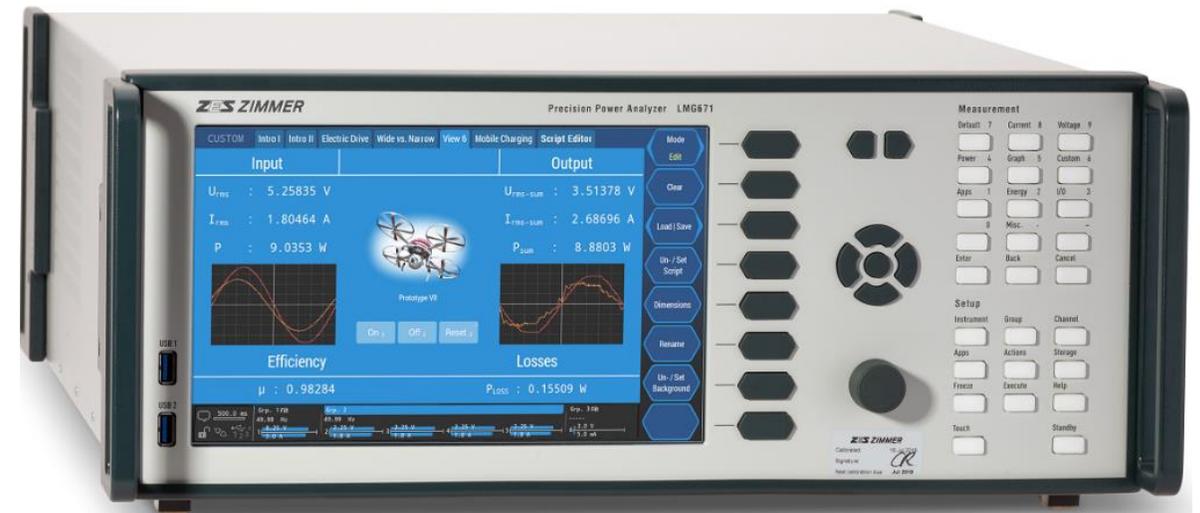


Selected Examples of Electric Power Measurements in Drive Systems

Power Electronics Event
June 19, 2019
Timothy Hertstein



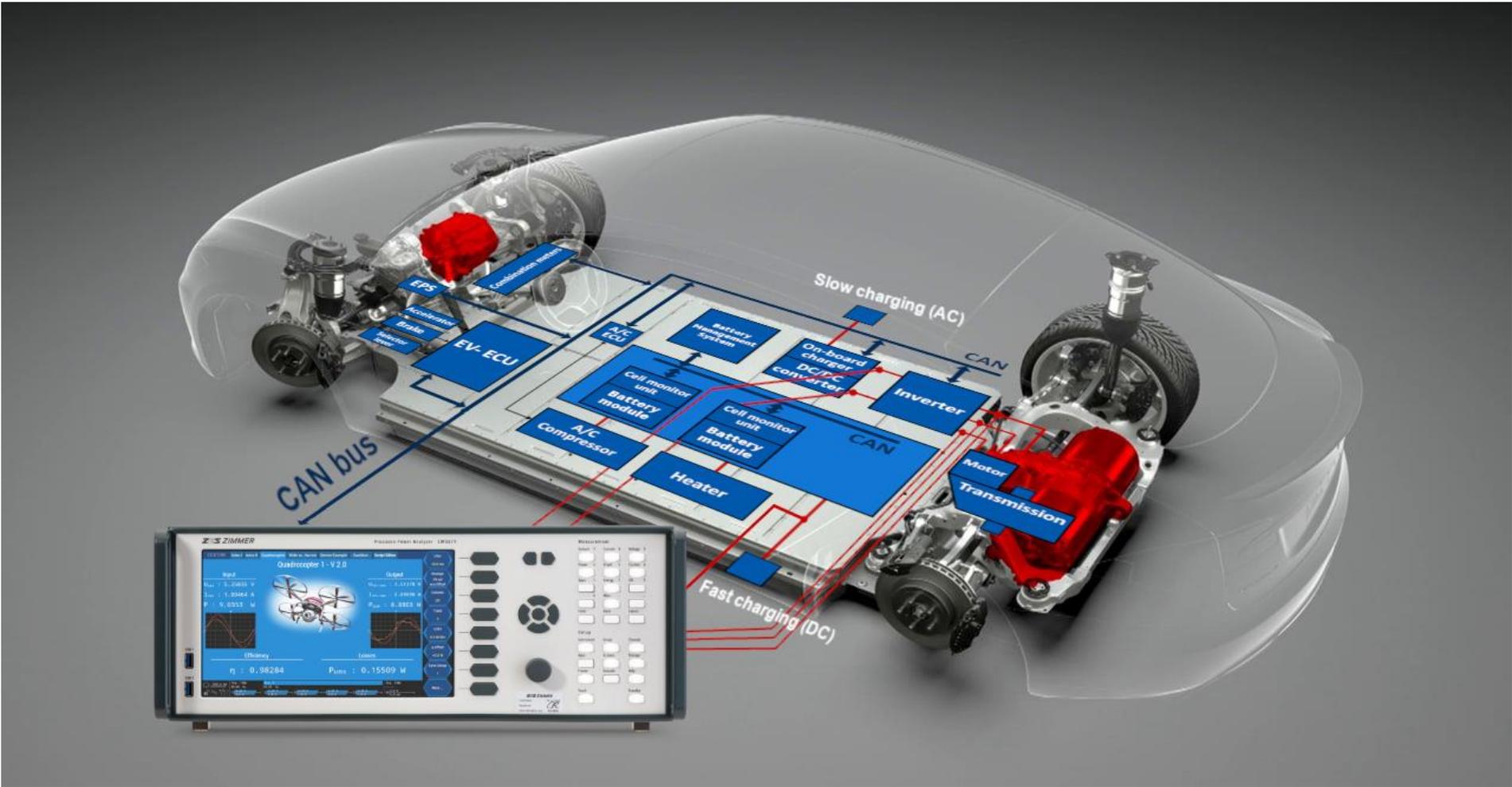
19 juni 2019
1931 Congrescentrum 's-Hertogenbosch

**POWER
ELECTRONICS** 2019

Challenges & Pitfalls

- The importance of synchronisation
- Why accuracy **and** bandwidth are necessary
- The influence of accuracy on efficiency and losses
- Aliasing and how to avoid it
- Requirements for DC link measurements
- How to measure sub-cycle behaviour
- Common mode errors and their prevention

