

Welcome to the webinar "Efficiency Testing on Electrical Drive Trains"

LIVE power calculations

....and....

continuous and synchronous acquisition of electrical and mechanical signals for verification and analysis

The webinar starts at 10 a.m.

- All participants' **microphones** are **muted** during the webinar.
- Please do not forget to **activate** your PC **speakers** to enable **audio** or connect **headphones** to your PC.
- Please use the '**Questions and answers**' window, if you have any questions. We will answer questions at the end of the presentation.



- We will email the presentation to you after the webinar.
- The webinar is recorded and will soon be made available on our website.

- Klaus Lang, Focus Sales Manager T&M
HBM Test and Measurement
- Degree in electrical engineering
- 30 years experience in
fast electrical data acquisition
- 10 years product manager for
GOULD digital storage oscilloscopes
- 10 years marketing manager for
NICOLET transient recorders
- Since the acquisition of NICOLET by HBM in 2009, responsible
as Focus Sales Manager for „eDrive“, which is defined as
"testing of inverters and inverter driven electrical machines“



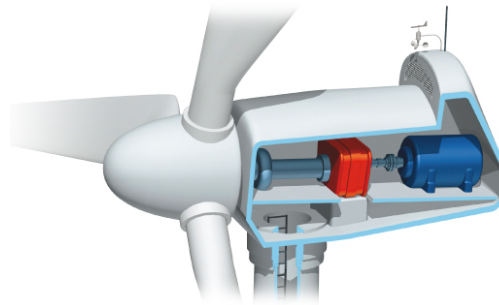
Dipl.-Ing. Klaus Lang
Focus Sales Manager T&M
HBM Test and Measurement

