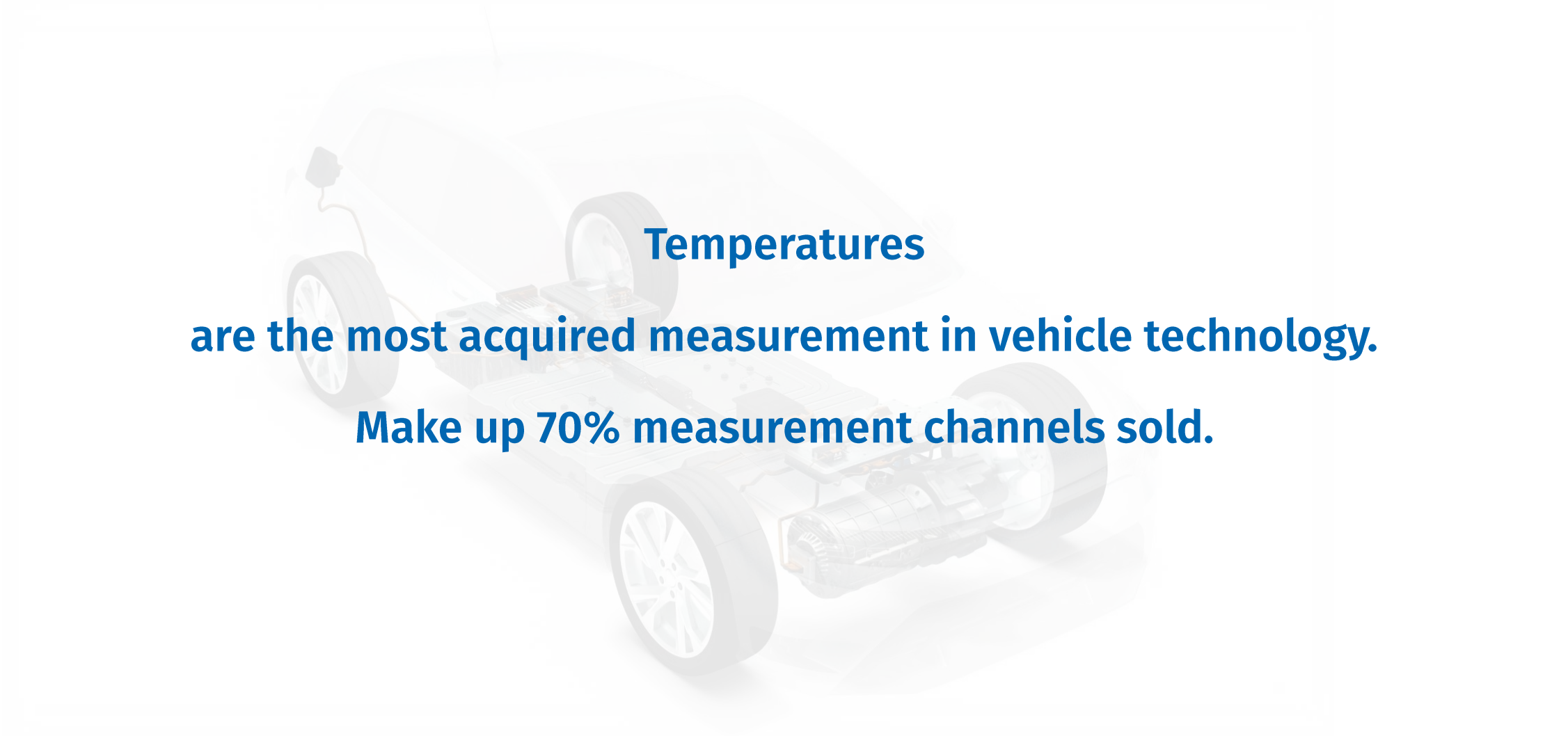
# Temperature measurement in e-mobility

## CSM Web Seminars


Innovative Measurement and Data Technology



**Temperatures**

**are the most acquired measurement in vehicle technology.**

**Make up 70% measurement channels sold.**

# Temperature measurement in e-mobility

**On-Board-Charger**

Charging efficiency

**HV Vehicle Electrical System**

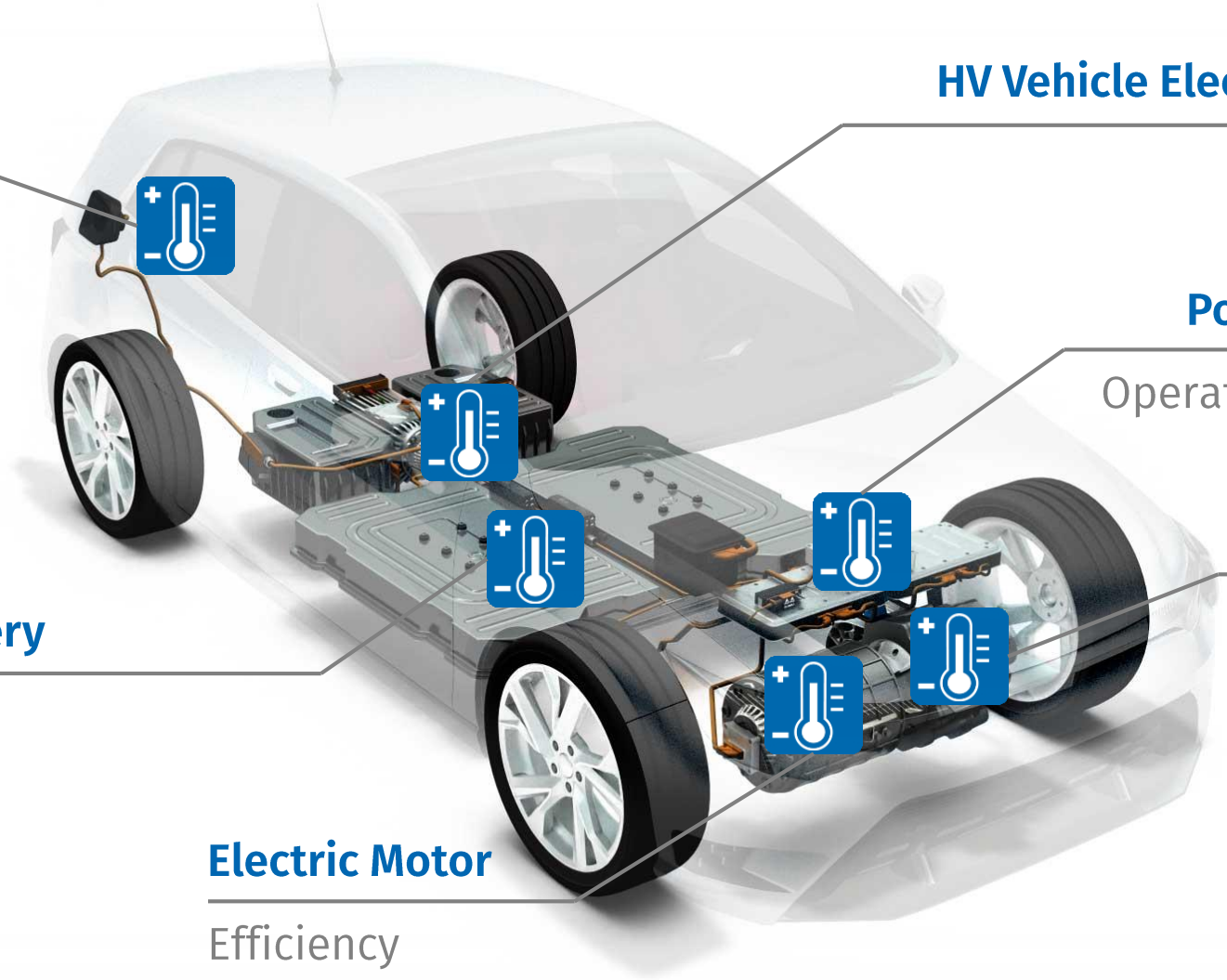
High currents

**Power Electronics**

Operational capability

**Inverter**

Electrical resistors



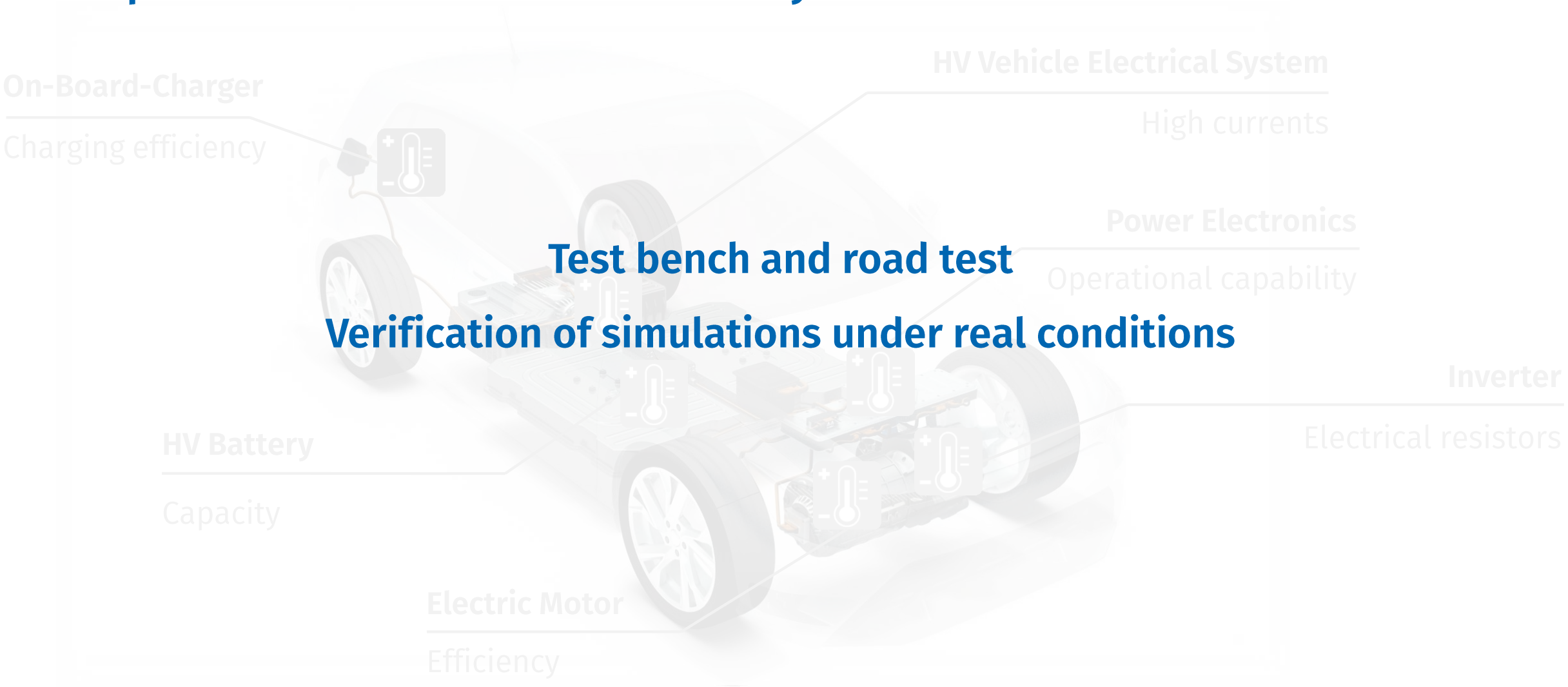
**HV Battery**

Capacity

**Electric Motor**

Efficiency

# Temperature measurement in e-mobility




## Test bench and road test

## Verification of simulations under real conditions

# Sensor technology for temperature measurements

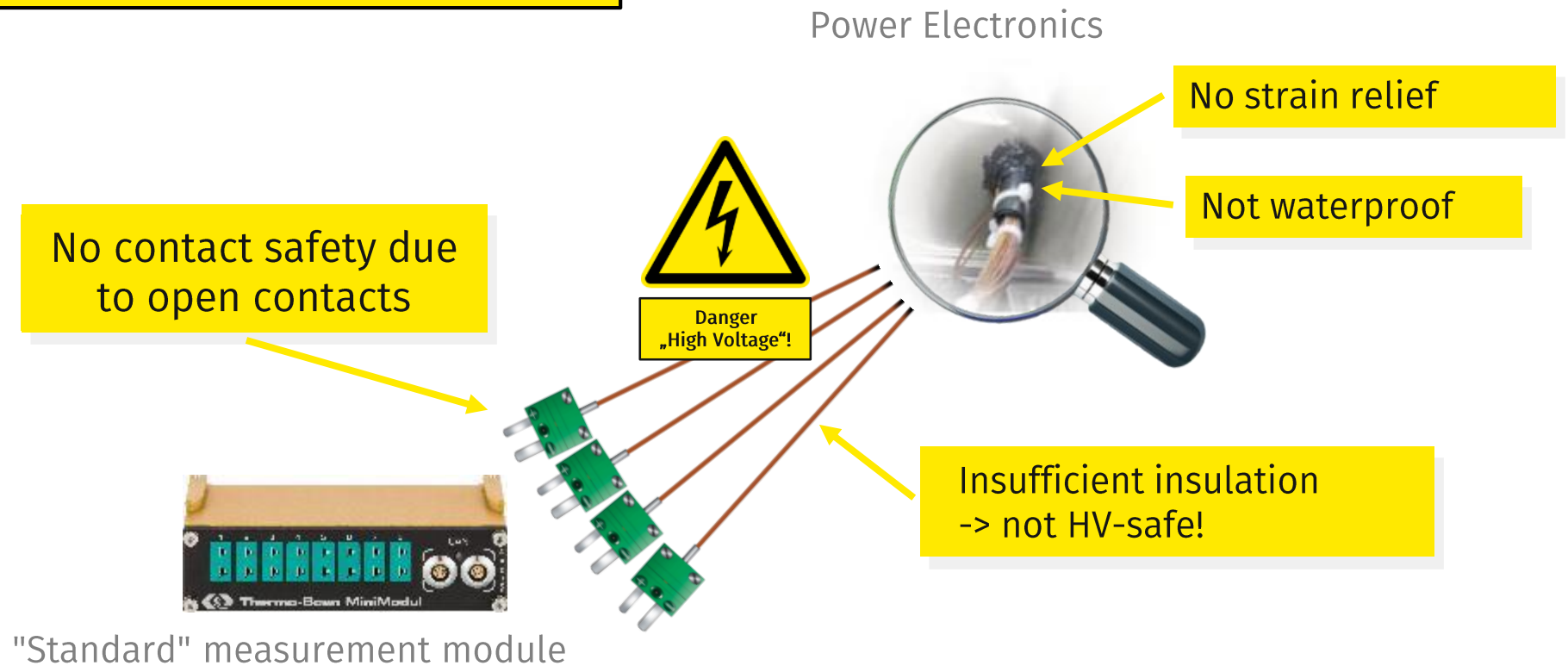
| | Thermocouples | PT100 / PT1000 RTD elements |
|---|---|---|
| + | Accuracy: approx. ±1.5 K<br>or 0.4 % of measured value (class 1) | Very good accuracy: approx. ±0.15 K<br>(Class A) |
| | Wide measuring range:<br>-40 °C to +1,000 °C (Class 1) | Sufficient measuring range:<br>-200 °C to +650 °C (class A) |
| | Easy handling | Low susceptibility to interference |
| | Good response times | |
| | | |
| – | Design depending on application | Complex cabling (4-wire) |
| | Susceptible to interference | Active power supply |
| | | Slow response times |