Drive system measurements: many sources, lots of data

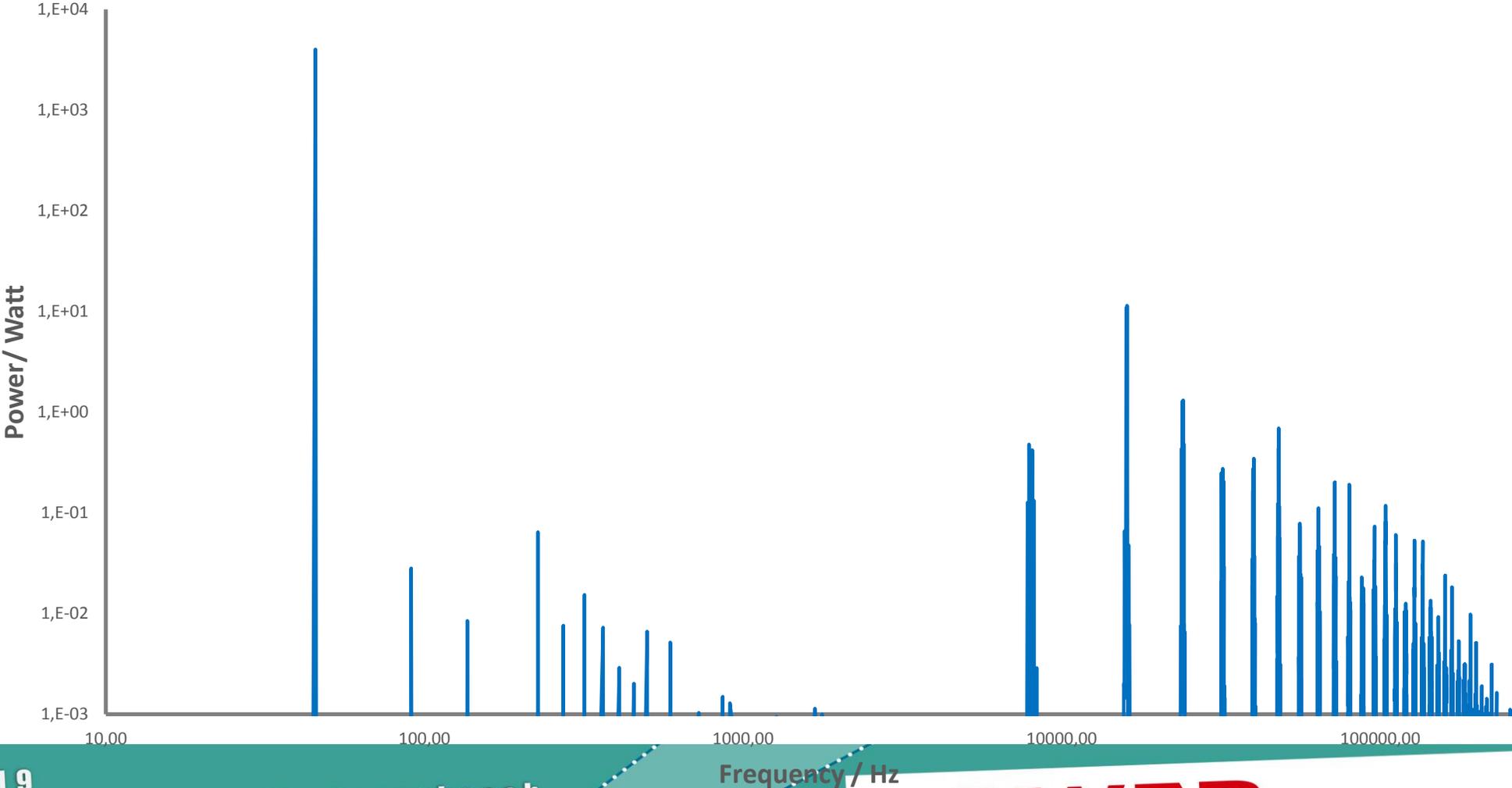


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**POWER
ELECTRONICS**

2019

Power Spectrum (18kW, no load, close to VFD)

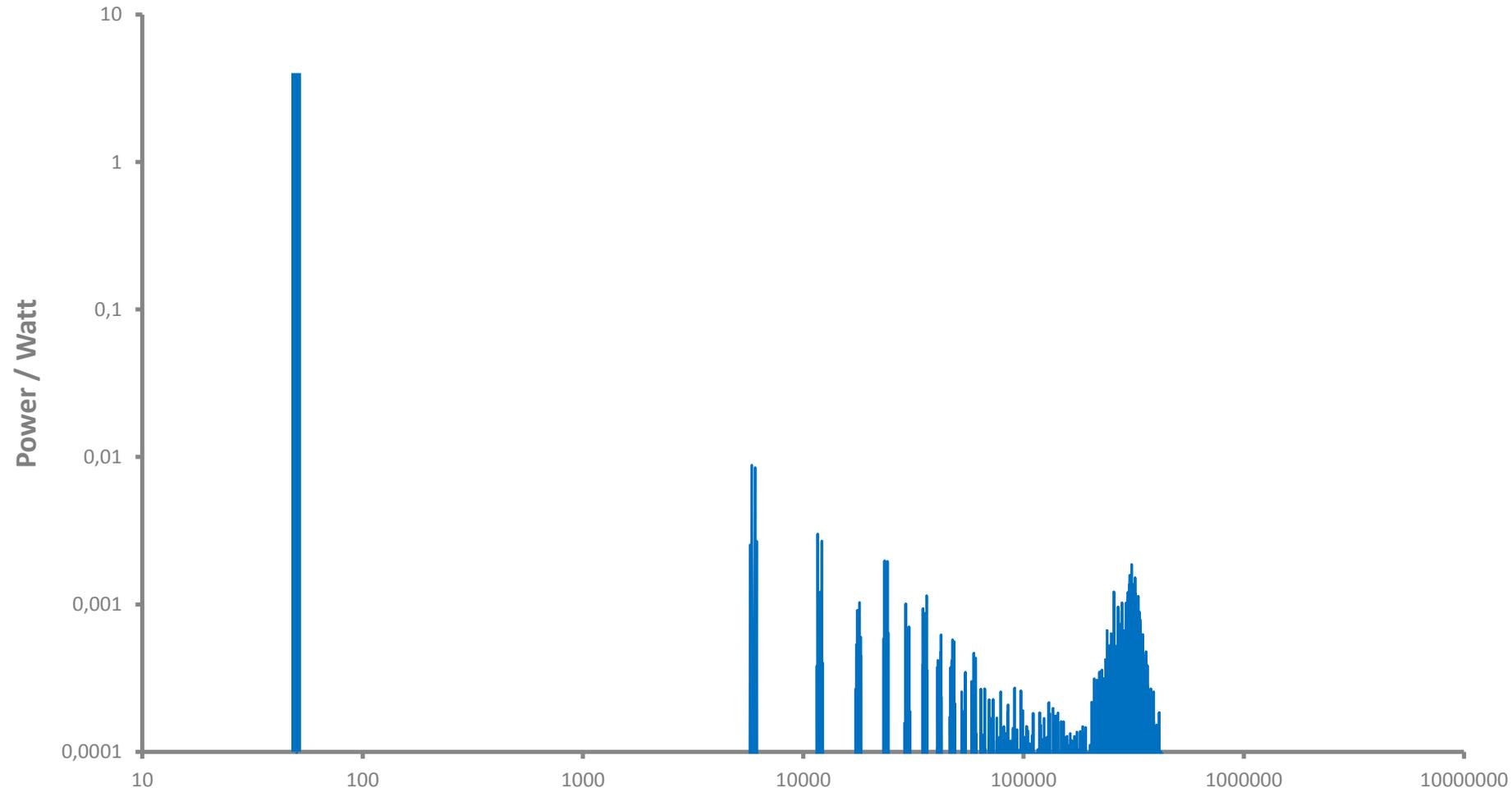


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POWER
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2019

Power Spectrum (4W, no load, 100m cable)