Tel. +49 6151 803 8382
E-Mail: klaus.lang@hbm.com

Electrical drives: Various application examples



Industrial VF inverter



Wind energy generator



Electrical or hybrid car



Electrical ship motor



Electrical
Forklifter



3ph AC
industrial motor

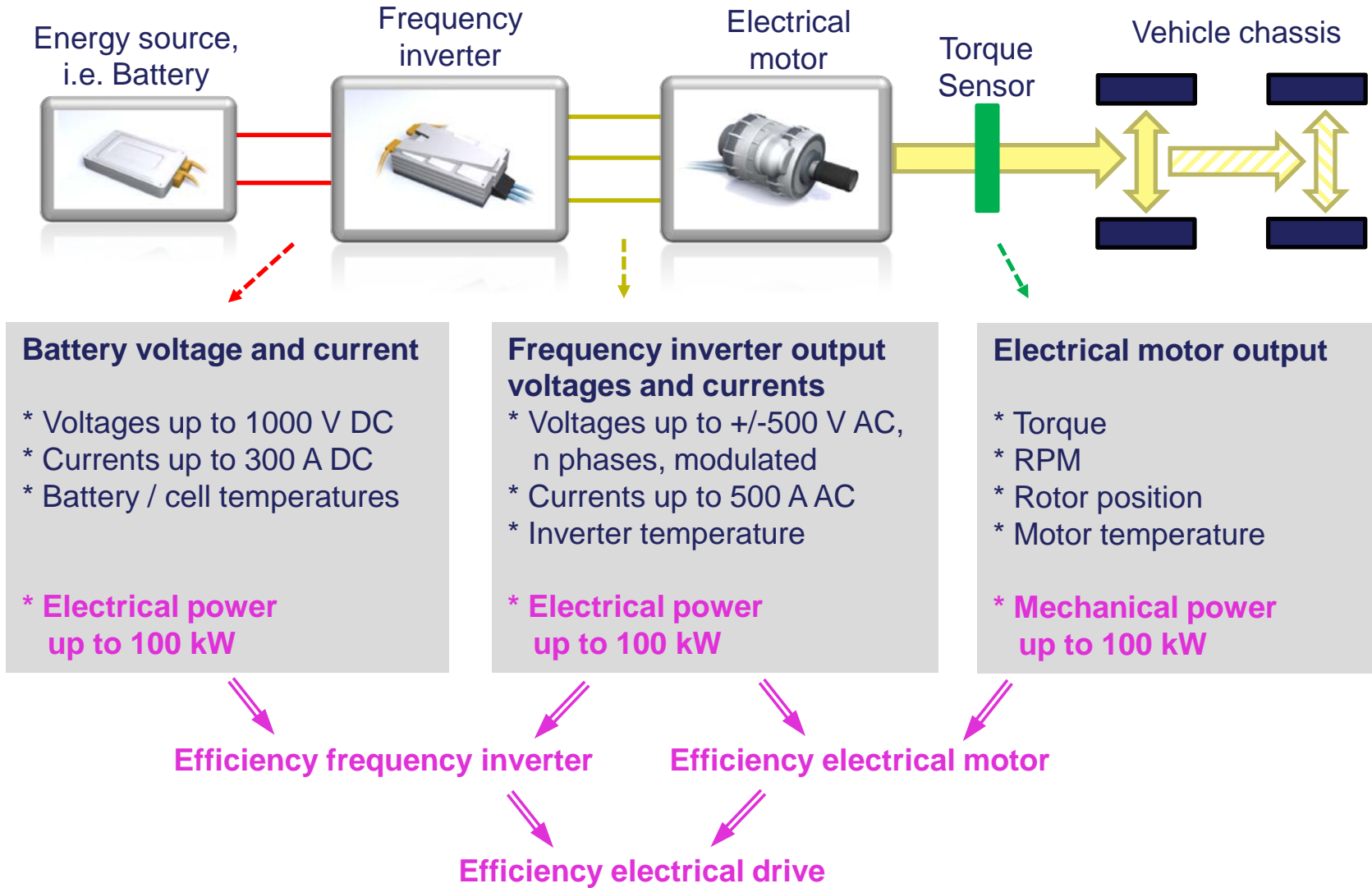


Electrical drive in A320

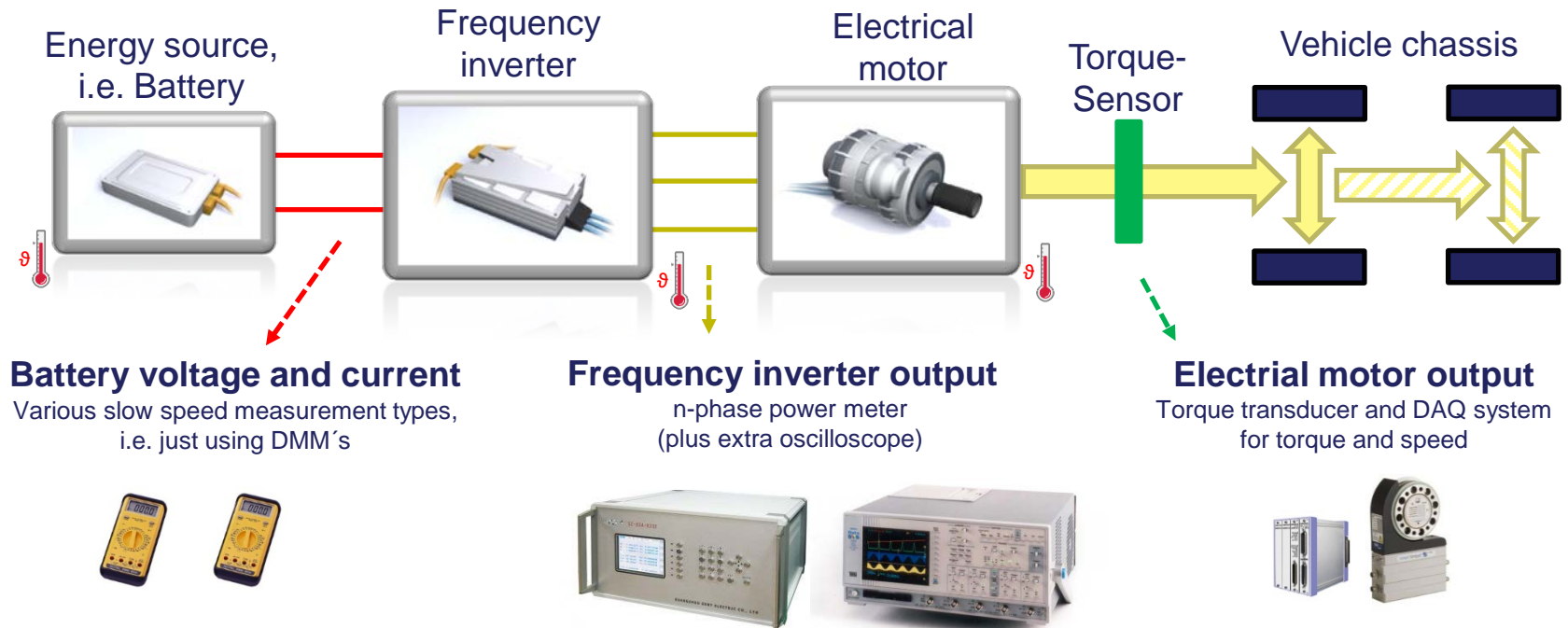


High Speed train

eDrive: DAQ requirements on electrical (hybrid) drive train



eDrive: Measuring efficiency – the typical method



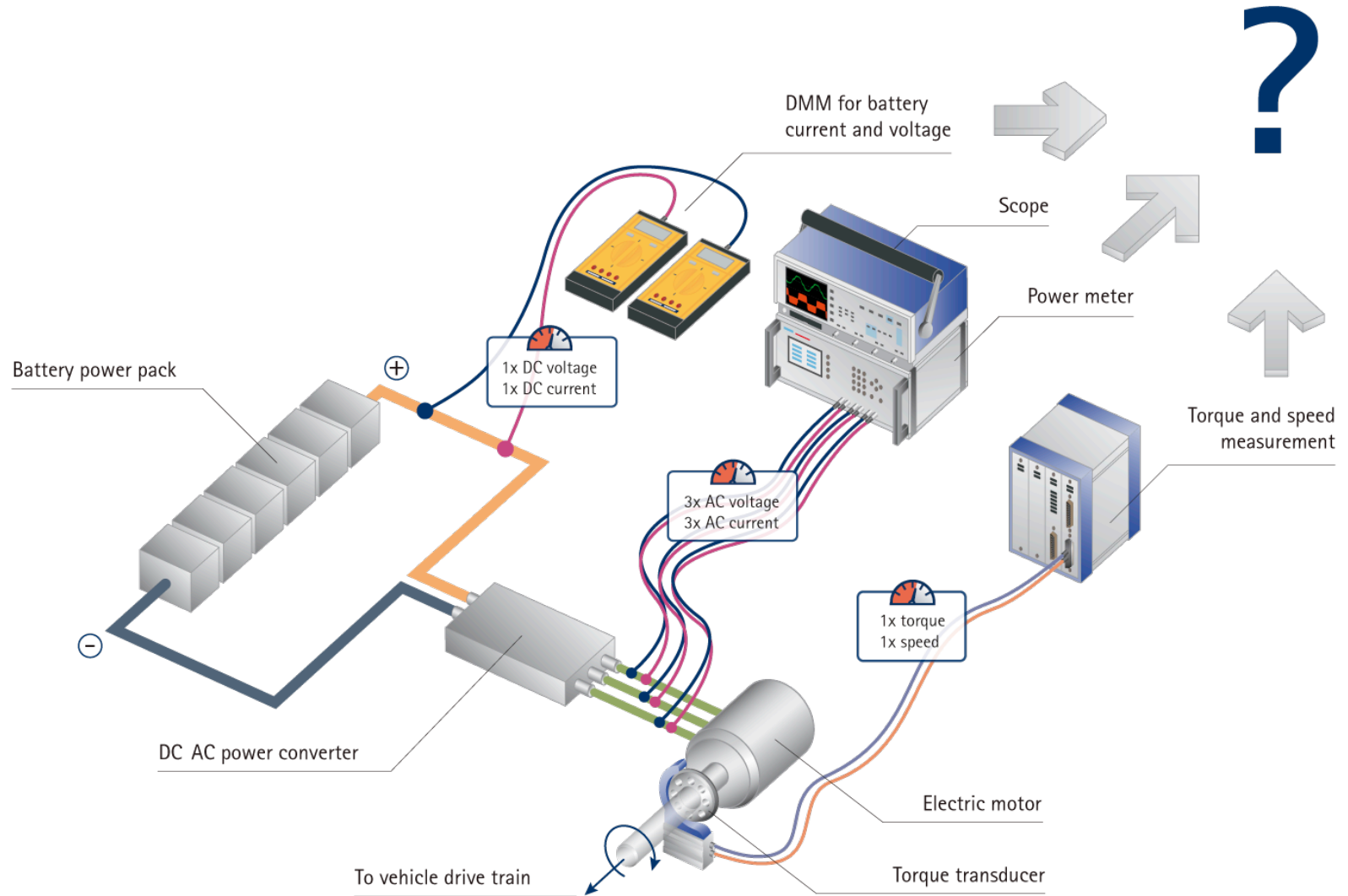
Problems:

1. Difficult time synchronization between different systems
2. Data storage in different systems & different formats
3. No continuous raw data available for verification or analysis
4. Slow calculation cycles of power meters and questionable results in dynamic load changes
5. No documented algorithms for power analysis, no verification possible



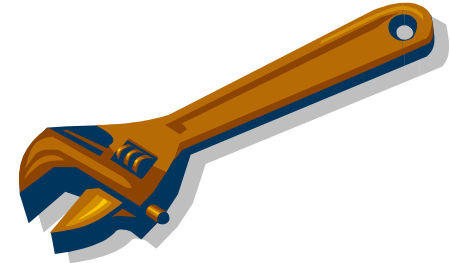
User comment:
„Sometimes we measure efficiency larger 1. We can't believe that, but we can't analyse further as we have no raw data.

eDrive: Measuring efficiency – the typical method

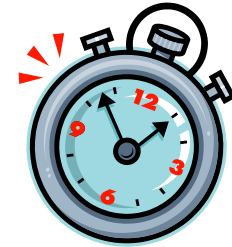


Note: For simplification, temperatures not shown

- Simple system configuration
 - One system for all different signals
 - Voltage, current, torque, speed
 - Position, temperatures, vibration....
 - Easy setup



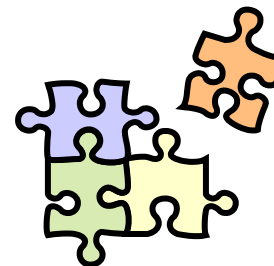
- Reliable acquisition
 - Simultaneous sampling of electrical and mechanical power
 - No phase shift caused by different data acquisition systems
 - Continuous storage to hard disc
 - One data format for all acquired data



