Voltage measurement in e-mobility

CSM Web Seminars

Innovative Measurement and Data Technology

Voltage measurement in e-mobility

§ Standards and guidelines (e.g. ECE R100, ISO 1010, DGUV 3, ISO 21498)

HV vehicle electrical system

Ripple

Component tests

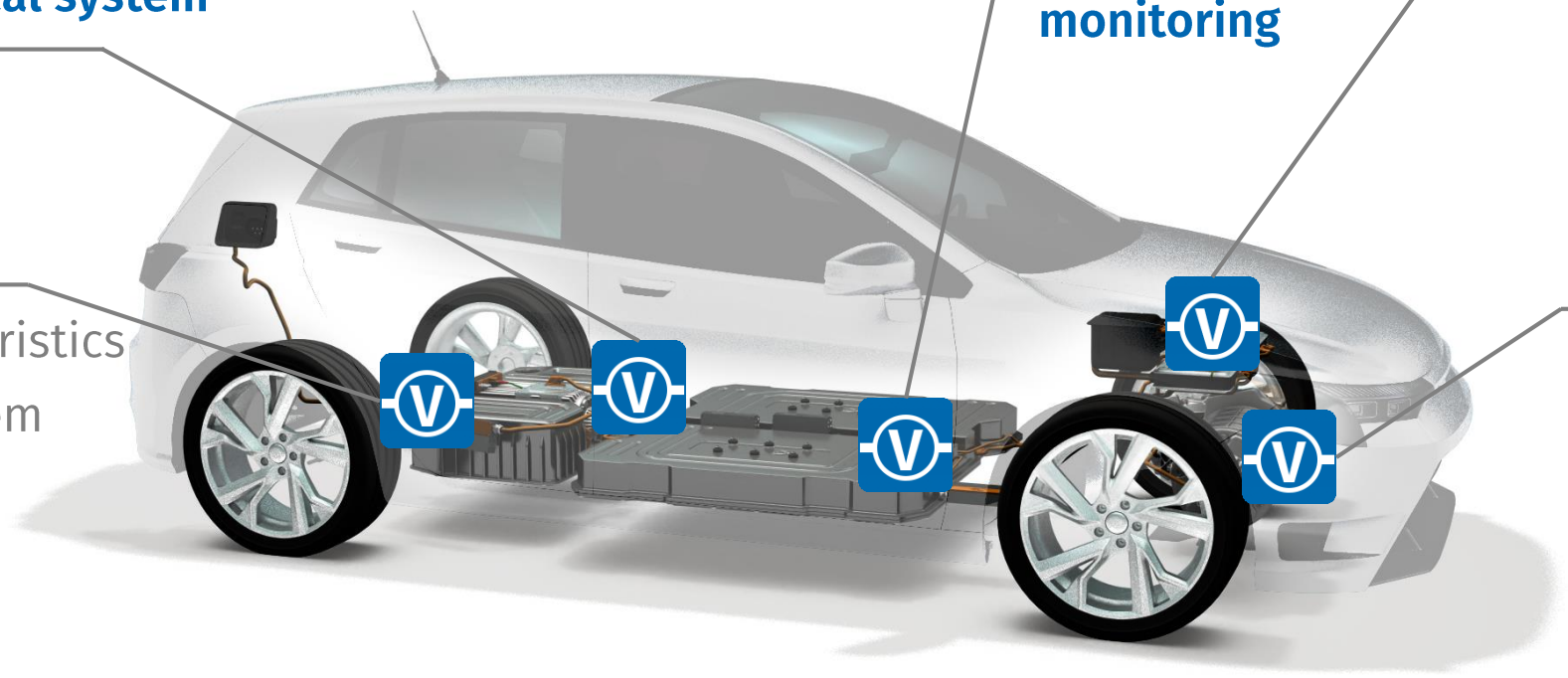
Charging characteristics of the entire system

HV Isolation monitoring

HV cut-off mechanisms

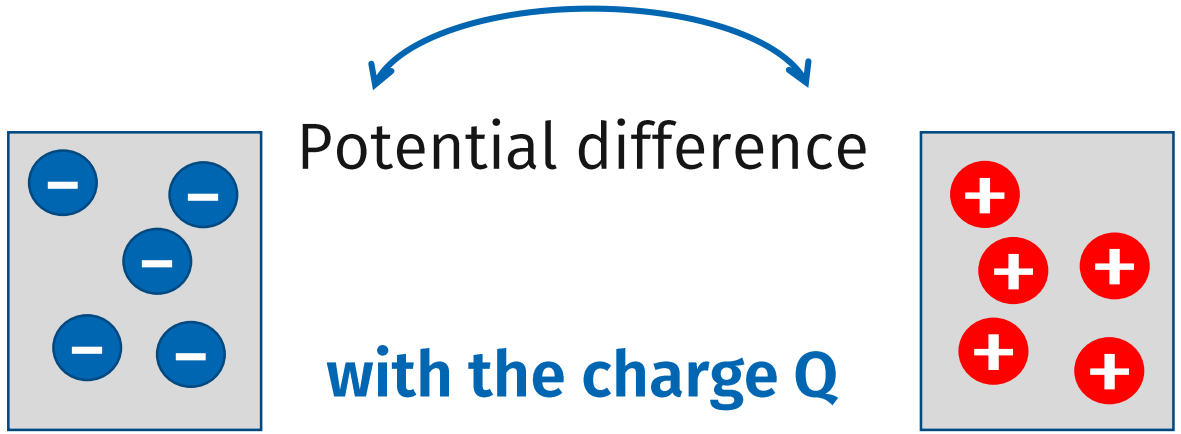
Powertrain

Proof of Performance
Consumption tests



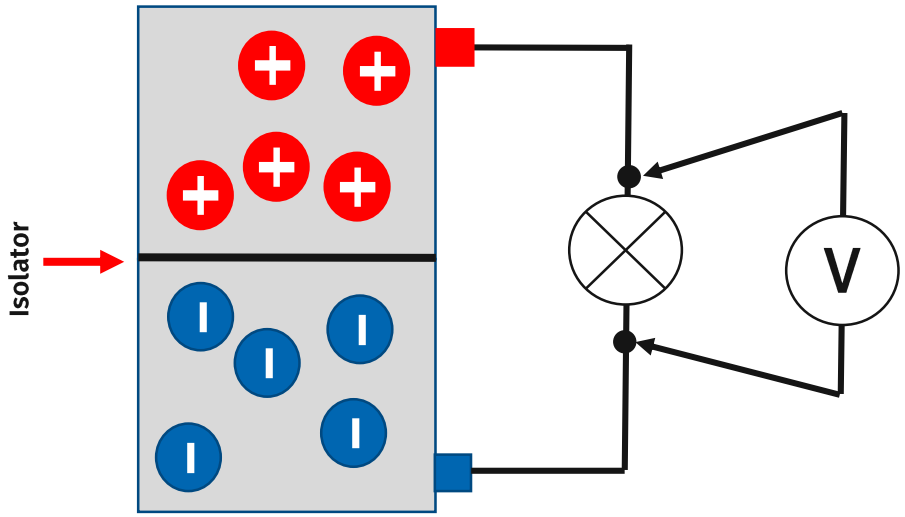
What is electrical voltage?

- When positive and negative **charges are separated**, the **electrical voltage U is generated**.
- Voltage is a **potential difference** between two points in the electric field.
- This potential difference acts as a **current source**.
- By connecting the two potentials by means of an **electrical conductor**, the electrons can move and a current flow is created.



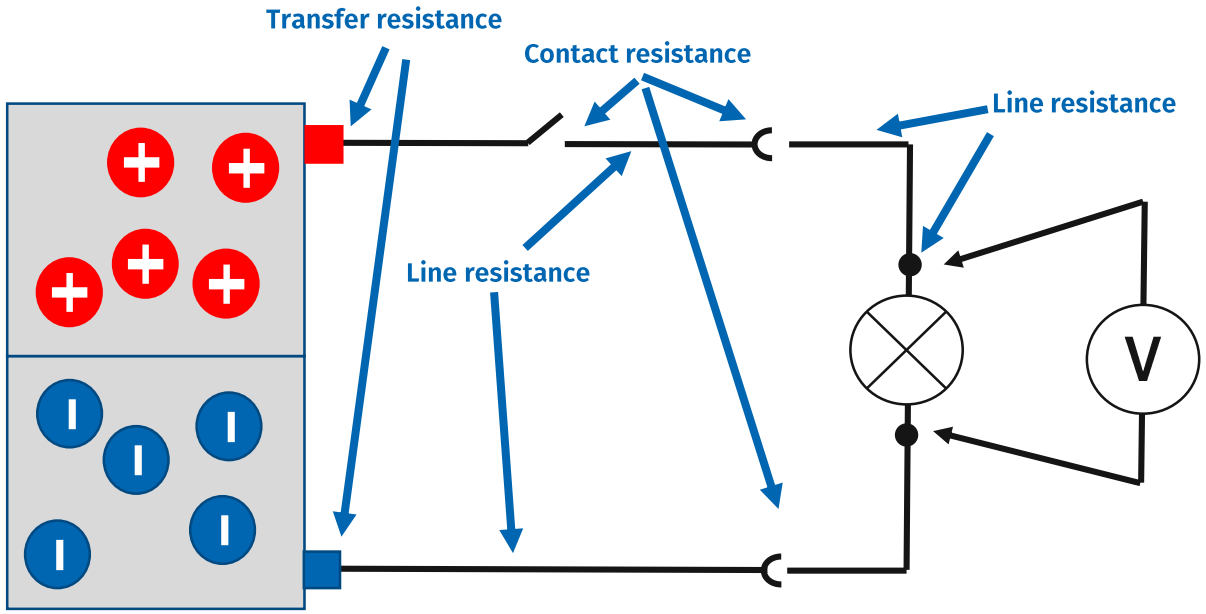
How do I measure the electrical voltage?

- Electrical voltages are always measured between two points.
- Two potentials are compared with each other and the difference is displayed.
- In the example, the DC voltage of a battery is measured across an incandescent lamp (ohmic resistor).



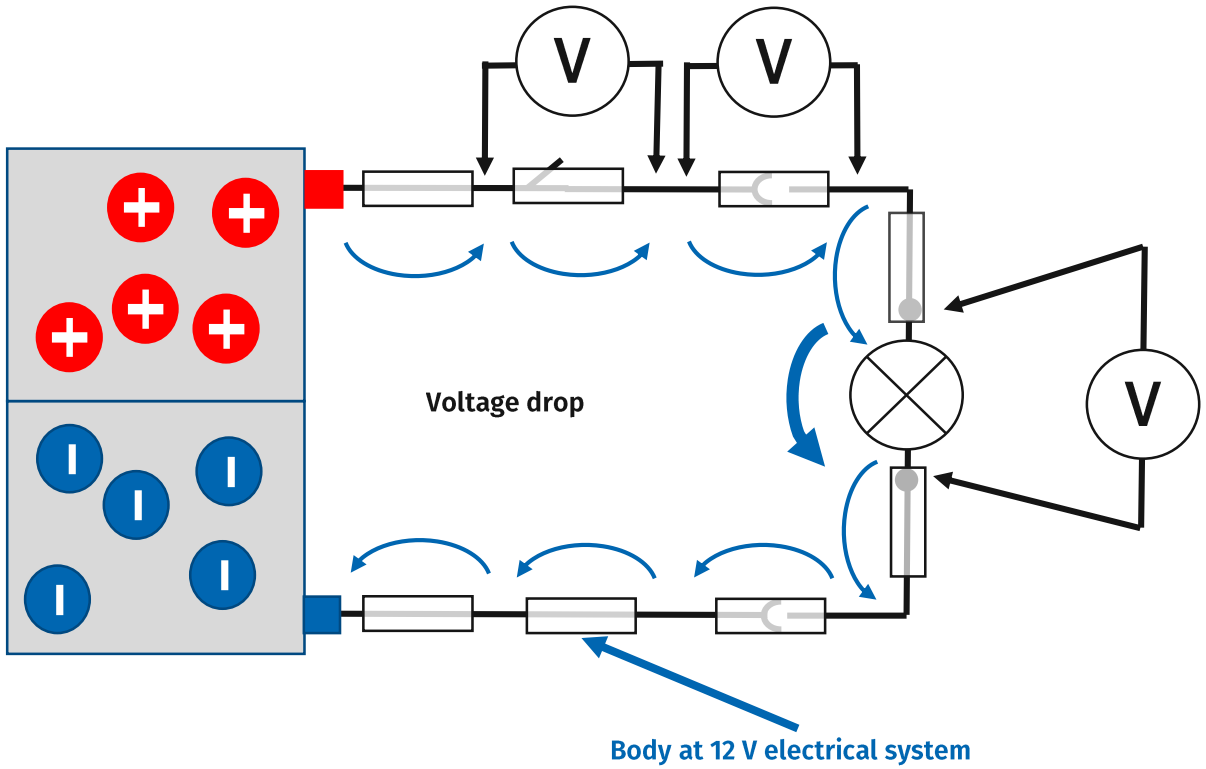
What do I have to consider when measuring?