19 juni 2019
1931 Congrescentrum 's-Hertogenbosch

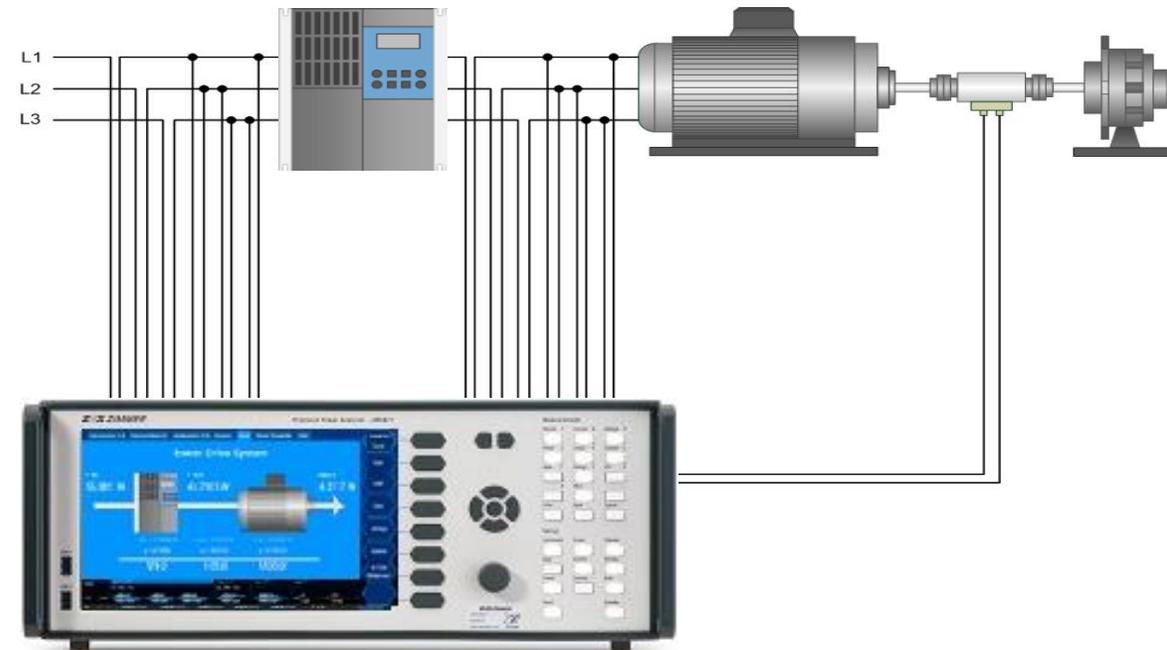
Frequency / Hz

POWER
ELECTRONICS

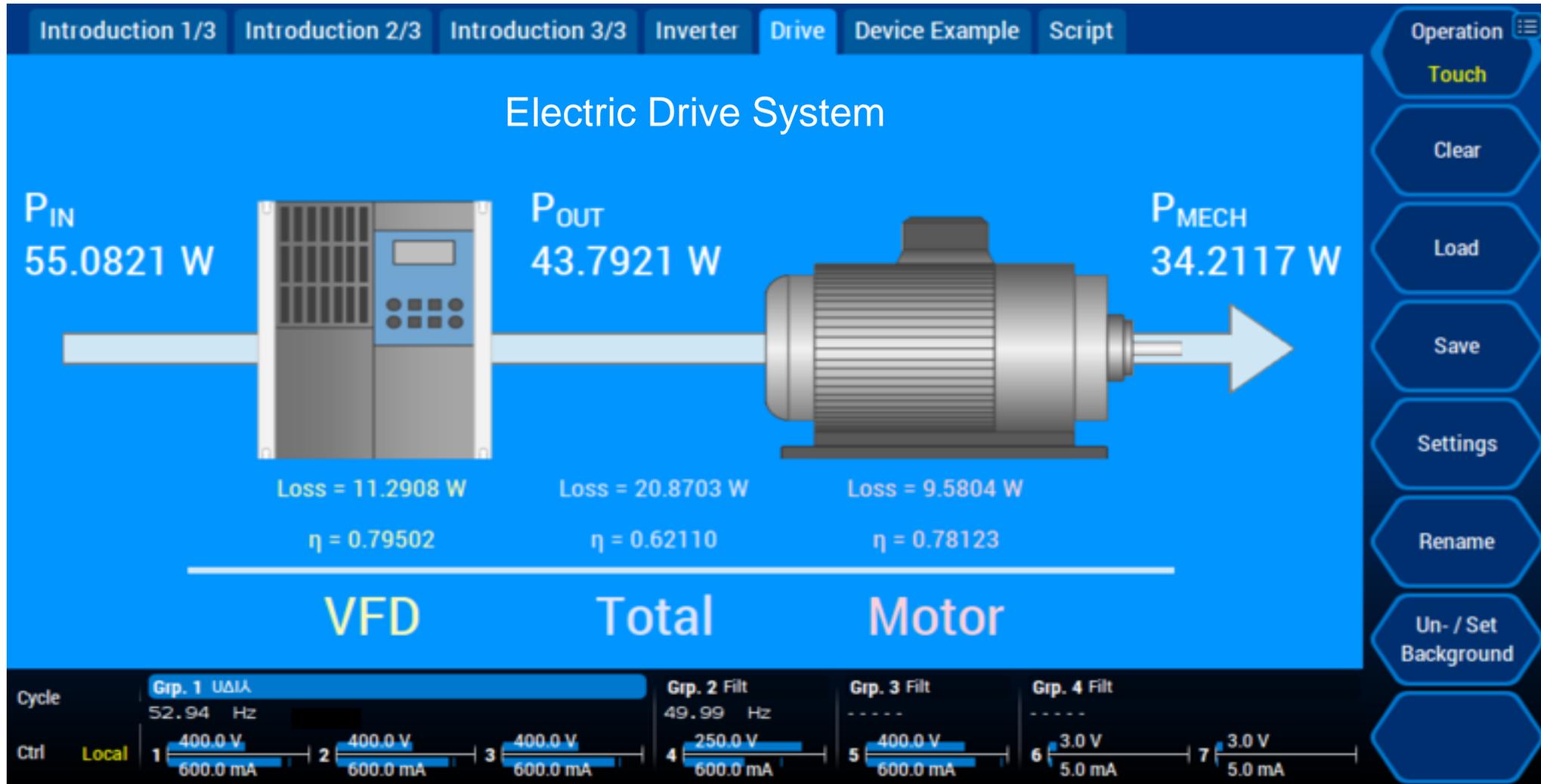
2019

Typical drive system measurements

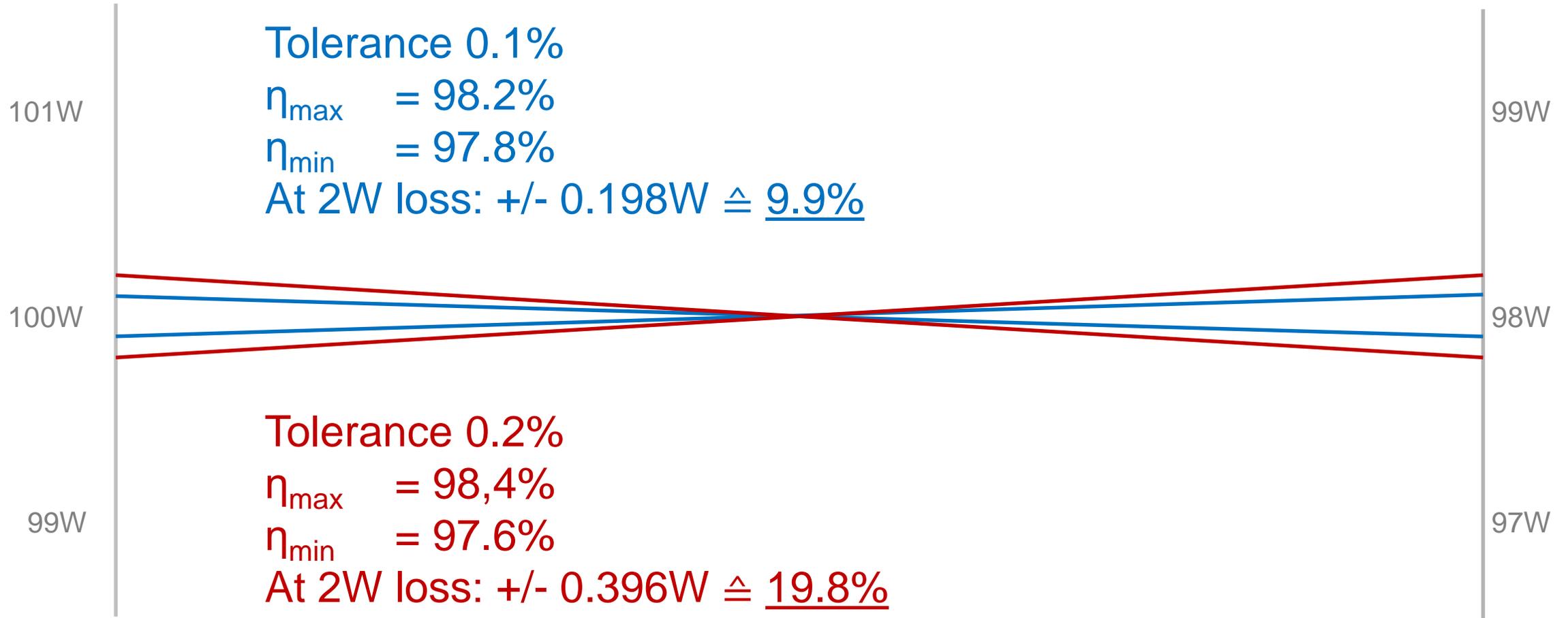
- Efficiency
 - Drive/frequency converter
 - Motor
 - Motor drive combination
- DC link
 - Residual ripple
- Start-up behaviour
- Error influences
 - General observations
 - Common mode errors