| | All contacts must be made of thermal material for accuracy | Decreasing measurement accuracy with increasing temperature |

# Sensor technology for HV environments

| | Thermocouples | PT100 / PT1000 RTD elements |
|---|---|---|
|   | Conventional sensor technology in the HV environment? | |
|  | Temperature measurements also possible with conventional sensor technology | |
|  | But:<br>▸ HV-safe cables<br>▸ HV-safe connectors<br>▸ HV-safe measuring devices incl. power supply | |

# Use of standard measurement technology - Danger to life

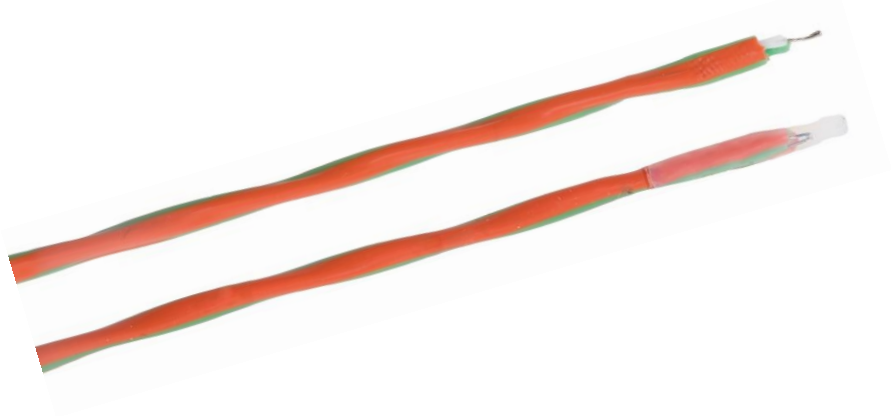
**Unsuitable and dangerous temperature measurement chain**



# HV-safe sensor technology

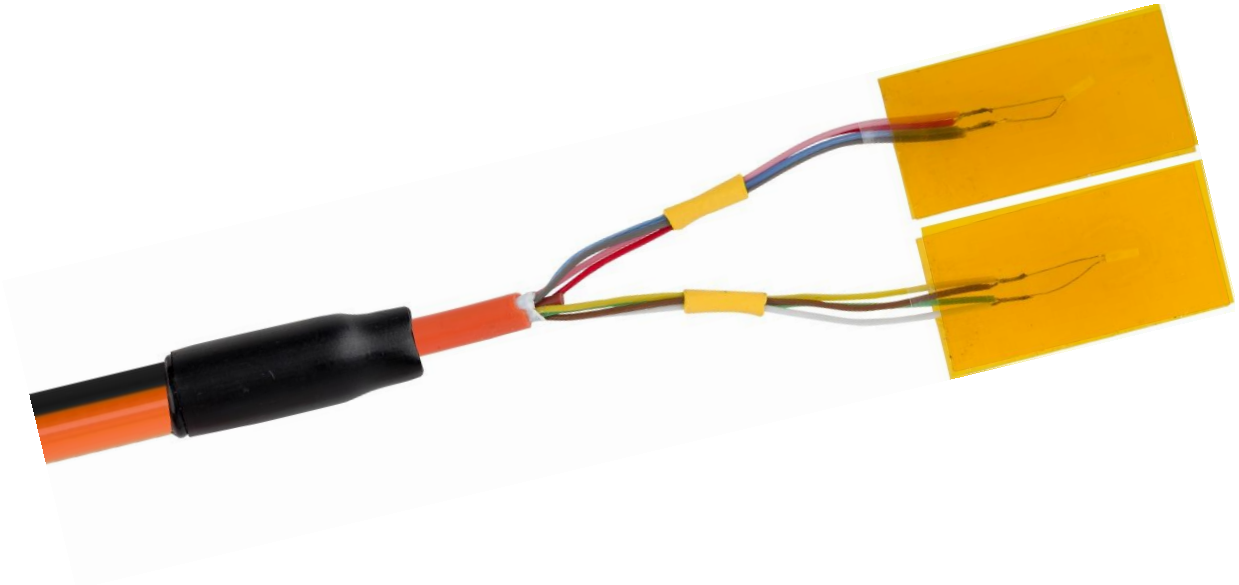
## Benefits with thermocouples

- Many individual variants of measuring tips possible
- FEP orange 1000v contact protection sheathing
- 2-wire, 4 temperatures on HV sum socket
- Various installation options, e.g. with very good temperature-conductive Kapton adhesive pad
- Temperature range (Class 1): -40 °C to +1,000 °C



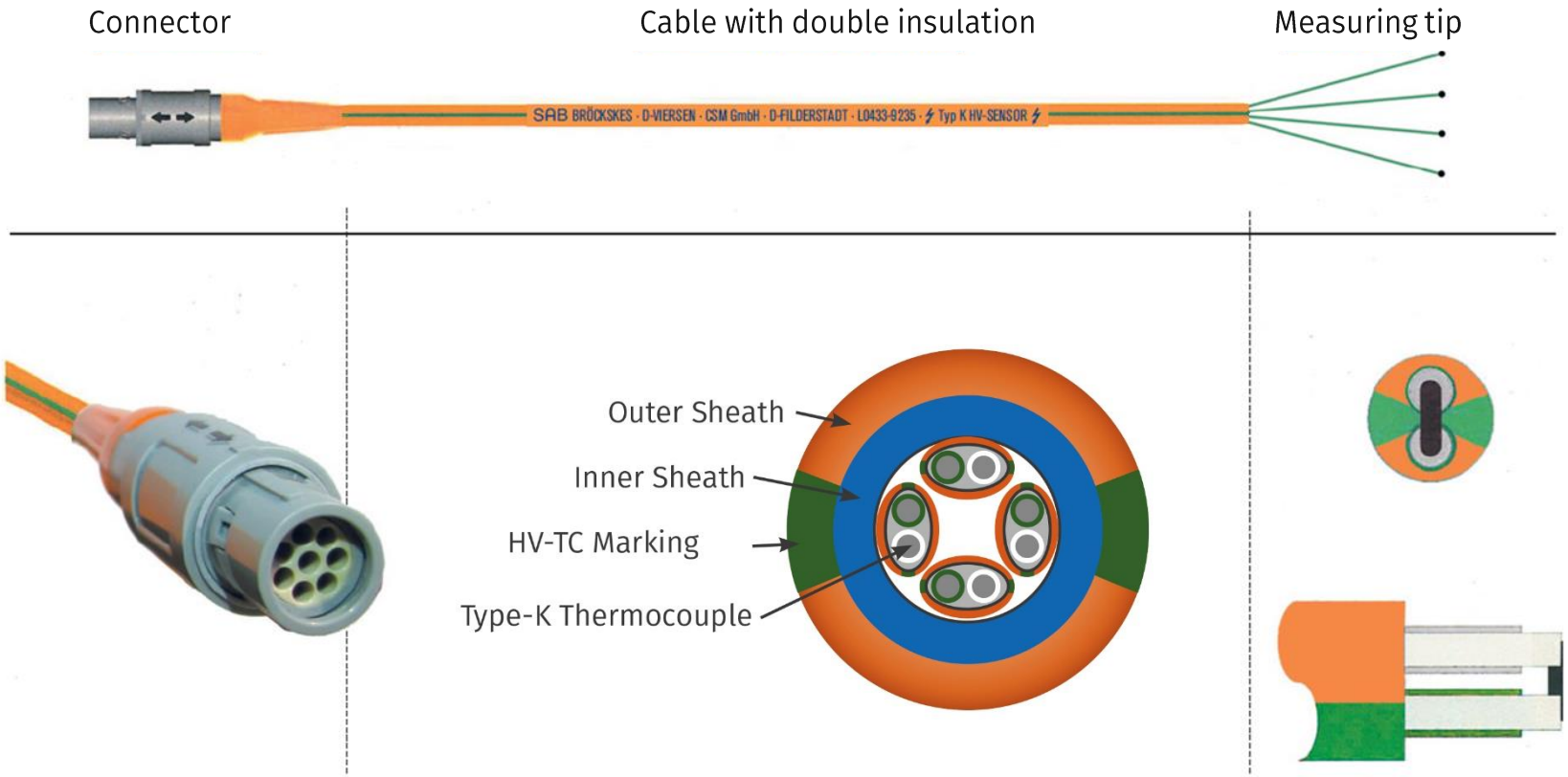
## Benefits with PT100 / PT1000 RTD sensors

- Very thin films possible (≤0.7 mm)
- Very high accuracy of the entire system incl. measuring module achievable (up to approx. ±0.3 K)
- Very good long-term stability



# HV-safe sensor cables

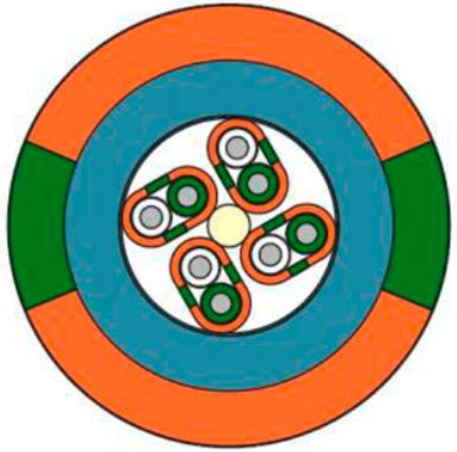
Using the example of a type K thermocouple