- Even with this simple example, the reality is much more complex.
- Consumers, but also lines, contact and material transition points themselves represent **electrical resistances**, which must correctly be considered individually.



What do I have to consider when measuring?

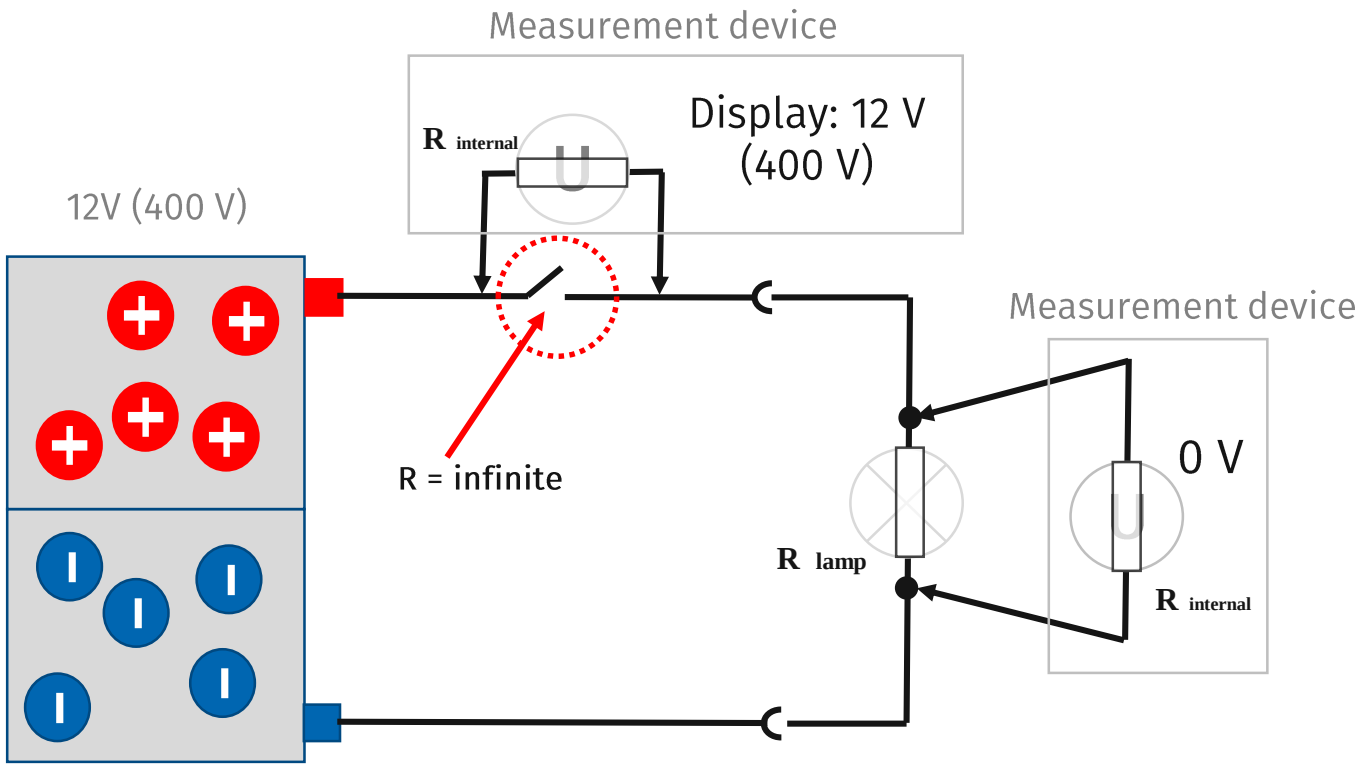
- Voltage drops at each resistor ("voltage drop").
- At high resistors, this usually leads to unwanted heating (thermal losses) up to vehicle fire.



Body Weld Stud

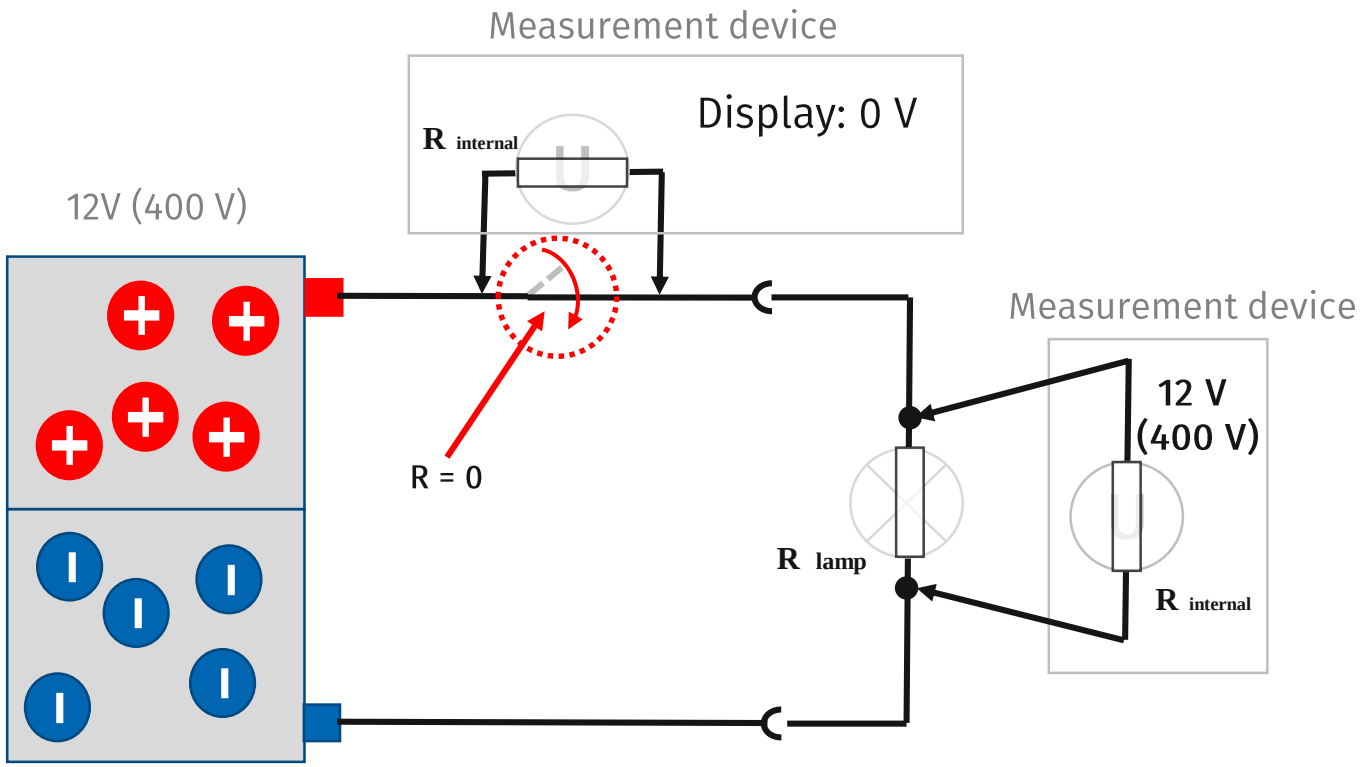
Does "switched off" also mean "voltage-free"?

The switch in the example is open - nevertheless, the full battery voltage is present across the switch!



What do I have to consider when measuring?

When the switch is closed, the full battery voltage is applied to the consumer (idealized!).



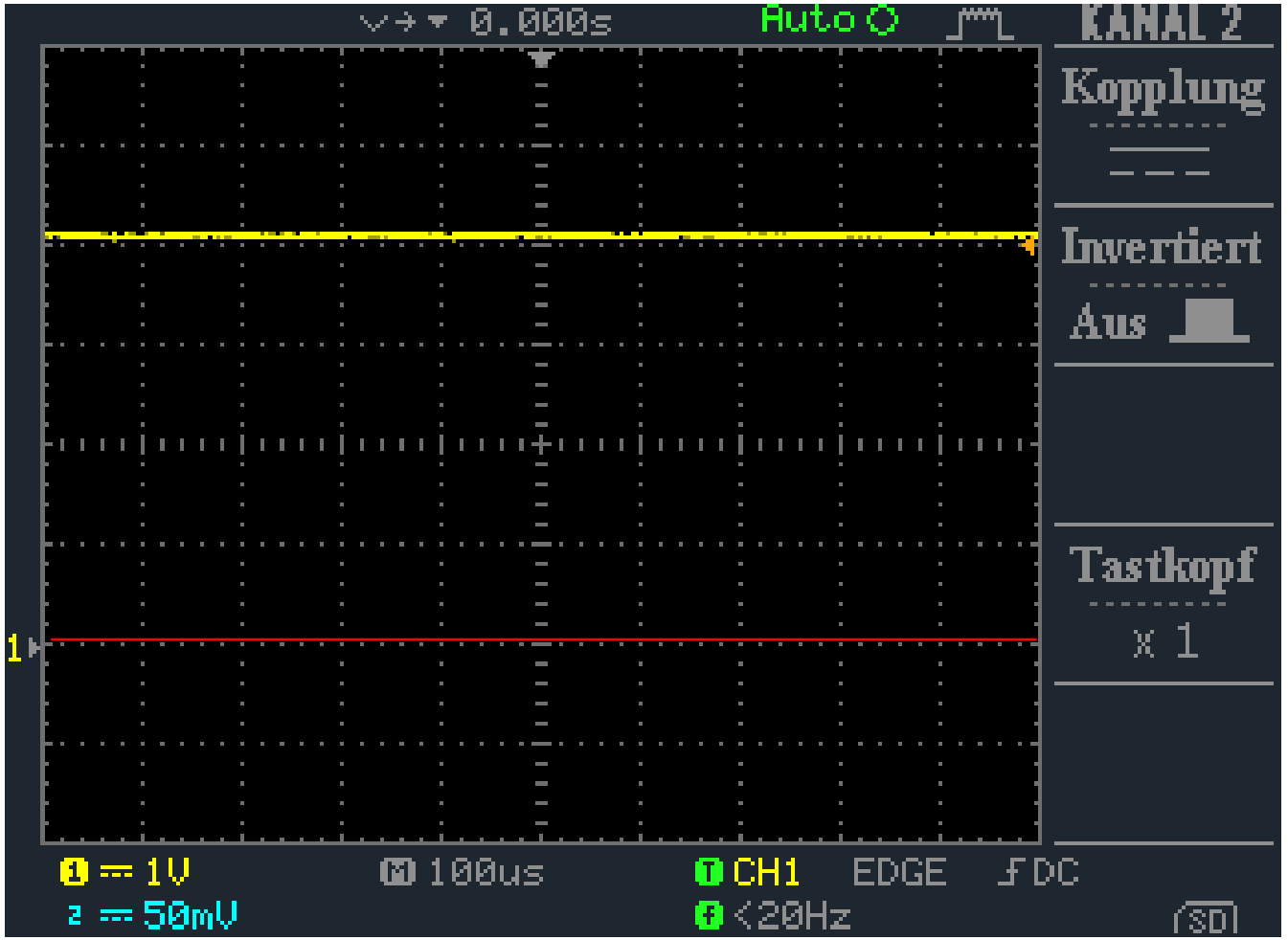
IMPORTANT:
Voltage measurement devices should have the highest possible internal resistance in order to not influence the system being measured.

What are the types of voltage?

12 V, 24 V, 48 V, 400 V, 800 V vehicle electrical system

- **DC voltage**
- AC voltage
- AC voltage with offset
- DC voltage with AC components
- Time intervals? - how fast to measure?

Zero line



DC voltage

Figure normalized to 1 V per box as an example.

You can multiply this by 100 and you are already in the 400 V system.