Efficiency considerations

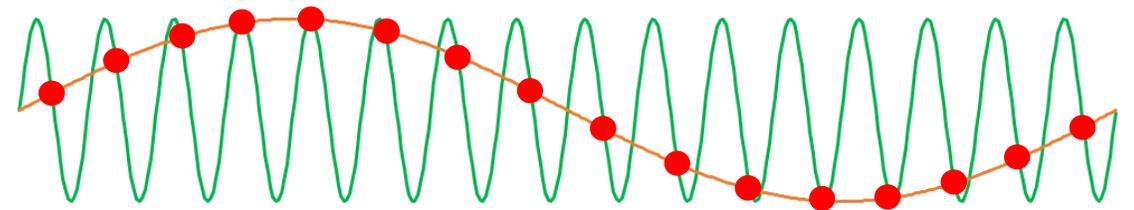


Influence of accuracy

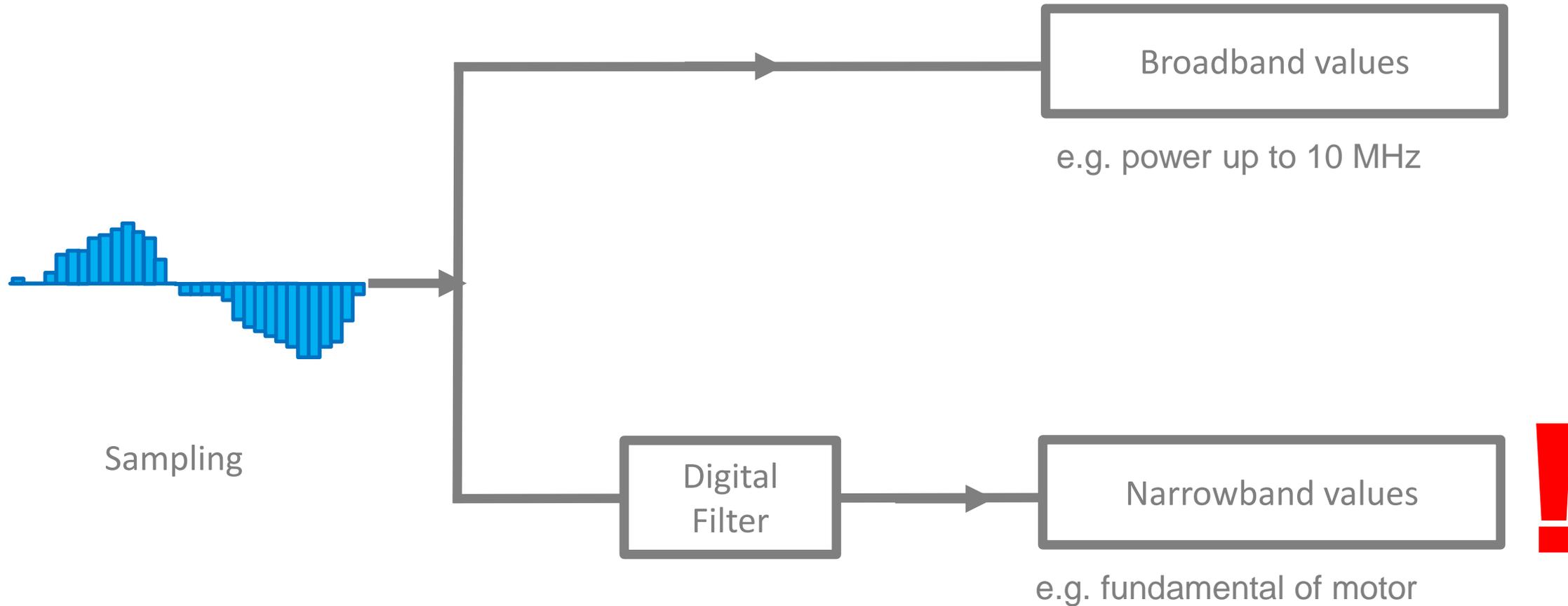


Filter Dilemma

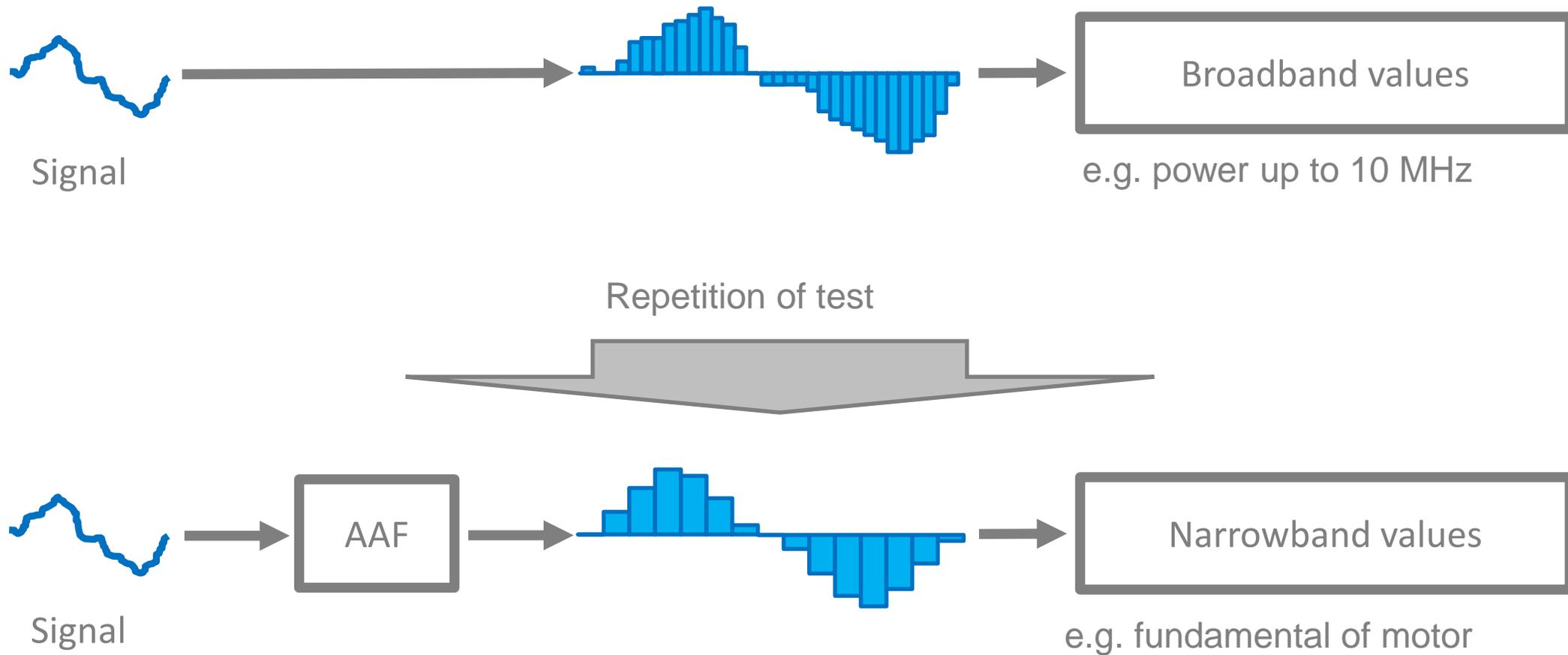
- Requirements for drive/motor efficiency measurements:
 - Determination of broadband RMS power
 - Undersampling not critical for RMS power measurement
- Requirements for measuring potentially torque-relevant portion at drive output:
 - Isolation of fundamental
 - FFT or filtering required
 - Danger of aliasing!