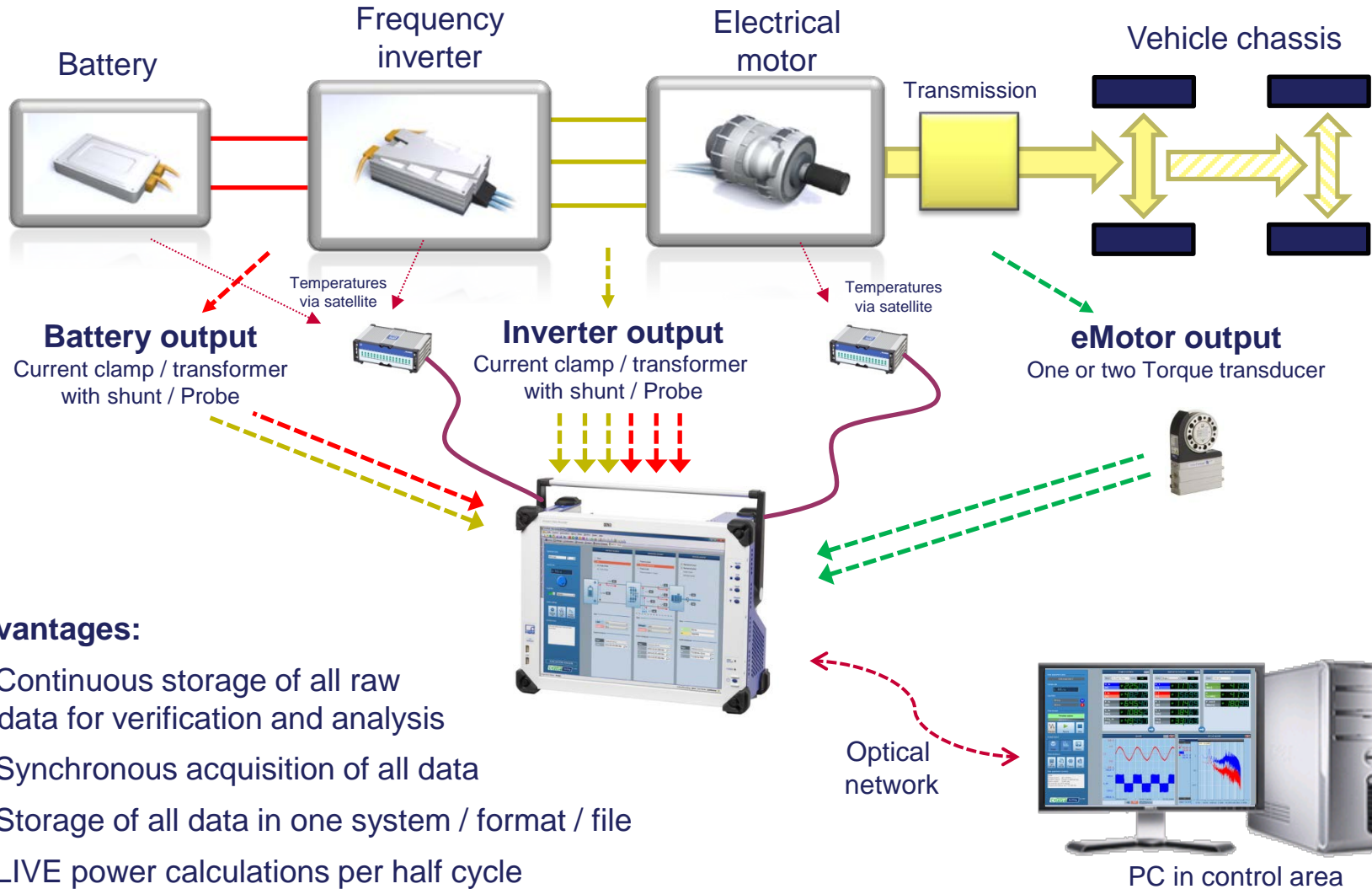
- Faster, better results
 - Analysis per half cycle with documented, traceable algorithms
 - Verification of results
 - Advanced analysis based on raw data



- Easier system integration
 - Open data format
 - Modern software interfaces



eDrive: HBM's testing concept



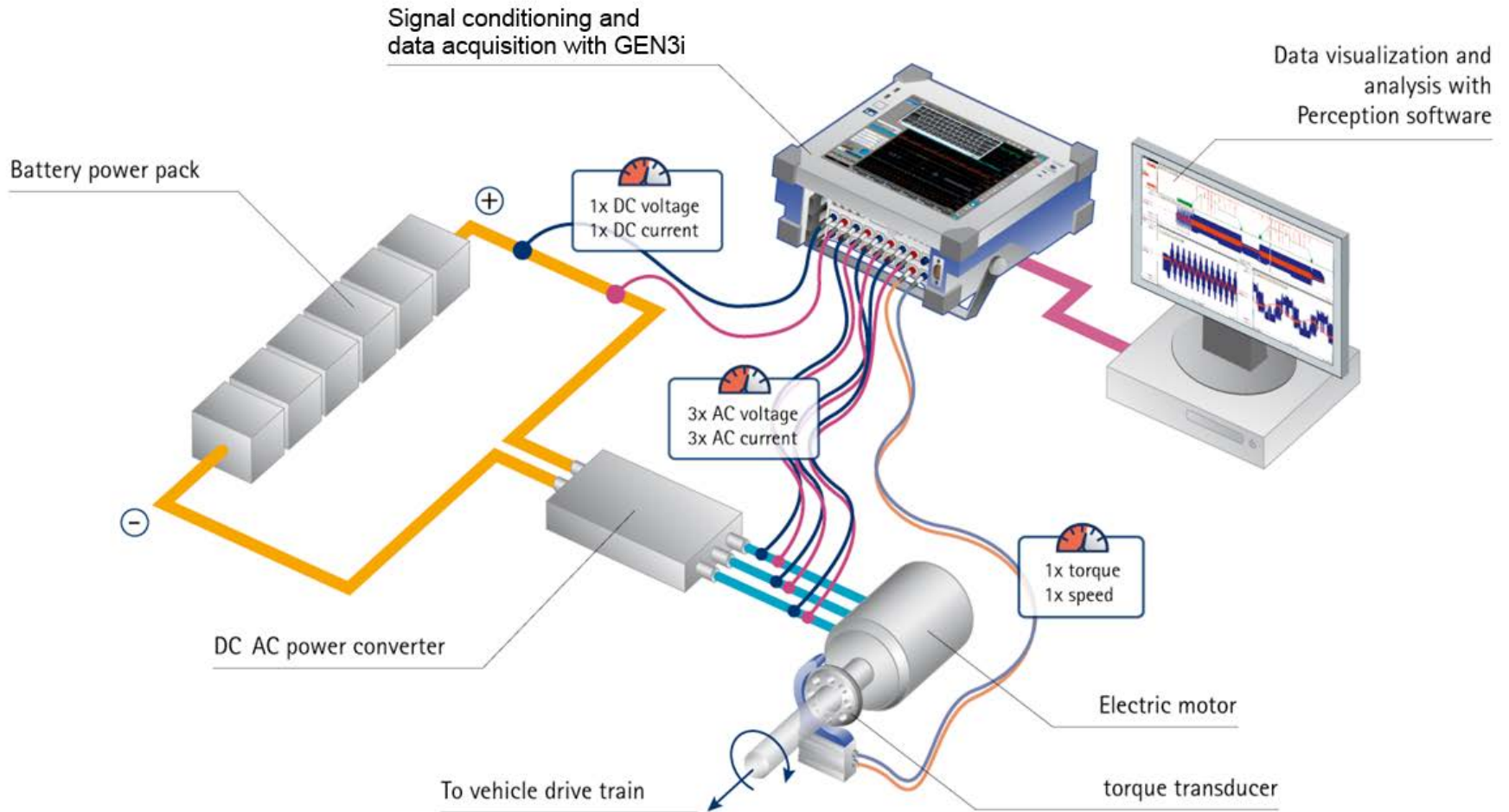
Advantages:

1. Continuous storage of all raw data for verification and analysis
2. Synchronous acquisition of all data
3. Storage of all data in one system / format / file
4. LIVE power calculations per half cycle
5. LIVE scope and FFT displays

- GEN3i mainframe (or GEN3t)
 - 3 slots for acquisition modules
 - 200 MB/s streaming to 500 GB SSD
 - Build in Win7 64 bit PC (GEN3i only)
- Isolated 1 kV input card
 - 6 isolated channels, ± 20 mV to ± 1000 V
 - Direct connection to HV signals without probes
 - Sample rate 2 MS/s @ 18 bit per channel
 - Isolation voltage 1,000 Vrms
 - Accuracy 0.1%
 - One torque & speed channel per board
- Plug-on artificial star module
 - Creates artificial star point for 3 phase measurements
 - Plugs directly into the card to minimize cabling
- Optional, remote temperature satellite
 - 16 channels type K or T
 - Keeps TC cables short for signal fidelity



eDrive: HBM's testing concept



Note: For simplification, temperature satellite not shown

eDrive: HBM's complete system for efficiency testing



Optional: 16ch temperature satellite

eDrive SETUP: Setting up the test in one single, simple menu



eDrive - Setup
eDrive - Live

Next experiment name

Motor 23 45

Sample rate

1 MS/s Change

Input filter

ON 100 kHz U

100 kHz I

System settings

System settings Create formulas Create display

Next experiment comment

You can enter your comment text over here

POWER SOURCE

None

DC

AC 1-phase

AC 3-phase: phase to phase

AC 3-phase: phase to neutral

INVERTER OUTPUT

Phase to phase

Phase to artificial star

Phase to star

Phase to phase n-1 (Aron)