# HV-safe sensor cables

Typical 8-wire sensor cables

- Good ratio between outer protective sheath, warning inner sheath, pair or bundle sheath and strands
- Still sufficiently thin and flexible
  - Single wires 1,000 V touch-proof

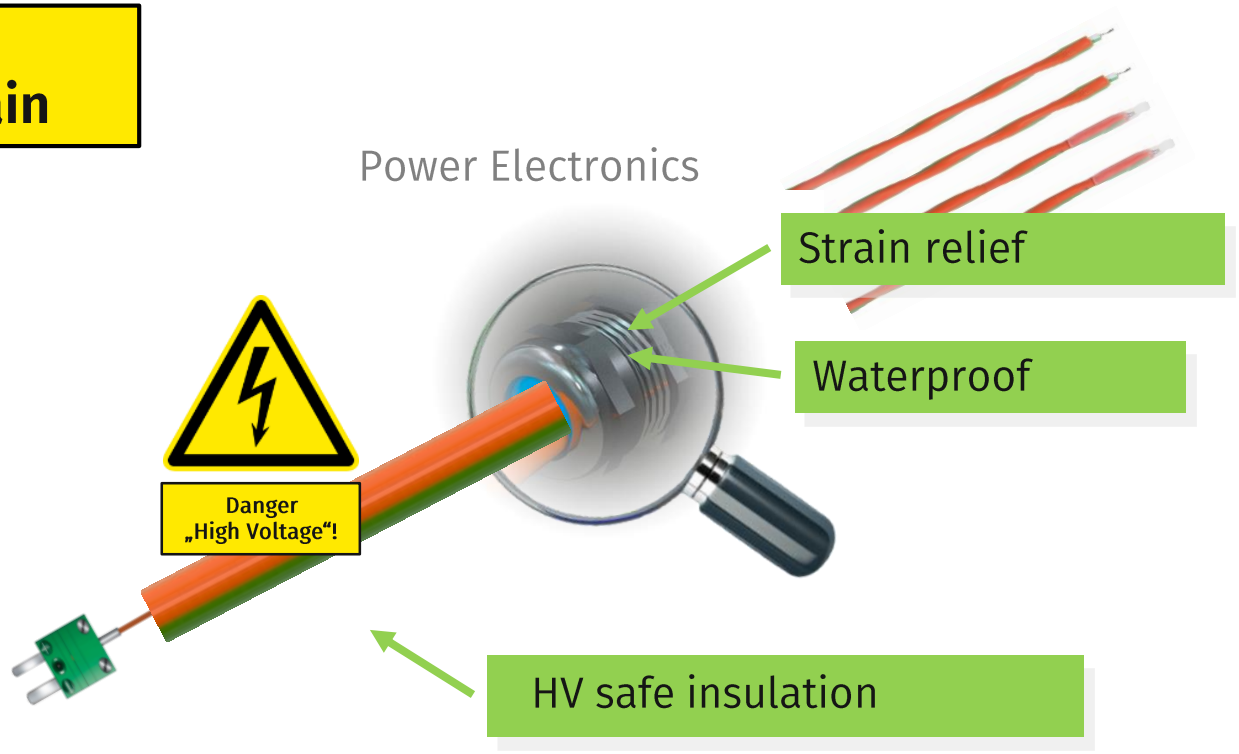


Thermo cable

PT100 cable

# HV-safe measurement chain for temperature measurements

**Unsuitable and dangerous temperature measurement chain**





"Standard" measurement module

# Connector

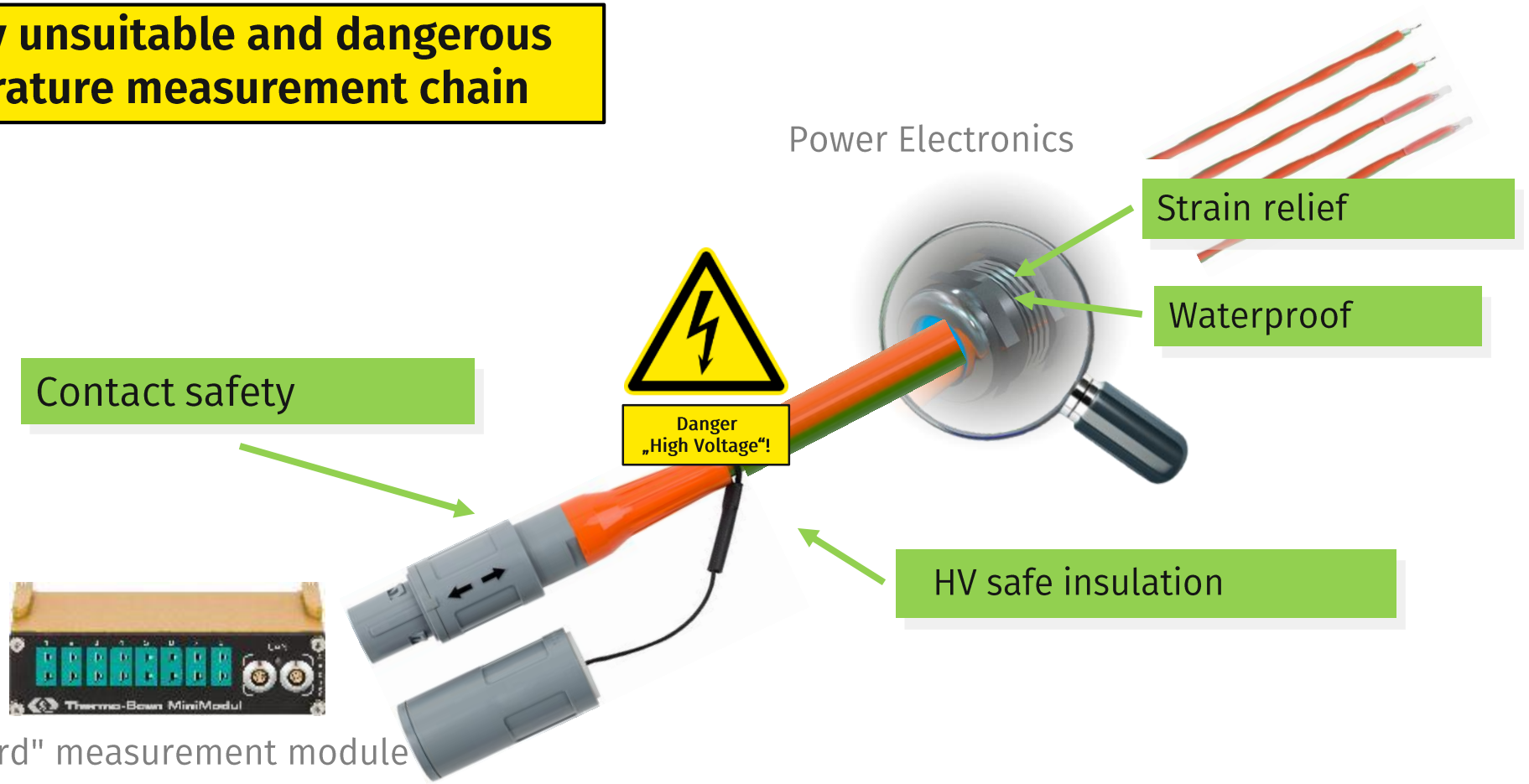
A special HV-safe connector concept is required:

- Features
  - Connector system (plug, socket) type-tested according to safety standard EN 61010-1:2010 to 1,000 V DC working voltage
  - Clearance and creepage distances >8 mm (when mated)
  - Fire protection class V - 0, i.e. self-extinguishing after 5 sec
  - Waterproof (protection class IP67)
  - Suitable for many mating cycles >1,000
  - Connections potted in plug and in module
  - Cover cap for protection


**The connector must not be assembled by the customer.**

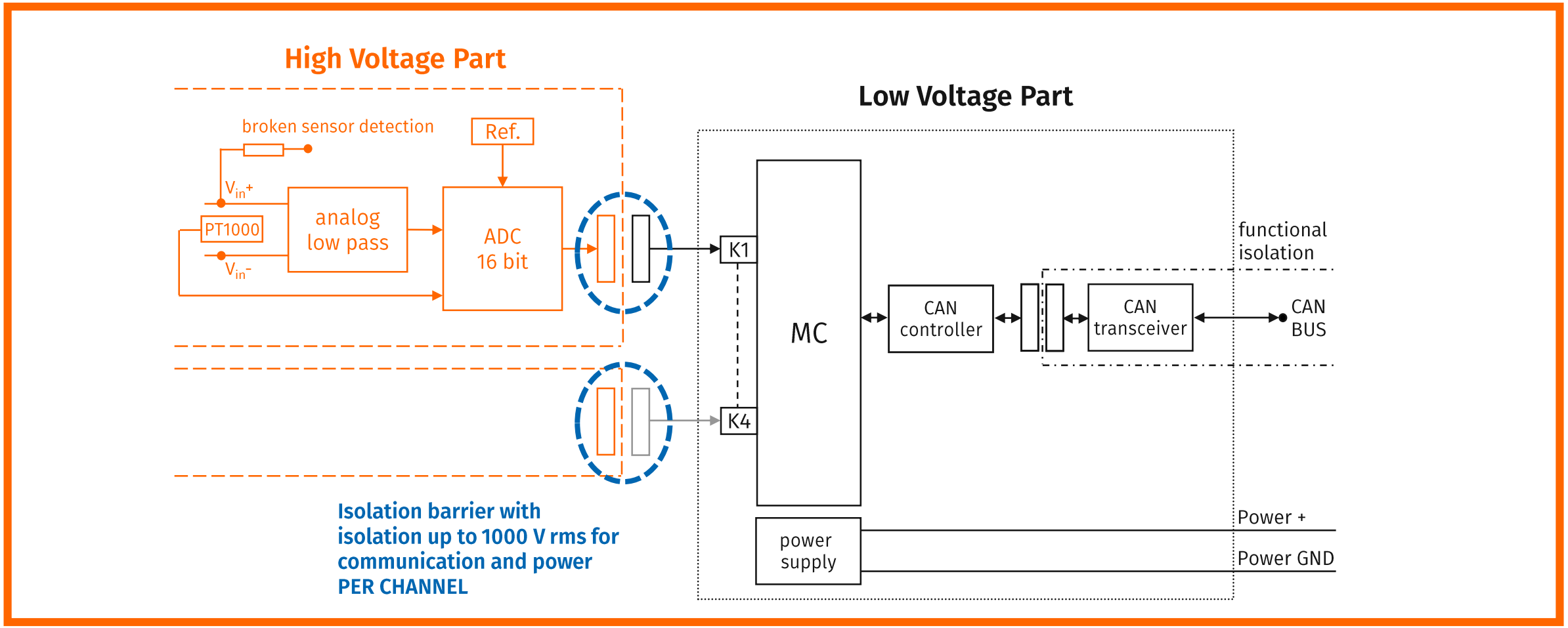
# HV-safe measurement chain for temperature measurements

**Partially unsuitable and dangerous temperature measurement chain**



# HV Isolation inside Measurement Modules


Example: of the CSM HV TH4 evo thermo measuring module



Find the
HV TH Modules
on www.csm.de

# HV-safe measurement equipment

## Example: CSM HV thermo modules (thermocouples)

- 4 or 8 NiCr-Ni (Type K) temperature channels
- Operating altitude: max. 5,000 m above sea level
- Operating temperature range: -40 °C to +125 °C
- IP65 / IP67
- Very high measuring accuracy




- HV-safe connector
- Mechanical connector guide for tightness and bend protection
- Reinforced insulation: 1,000 V RMS
  - Channel / channel, channel / CAN, channel / power supply
- Type-tested according to safety standard EN61010 by accredited test laboratory
- Unit test with certificate
- 3,100 V ramp each 5 sec

