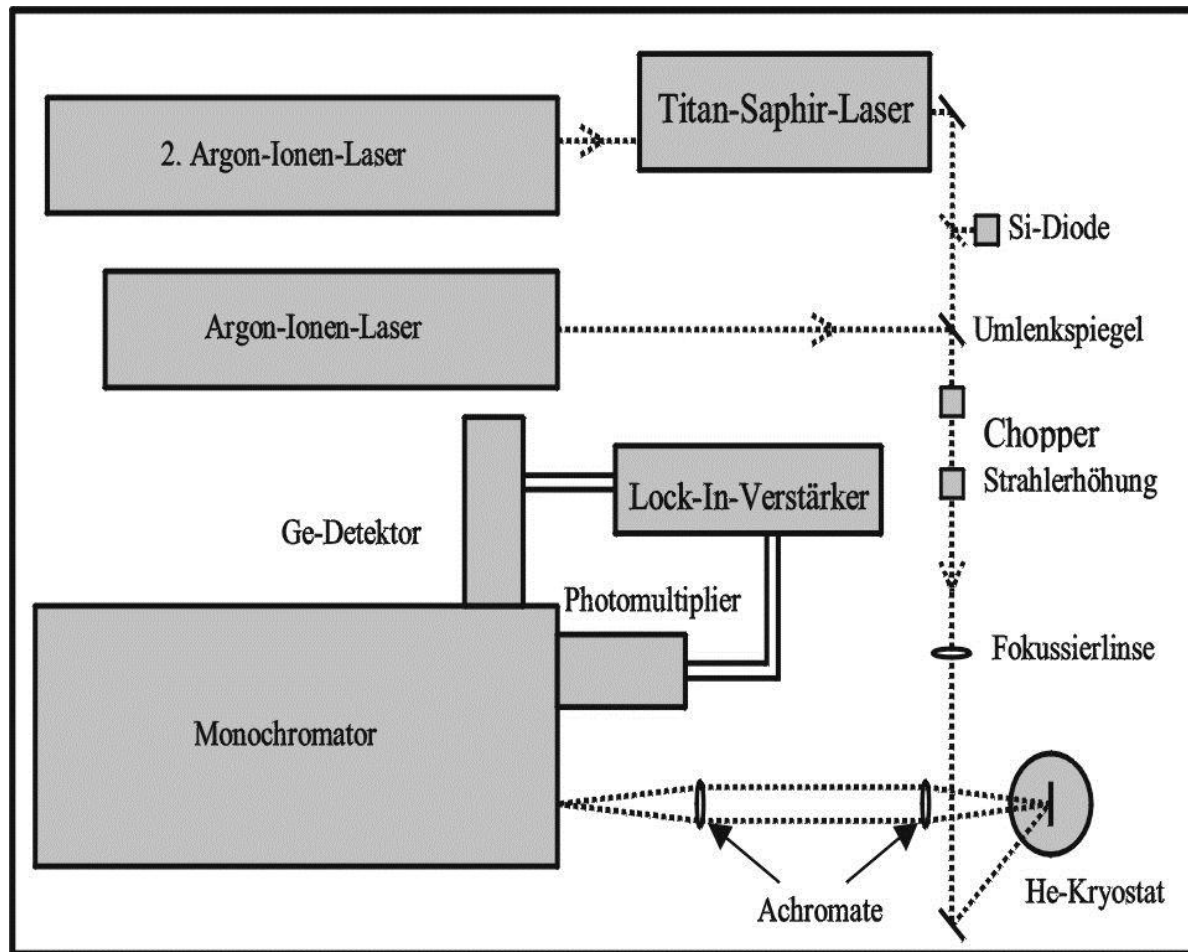
Fig. 5.37 General circuit of Wheatstone bridge

