Safe measurement in high-voltage environments - Precise from sensor to data acquisition

CSM web seminars

CSM Xplained
measurement technology

SPECIAL CABLES
SAB BRÖCKSKES

Innovative Measurement and Data Technology

From Conventional to Electric Vehicle

Components	Conventional Vehicle	Electric Vehicle
Drive	mechanical	electric
Drive control	mechanical	electric
Heating	mechanical	electric
Air conditioning compressor	mechanical	electric
Energy storage	Fuel tank	High-voltage battery
System voltage	**12 Volts, 24 Volts**	**≥ 400 Volts**

- On-board power systems of vehicles with only internal combustion engines manage with “non-dangerous” voltages
- The system voltage is below 60 Volts

- In vehicles with electric drive, essential parts of the drive and many other components are electrified
- The system voltages are well above 60 Volts

Low Voltage & HV On-Board Network

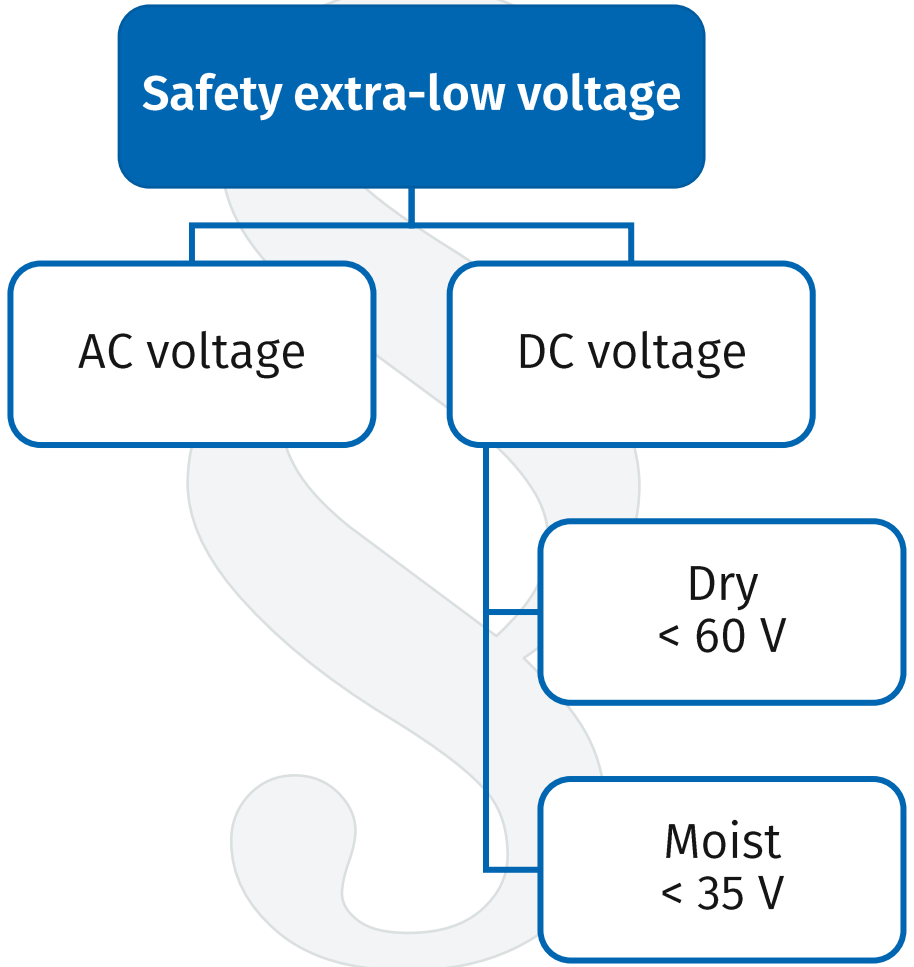
IEC 61010

- For HV on-board power supplies with high voltages **> 60 V DC**

OSHA 29 CFR 1910.303 (g)(2)(i)

- For **50 V and higher** AC or DC

Various standards specify that **insulation and safety measures have to be implemented** to protect persons from accidents when touching HV components.