Find the
HV PT Modules
on www.csm.de

# HV-safe measurement equipment

## Example: CSM HV PT modules (RTD sensors)

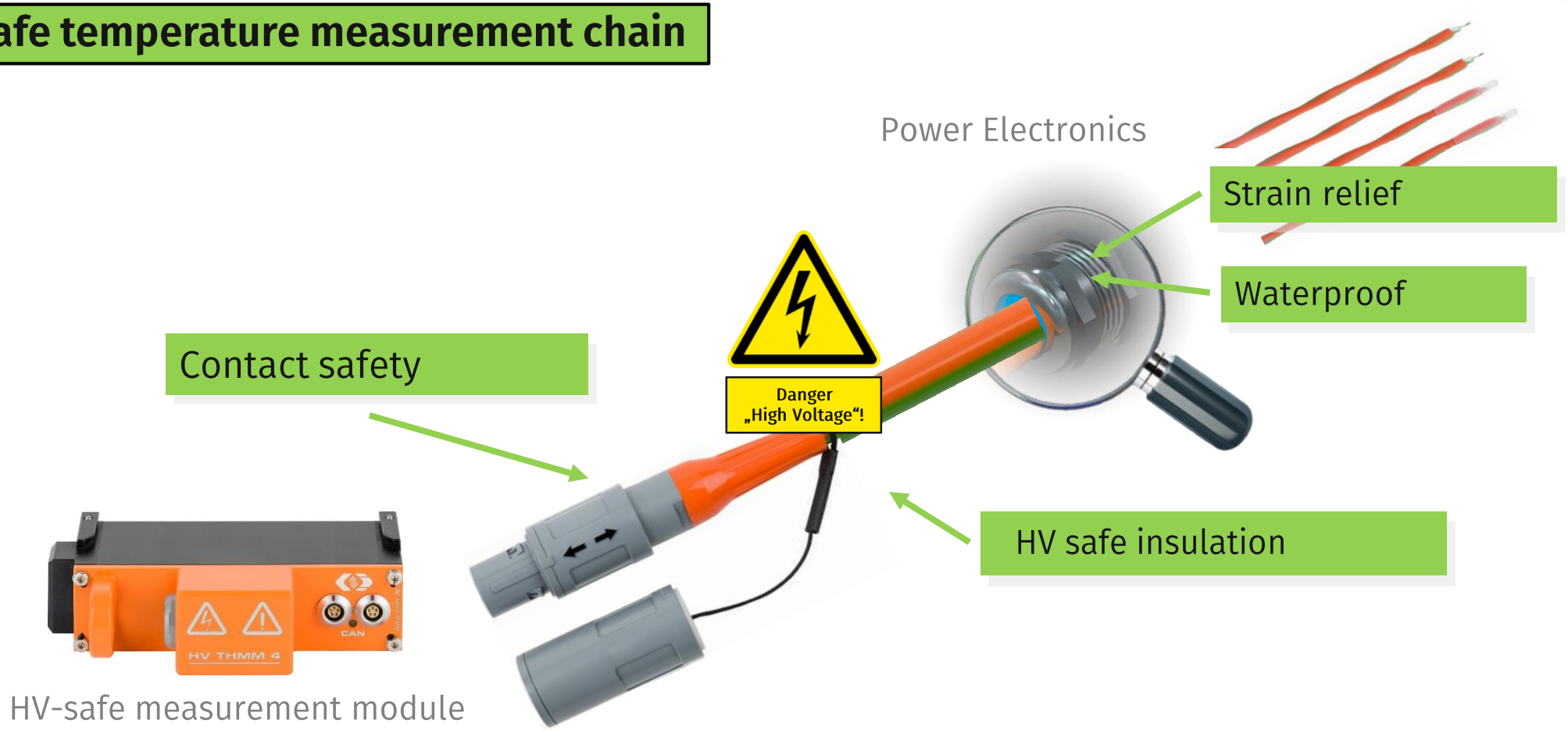
- 2 or 8 PT100/PT1000 temperature channels
- 4-wire technology, i.e. 2 inputs per HV-safe connector
- Input of individual PT coefficients for best possible adjustment to the sensor
- Extremely high measuring accuracy



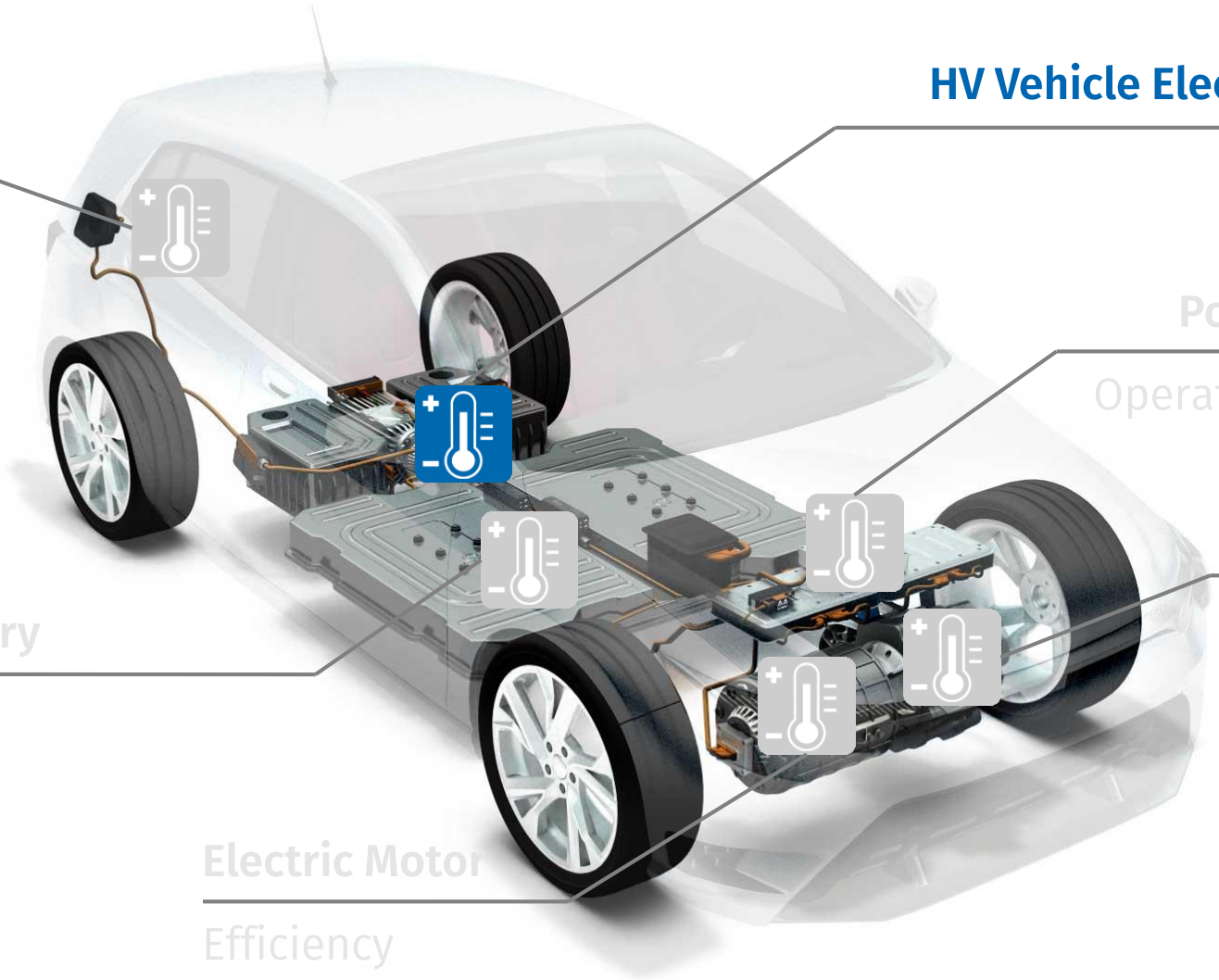

- HV-safe connector
- Mechanical connector guide for tightness and bend protection
- Reinforced insulation
  - Channel / Channel, Channel / CAN, Channel / Power supply
- Type-tested according to safety standard EN61010 by accredited test laboratory
- Unit test with certificate
- 3,100 V ramp each 5 sec