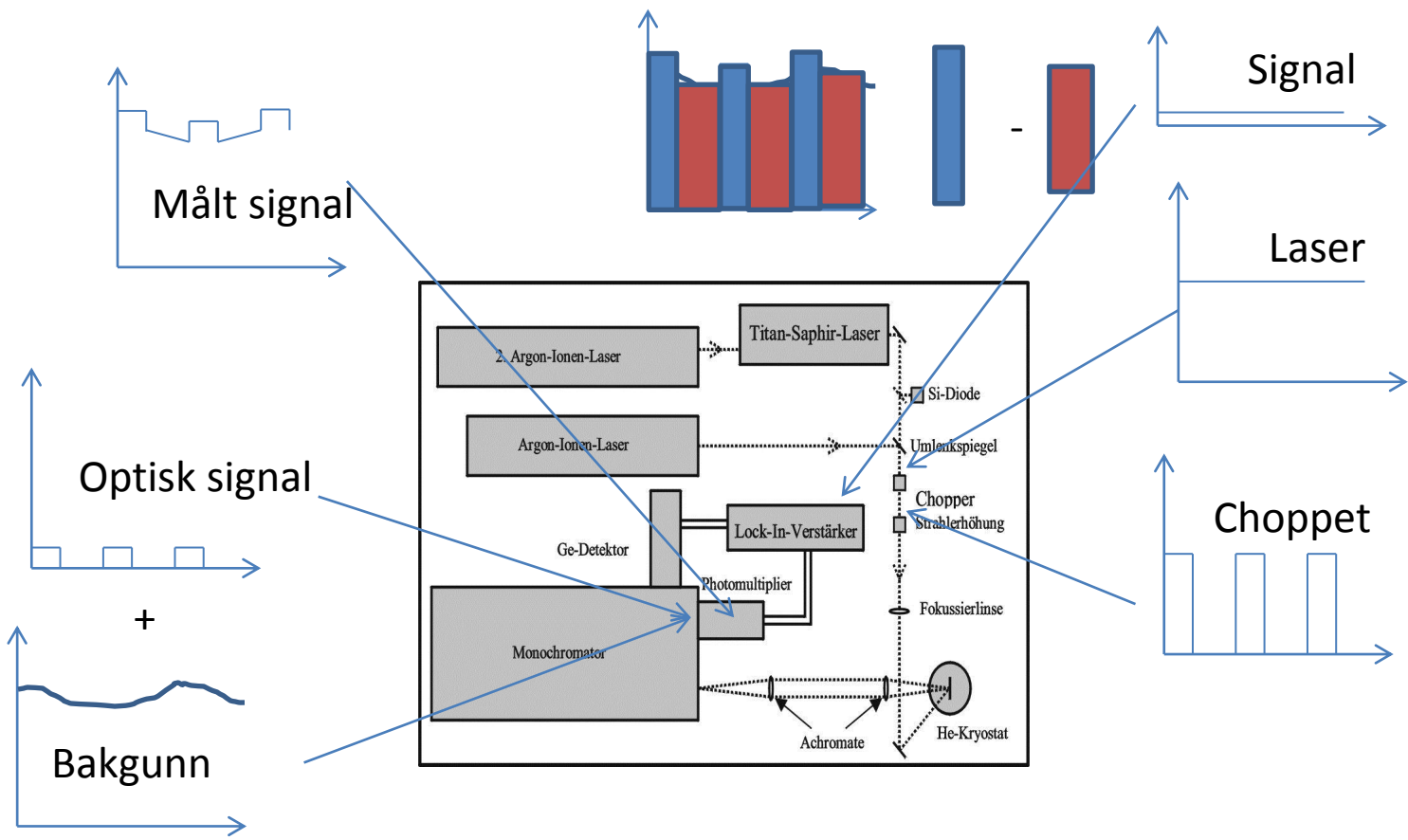


$$V_{out} = \left(\frac{Z_1}{Z_1 + Z_2} - \frac{Z_3}{Z_3 + Z_4} \right) V_{ref},$$

A red box containing an exclamation mark (!) is positioned above the minus sign in the equation, with a red arrow pointing to it.