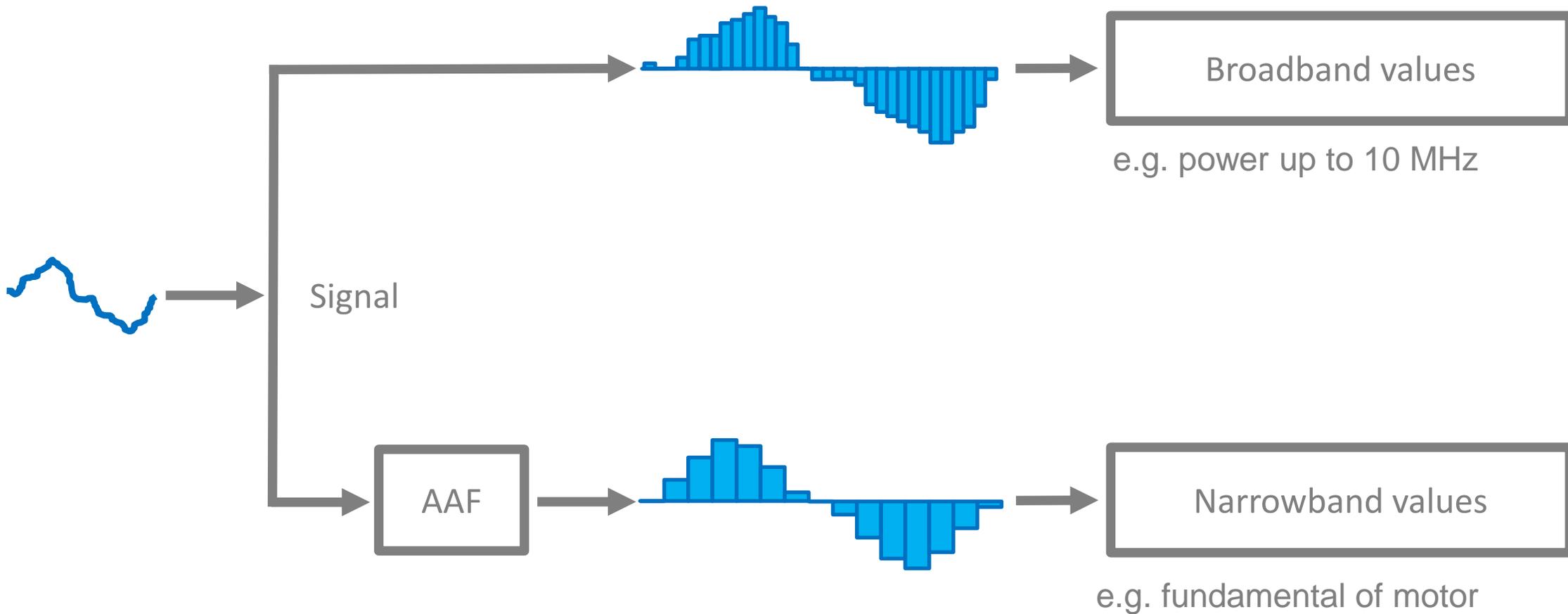
Risky: Sampling without Anti-Aliasing Filter