# HV-safe measurement chain for temperature measurements

## Safe temperature measurement chain



# Application



**HV Vehicle Electrical System**

High currents

On-Board-Charger

Charging efficiency

Power Electronics

Operational capability

Inverter

Electrical resistors

HV Battery

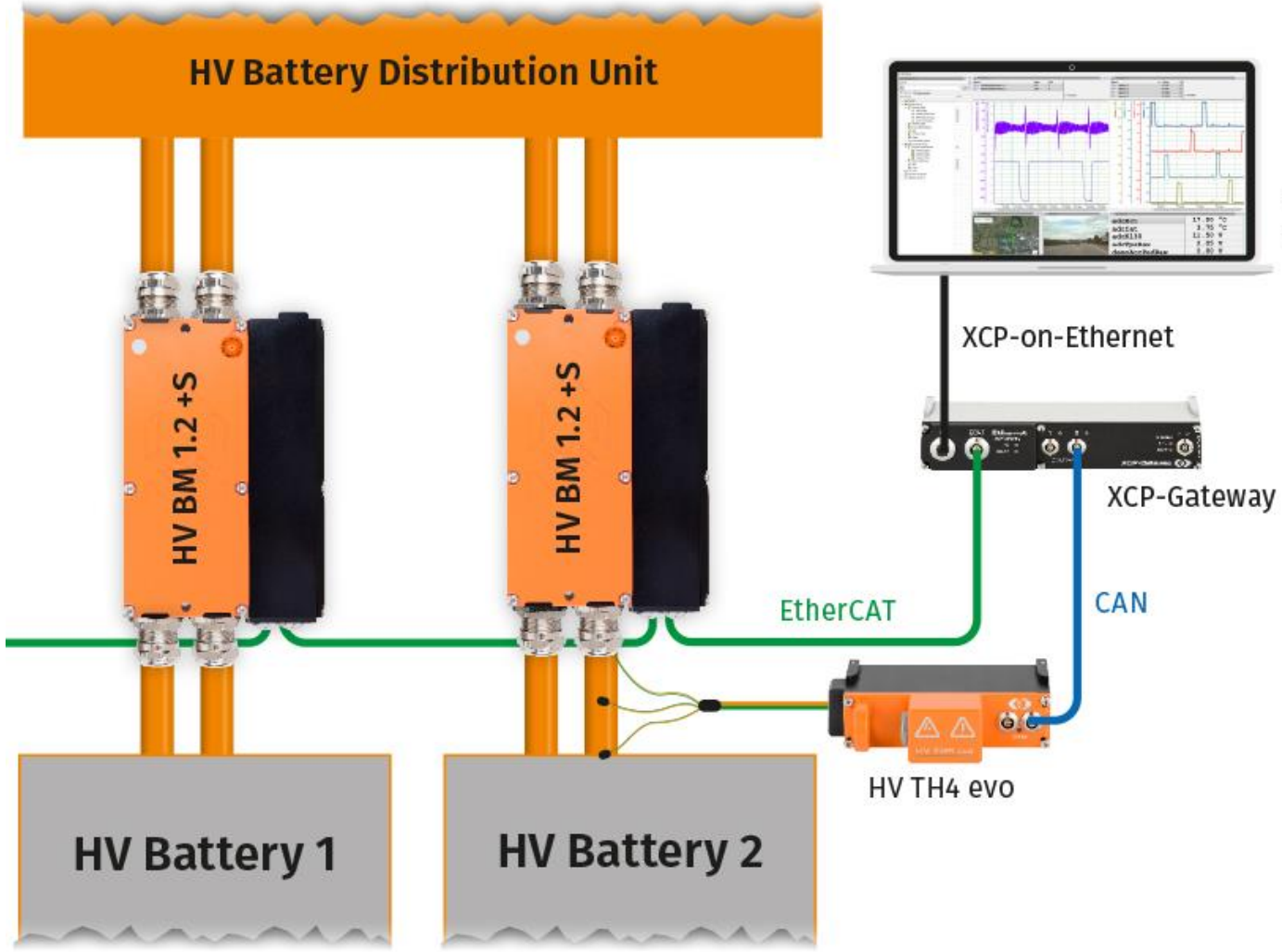
Capacity

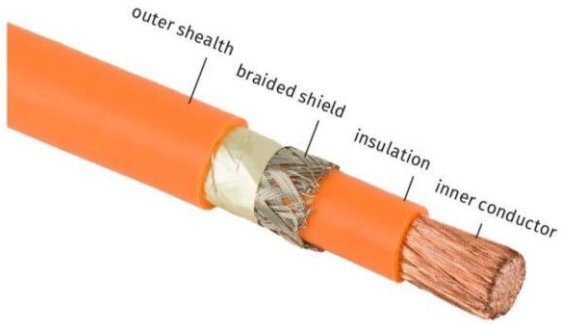
Electric Motor

Efficiency

Read the application example on www.csm.de

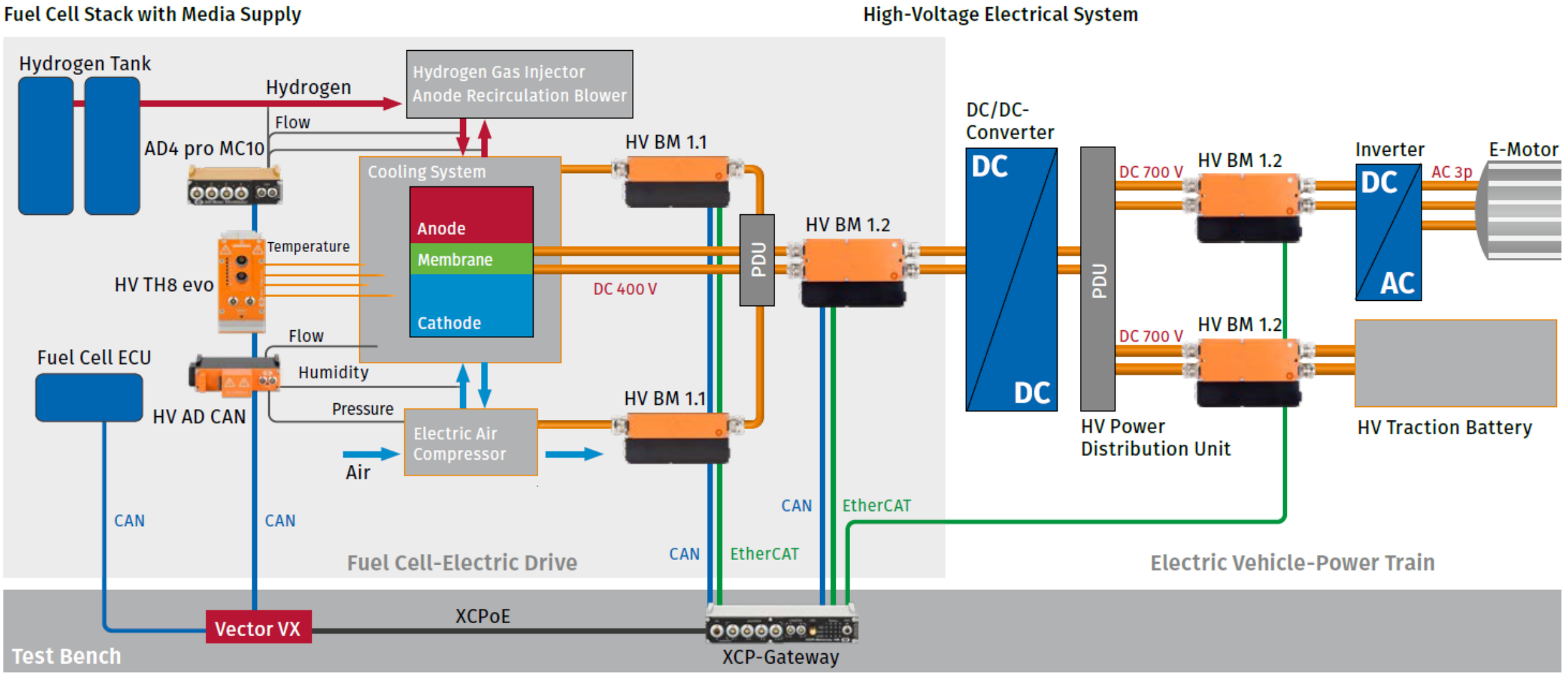
# Measuring Shield Currents and Temperatures



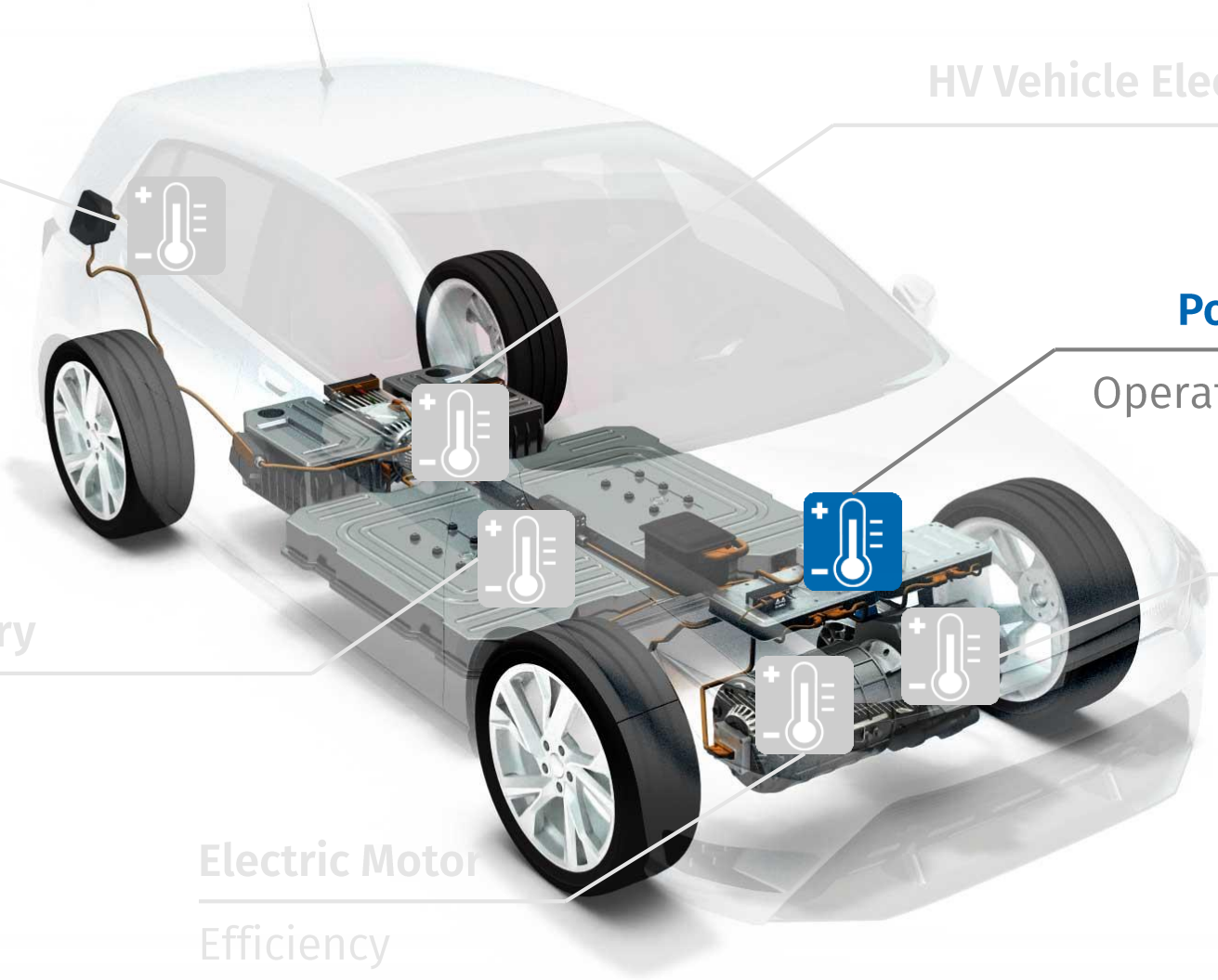



Read the application example on www.csm.de

# Temperature and Power measurement in Fuel Cell



# Application: Temperature & voltage measurement in power electronics



On-Board-Charger

Charging efficiency

HV Vehicle Electrical System

High currents

**Power Electronics**

Operational capability

Inverter

Electrical resistors

HV Battery

Capacity

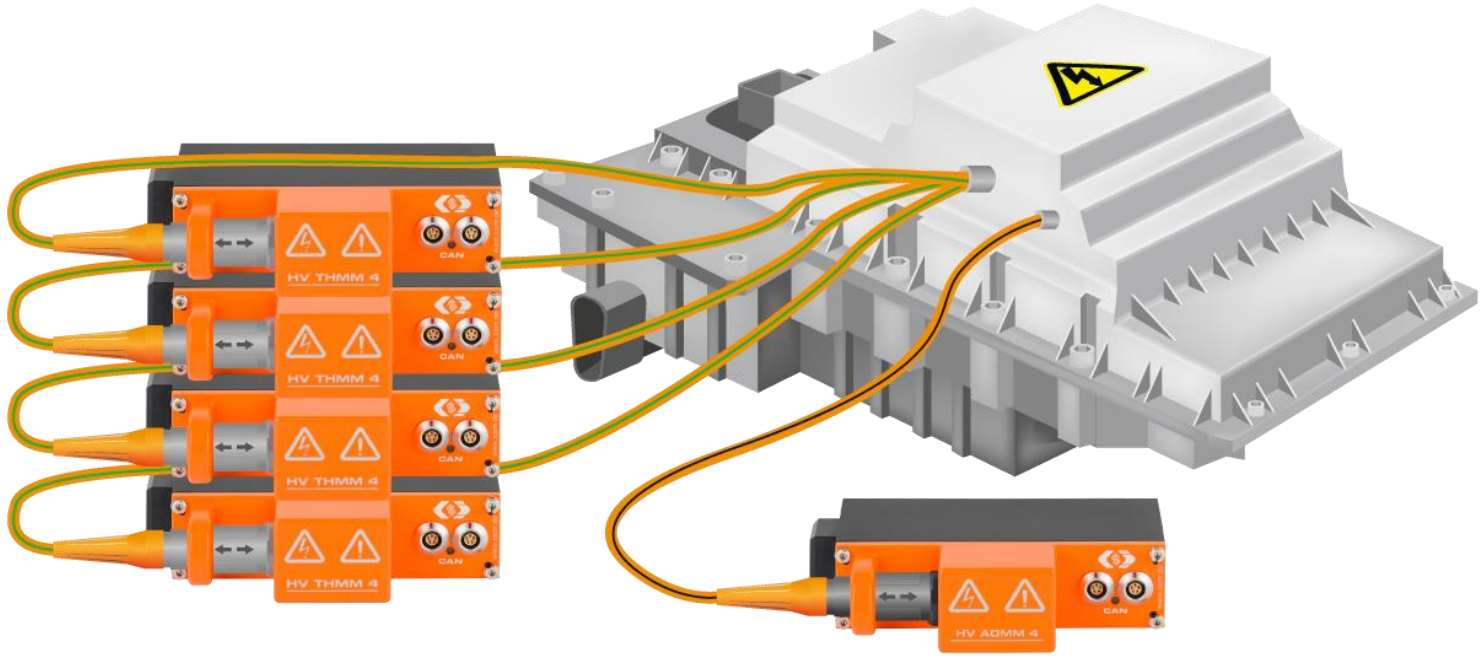
Electric Motor

Efficiency

# Application: Temperature & voltage measurement in power electronics

For the validation of power control units

- Typically 16 - 40 temperatures are acquired on the various electronic components in the control unit
- Additionally the switching voltages are measured
- Daisy chain all modules on 1 CAN Bus




