Friedrich-Alexander-Universität Erlangen-Nürnberg

System Identification of Power Amplifiers Using PHiL-Simulation

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UGM RTDS USER'S GROUP MEETING

2024 EUROPE USER'S GROUP MEETING
DELFT, NETHERLANDS

RTDS Technologies AMETEK

Structure

GEFÖRDERT VOM
KOPERNIKUS PROJEKTE Die Zukunft unserer Energie
Bundesministerium für Bildung und Forschung

1. Motivation
2. Experimental setup and used hardware components
   CMS 356, DM APS 30000, NovaCor, PQ-Box 300
3. Examination of the measuring properties of the measuring device
   Noise, Time Synchronization, High-Pass Filter
4. Investigation of the transmission behavior of the linear amplifiers
   Amplifier Noise, Dead Time, Step Response, Frequency Response
5. Conclusion

Motivation

Power-Hardware-in-the-Loop-RTS

Linear amplifier → **Data sheet**

- ➢ Dead time
- ➢ Signal bandwidth (-3 dB)

Real-Time-simulation

Non-ideal transmission behavior

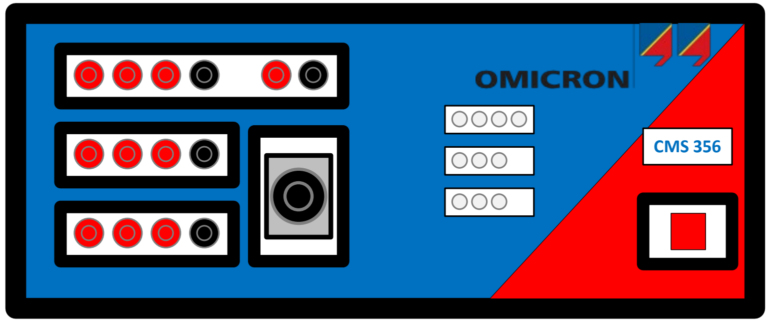
- ➢ Dead time
- ➢ Analog filter
- ➢ Sampling effects

Reality → Measuring Device

Measuring Equipment

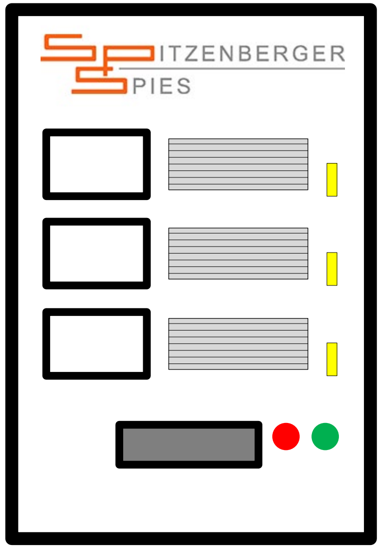
Linear Amplifiers

CMS 356
Omicron
Analog Operation



Max. rated power:	3 x 100 VA
Max. Voltage (RMS):	300 V
Dead Time[1]:	< 500 µs
Bandwith (-3 dB):	DC … 2.5 kHz
Sampling Frequency[1]:	10 kHz

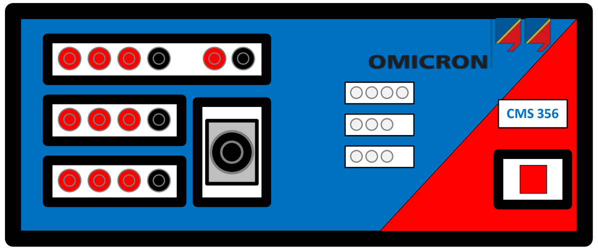
DM APS 30000
Spitzenberger & Spies
Sampled-Values – Optical Fiber



Max. rated power:	3 x 10 kVA
Max. Voltage (RMS):	300 V
Dead Time[1]:	< 5 µs
Bandwith (-3 dB):	DC … 30 kHz DC … 50 kHz (Small signal)
Sampling Frequency:	≙ Simulation Time Step

[1] Analog operation

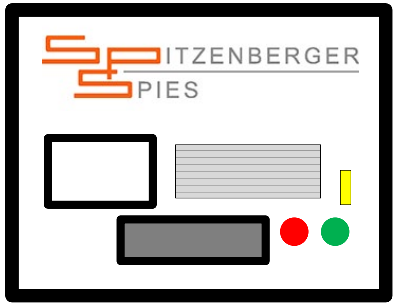
Communication with *RTDS NovaCor*



Min. Time Step: 4 µs

Interface: GTAO-Karte

$\Rightarrow f_{Nyq} = 125\ \text{kHz} \curvearrowright 5\ \text{kHz}$[1]