Note: Further specifications and definitions exist worldwide

Selection of Suitable Measurement Equipment

Taking into consideration:

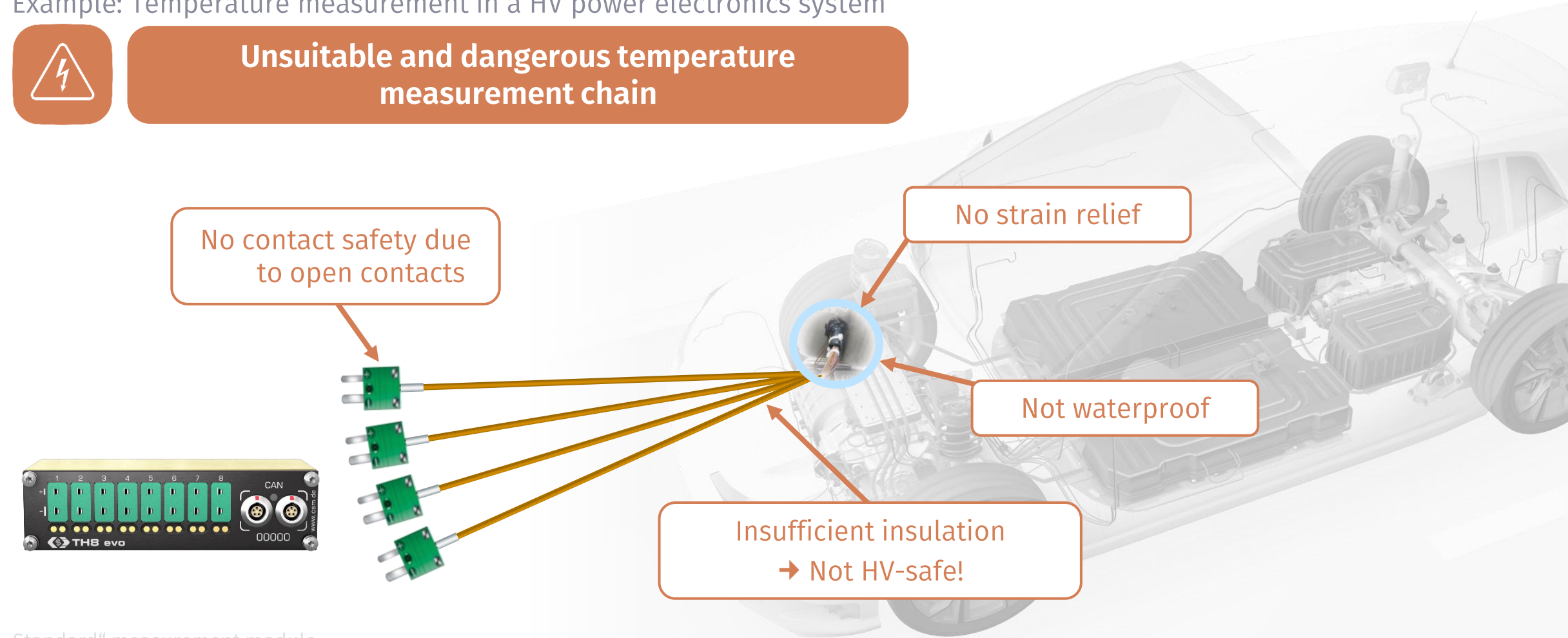
- Application scenario (test bench / laboratory / mobile / field use)
  - Channel count (number of sensors and measurements)
  - Sampling rate
- Climatic conditions (ambient temperature, humidity)
- Degree of pollution (exposure to water / salt / dust / chemicals)
- Sampling rates and data transfer frequencies to be acquired (useful bandwith of the measurement channels)
- **Operating voltage**
  - **Selection of proper, safe equipment required when > 50 V (per OSHA) of the Device Under Test**

Danger „High-Voltage“!

Conventional Measurement Technology in the HV Environment?