4 × HV THMM 4 HV ADMM 4

# Application: Thermal characterization of high-voltage batteries

**On-Board-Charger**

Charging efficiency

**HV Vehicle Electrical System**

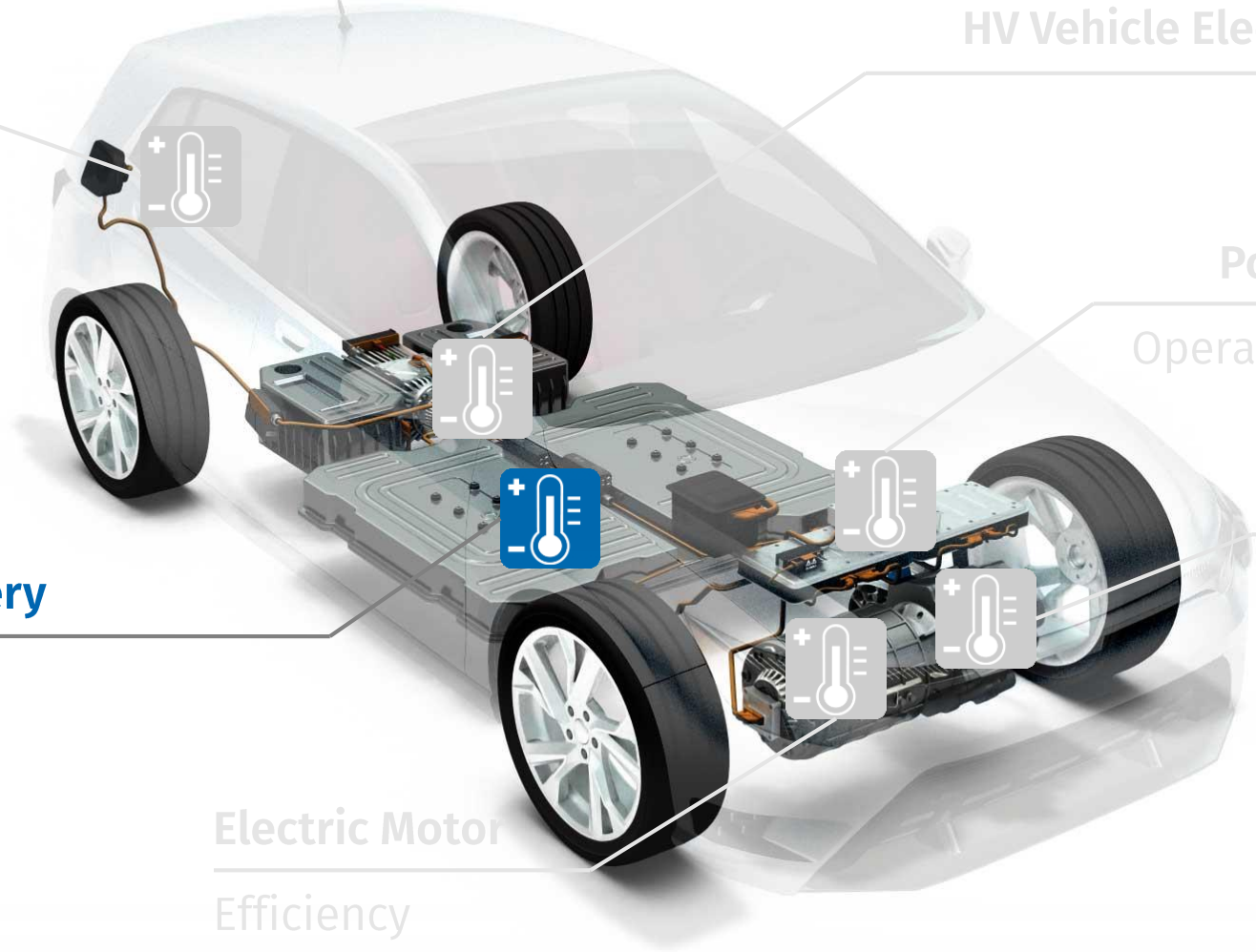
High currents

**Power Electronics**

Operational capability

**Inverter**

Electrical resistors



**HV Battery**

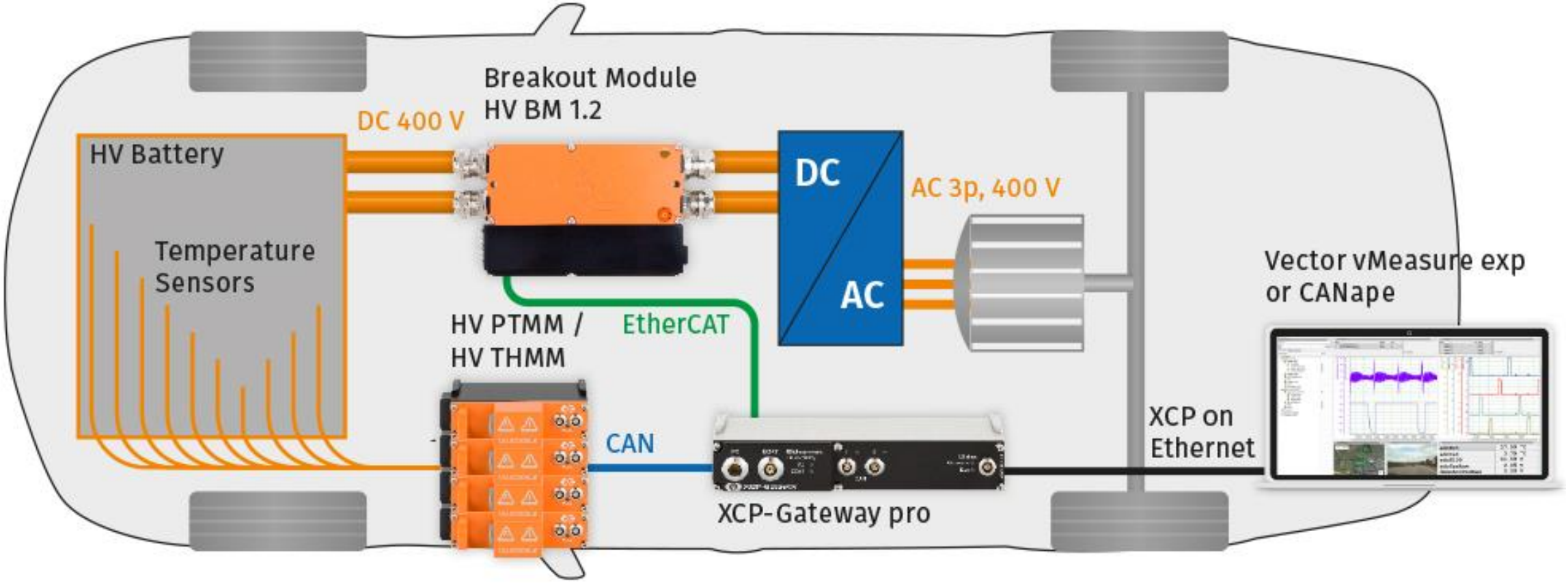
Capacity

**Electric Motor**

Efficiency

Read the application example on www.csm.de

# Temperature Measurement and Power in High-Voltage Batteries



# Application: Thermal characterization of high-voltage batteries

## Temperature measurement at battery module level

## Temperature measurement at battery level

- Busbars
- Charging electronics
- BMS
- Other components

## Temperature measurement at cell level

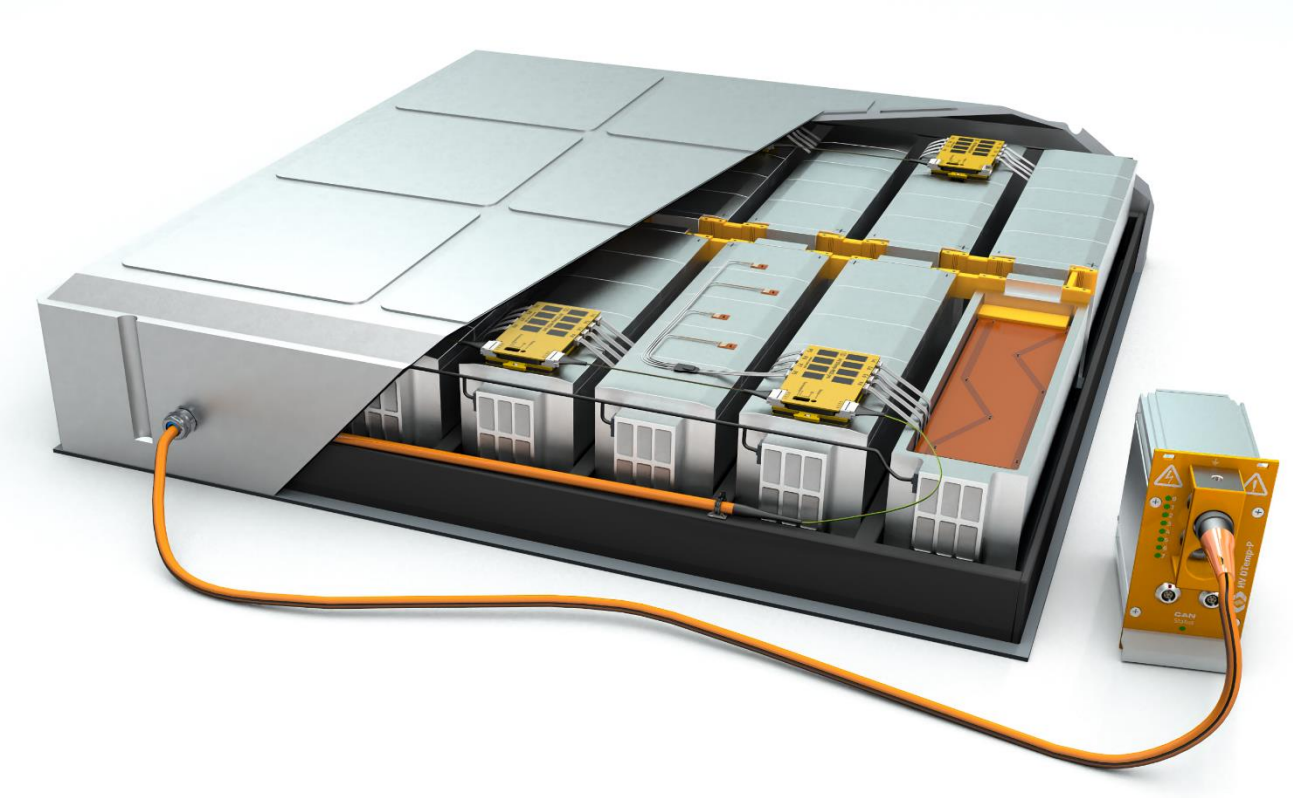
**Important:**

- Exact and reproducible positioning of sensors between individual battery cells
- Extremely high measurement accuracy

## A total of 50 to >500 measurement points

Find the
HV DTemp
on www.csm.de

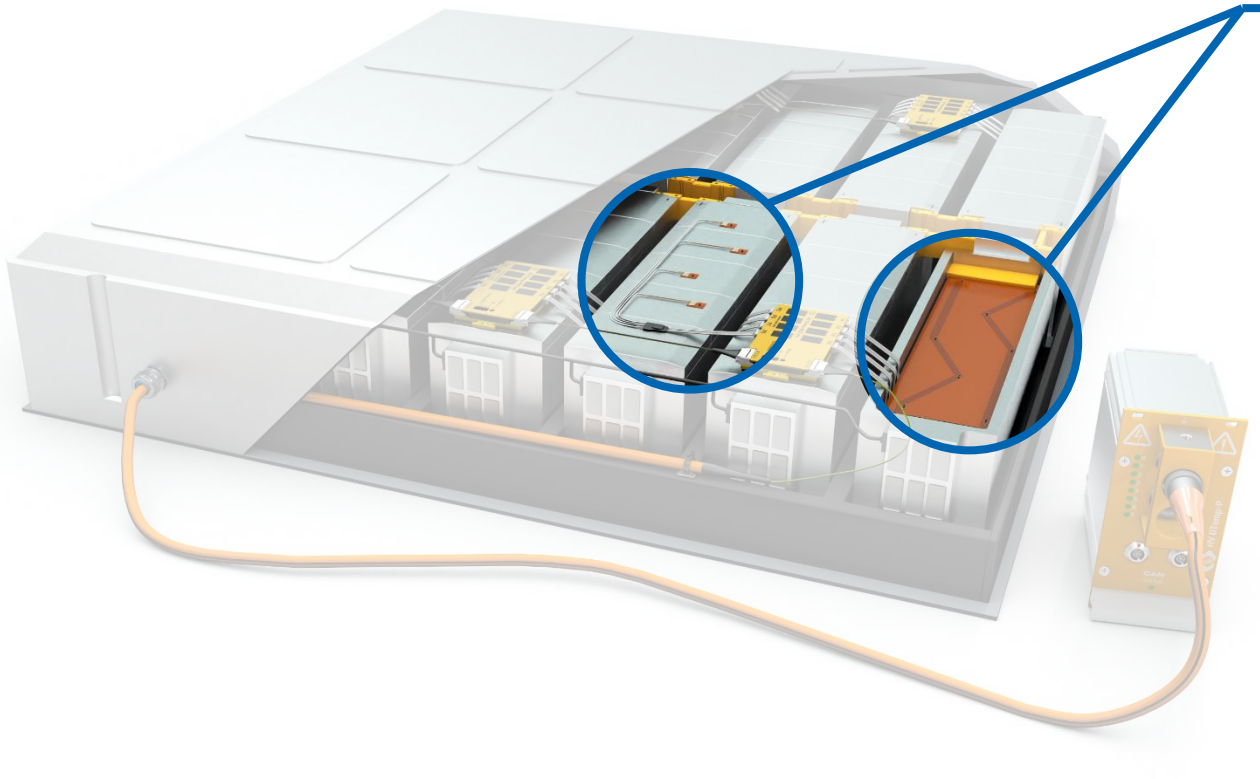
# Solution: HV DTemp Measurement System



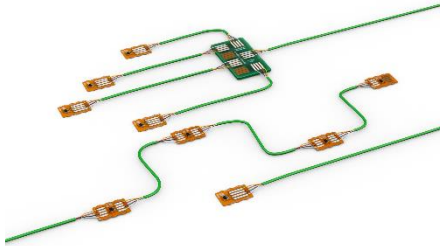
- Digital temperature measurement system
- Up to 512 sensors per measurement system
  - One HV Safe Sensor Cable
- Measuring accuracy (total system):
  - ± 0.1 K