Min. Time Step: 6 µs

Interface: Aurora

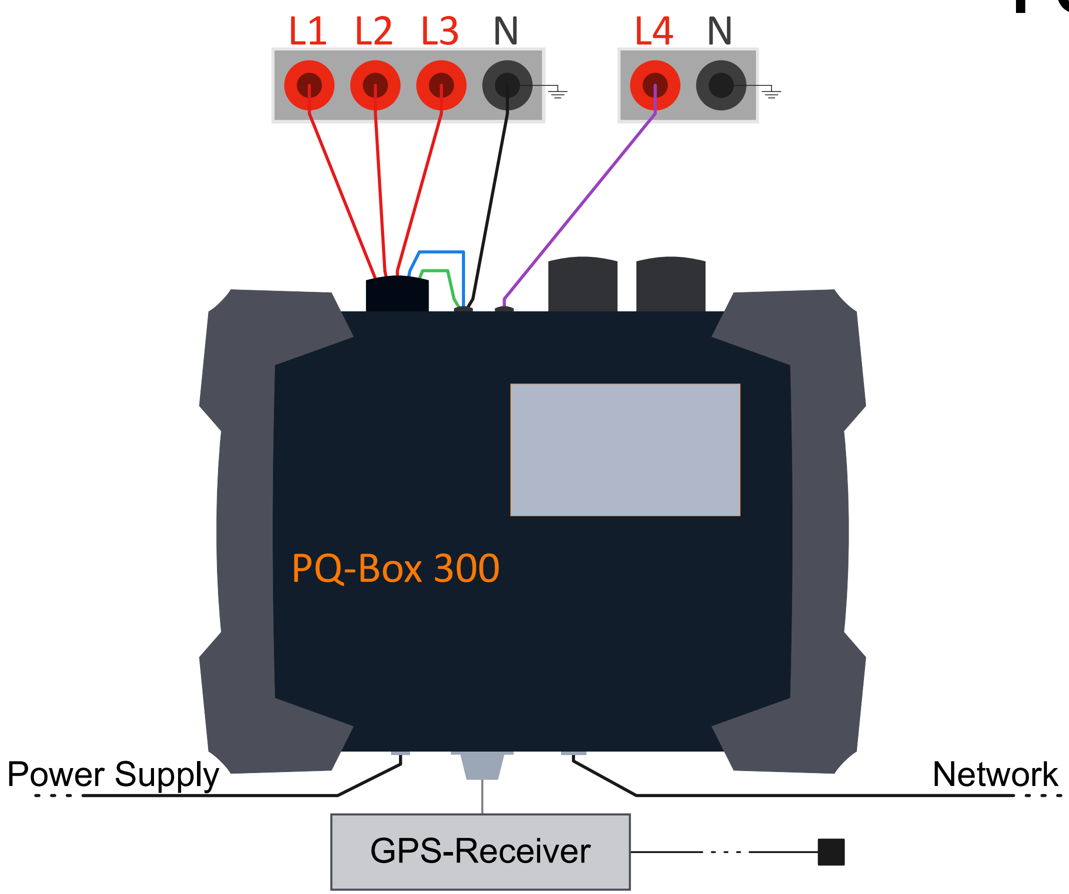
$\Rightarrow f_{Nyq} = 83.3\ \text{kHz}$