Example: Temperature measurement in a HV power electronics system

Unsuitable and dangerous temperature measurement chain

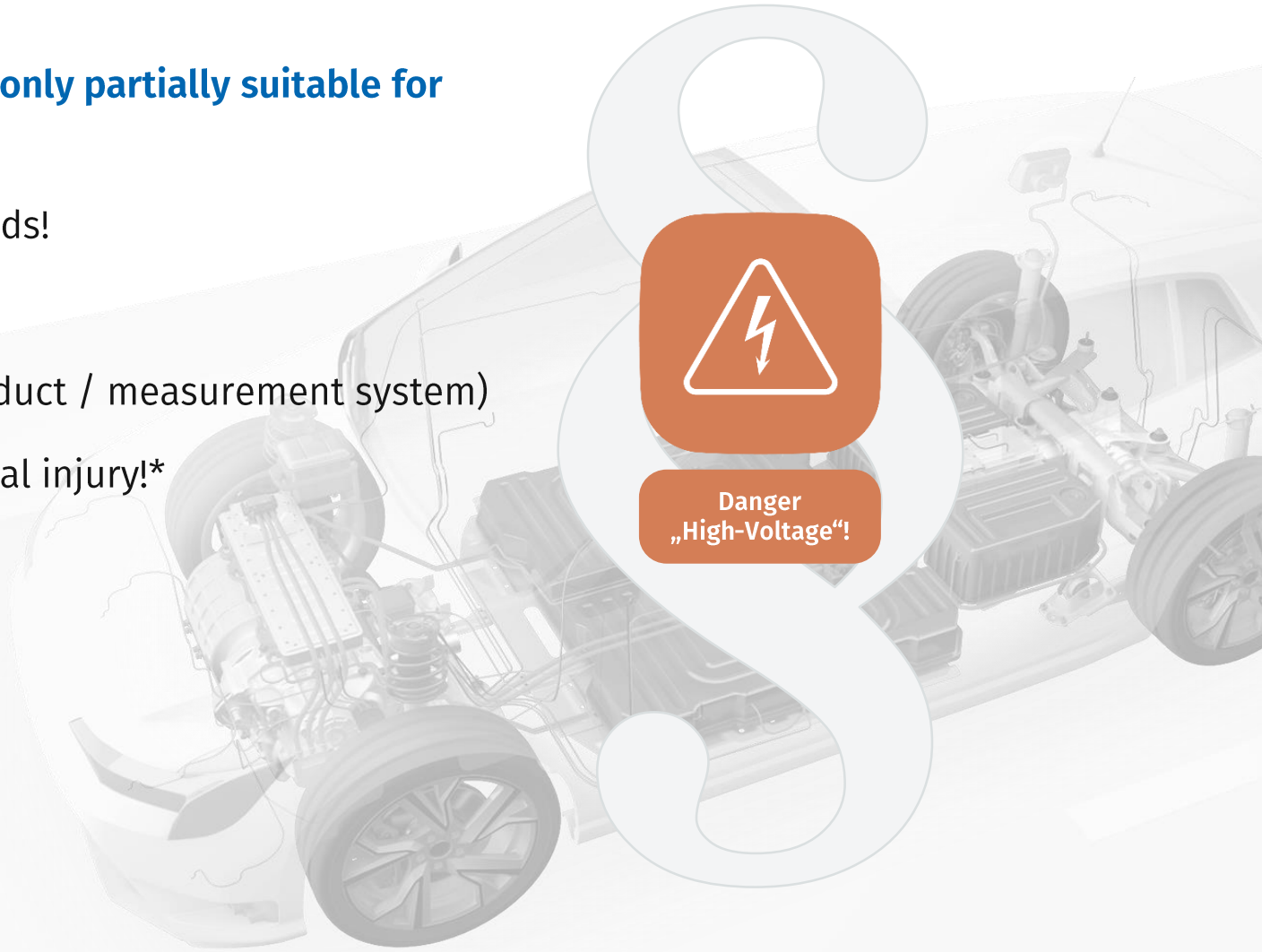


„Standard“ measurement module

Consequences

When using measurement technology that is not or only partially suitable for High Voltage on-board power supplies:

- Not meet the required common safety standards!
  - **Danger to the user‘s life!**
  - Risk to capital investment (prototype / product / measurement system)
- Possible legal consequences in case of personal injury!*
  - Liability law
  - Criminal law
  - Civil law
  - Employment law