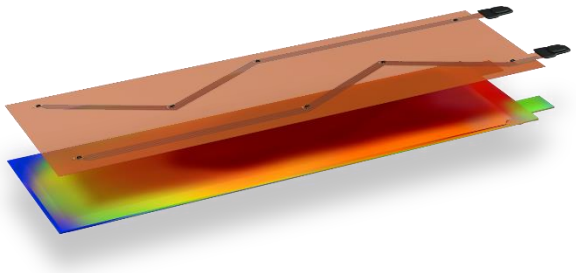
# Solution: HV DTemp Measurement System

## IC temperature single sensors and flexible circuits on digital data bus inside battery

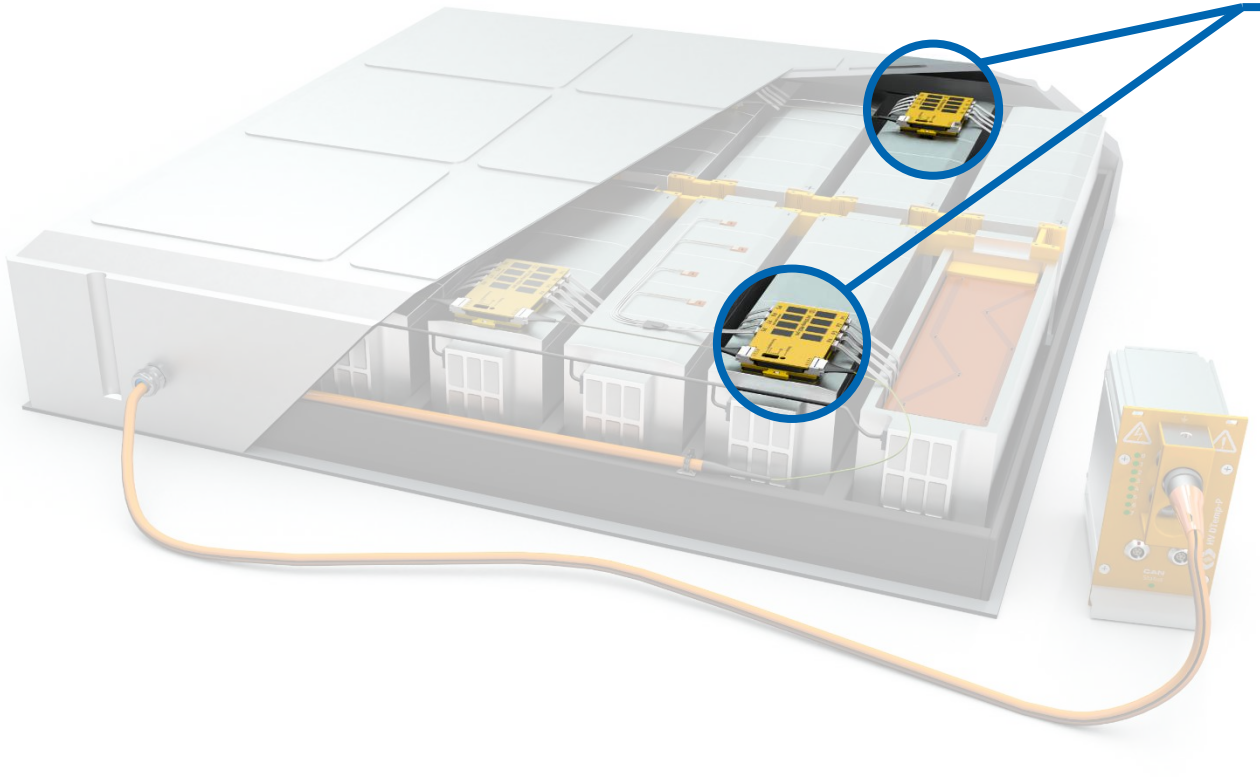


- Miniaturized, highly accurate, robust
- Highly interference-resistant (every incoming measured value is correct)
- Exact sensor location and clearly identifiable



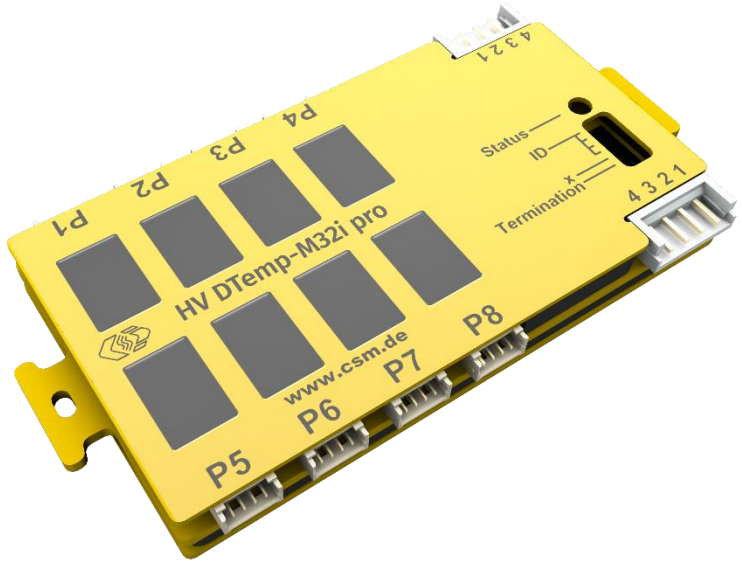


# Solution: HV DTemp Measurement System

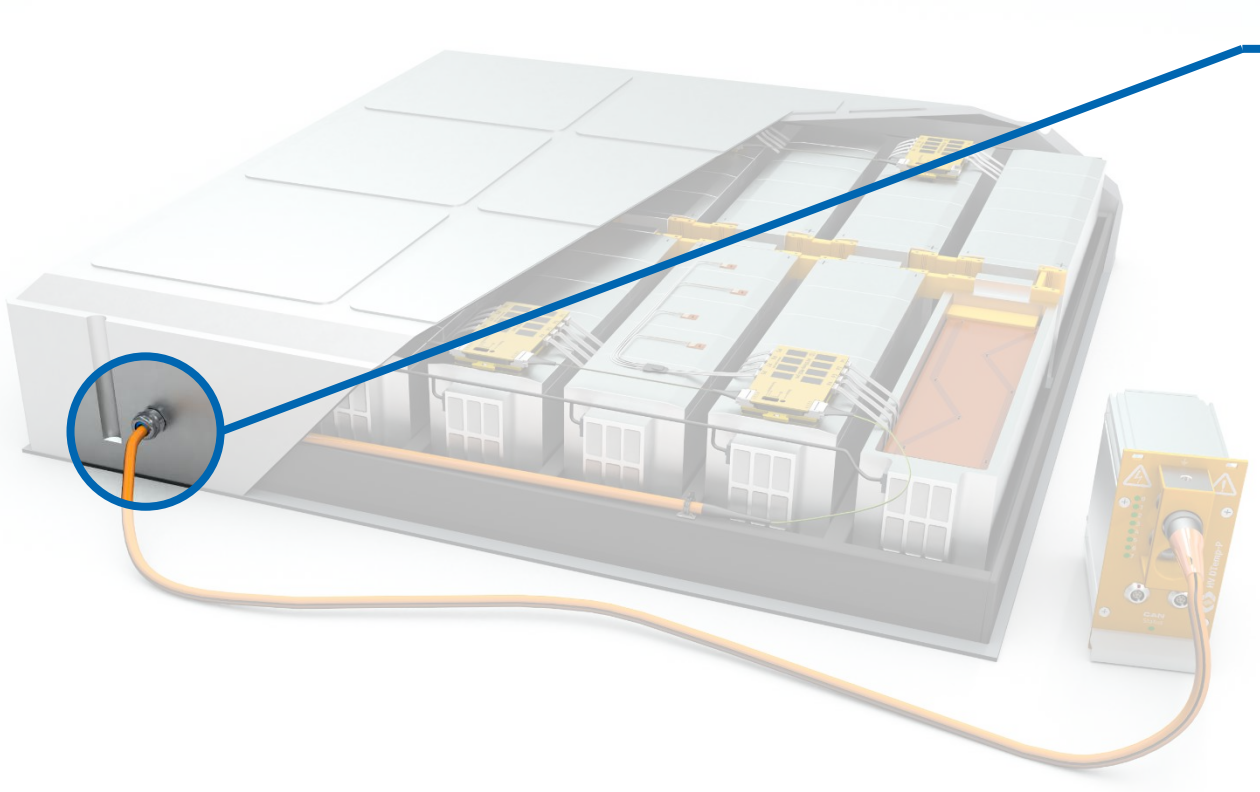


## HV DTemp Controller

- Required measurement electronics inside the battery (controller)
- Miniaturized and HV-safe