[1] Analog operation

Measuring Device

PQ-Box 300

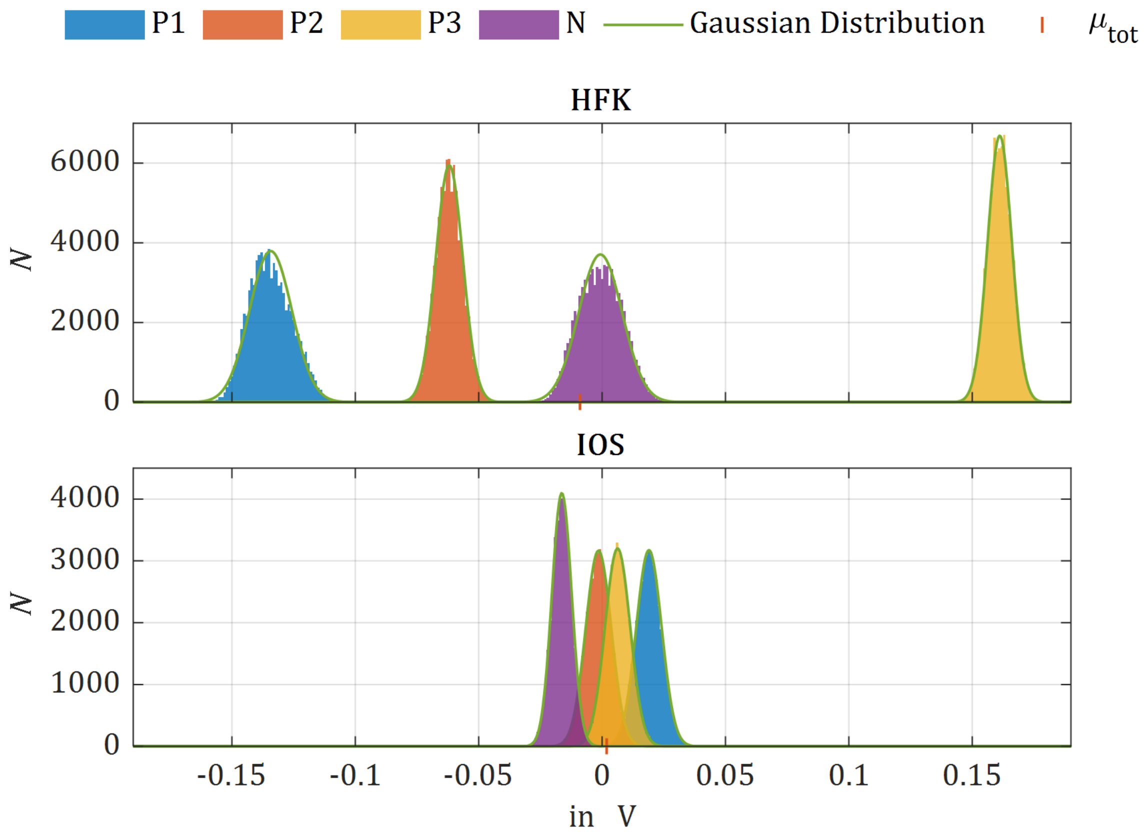
A. Eberle

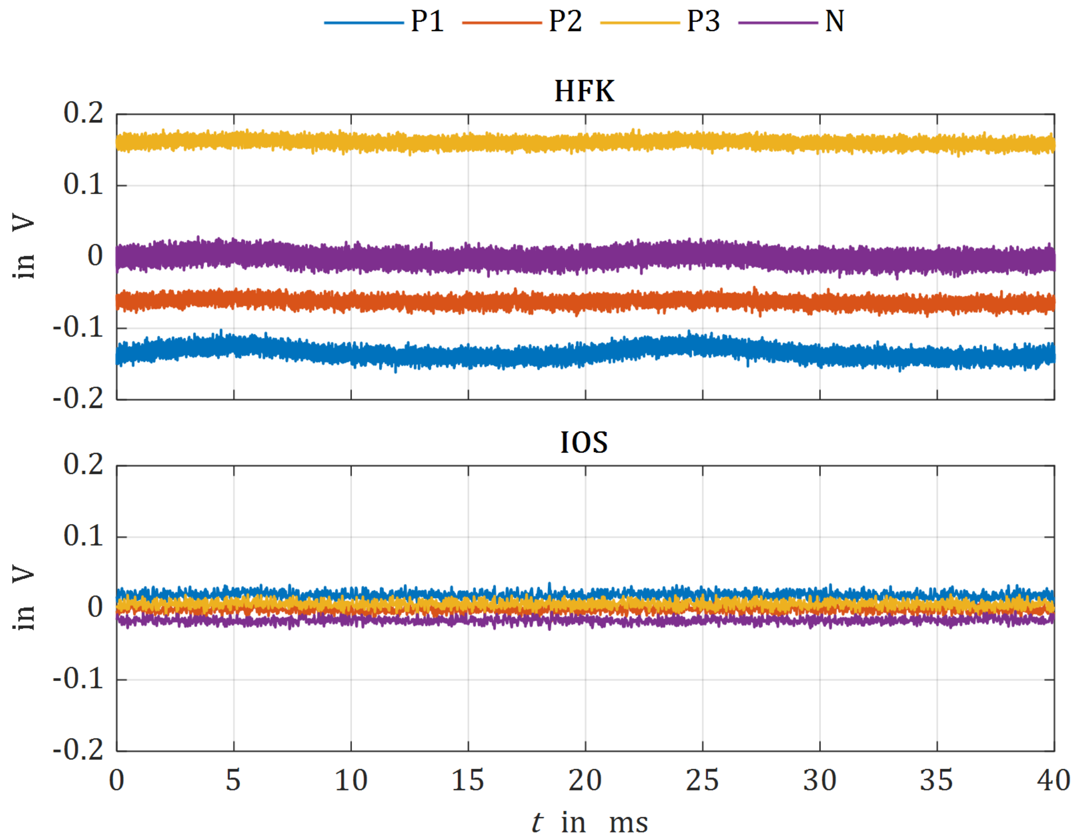


	HFK $\Rightarrow f_{Nyq,M} = 204.8$ kHz	IOS $\Rightarrow f_{Nyq,M} = 20.48$ kHz
Duration of a single measurement:	40 ms	> 200 ms
Number of Data Points of a Single Measurement	2^{14}	2^{13}
Avarage Sample Time:	2.44 µs	24.4 µs