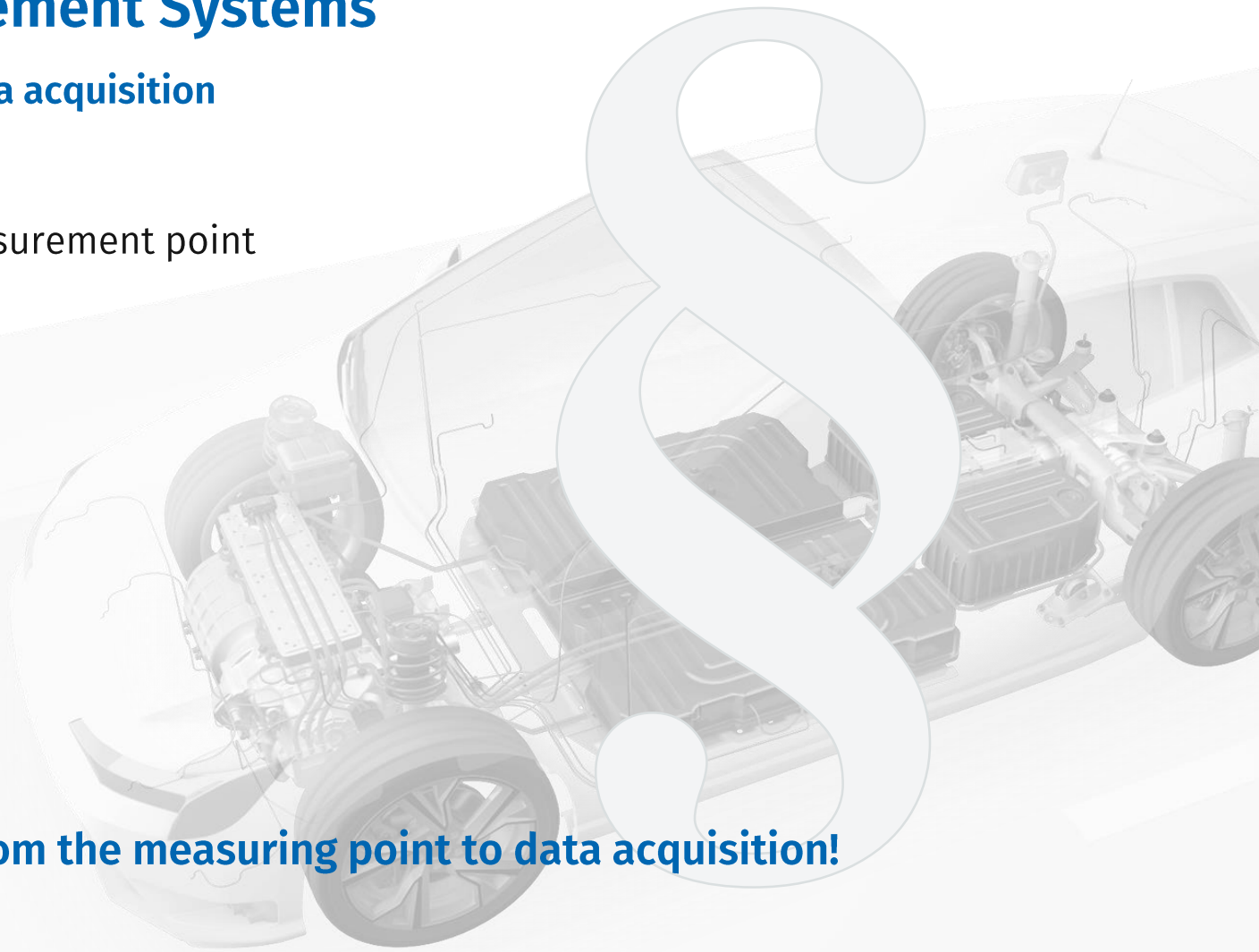


* Depending on local laws

Requirements for HV-safe Measurement Systems

Certified safety from the measurement point to data acquisition

- Touch-proof and insulated overall system
- Can be used in the immediate vicinity of the measurement point
- Suitable for mobile applications and test bench
- Color coded specifically for high-voltage use
- Precise and reliable measurement results
- Easy and secure handling



Seamless operating and operational safety from the measuring point to data acquisition!