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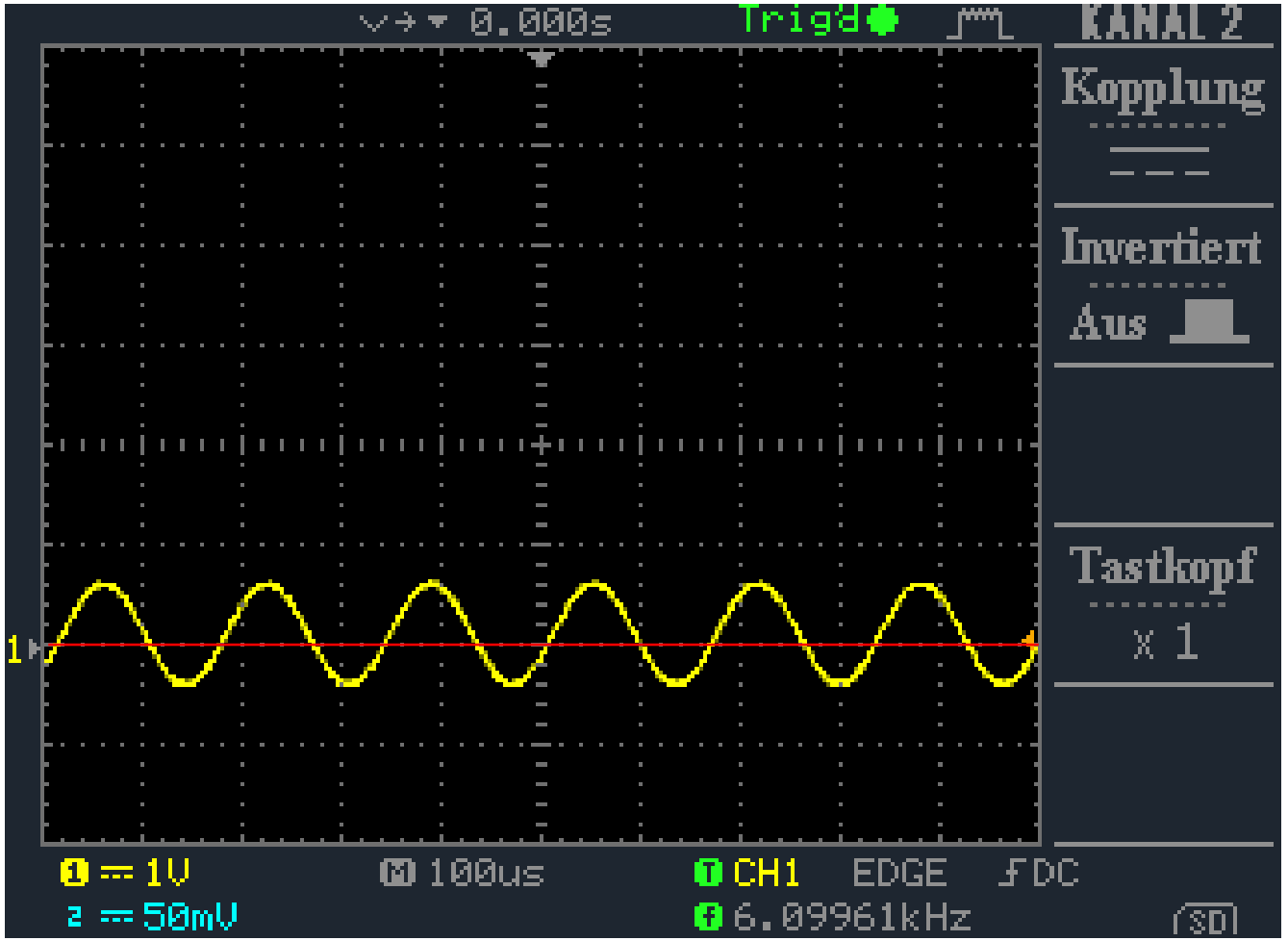

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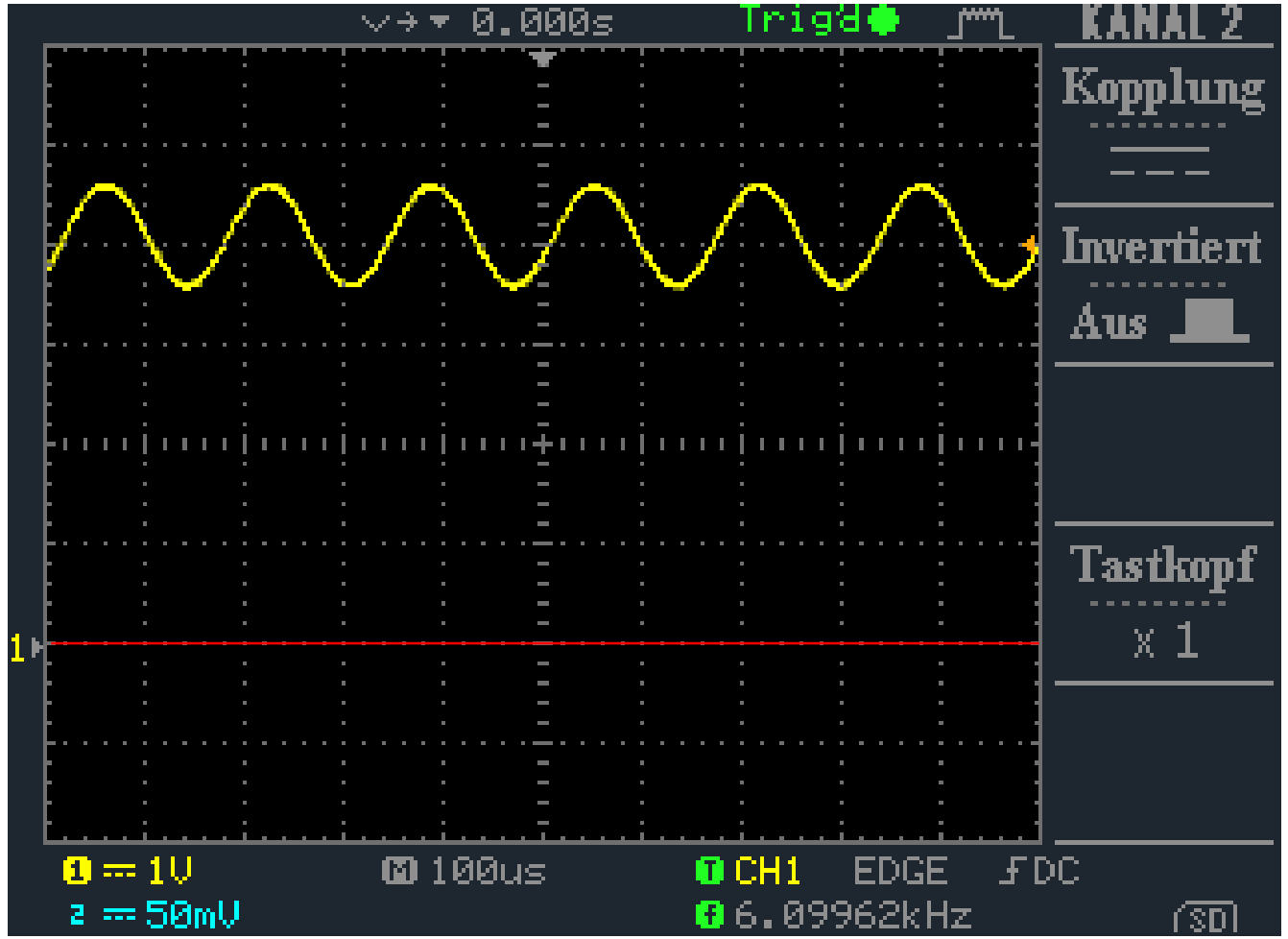

Zero line

AC voltage **with offset**

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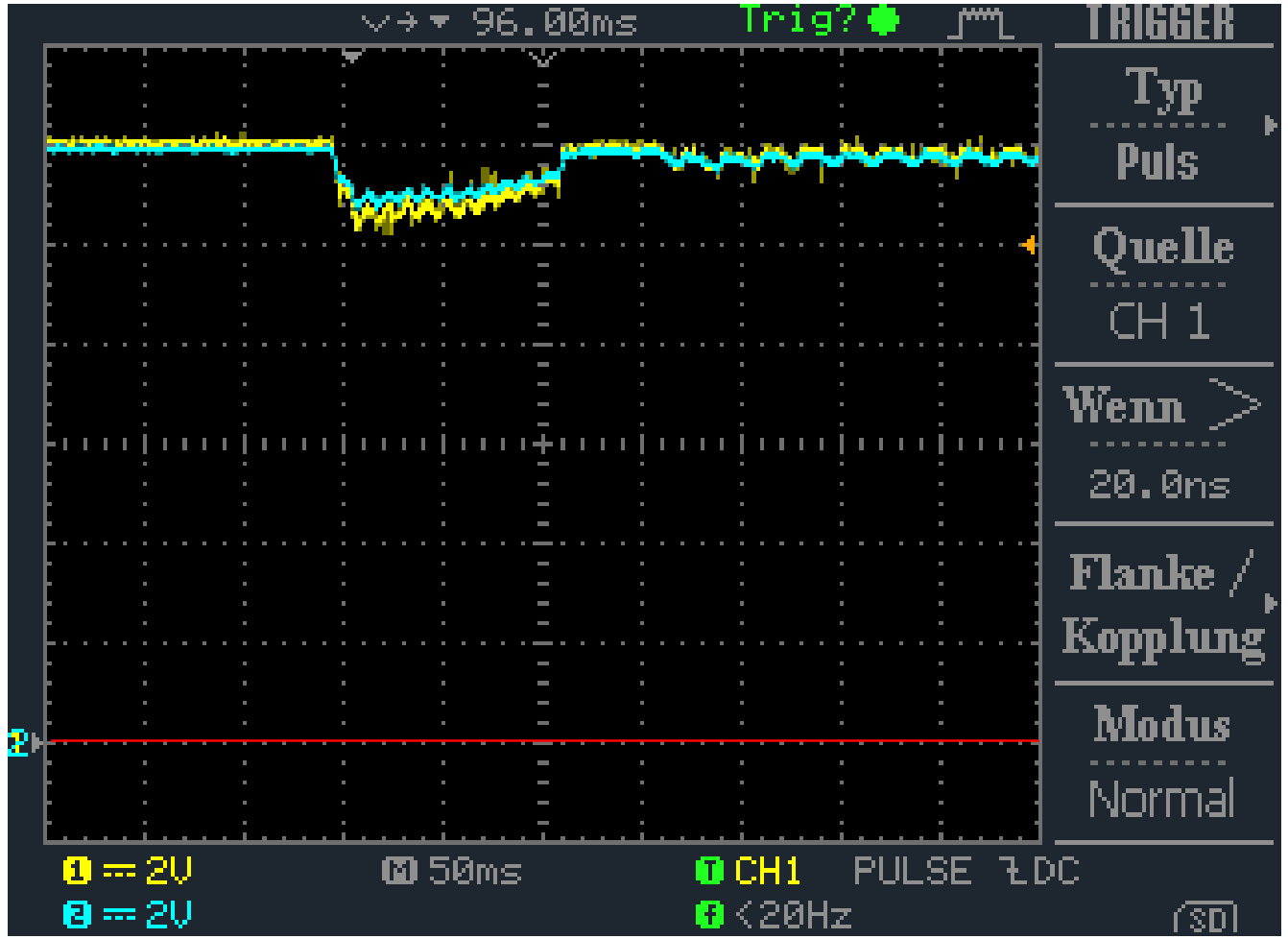


Zero line

DC voltage **with AC components**

Figure normalized to 1 V per box as an example.

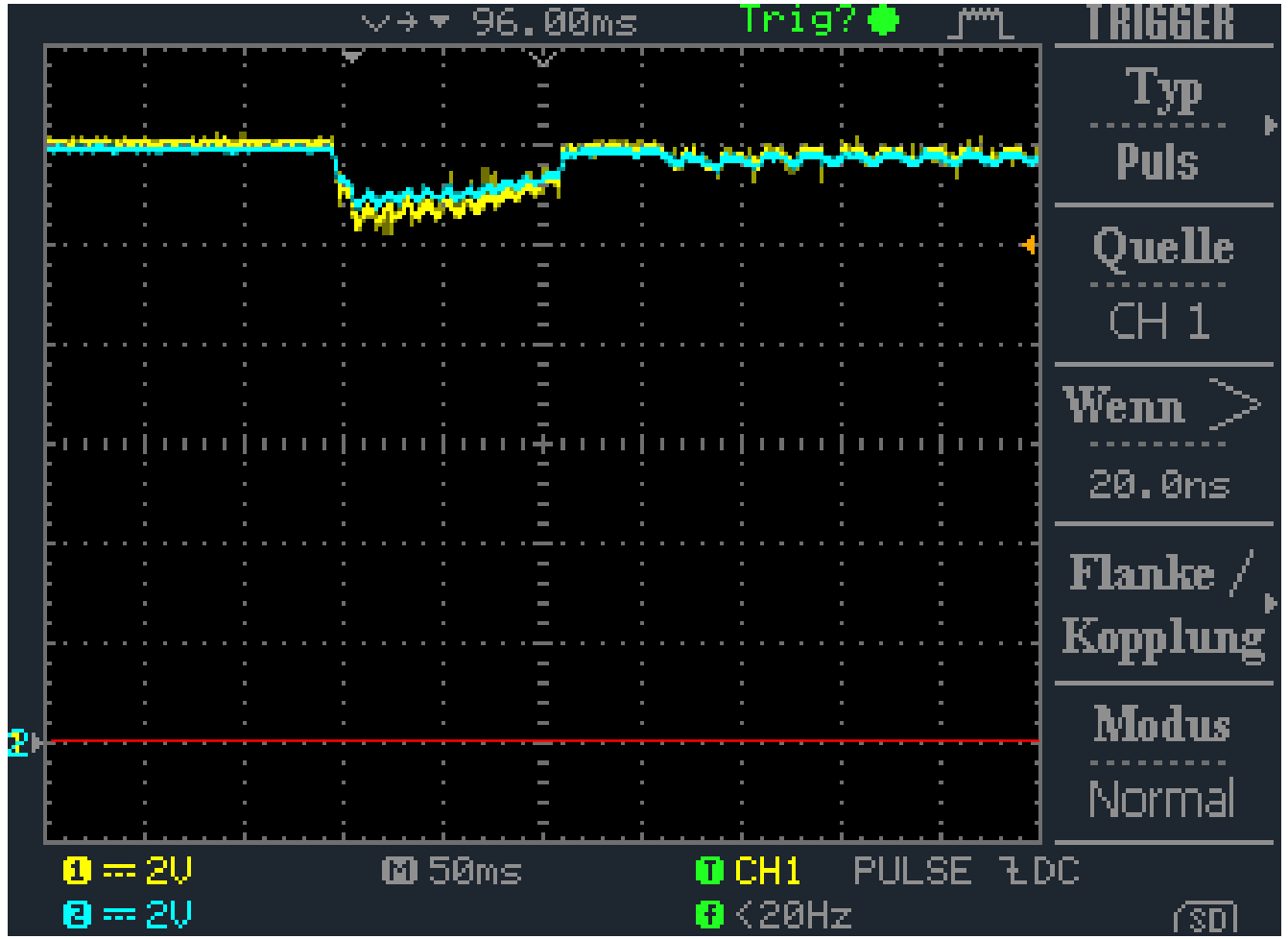
You can multiply this by 100 and you are already in the 400 V system.