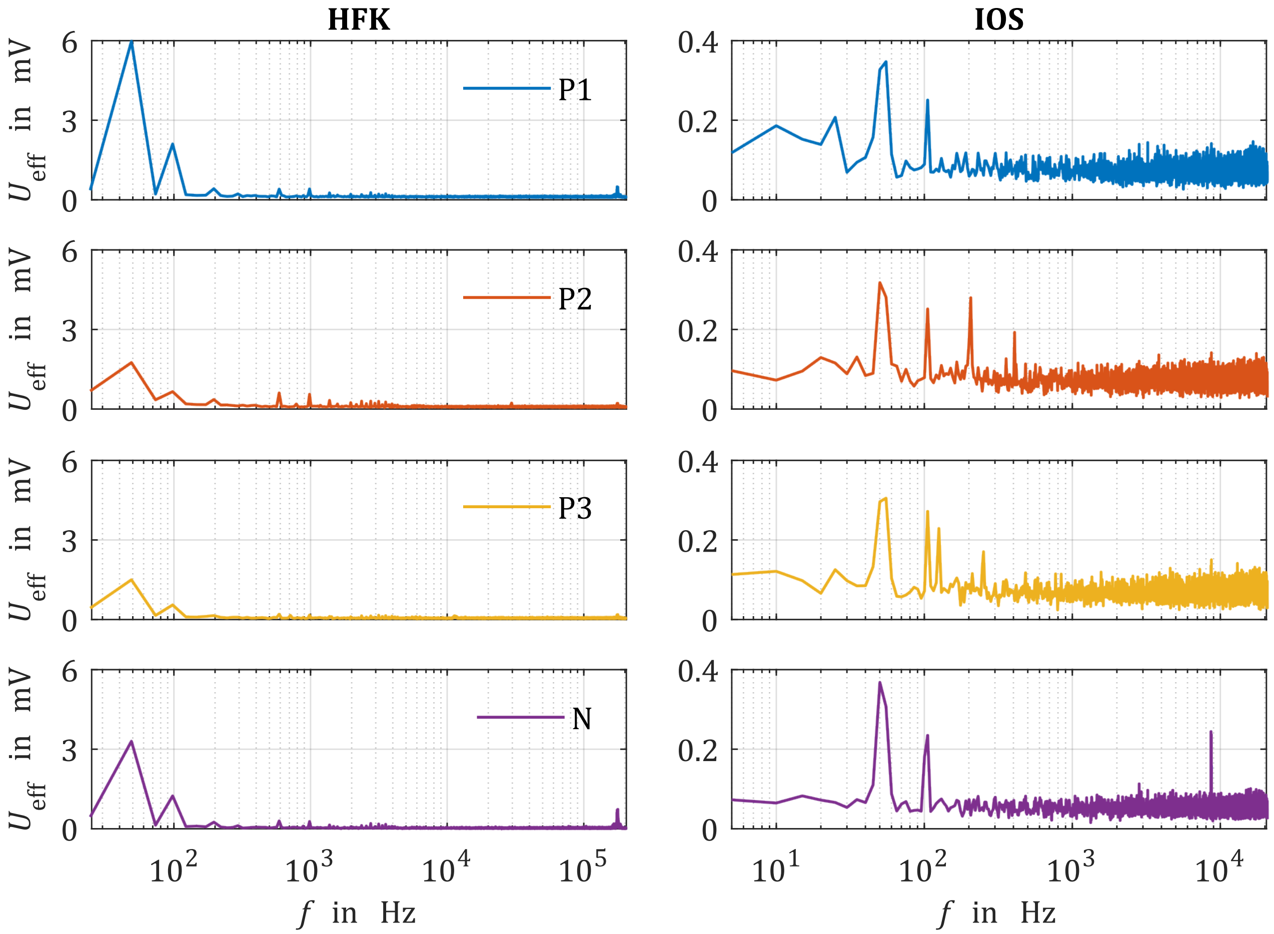
[1] Analog operation

Measurement of the Background Noise





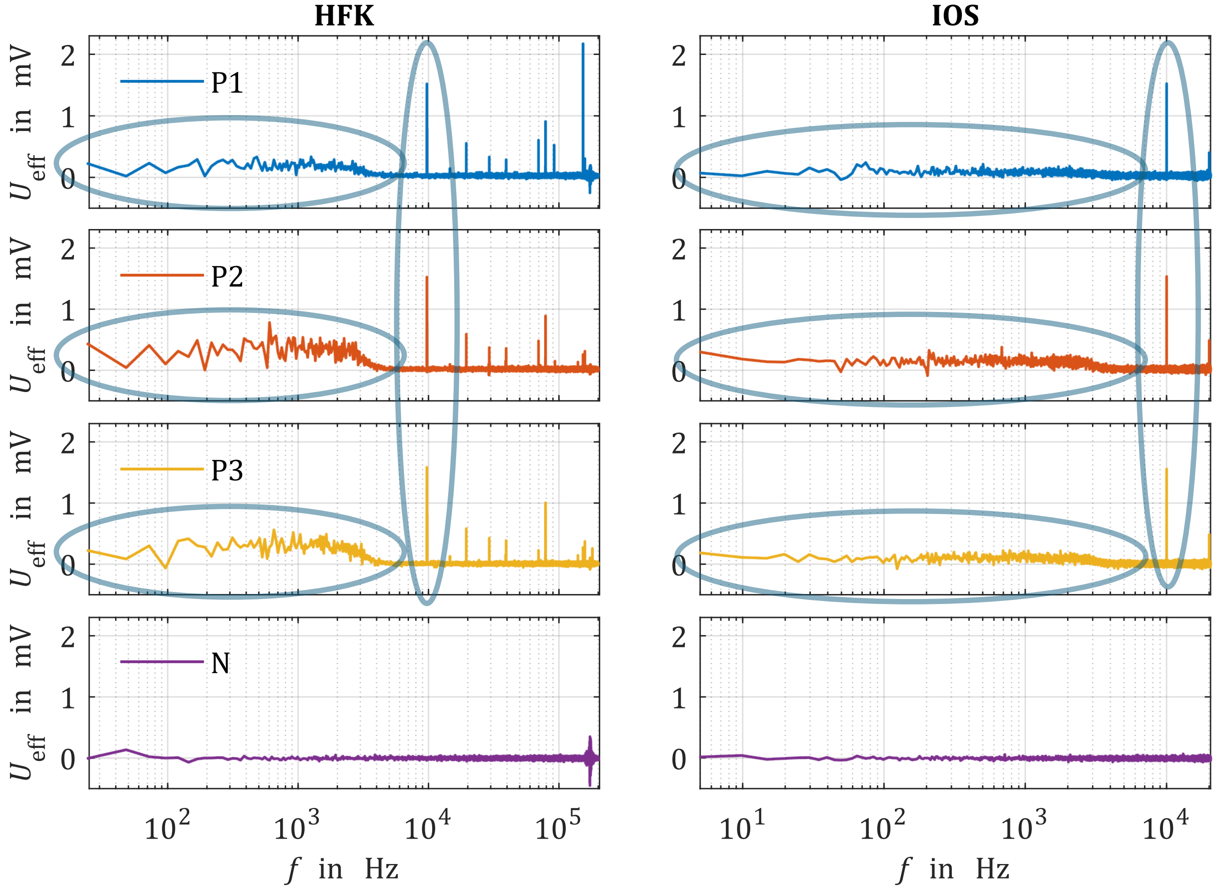
Frequency Behaviour of the Background Noise