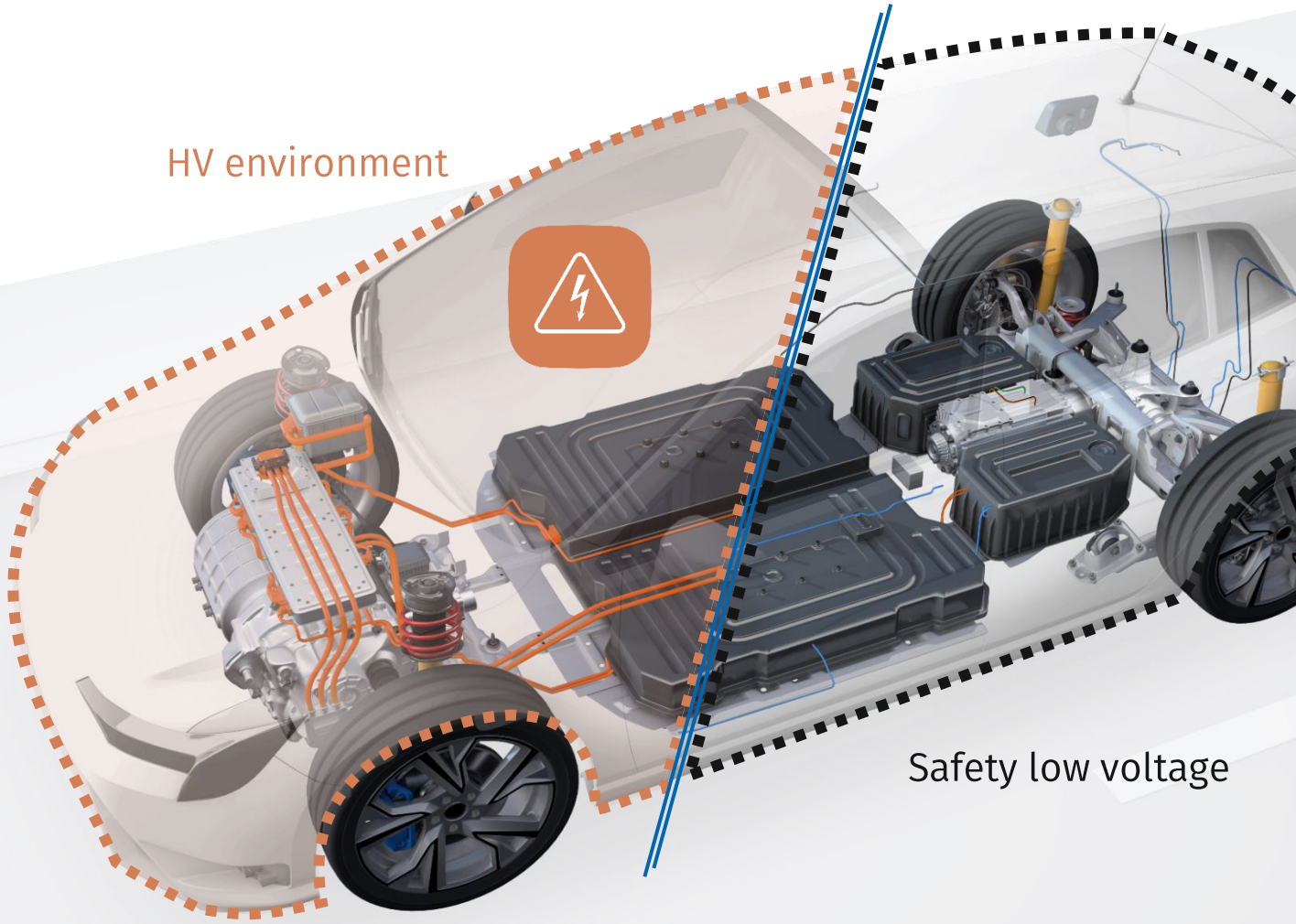
Separation of HV Environment and 12 / 24 / 48 Volt Electrical System

Galvanic isolation

between **HV electrical propulsion system** and **LV auxiliary electrical system** and thus also the vehicle body.

This vehicle safety concept **must not be undermined** by measurement technology.