MOTOR OUTPUT

None

Shaft only

Shaft and transmission

Differential lock only

Span

u_in: 1 kV

i_in: 10 A

Current transducer

Type: Database sensor

i_in: AYA M1V AC

Span

Voltages: 1 kV

Currents: 10 A

Current transducer

Type: Database sensor

i_1: AYA M1V AC Current L1

i_2: AYA M1V AC Current L2

i_3: AYA M1V AC Current L3

Span

M: 200 Nm

n: 200 RPM

Torque transducer

Type: Database sensor

M: T12 500 Nm 10 kHz

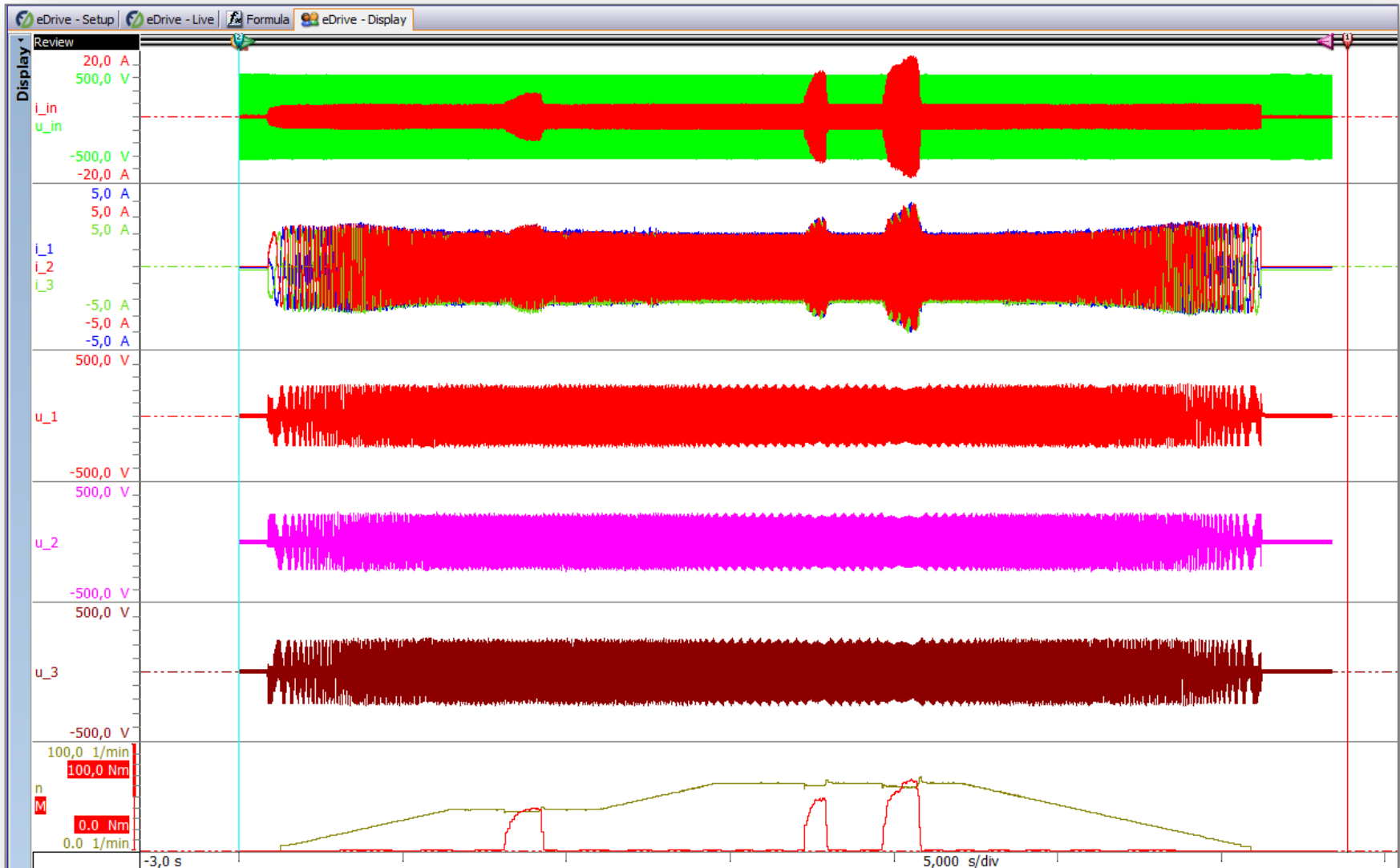
n: T12 500 Nm RPM

by HBM

eDrive LIVE: Numerical results and scope and FFT



eDrive REVIEW: Typical signals, continuously acquired for 1 minute



- Input signals (to be measured)

- Voltage = u
- Current = i
- Torque = M
- Speed = n

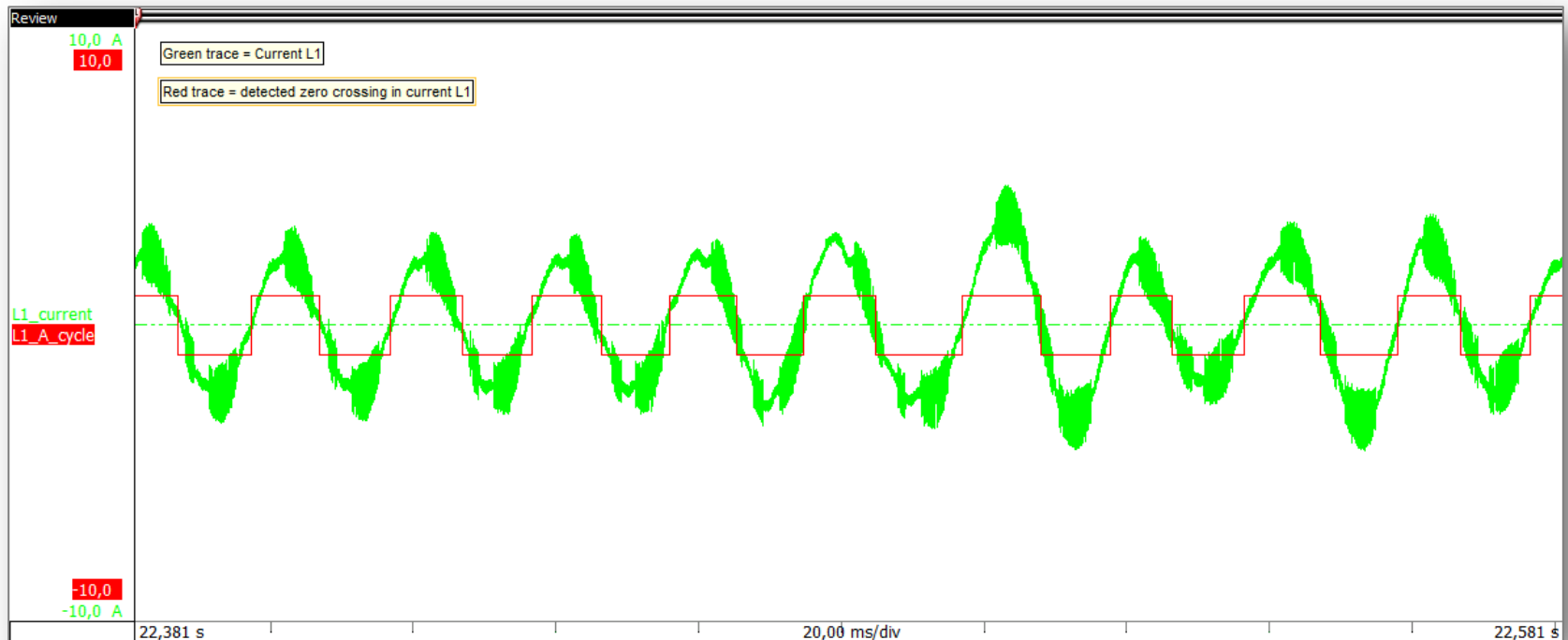
- Power calculations (simplified)

- True power $P = \text{MEAN}_{\text{cycle}} (u \times i)$
- Apparent power $S = (\text{RMS}_{\text{cycle}} u) \times (\text{RMS}_{\text{cycle}} i)$
- Mechanical power $P_{\text{mech}} = \text{MEAN}_{\text{cycle}} (2 \times \pi \times n \times M)$