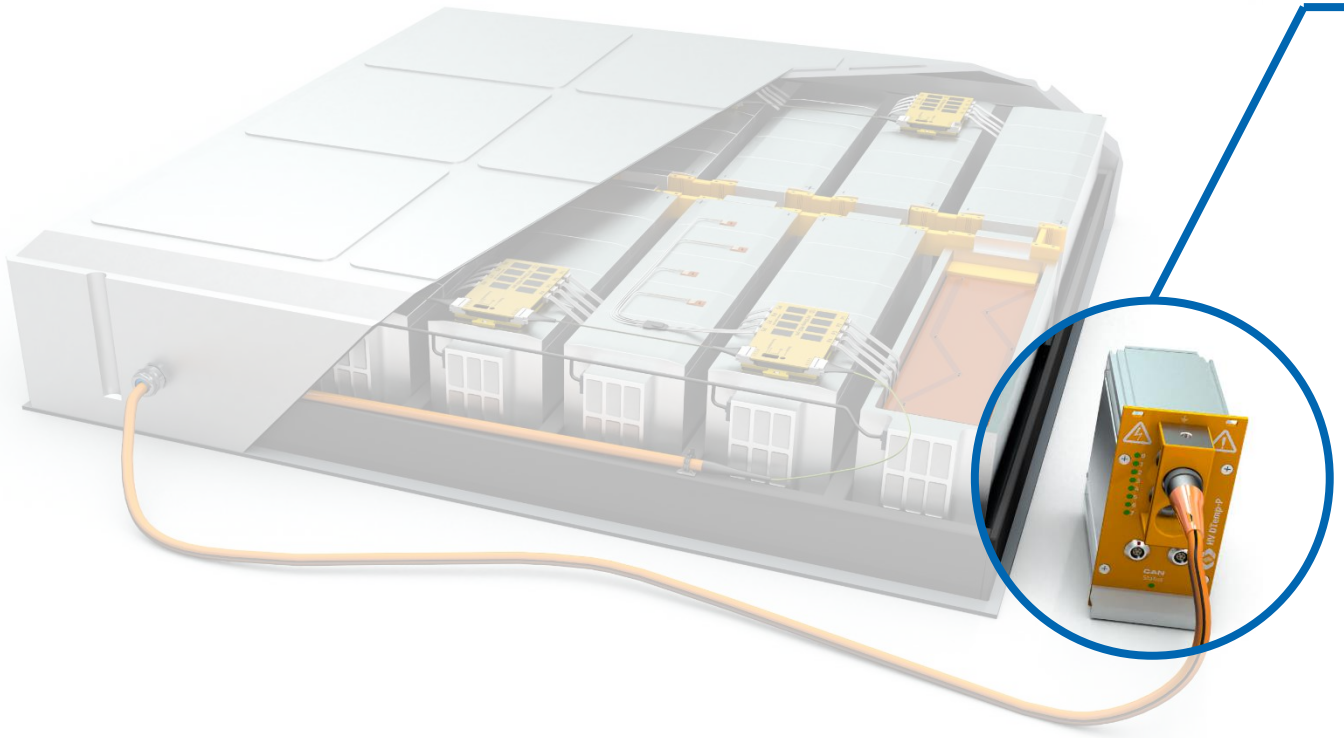
# Solution: HV DTemp Measurement System



## HV DTemp Controller

- Up to 8 controllers cascaded
- One HV-safe cable to the outside

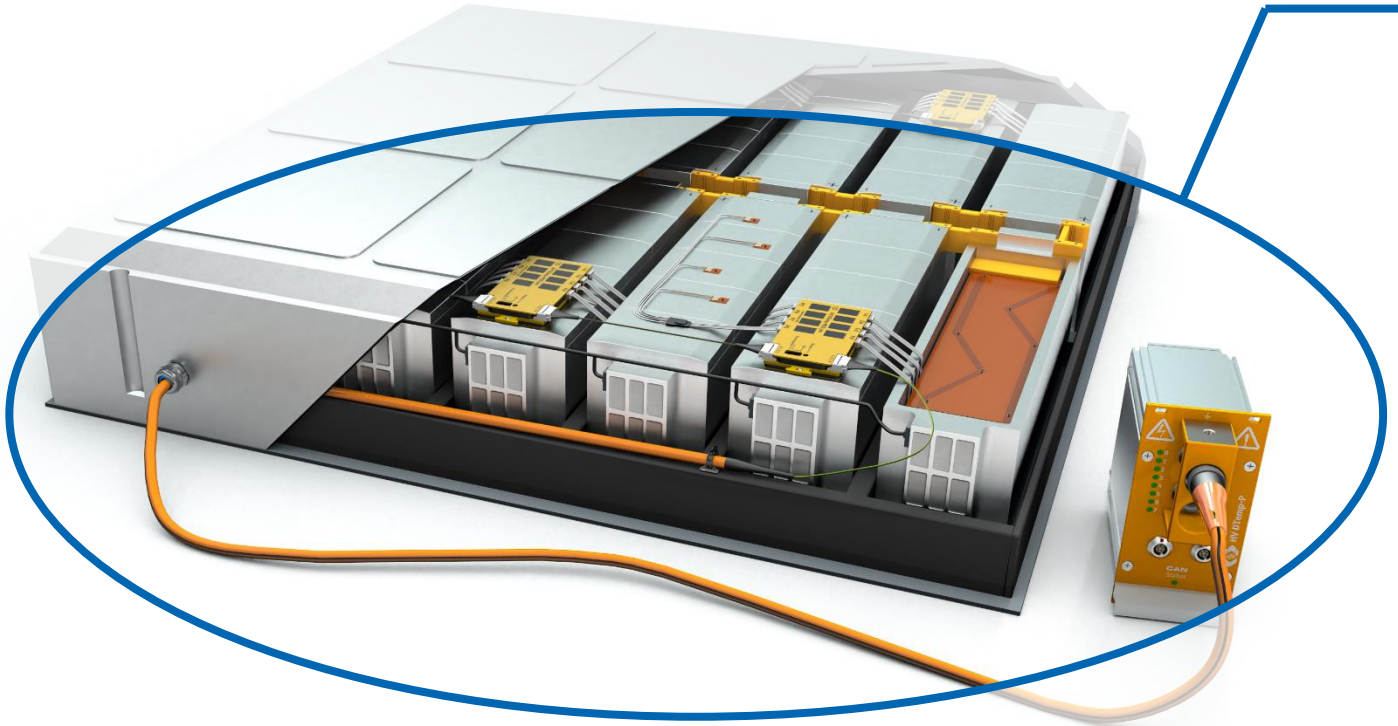
# Solution: HV DTemp Measurement System



## HV DTemp-P Central Unit

- CAN bus central unit for up to 512 sensors

# Solution: HV DTemp Measurement System

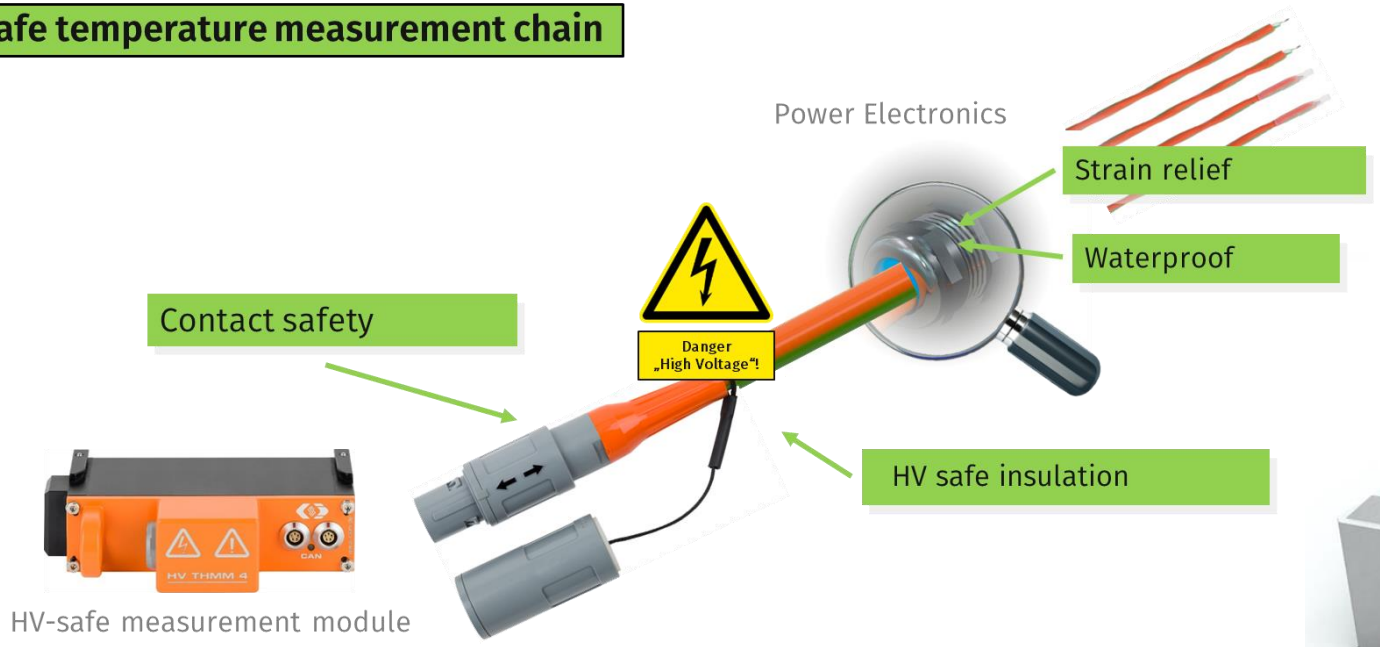


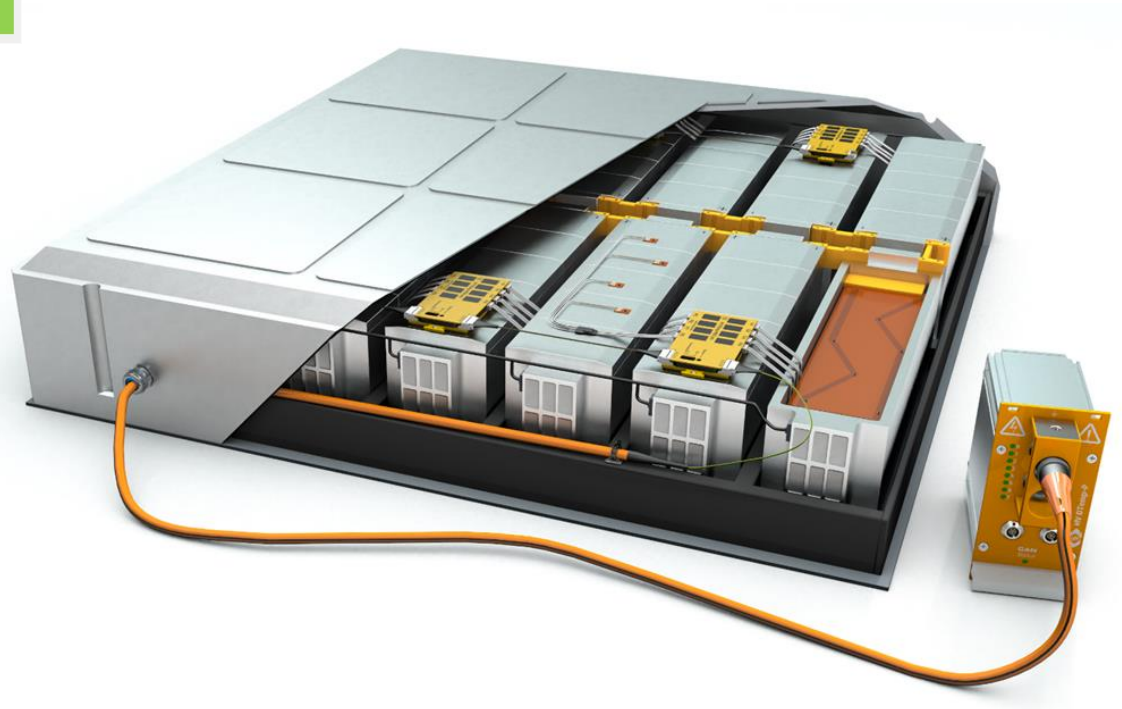
## HV safety up to 1,000 V RMS

- IC sensors encapsulated
- Sensor cables 1,000 V touch-safe
- Controller: separate ports
- HV-safe sensor cable to central unit

# HV-safe measurement chain and HV DTemp Measurement System

**Safe temperature measurement chain**



# 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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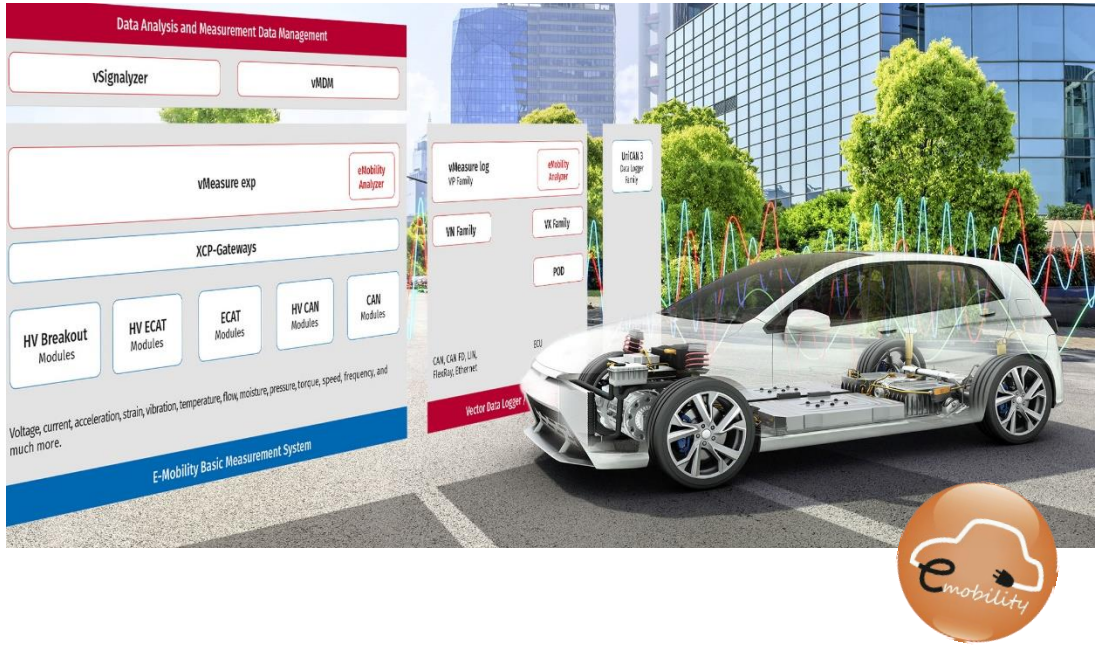

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