What are the types of voltage?

Example 12 volt electrical system (combustion engine):

- With engine at standstill = almost DC voltage 12 V
- After the combustion engine has been started, the alternator and consumers such as the ignition system cause feedback effects in the vehicle electrical system, so that the DC voltage is distorted.

Zero line



DC voltage **with AC components**

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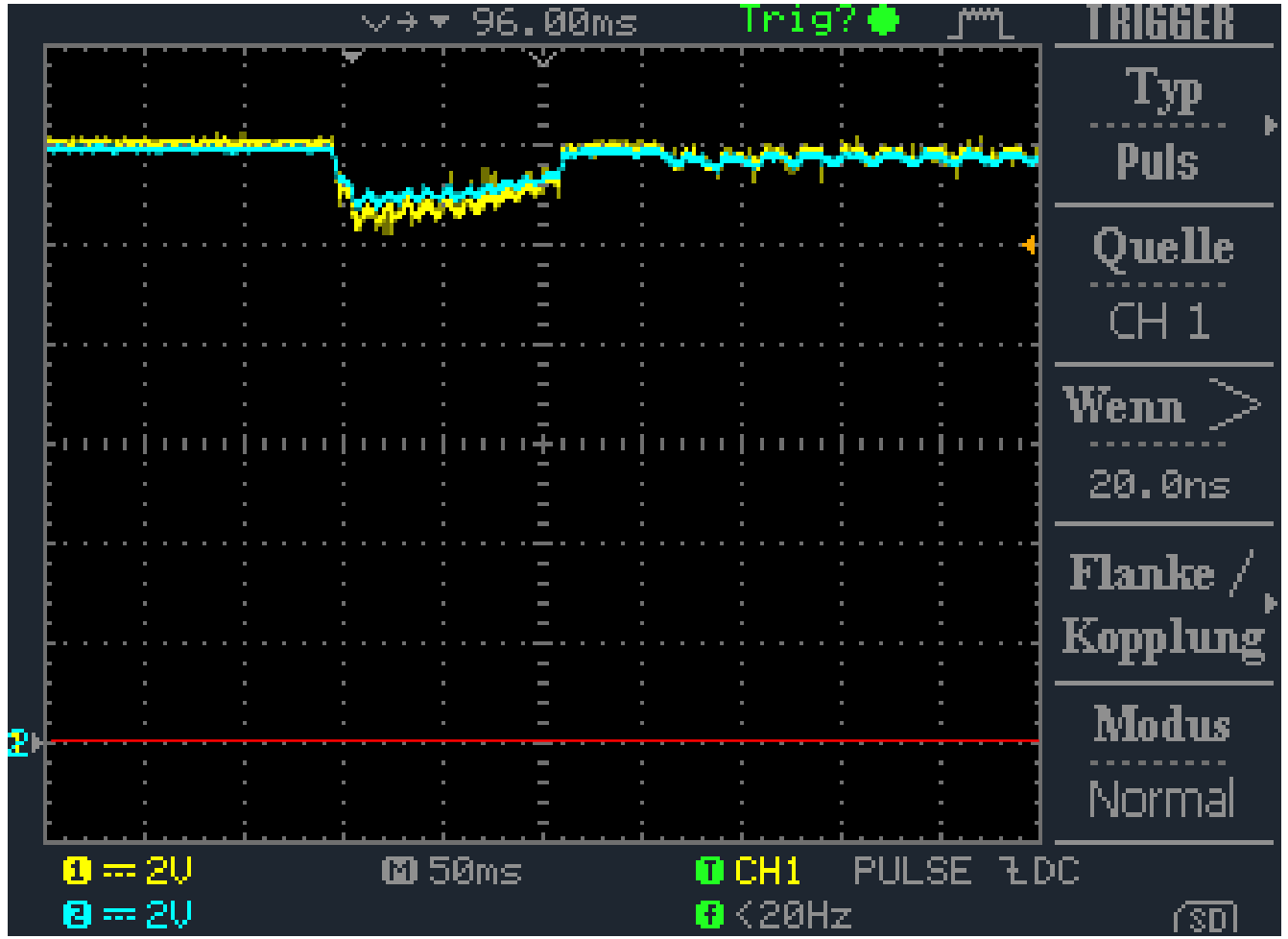
- DC voltage
- AC voltage
- AC voltage with offset
- DC voltage with AC components
- **Time intervals? - how fast to measure?**

Despite battery DC voltage, the vehicle electrical system is always subject to frequency mixtures.

In order to detect these alternating components, measurements must be performed at high data rates (depending on the application).



DC voltage **with AC components**

What should be considered when using measurement technology for voltage measurement?

Different voltmeters for different applications

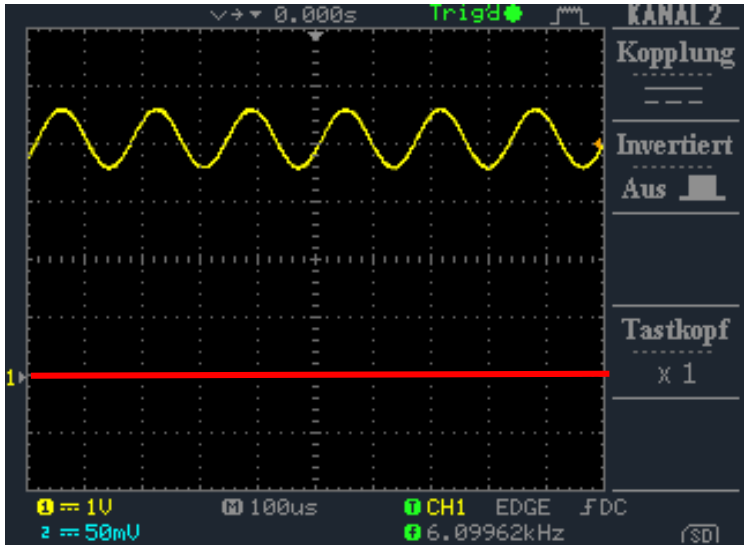
- DC voltage / AC voltage / DC voltage with AC components
- Extra-low voltage (µV), low voltage (<60 V), high voltage (60 V to 1,000 V)

Which measuring device do I use?

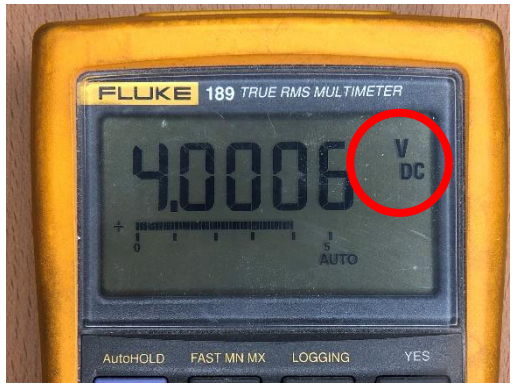
- How fast do I have to measure? — Data rate: 1 Hz to 1 MHz
- What is my expected voltage? — Measuring range: ±3 mV to ±2,000 V
- Low voltage / high voltage — Limits: 60 V DC / 30 V AC
- Who is allowed to install and measure? — Consider laws!

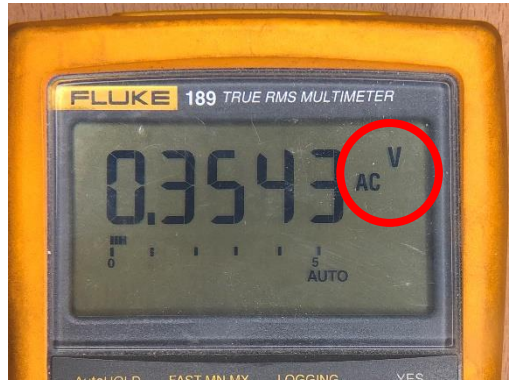
For voltages above 60 V DC and 30 V AC: **Comply with HV guidelines!**

Comparison: What does a multimeter display?



Measured signal:
6 kHz sine with ±0.5 V amplitude, 4 V offset

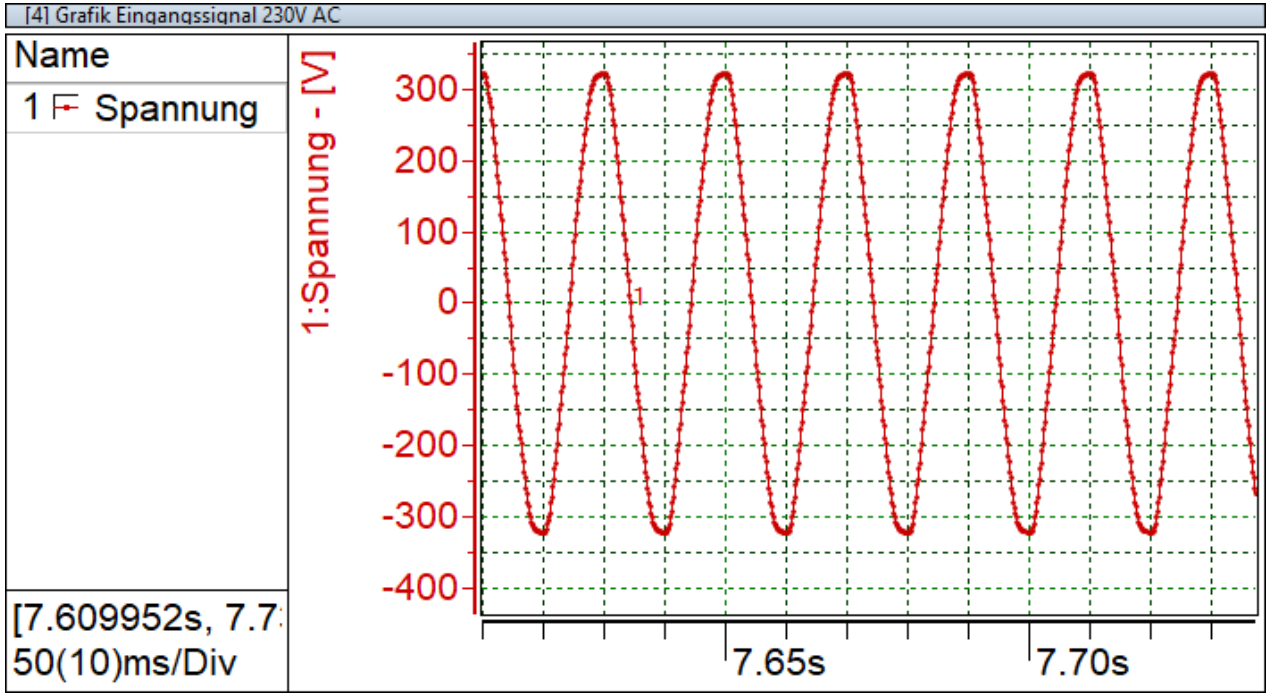


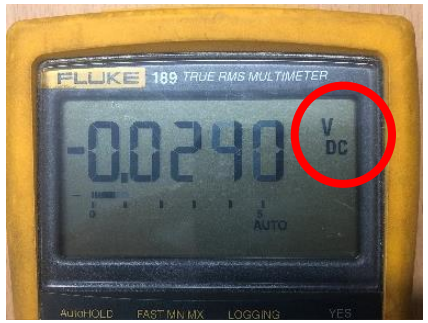


Multimeter displays effective value of the AC signal

Comparison: Multimeter vs. raw data acquisition

Example: common European socket (50 Hz, 230 V)