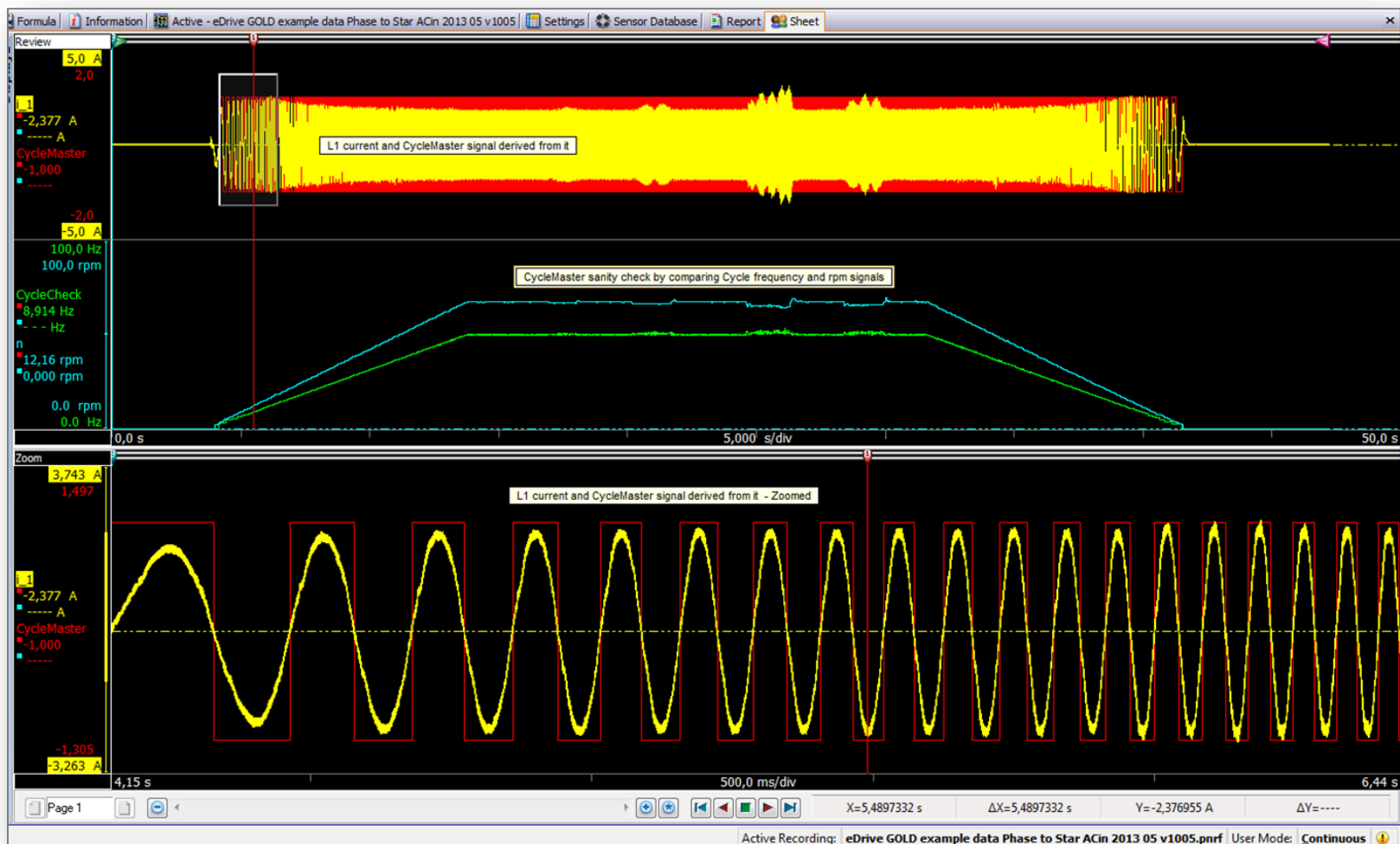
- Efficiency calculation

- Efficiency electrical motor $\eta (\text{Eta}) = P_{\text{mech}} / P$

- To compute the TrueRMS the real “cycles” of the signals are needed
- Detecting the zero crossing is difficult due to noise
- Perception detects the zero crossings using advanced algorithms
 - Result can be shown for verification



Verification of detected cycles



- The “cycle detect” integrity can be checked by computing the cycle frequency to compare it with the rpm trace
 - Must be the same “waveshape”
 - Cycle Frequency must not have peaks or drops (= double / missing cycles)

- RMS per phase and cycle
 - Cycle detection in current i_1
 - RMS value of current per phase and per „cycle“
 - RMS value of voltage per phase and per „cycle“ of the current

- True power
 - Multiplication of u and i gives the instantaneous power per phase
 - Doing a MEAN over a cycle gives true power per phase
 - Summing up phases gives total P

- Mechanical power
 - Multiplication of torque and speed

- Motor efficiency
 - Ratio of mechanical to real power

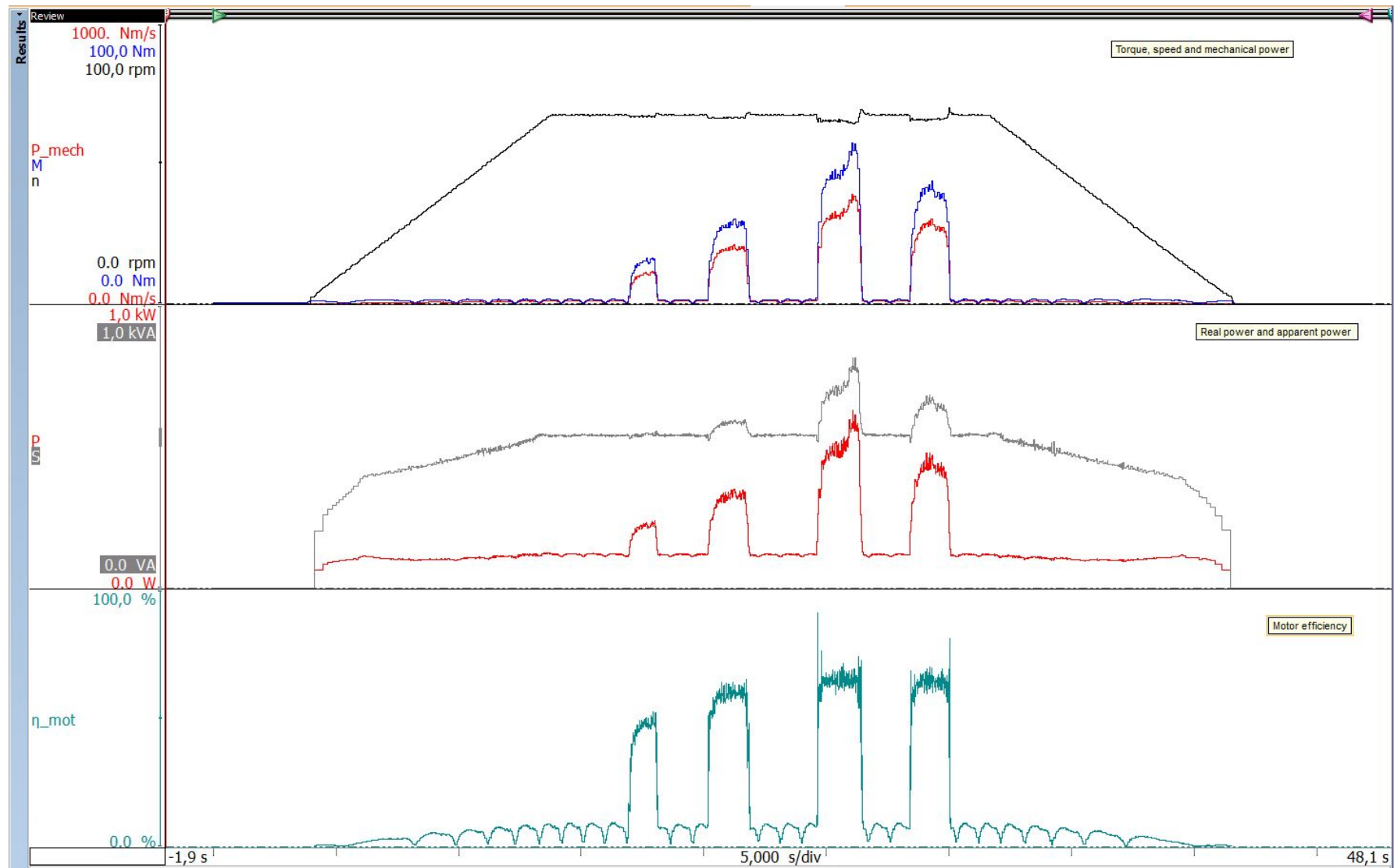
56	CycleMaster	@CycleDetect (Formula.i_1;0;1)
57		
58	I_1	@CycleRMS (Formula.i_1; 1; Formula.CycleMaster)
59	I_2	@CycleRMS (Formula.i_2; 1; Formula.CycleMaster)
60	I_3	@CycleRMS (Formula.i_3; 1; Formula.CycleMaster)
61		
62	U_1	@CycleRMS (Formula.u_12; 1; Formula.CycleMaster)
63	U_2	@CycleRMS (Formula.u_23; 1; Formula.CycleMaster)
64	U_3	@CycleRMS (Formula.u_31; 1; Formula.CycleMaster)