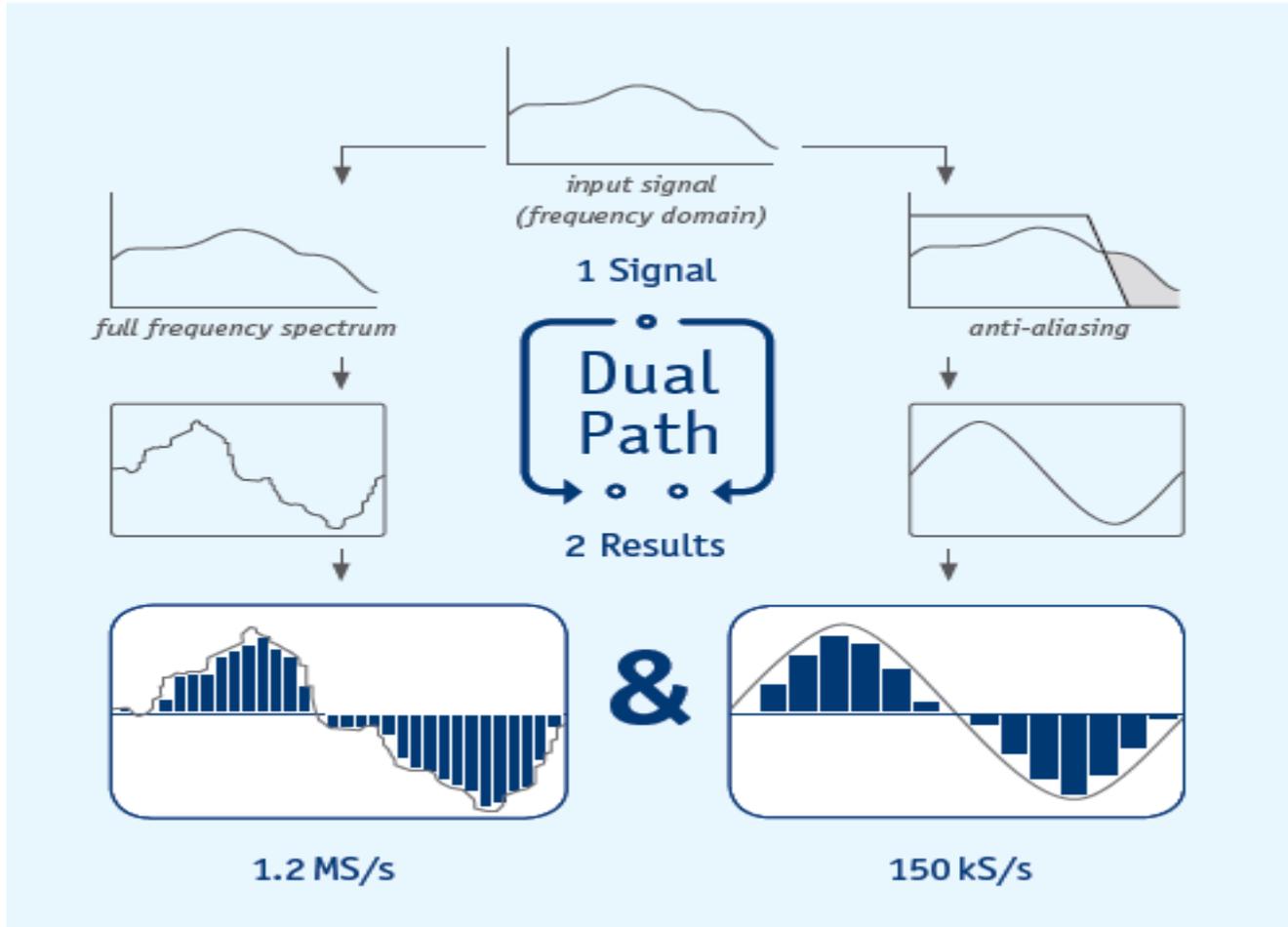
Safe, but laborious: repeated sampling



Safe: double, parallel sampling

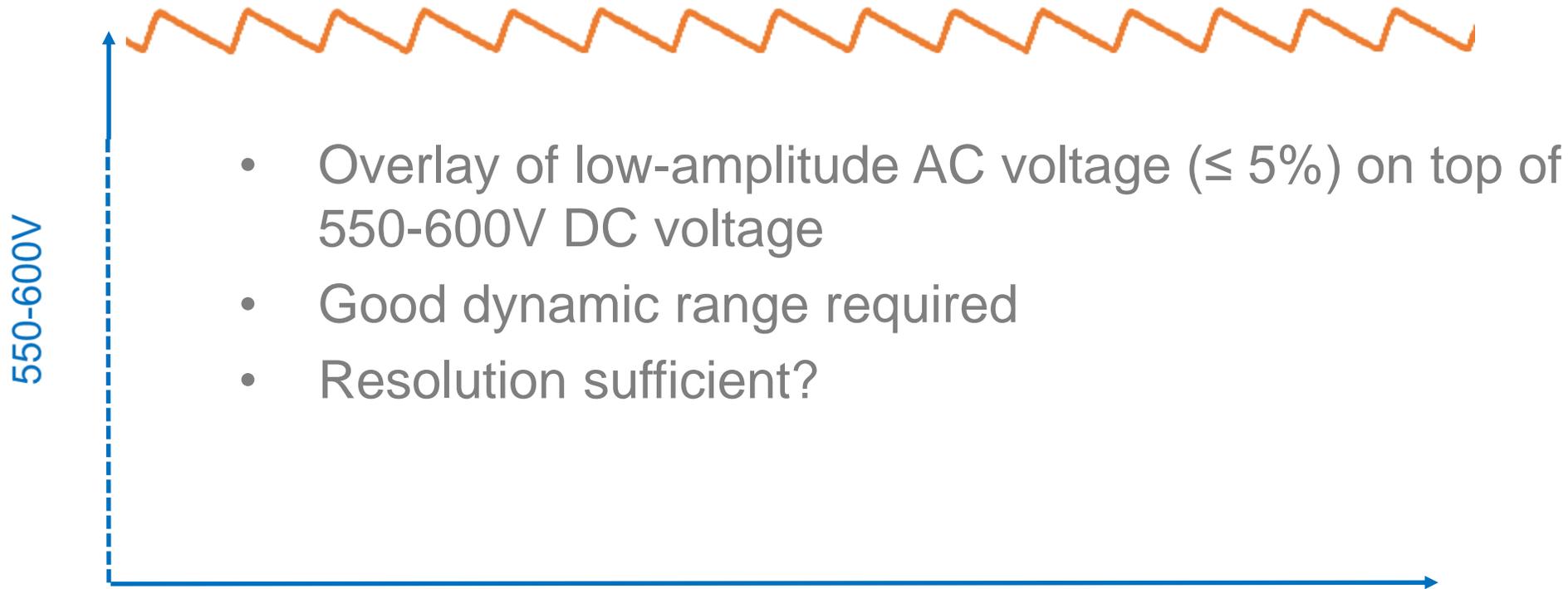


Novel approach: Dual Path



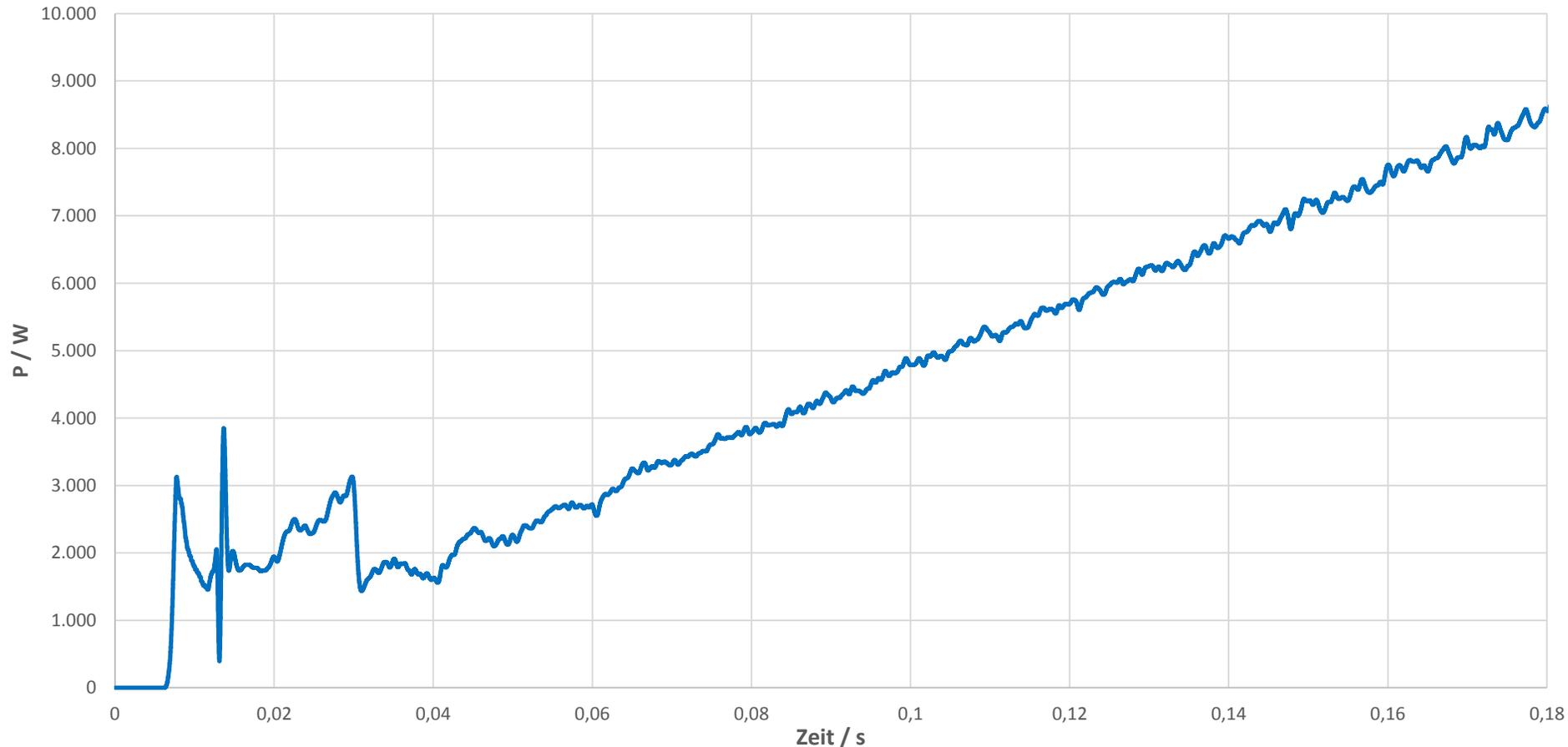
- Truly parallel measurement of broad- and narrowband values only possible with additional hardware
- Aliasing risk eliminated
- Time-savings by eliminating repeat measurements