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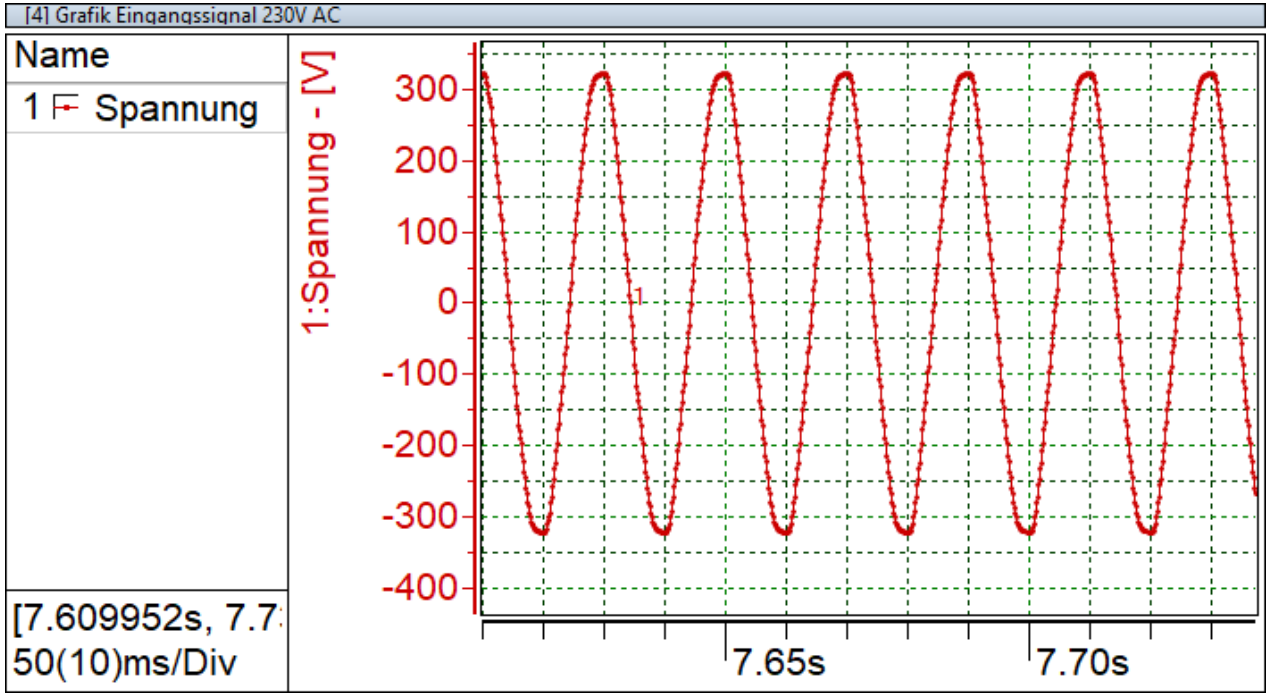
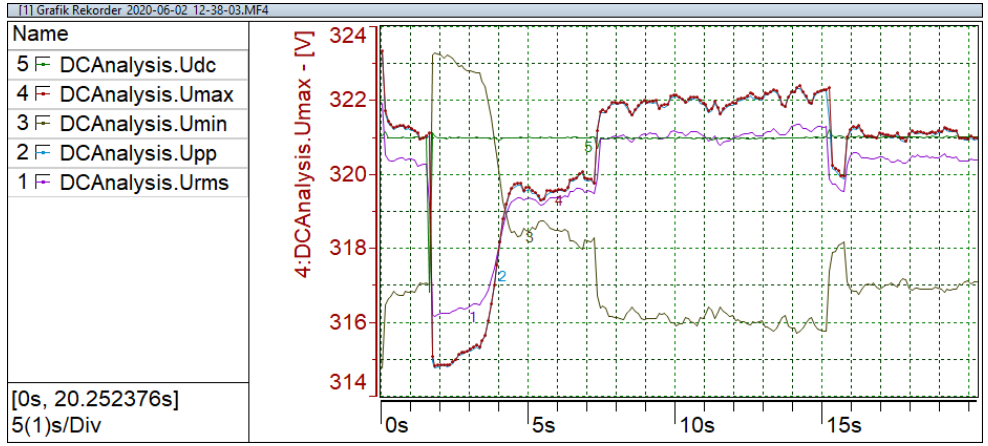
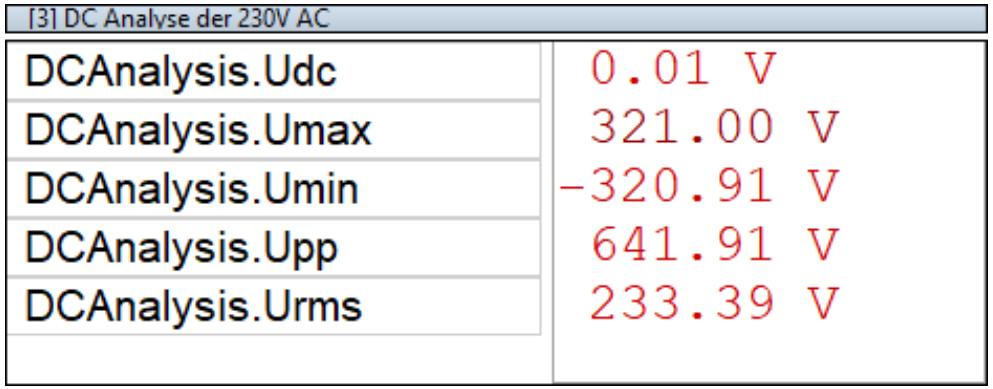






Find ECAT AD measurement modules on www.csm.de

Suitable measuring devices for voltage up to 90 V

Example: CSM CAN and ECAT AD measurement modules

- Measuring ranges: from ±10 mV to ±90 V
- Sampling rates: up to 1,000 kHz
- Operating temperature range: -40 °C to +125 °C,
- IP67

CAN measurement module
AD4 MX2

ECAT (EtherCAT®) measurement module
AD4 OG1000

*Beispielhafte Messmodule

Find HV safe measurement modules on www.csm.de

Suitable measuring devices for voltage up to 1,000 V

Example: CSM HV CAN and HV ECAT AD measurement modules

- Measuring ranges: from ±1 V to ±1,000 V(± 2,000 V peak)
- Sampling rates: up to 1,000 kHz
- Operating temperature range: -40 °C to +100 °C,
- IP67

HV ECAT measurement module
HV AD4 XW1000

HV CAN measurement module
HV AD4 XW20

- HV-safe connector
- Mechanical connector guide for tightness and bend protection
- Reinforced isolation
- Type-tested according to safety standard EN61010 by accredited test laboratory
- Unit test with certificate
- 3,100 V ramp 5 sec each

*Beispielhafte Messmodule

Find
HV Breakout Modules
on www.csm.de

Suitable measuring devices for voltage up to 1,000 V

Example: CSM HV Breakout Modules (BM)

- Measuring range: ±50 V to ±1,000 V (±2,000 V peak)
- Sampling rates: up to 1,000 kHz
- Operating temperature range: -40 °C to +120 °C

HV BM 1.2 HV BM 1.1

- Reinforced Isolation
- Type-tested according to safety standard EN61010 by accredited test laboratory
- Unit test with certificate
- 3,100 V ramp 5 sec each

*Beispielhafte Messmodule

Suitable measuring devices for voltage up to 1,000 V

Example: CSM HV Breakout Modules (BM)

- Direct installation in (HV) lines of the vehicle electrical system
- Simultaneous and fully synchronized acquisition of U and I with high data rates (up to 1 MHz per channel)
- Acquisition of raw data and real-time calculation of instantaneous power (P = U x I)
- Bus connection via EtherCAT® and CAN bus
- Additional online signal processing via Vector eMobility Analyzer (CANape and vMeasure Expert)

Applications

§ Standards and guidelines (e.g. ECE R100, ISO 1010, DGUV 3, ISO 21498)

HV vehicle electrical system

Ripple

Component tests

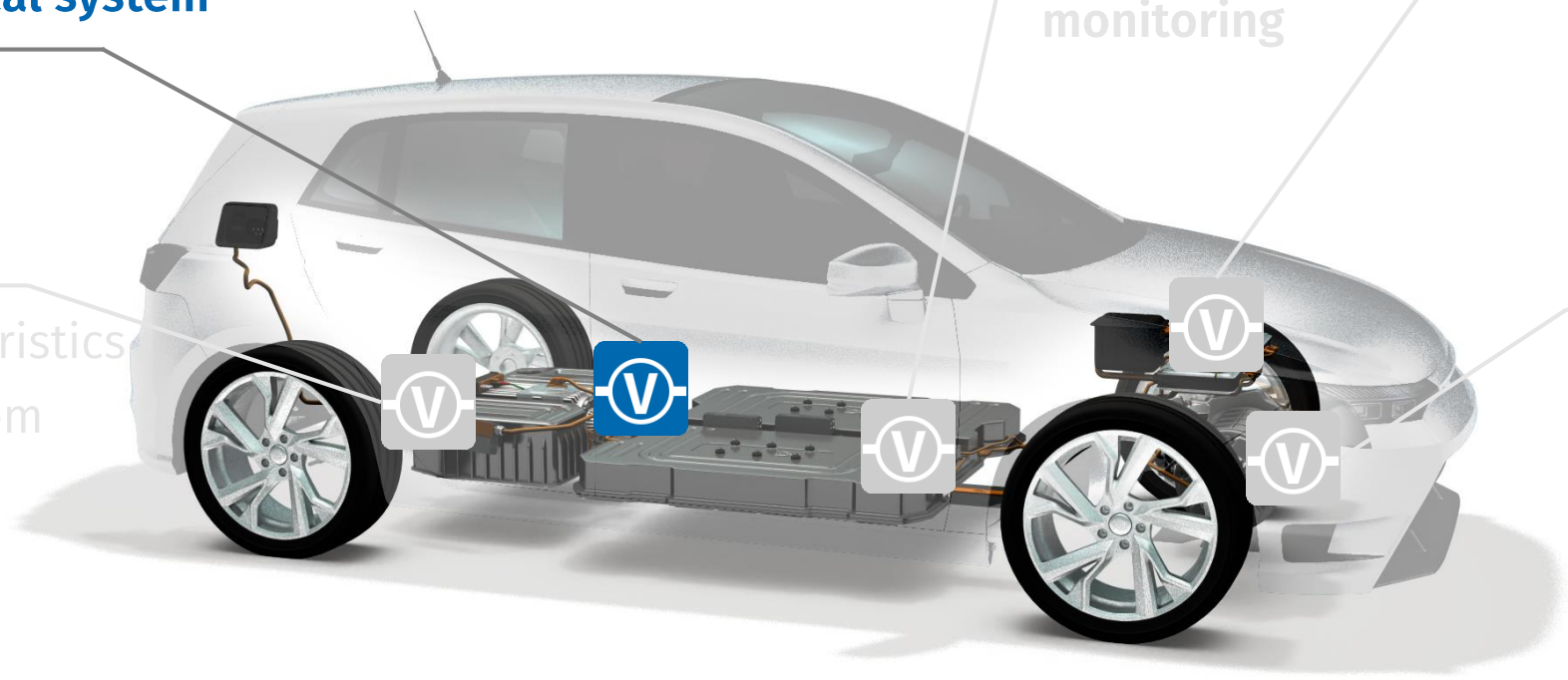
Charging characteristics of the entire system

HV insulation monitoring

HV cut-off mechanisms

Power train

Proof of Performance
Consumption tests

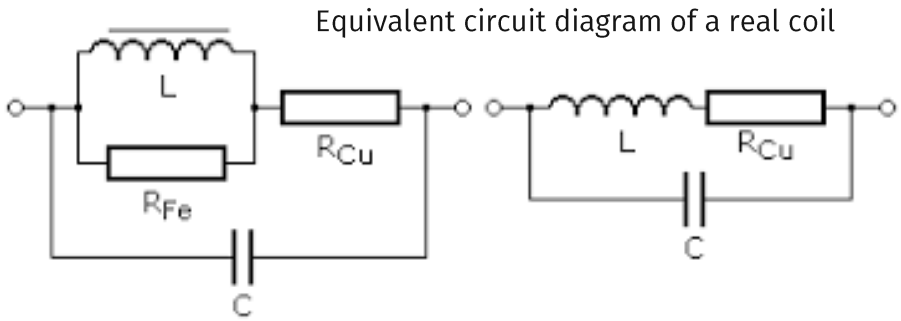


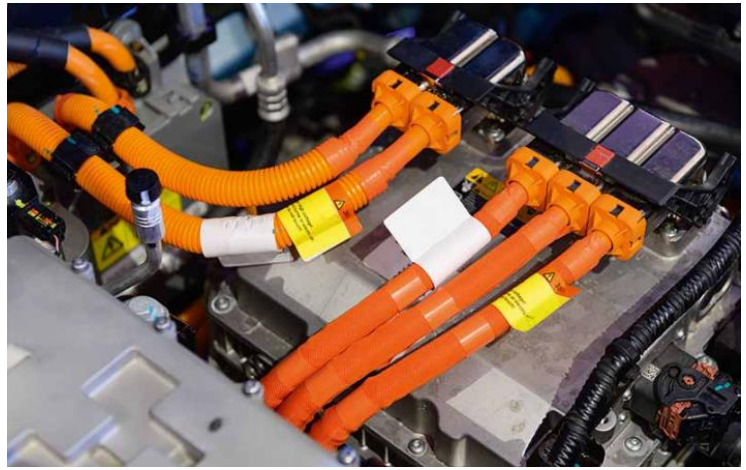
Verifying the quality of the vehicle electrical system (new characteristics)

The interaction of the individual components of an HV system

- Air conditioning / Inverter DC-AC / DC-DC converter / Heating (PWM)
- What are the typical characteristics and interactions of HV voltages in vehicles?