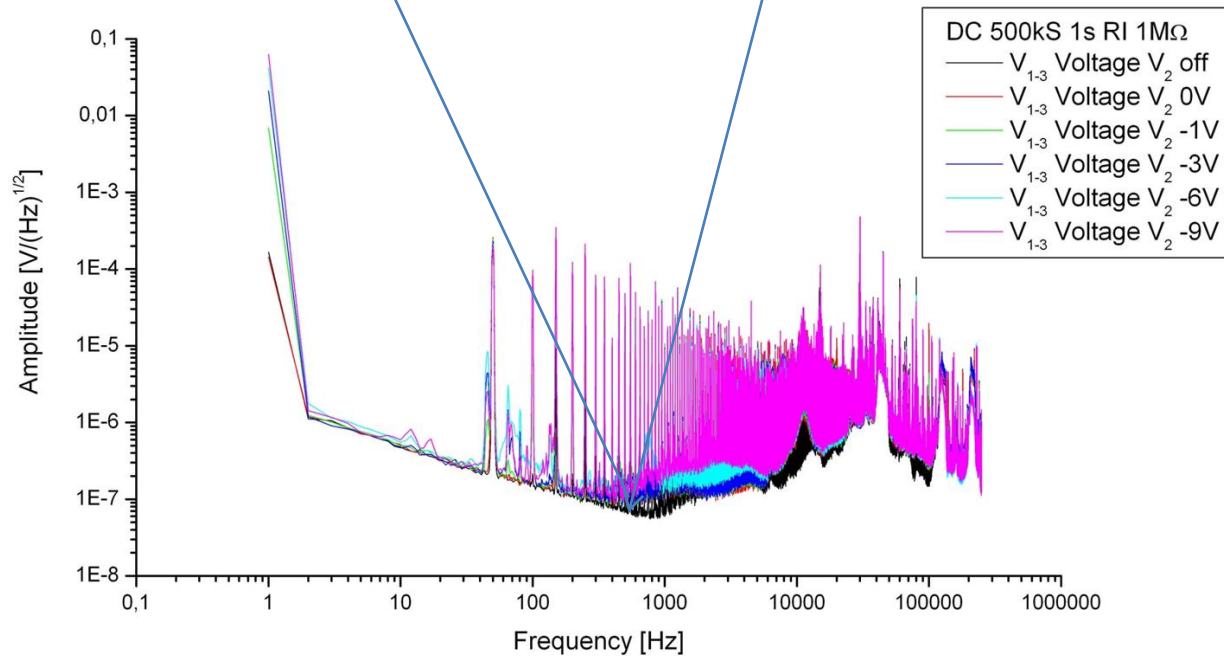
Lock-in forsterker i fotoluminiscence oppsett – Subtraksjon i tid





Brokobling - modulasjon

$$V_{out} = \left(\frac{Z_1}{Z_1 + Z_2} - \frac{Z_3}{Z_3 + Z_4} \right) V_{ref}$$

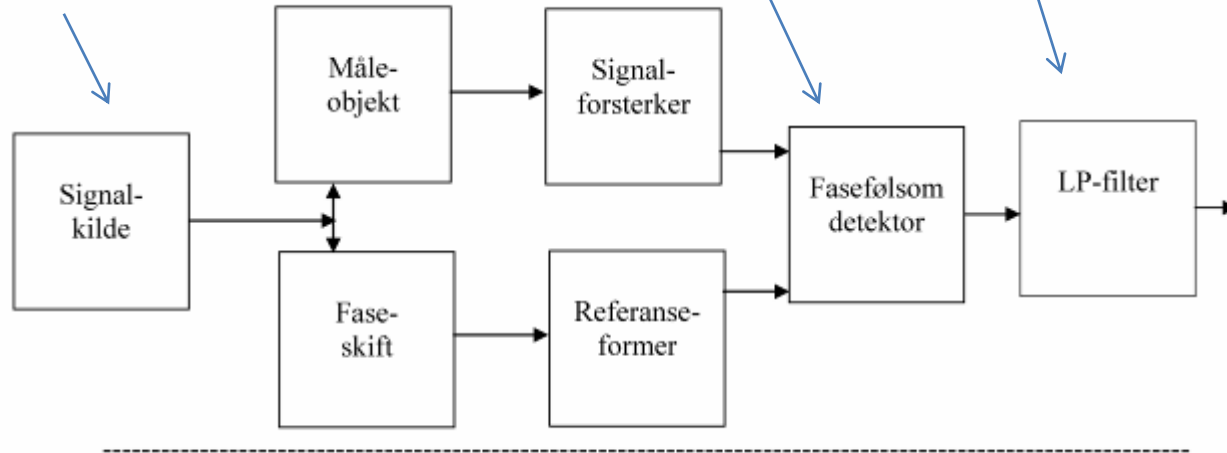


Lab 3

Fjerner støyen som har blitt med

Flytter resultatet ned igjen

Flytter målingen opp i frekvens



Noen viktige punkter

Brokobling:

1. Tar en differanse (gjør om en liten forskjell til et fullt signal)
2. Kan subtrahere støy (typisk temperatur)
3. Kan i tillegg moduleres
 - Induktive og kapasitive elementer MÅ moduleres
 - PN isolerte motstander kan IKKE uten videre moduleres

Kjært barn – mange navn

- Lock-in (forsterker)
- Fasefølsom deteksjon
- Synkron deteksjon