[1] Analog operation

Noise of the Amplifiers

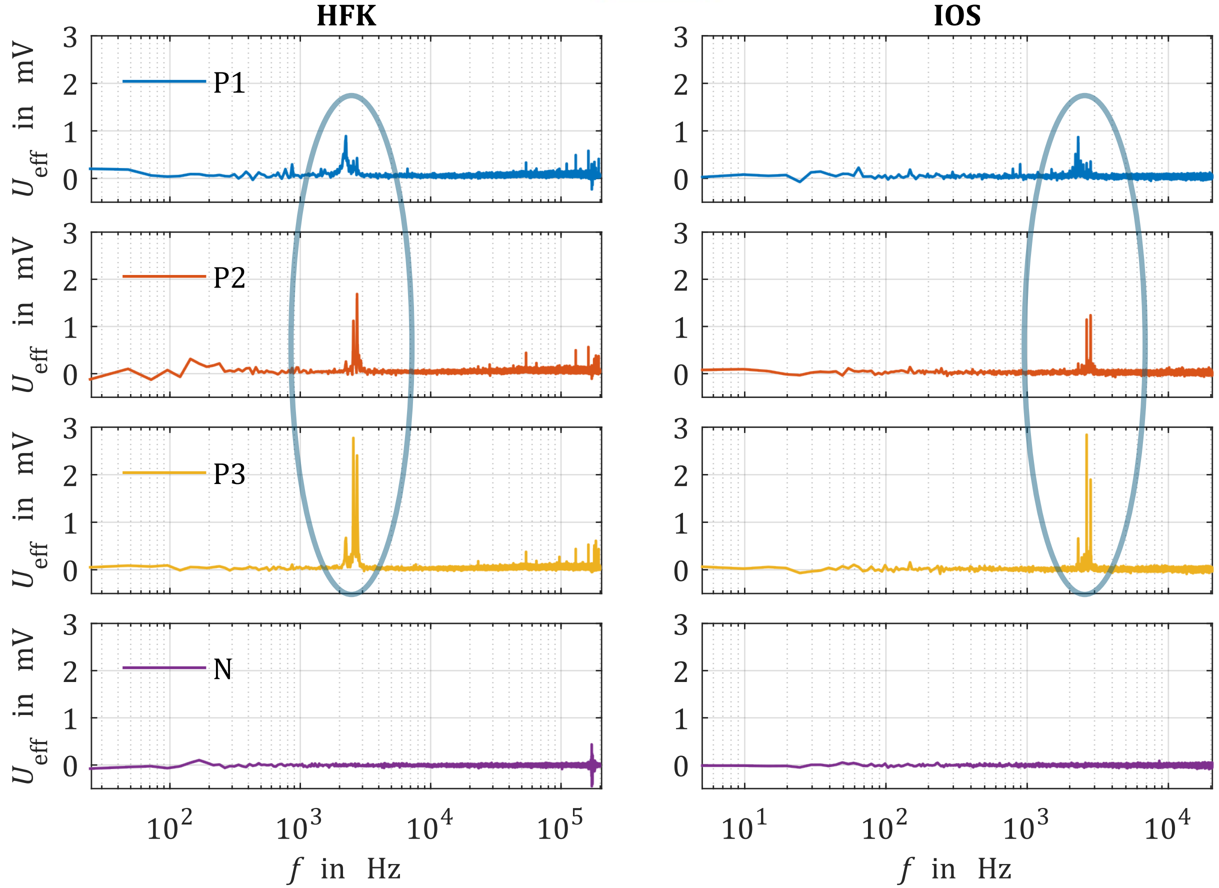
OMICRON



⇒ Sampling Frequency of the Analog Input

⇒ Transmission of the Noise of the Analog Input

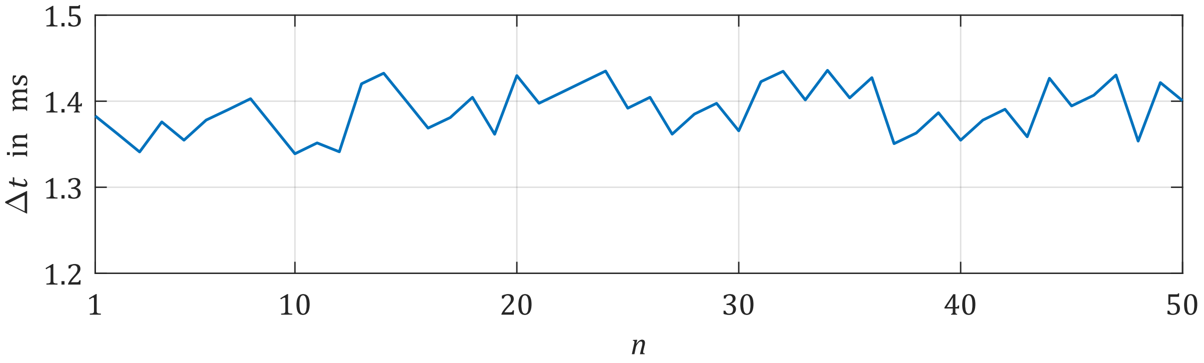
SPITZENBERGER SPIES



⇒ Unknown Cause

Dead Time

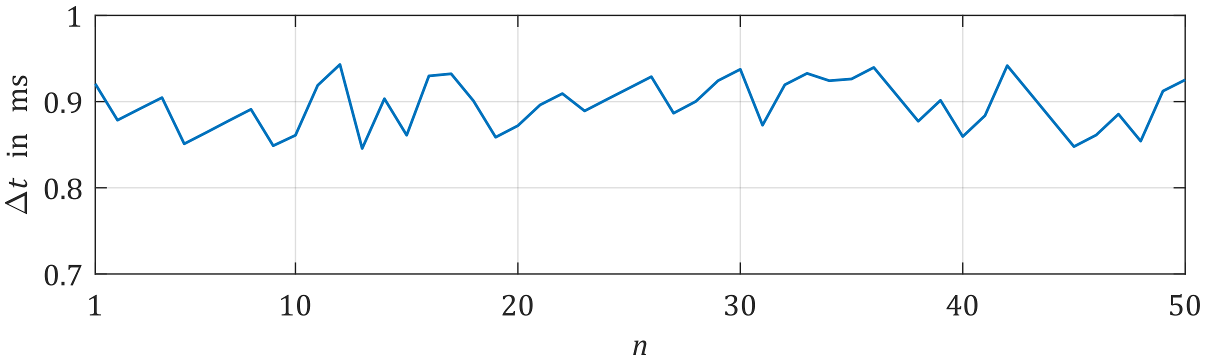
OMICRON



$\Delta t = 1.39 \pm 0.03$ ms

$\Delta t_H = \Delta t_{H,A} + \Delta t_{H,GTAO} = 0.51$ ms

SITZENBERGER SPIES



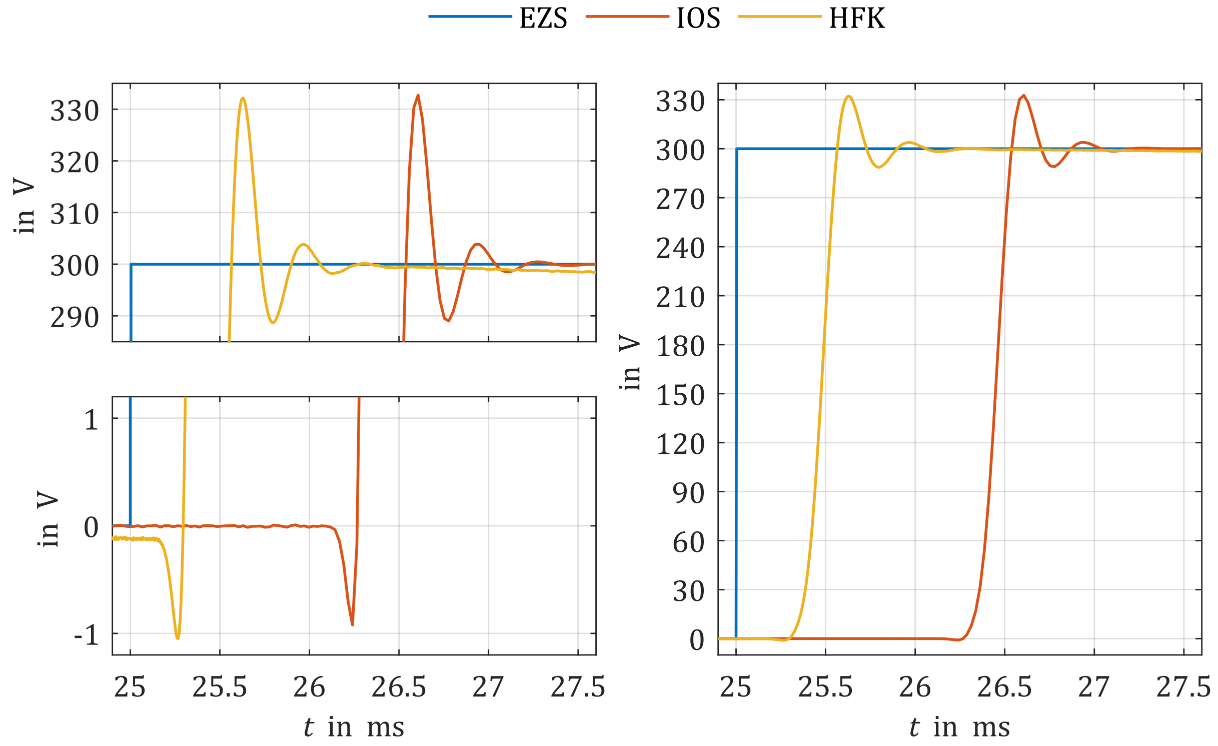
$\Delta t = 0.90 \pm 0.03$ ms

$\Delta t_H = \Delta t_{H,A} + \Delta t_{H,OF} = 6.4$ μs

$\Delta t_{PQ} = \Delta t - \Delta t_H = 0.89$ ms $\Rightarrow$ Dead Time of the Measurement itself