DC link measurements: residual ripple



Motor start-up behaviour

Power at motor start-up

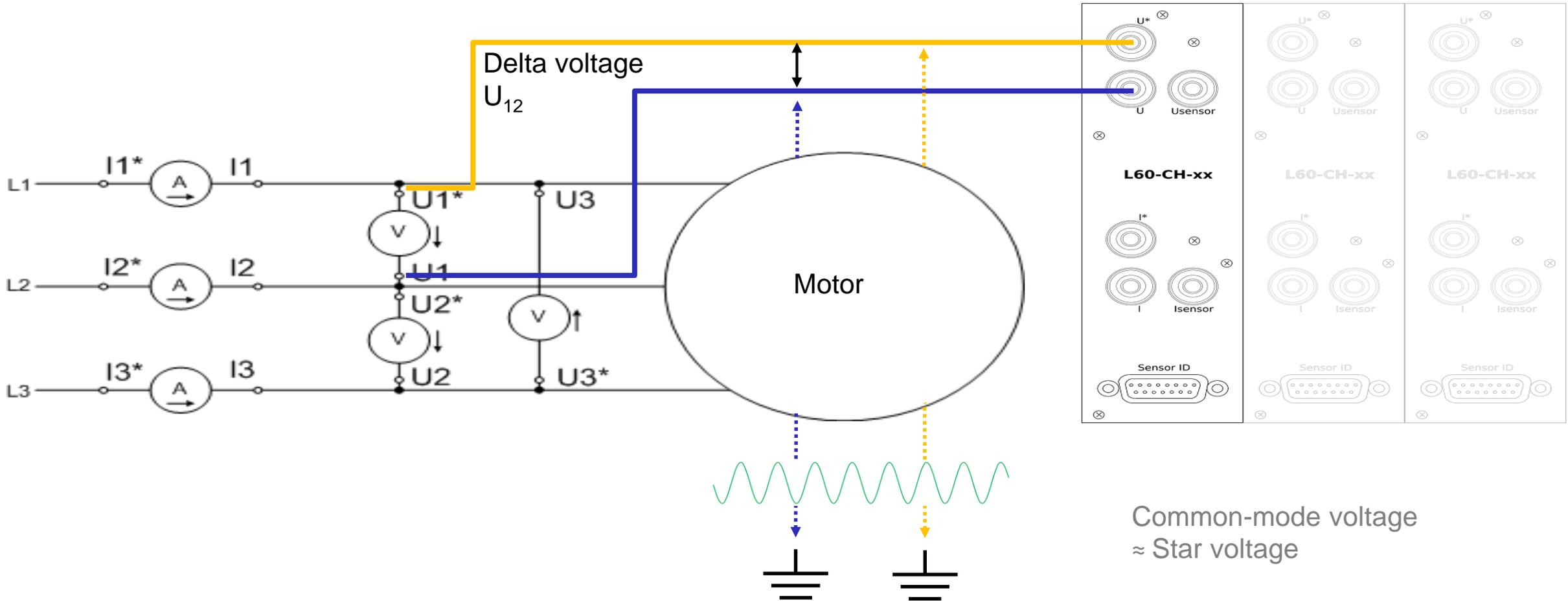


“In three-phase electrical systems the instantaneous real power presents symmetries [...], depending on the system being balanced or not, and having or not even harmonics.

Since the instantaneous zero-sequence power presents an equal or smaller symmetry period, the instantaneous three-phase power, [...], presents the same kind of symmetries.

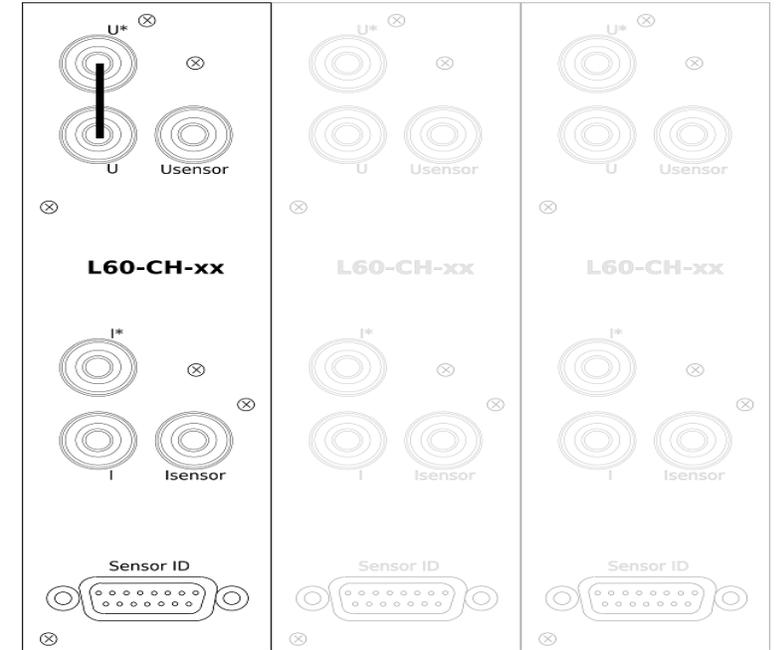
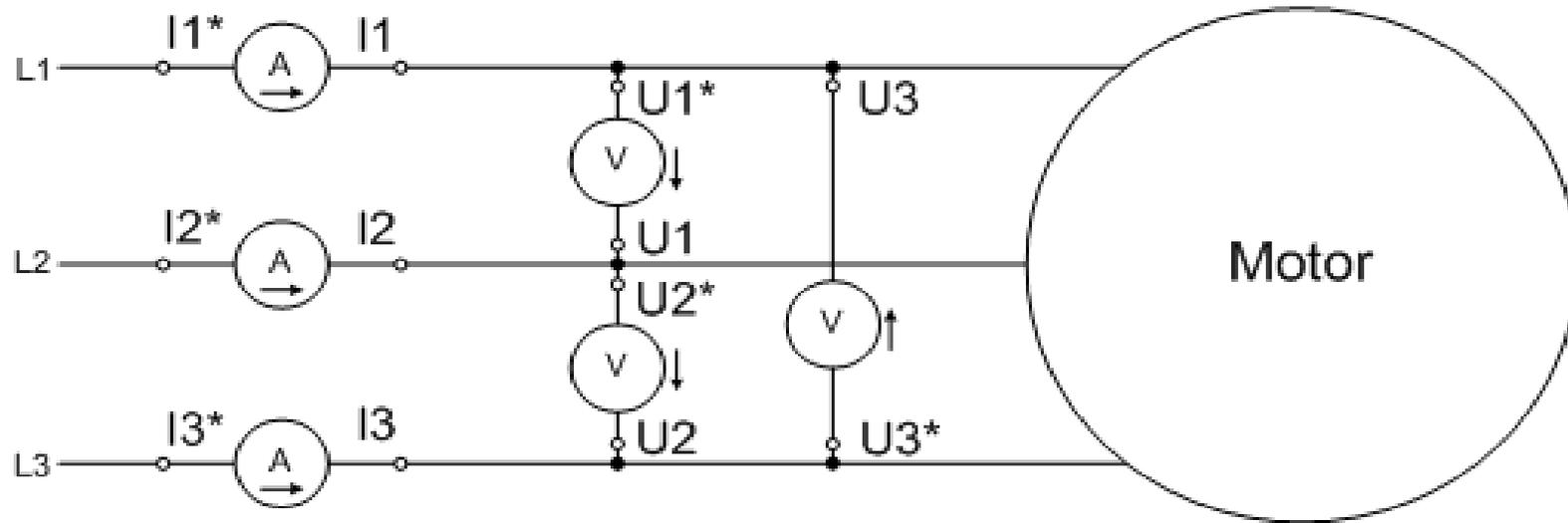
This paper suggests the utilization of a sliding window, in a digital control system, to calculate the mean value of the instantaneous real power, exploiting the symmetries described above.”