73	p_1	Formula.u_1 * Formula.i_1
74	p_2	Formula.u_2 * Formula.i_2
75	p_3	Formula.u_3 * Formula.i_3
76		
77	P_1	@CycleMean (Formula.p_1; 1; Formula.CycleMaster)
78	P_2	@CycleMean (Formula.p_2; 1; Formula.CycleMaster)
79	P_3	@CycleMean (Formula.p_3; 1; Formula.CycleMaster)
80		
81	P	Formula.P_1 + Formula.P_2 + Formula.P_3

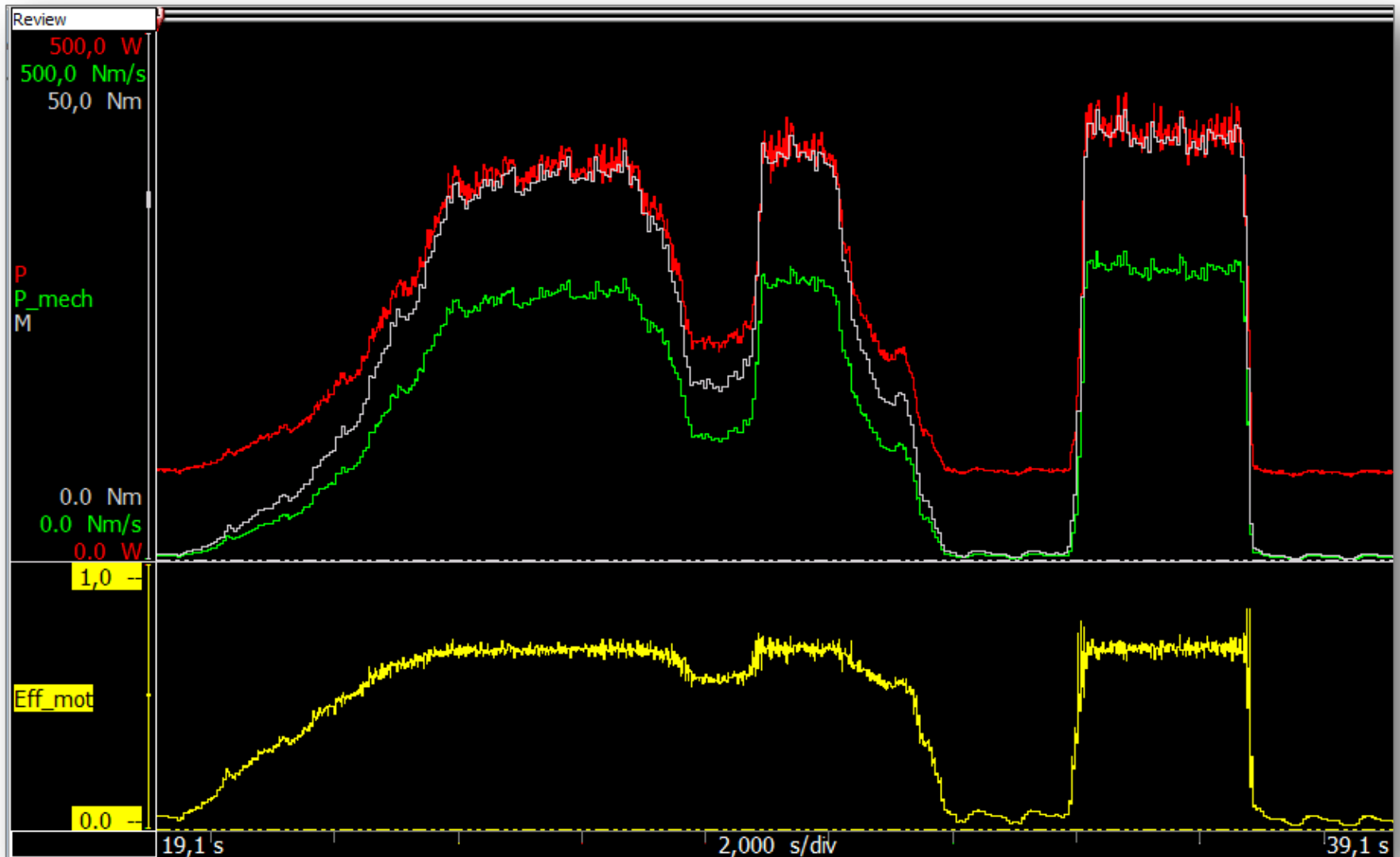
119	P_mech	$2 * \text{System.Constants.Pi} * \text{Formula.n} / 60 * \text{Formula.M}$	Nm/s
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131	η_{mot}	$(\text{Formula.P}_{\text{mech}} / \text{Formula.P}) * 100$	%
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Some computed results as shown in Perception software



Top to bottom: Mechanical power, electrical power (P, S), motor efficiency

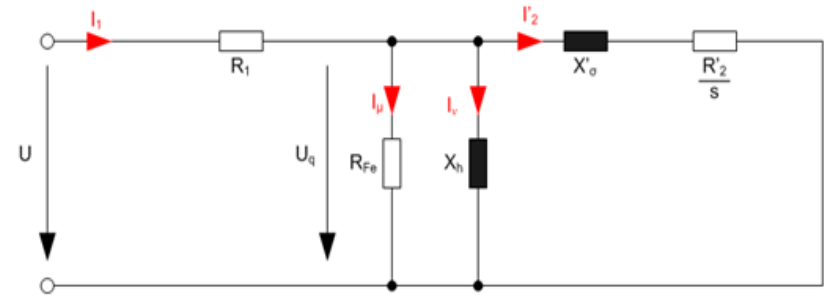


Torque, mechanical power and true power on top, motor efficiency underneath

- As all RAW data is stored, advanced analysis of motor and inverter data is possible using Perceptions formula database

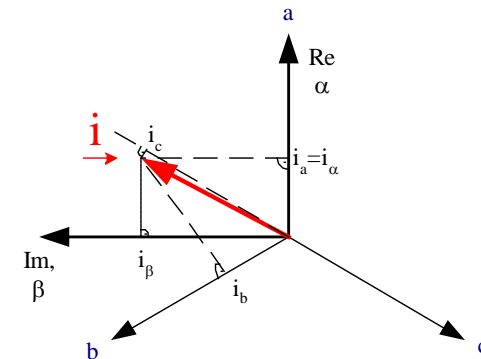
- Potential Motor analysis

- Equivalent circuit diagram
- Iron losses
- Main inductance
- Starting currents
- Armature currents
- Airgap torque
- Torque ripple
- Cogging torque
- Saturation effects