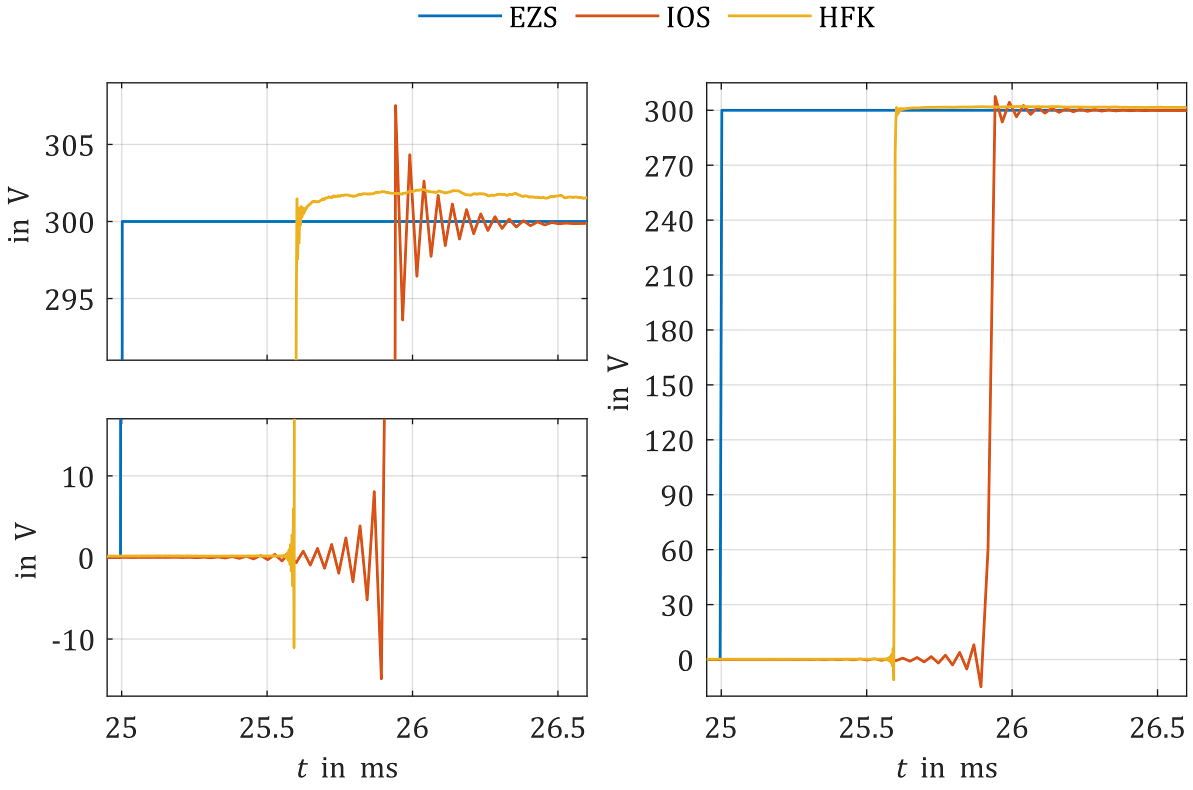
Step Response

OMICRON



$\Rightarrow f_E = 3$ kHz

SPITZENBERGER SPIES



$\Rightarrow f_E = f_{Nyq,M}$

Measurement of the Frequency Behavior

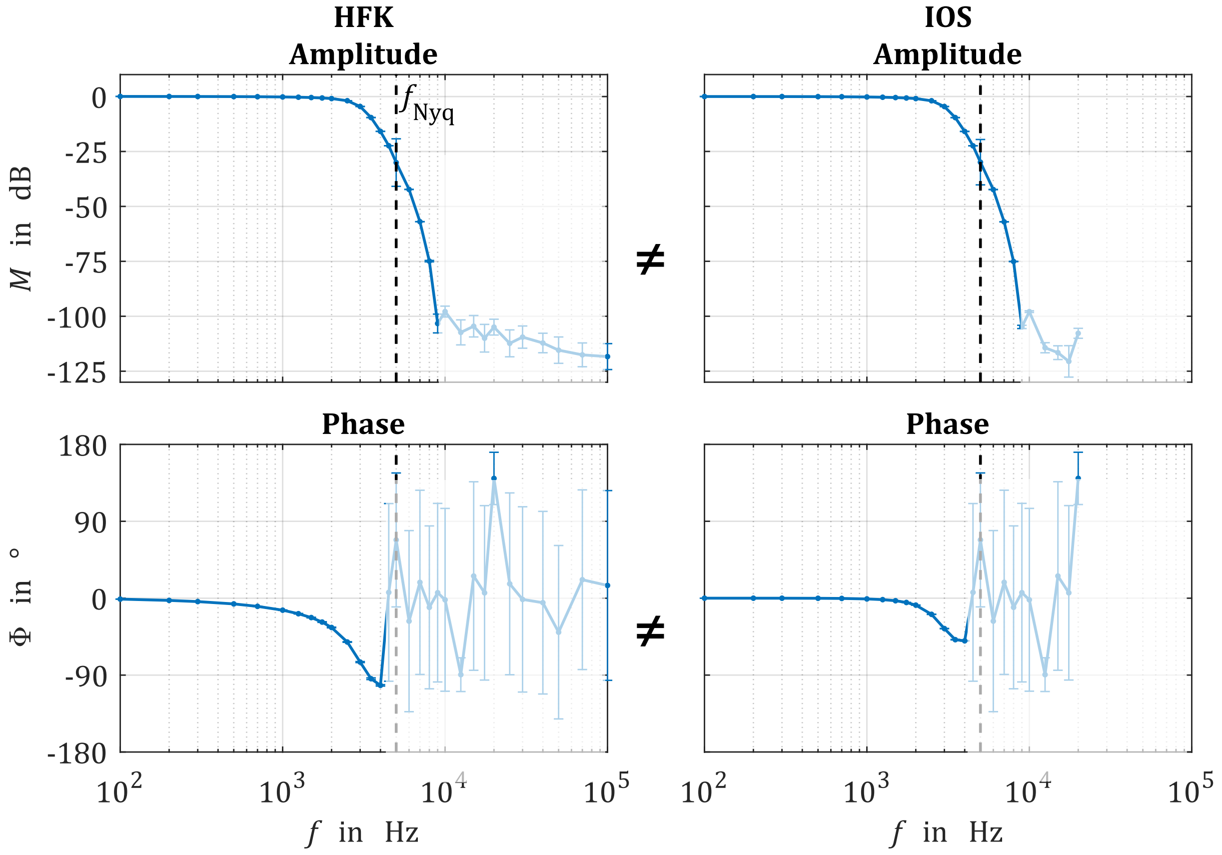
Double Sine Wave Series

$f_F = 50$ Hz $f_{H,i}$