Equivalent circuit diagram of a real coil



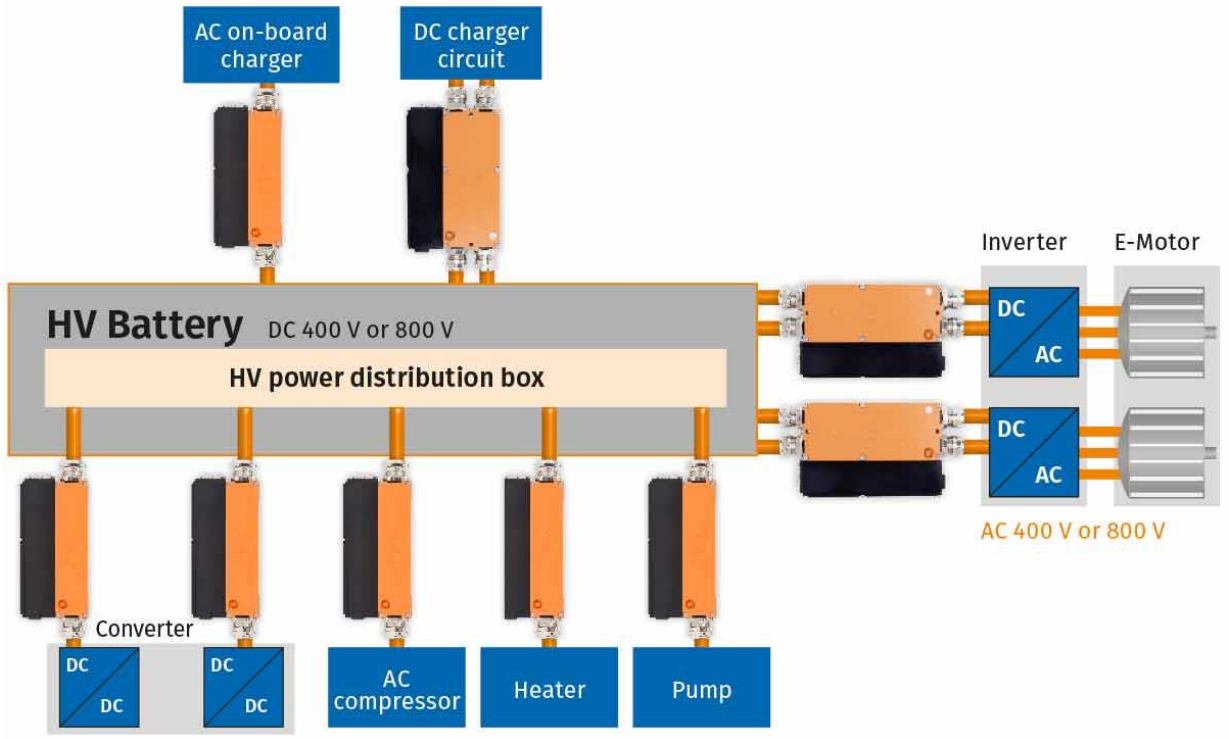


Read the application example on www.csm.de

Verification of the high-voltage vehicle electrical system quality

Testing the residual ripple of the HV DC voltage

- HV battery = energy source
- Components:
  - Compressor
  - Water pump
  - PTC Heater
  - DC/DC Converter
  - Steering aid
  - Prime mover
- New component performance req'ts
- New test requirements



Applications

Standards and guidelines (e.g. ECE R100, ISO 1010, DGUV 3, ISO 21498)

HV vehicle electrical system

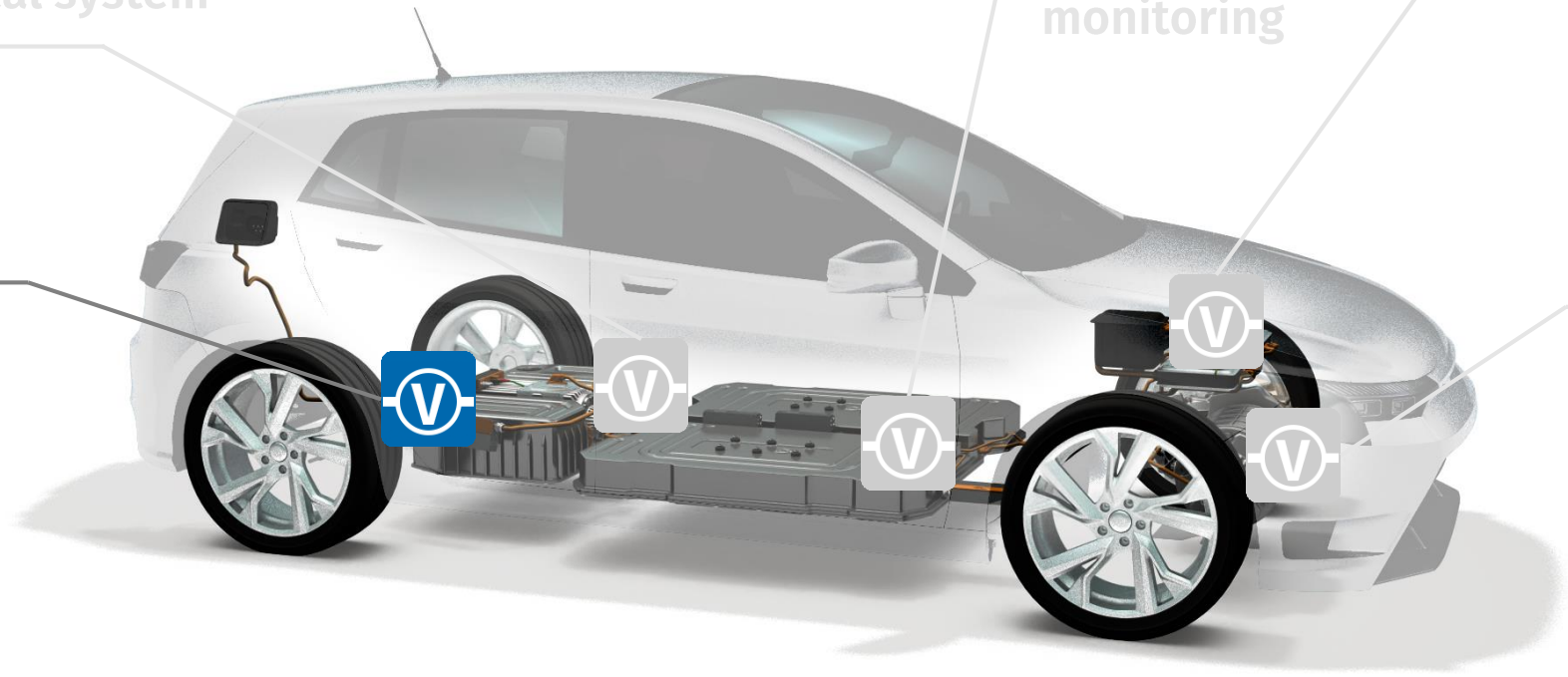
Ripple

Component tests

Electric axle

HV insulation monitoring

HV cut-off mechanisms

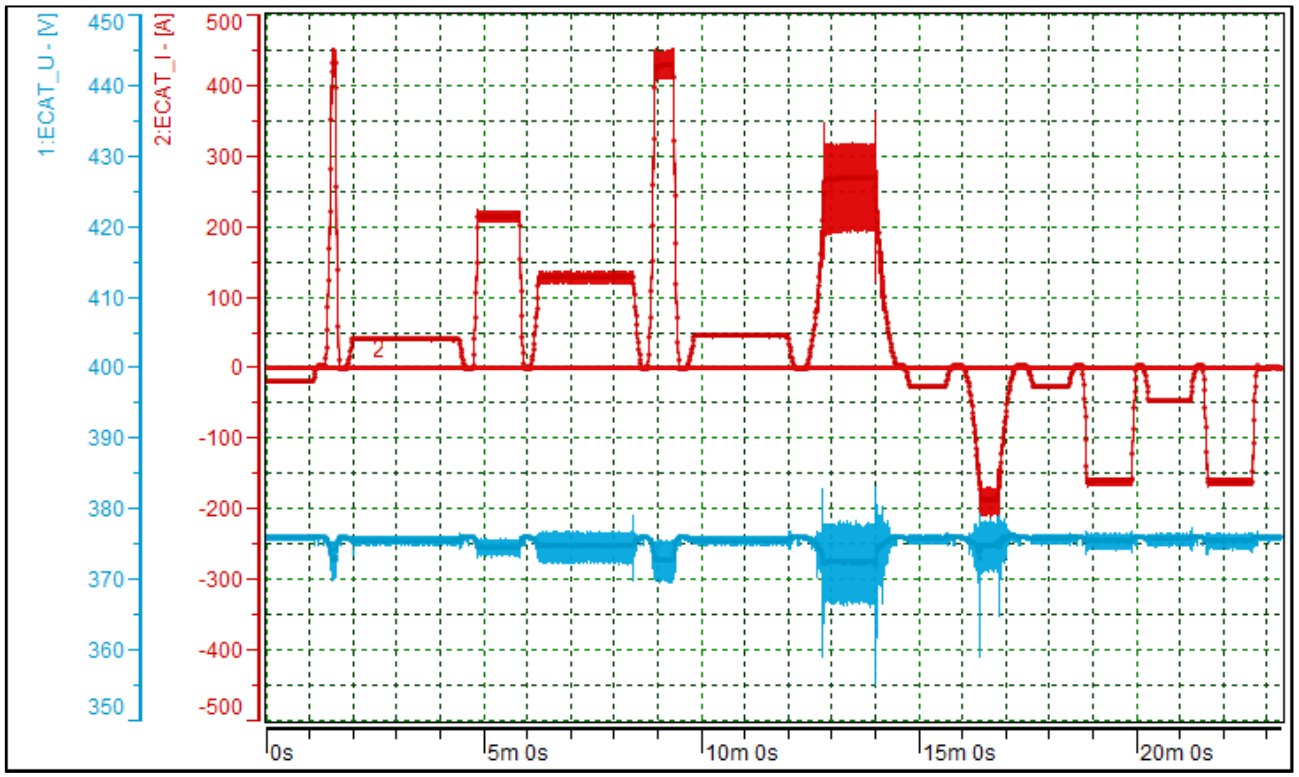


Power train

Proof of Performance

Consumption tests

Measurement of an electrical axle with HV BM 1.2



- Road test
- Different driving cycles
- Driving (I > 0 A)
- Recuperation (I < 0 A)

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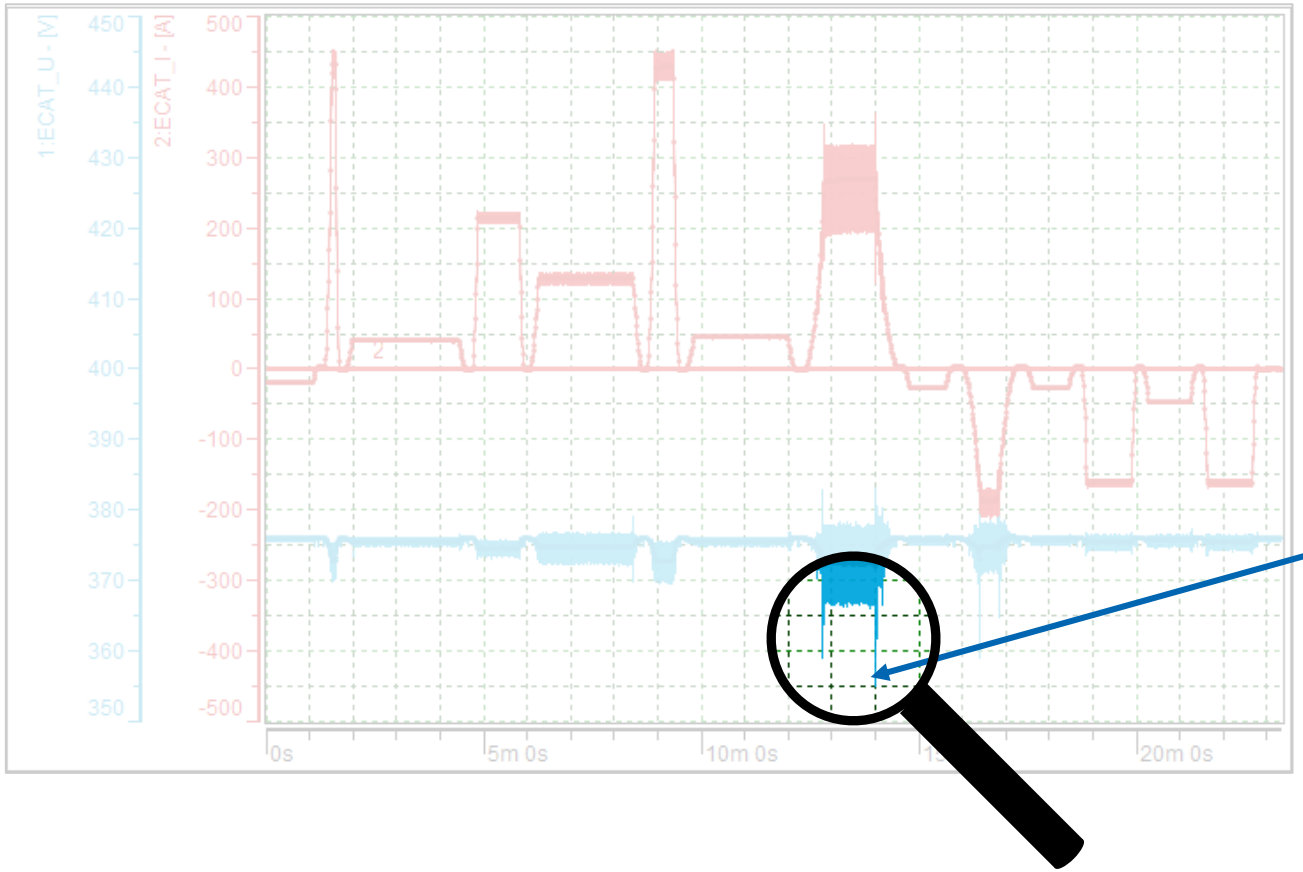