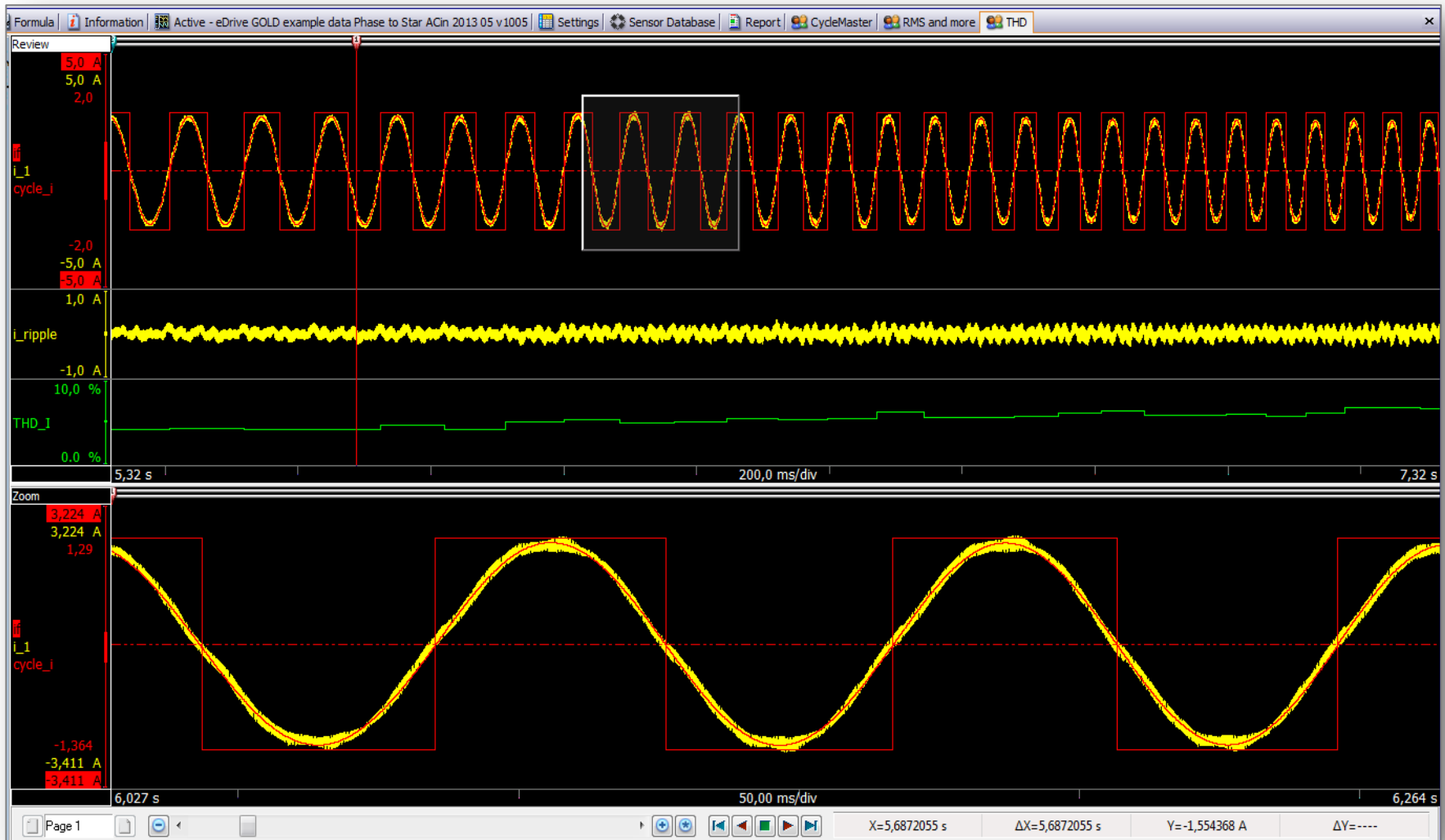
- Potential Inverter analysis

- Space vector / DQ0 transformation
- Inverter control behaviour
- Modulation method
- Frequency & amplitude of fundamental
- THD of voltage and current
- Switching frequency

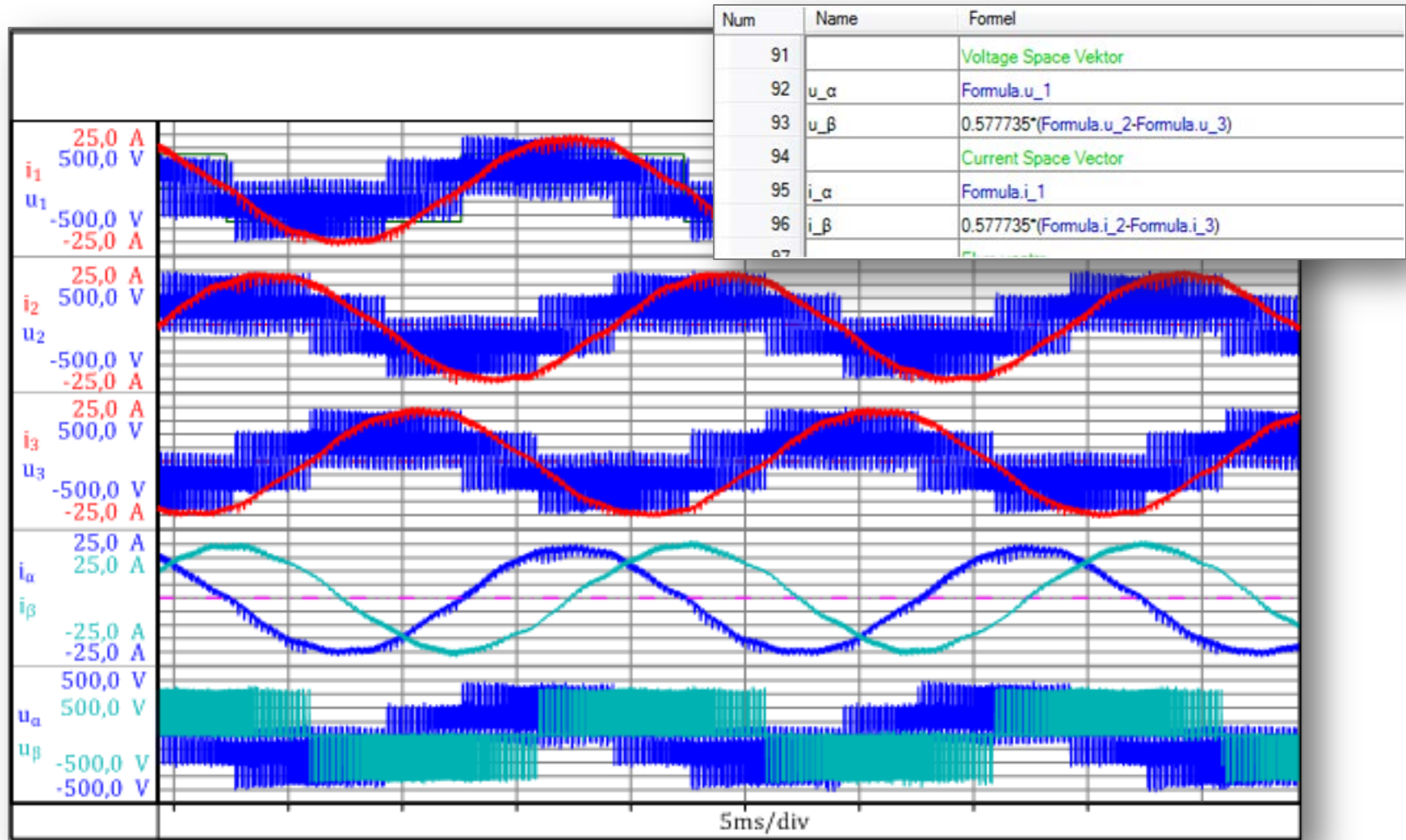


$$\vec{i} = i_{\alpha} + j i_{\beta} = \frac{2}{3} (i_a + a \cdot i_b + a^2 \cdot i_c)$$