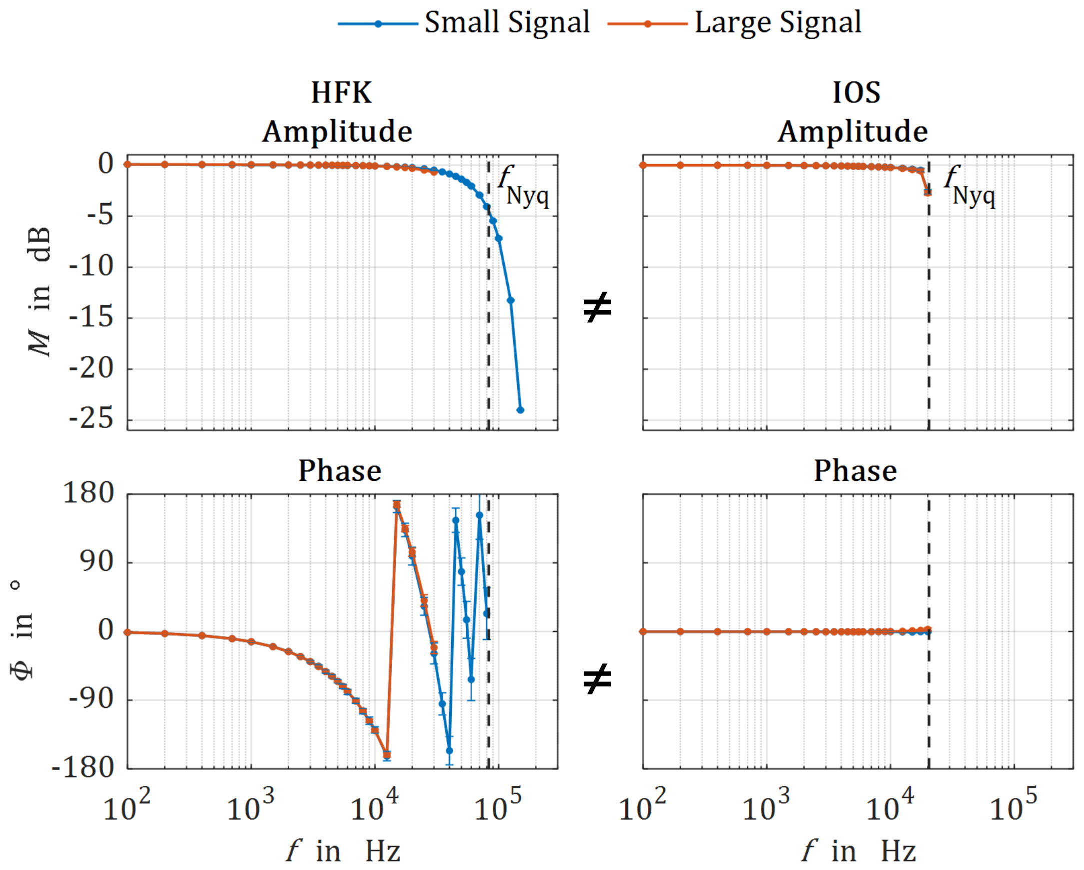
- Constant magnitude in the frequency range
- Time reference for precise measurement of the phase response
- Avoidance of the leakage effect
- Simple signal generation in RSCAD
- High signal-to-noise ratio for each individual measurement