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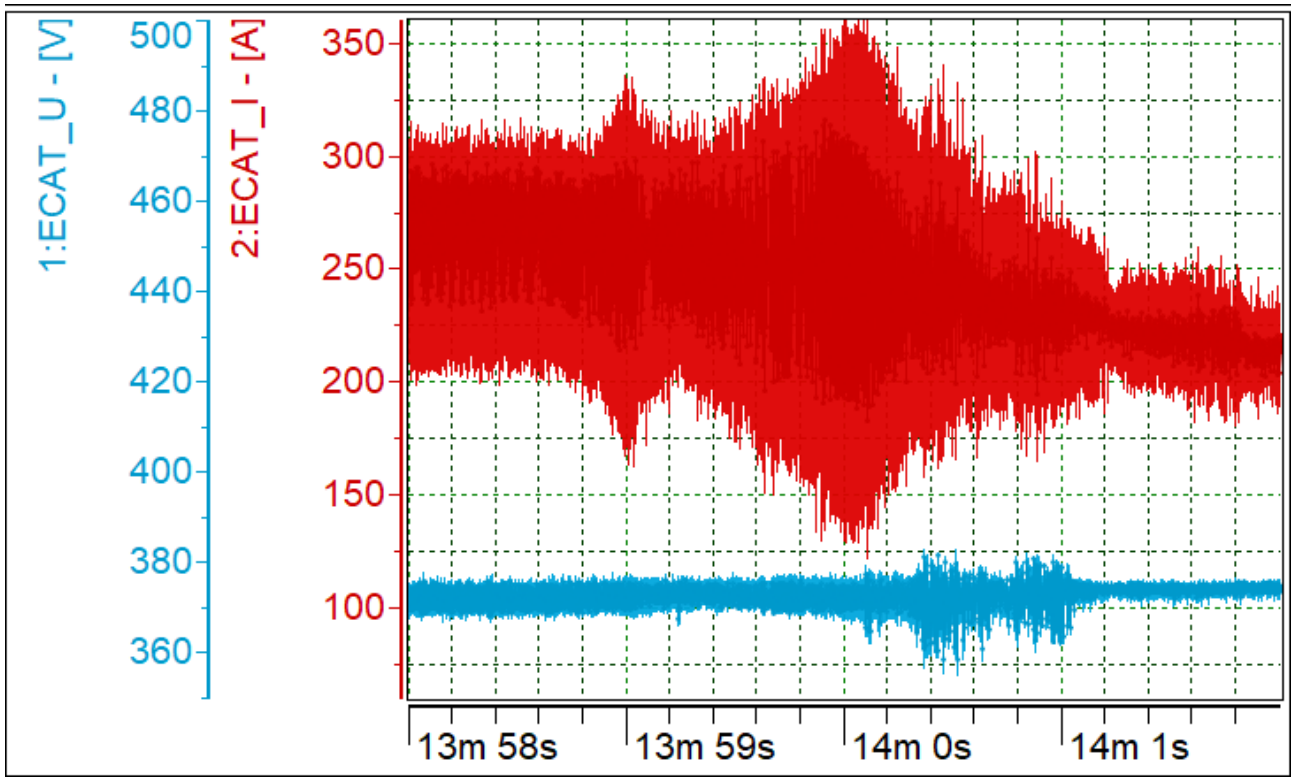
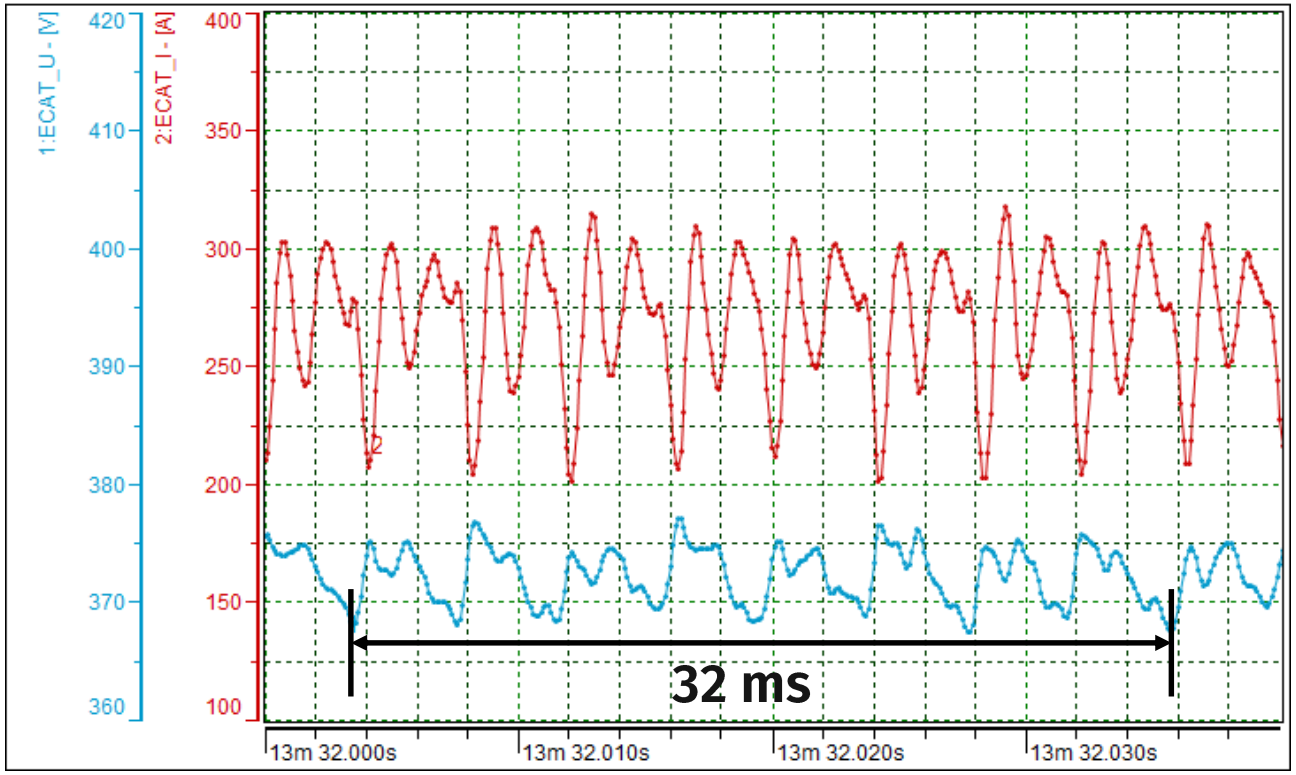
Too large voltage peaks

Measurement of an electrical axle with HV BM 1.2



- High ripple of I
  - I_{eff} = 249 A
  - I_{min} = 122 A
  - I_{max} = 364 A
  - σ_I = 40,2 A
- **Too high** ripple of U
  - U_{eff} = 373 V
  - U_{min} = **355 V**
  - U_{max} = 383 V
  - σ_U = 2,8 V

Measurement of an electrical axle with HV BM 1.2



@ P_{el} ~ 100 kW

1 box 2 ms

- High current ripple
- Acceptable voltage ripple

  => ISO 21498

- I_{eff} = 271 A
- I_{min} = 203 A
- I_{max} = 312 A
- σ_I = 27,6 A
- U_{eff} = 372 V
- U_{min} = 368 V
- U_{max} = 377 V
- σ_U = 2,3 V

Accurate measured values only at sampling rates beyond 100 kHz

Applications

Standards and guidelines (e.g. ECE R100, ISO 1010, DGUV 3, ISO 21498)

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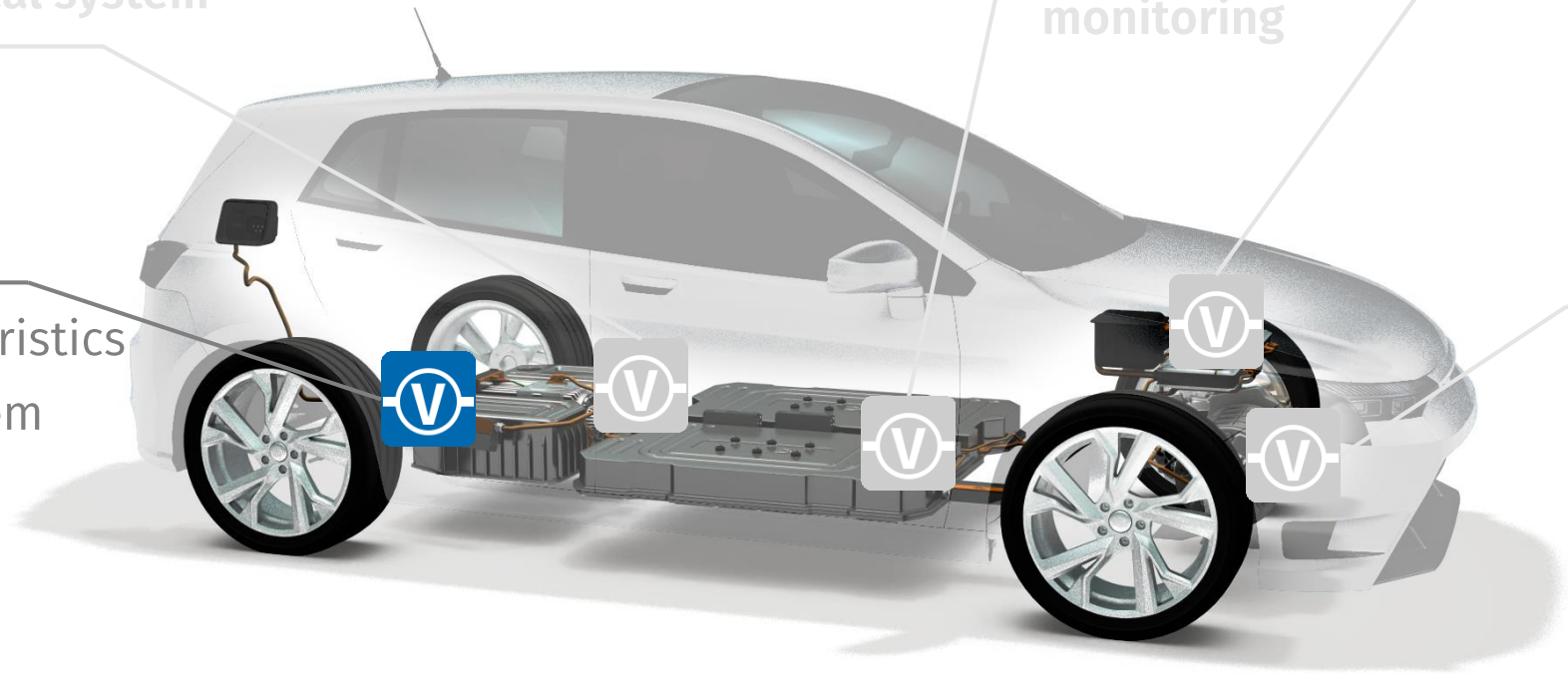
HV insulation monitoring