Influence of common-mode signals



Common-mode errors: a simple test (Step 1)

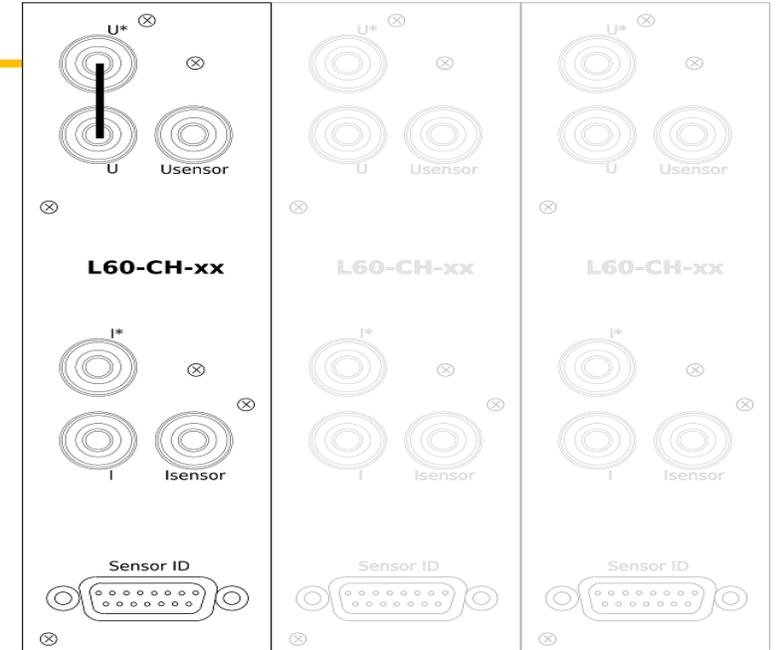
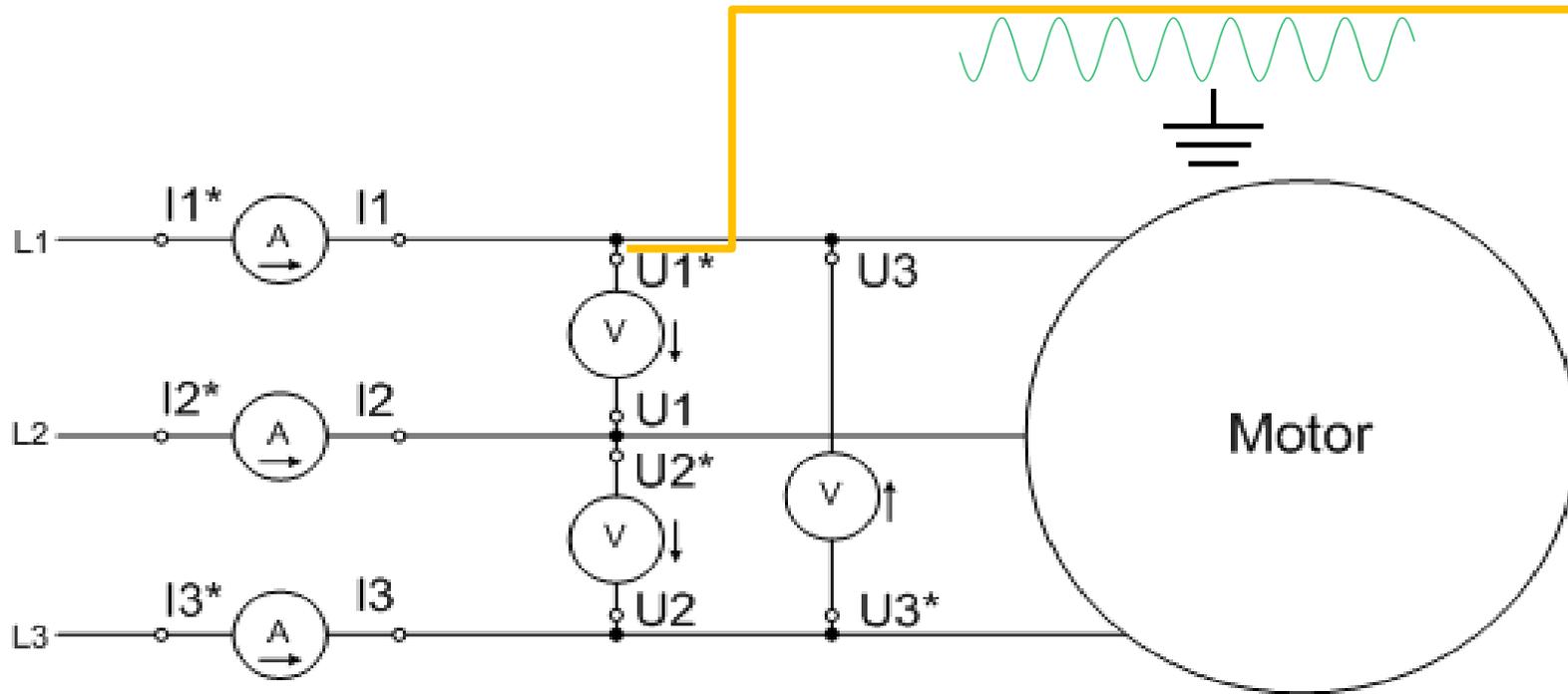
Shorting voltage input
Filters deactivated!



	1
U_{tms}	0.009 V

Common-mode errors: a simple test (Step 2)

Applying frequency converter phase voltage



	1
U_{tms}	0.021 V

Common-mode error: numerical estimation

Measured value with shorted voltage channel:

$$\sqrt{U_{DC}^2 + U_{NOISE}^2} = 9\text{mV}$$

Measured value with frequency converter phase voltage applied:

$$\sqrt{U_{DC}^2 + U_{NOISE}^2 + U_{CM}^2} = 21\text{mV}$$

Common-mode voltage influence on measured value:

$$U_{CM} = \sqrt{21\text{mV}^2 - 9\text{mV}^2} \approx 19\text{mV}$$

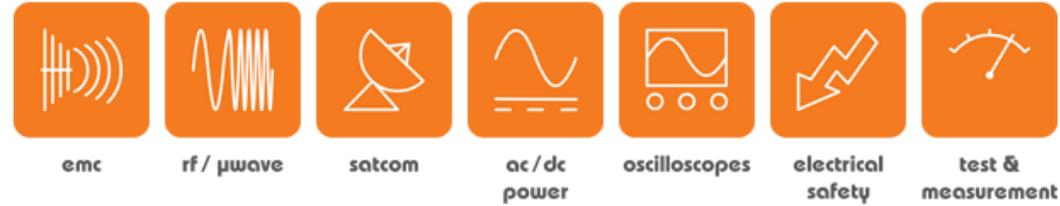
Relative influence common-mode signal at 180V phase voltage:

$$0,019\text{V}/180\text{V} \approx -80\text{dB}$$

References

p-q Theory Power Components Calculations, João L. Afonso, Member, IEEE, M. J. Sepúlveda Freitas, and Júlio S. Martins, ISIE'2003 - IEEE International Symposium on Industrial Electronics, Rio de Janeiro, 2003

ZES ZIMMER Applikationsbericht 109 (Rev. 1.4): Elektrische Leistung und Wirkungsgrad am Frequenzumrichter zuverlässig messen, Thomas Jäckle, Oberursel, 2014



Thank you very much for your attention!
Questions?



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