Measured Frequency Response

OMICRON



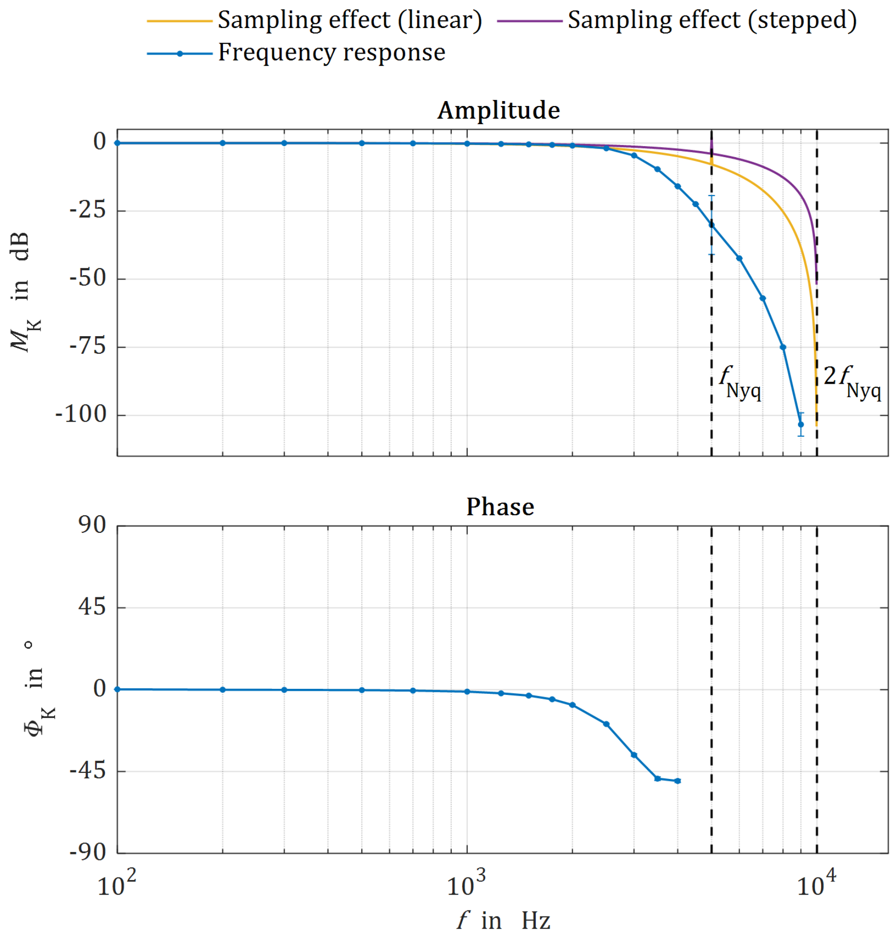
SPITZENBERGER SPIES

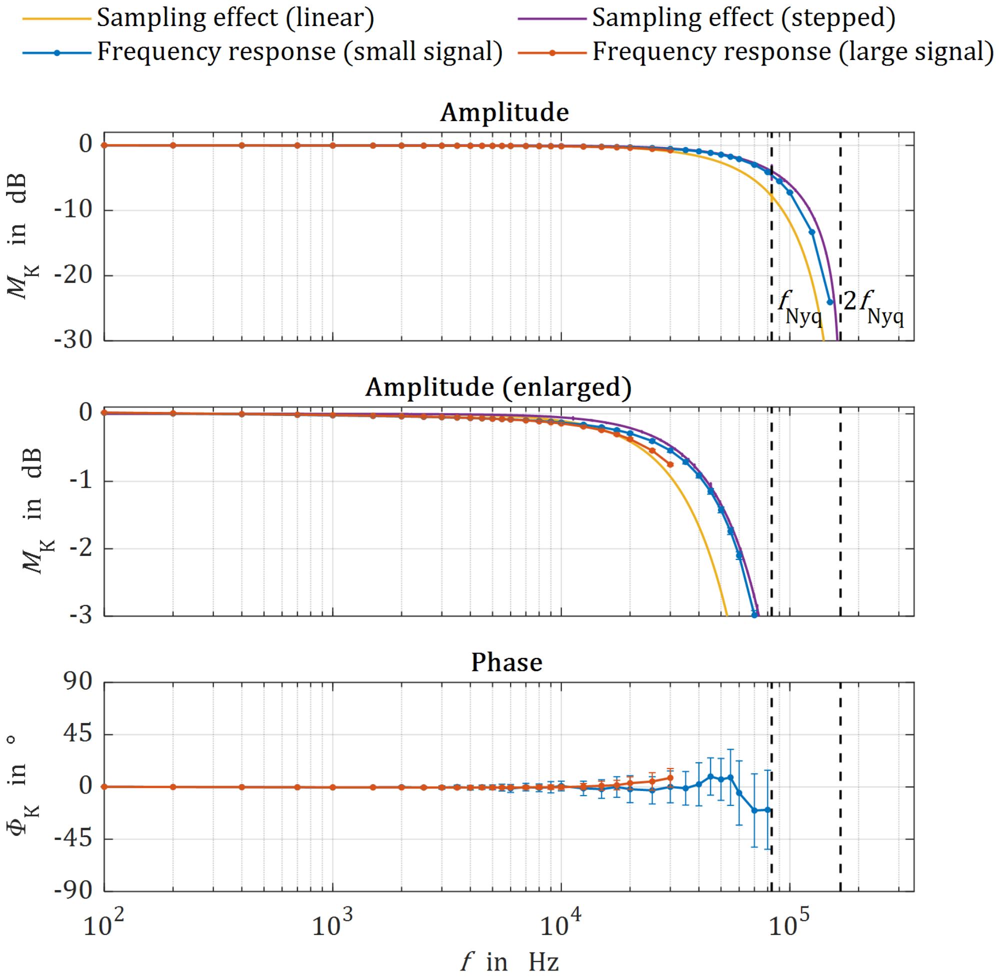


OMICRON

Measured Frequency Response

SITZENBERGER SPIES





Conclusions

The transmission behavior of a linear amplifier is strongly influenced by the effects of sampling:

- With the DM APS 30000 almost exclusively
- With the CMS 356 in superposition with the analog filters in the signal path

Outlook & To Dos

- Validation of the measurement results using another measuring device
- Comparasion of the Open Loop results with Closed Loop Measurements
- Transmission behavior under load

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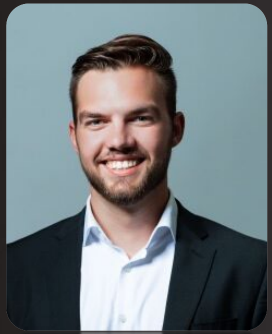
Thank you for your attention!



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