HV-Abschalt-mechanismen

Component tests

Charging characteristics of the entire system



Power train

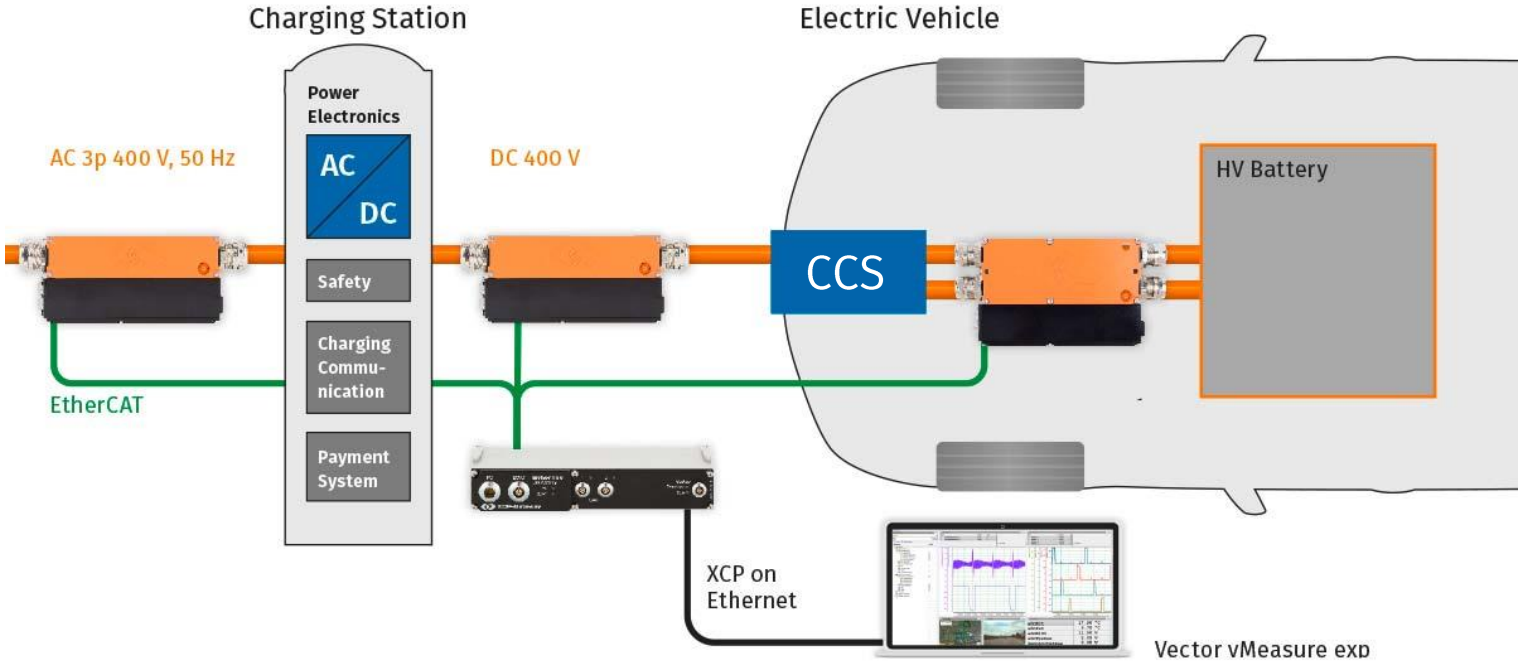
Proof of Performance

Consumption tests

Read the application example on www.csm.de

High voltage measurement at fast charging stations

Verifying the interaction of different converters and power electronics in charging stations and different vehicle types requires measurements at many points throughout the charging chain.



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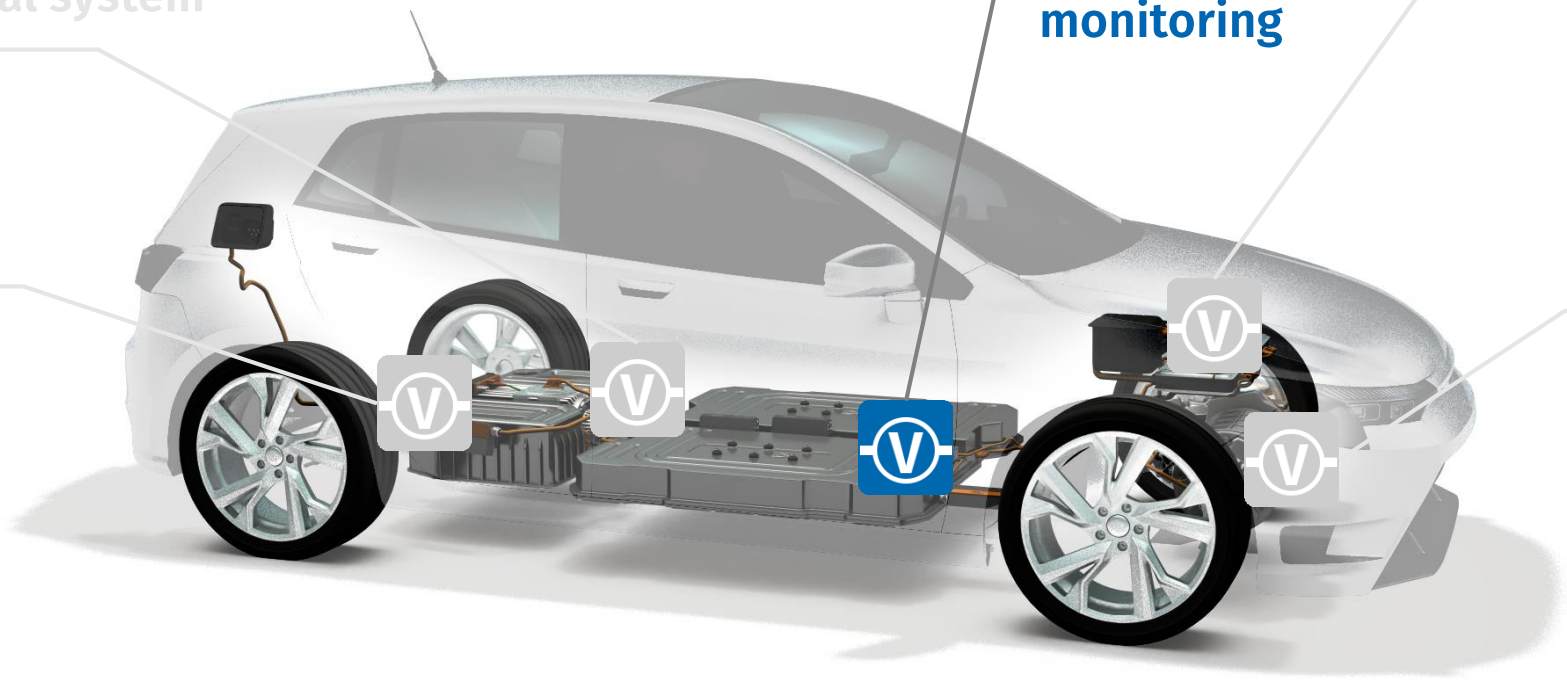
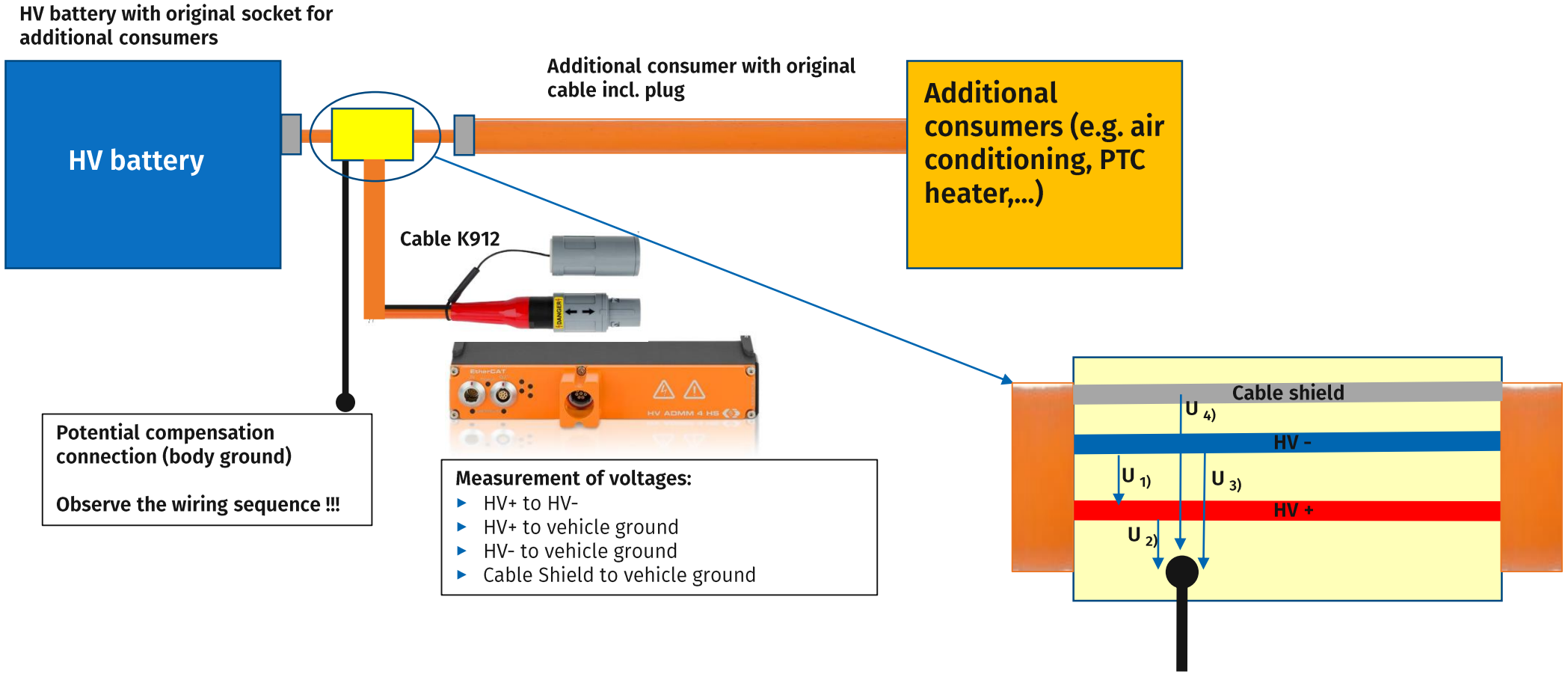


Verifying the protective mechanisms in the non-grounded HV vehicle electrical system



Voltage Measurement in E-Mobility

	CAN & ECAT - Measurement technology	HV CAN & ECAT - Measurement technology	HV Breakout Modules
Measuring range	±10 mV to ±90 V	±1 V to ±1,000 V (± 2,000 V peak)	±50 V to ±1,000 V (±2,000 V peak)
Sampling rate	Up to 1,000 kHz	Up to 1,000 kHz	Up to 1,000 kHz
Isolation **(according to EN 61010)**	Basic Isolation	Reinforced Isolation	Reinforced Isolation
Feature	Low voltage environment	High Voltage environments	Simultaneous current measurement and power calculation

About CSM

CSM has been setting technological standards for decentralized measurement technology in vehicle development for over 35 years. Our CAN bus and EtherCAT® measurement devices support worldwide renowned vehicle manufacturers, suppliers and service providers in their developments.

Continuous innovation and long-term satisfied customers are our guarantee for success. Together with our partner Vector Informatik, we have developed an easily scalable and powerful E-Mobility Measurement System for hybrid and electric vehicles and are constantly expanding the areas of application. With our high-voltage safe measurement systems designed for fast and synchronous measurements and power analyses, we actively accompany the change to E-Mobility.

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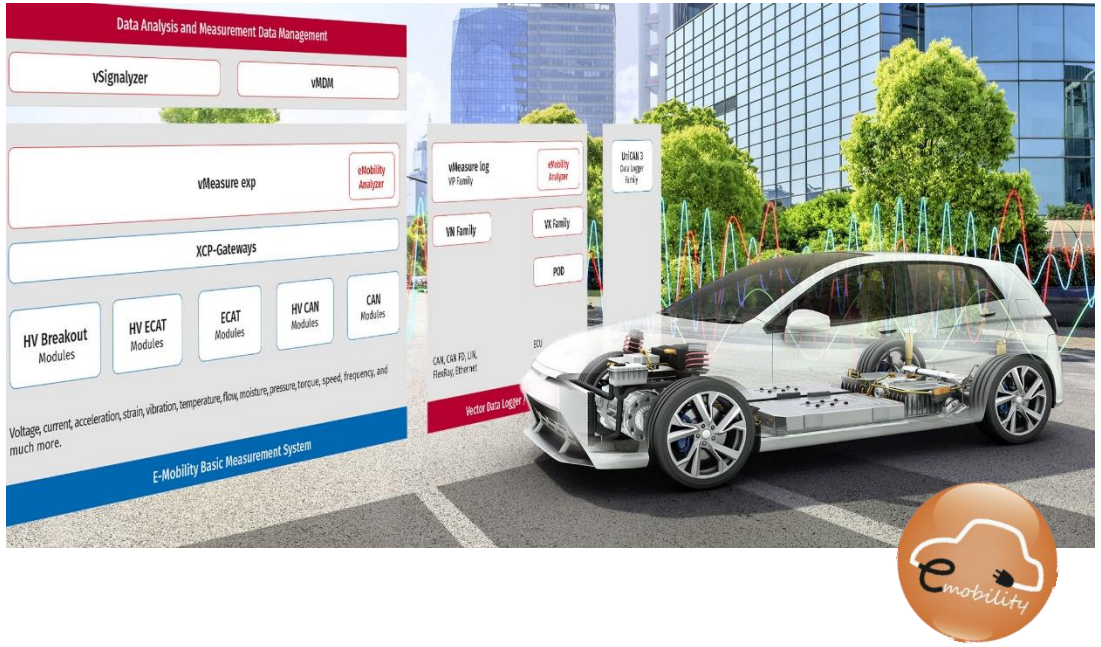

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