eDrive: Fundamental of current, ripple current, THD computation

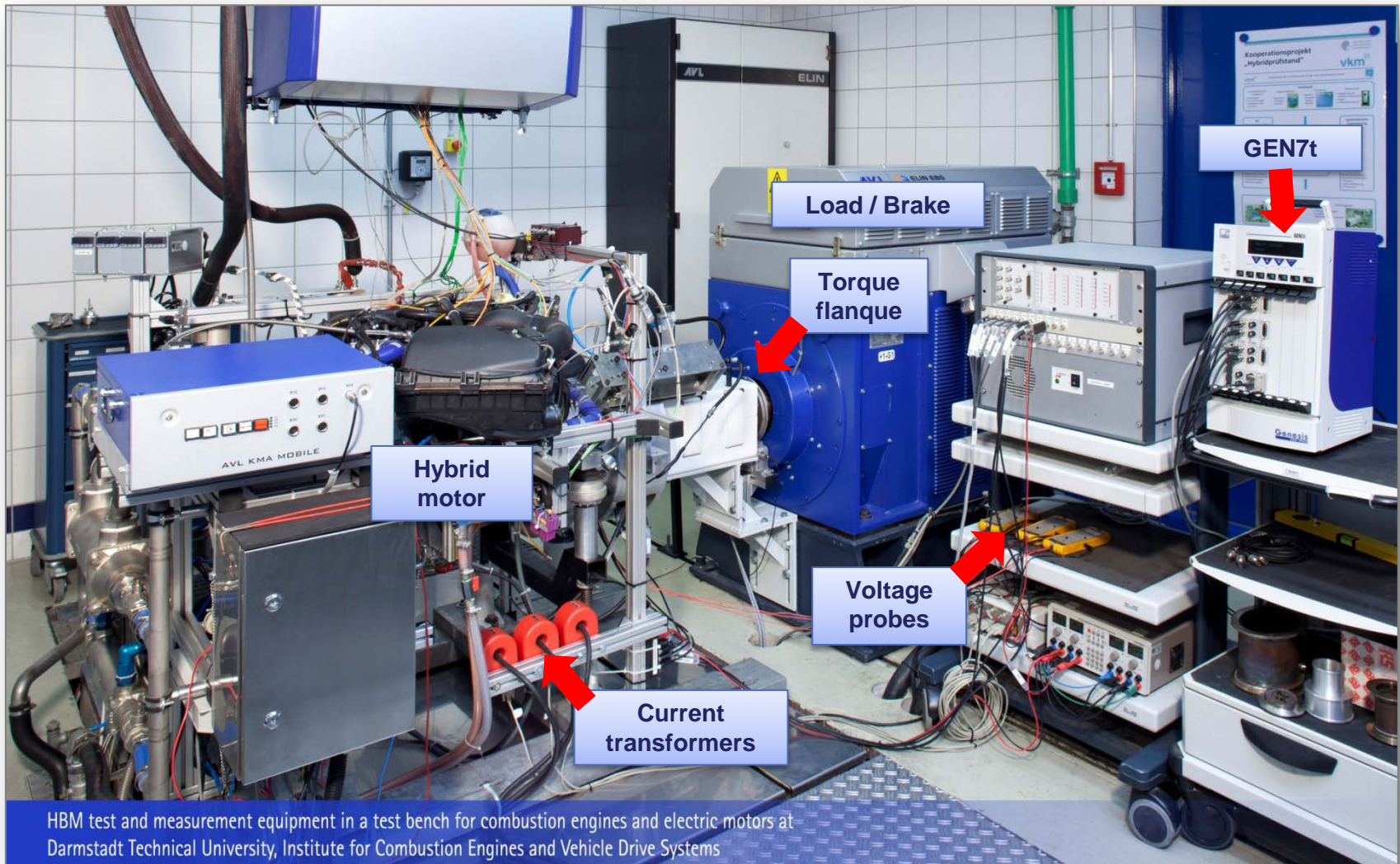


Current (lower yellow), fundamental of current (lower red sinewave), ripple current (mid yellow), THD (green)



From the known signals u_1, u_2, u_3 and i_1, i_2, i_3 the space vectors u_α, u_β and i_α, i_β are calculated

Hybrid motor test cell equipped with T10 and GEN7t from HBM



HBM test and measurement equipment in a test bench for combustion engines and electric motors at Darmstadt Technical University, Institute for Combustion Engines and Vehicle Drive Systems

- HBM GEN DAQ is able to **connect to all signals** being high voltage, currents, torque, speed, temperatures, vibration.....
- All signals are sampled **simultaneously** and displayed live
- Sampling is done with **high sample rate** and high resolution
- **Continuous raw data storage** allows verification and analysis
- Setting up the measurement is done in **one simple menu**
- Power calculations are done **LIVE and per half cycle**
- Perception's formula database offers all tools for further, detailed **motor and inverter analysis**
- **So we offer an integrated tool not only to measure efficiency, but also to understand how to improve efficiency**

- www.hbm.com/edrive

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Measurement and Testing of Electric Motors and Inverters

The eDrive testing solution from HBM:
A tool for increased efficiency in the analysis of electric machines and drives



The future belongs to electric drives and thus to vehicles or ships with an electric drive. Increasing the efficiency of the electric drive train including inverter and electric motor plays a key role.

A problem so far: The standard methods for performance testing and efficiency measurement of electric drives give only inadequate results. Power analyzers that are often used for this purpose, provide calculated results, however, they do not provide any raw data.

Using HBM's innovative eDrive testing solution makes the difference: Our 'power trio' including the [T12 torque sensor](#) and the [GEN3i data acquisition system](#) and the optional [QuantumX 1609B temperature satellite](#) allows synchronous, dynamic and continuous acquisition of mechanical and electrical signals. As well as live analyses.

The raw data acquired is available already during measurement for detailed analysis by developers. This allows live analyses for determining active and reactive power, as well as energy conversion efficiency. It is also possible to carry out further, more detailed analyses of fundamental and switching frequency, air-gap moment, slip, iron loss, control behavior etc.

Webinar eDrive testing

 Join the webinar 'Efficiency Testing on Electrical Drive Trains' on June 5, 10:00 AM. [Register now for free](#)

 Standard approach using three different acquisition systems  New HBM testing concept - one integral system



The diagram illustrates the eDrive testing system. It shows a flow from a Battery to a Frequency inverter, then to an Electrical motor, and finally to a Vehicle chassis. The Battery provides DC voltage and DC current to the Frequency inverter. The Frequency inverter provides AC voltage and AC current to the Electrical motor. The Electrical motor provides Torque and rotational speed to the Vehicle chassis. The GEN3i data acquisition system is connected to the Battery, Frequency inverter, and Electrical motor to measure these parameters.

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Efficiency Testing on Electric Drivetrains	Jun 10, 2014	2:00 PM ET	■
More efficient ordering, easier configuration: Tips and tricks for using the HBM online shop	Jun 24, 2014	10:00 AM CET	■
What's new in QuantumX and catman Data Acquisition Software?	Jun 25, 2014	10:00 AM CET	■
Good Data Gone Bad	Jun 26, 2014	10:00 AM CET	■
Residual stress analysis using the hole drilling method	Jun 27, 2014	10:00 AM CET	■
An Introduction to Split-Hopkinson Bar Testing and Dynamic Strain Measurements	Aug 05, 2014	2:00 PM ET	■

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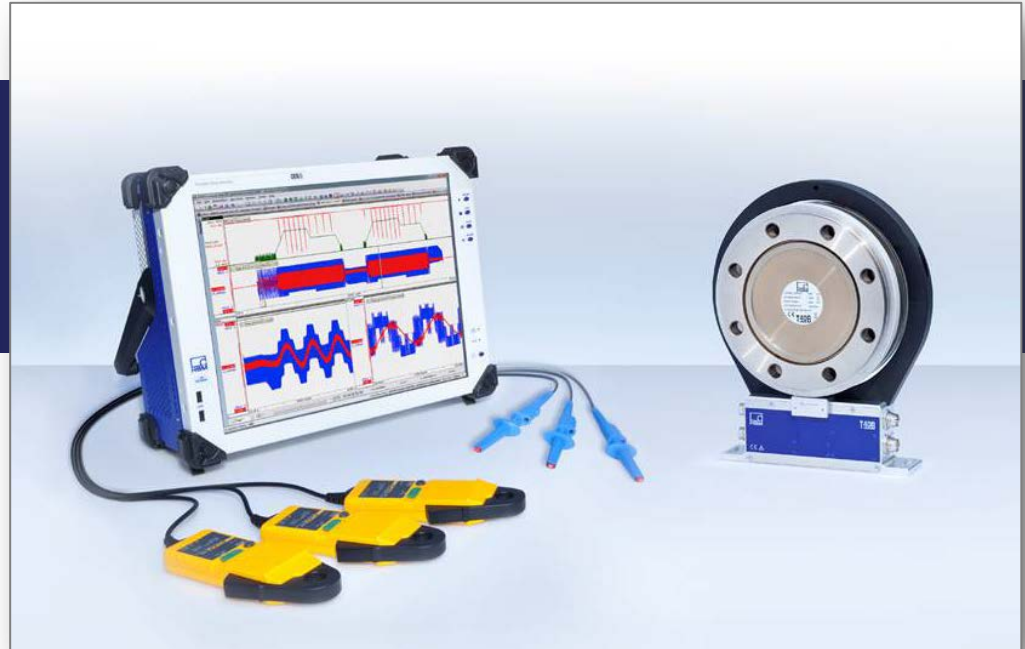
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Klaus Lang
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