(ISO 6449-3: Electrically propelled road vehicles - Safety specifications – Part 3: Electrical safety)



CSM Safety Concept to meet EN 61010-1

High-voltage safe sensor cables

- Allows for use of standard sensors inside High Voltage environment
- Protects Equipment
- Protects Personnel

Galvanic Isolation of 1000 V_{rms} per channel inside measurement module

- Keeps **HV measurement environment** separate from **CAN/EtherCAT communication environment**

SAB Bröckskes

FOUNDED

1947 by Peter Bröckskes senior

an independent, medium-sized company

SAB Bröckskes on
www.sab-kabel.de

MANAGEMENT

Peter Bröckskes and Sabine Bröckskes-Wetten (in 3rd generation)

PRODUCTS

Special cables and wires

Cable harnessing

Measurement technology

PLANT & LOCATION

In Viersen (Lower Rhine) with a floor area of 110.000 m²

Own manufacturing from copper conductor to outer sheath

VDE proved burn chamber and laboratory within the company

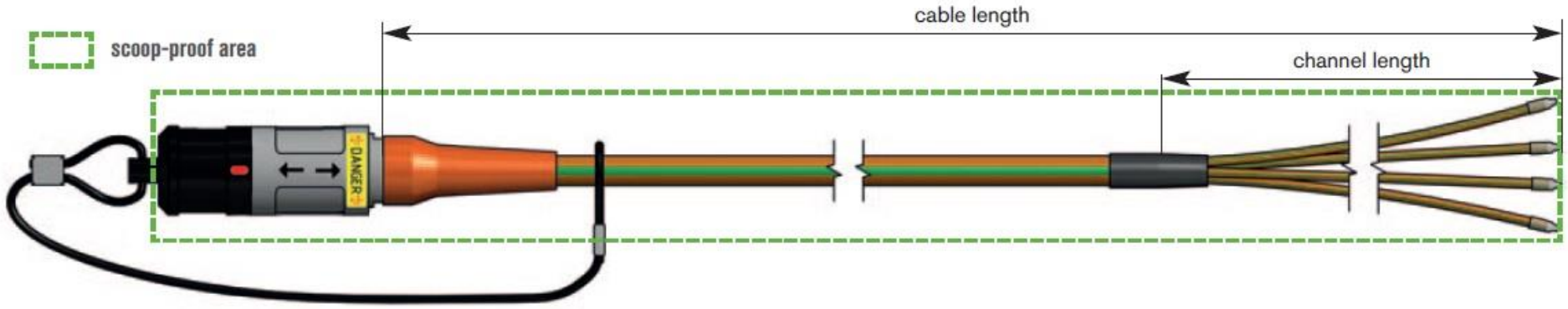
EMPLOYEES

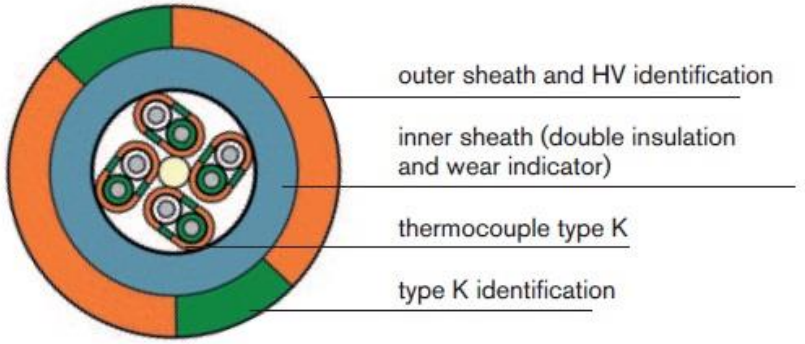
550 employees worldwide, approx. 430 at the plant in Viersen

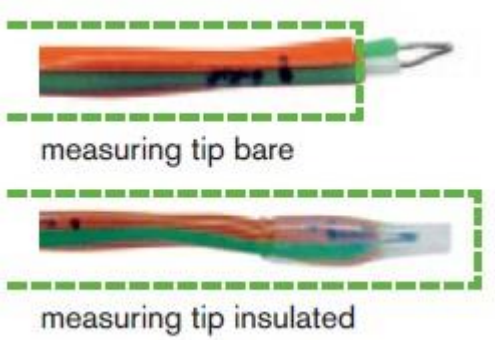
With our Partner

HV-safe Sensor Cables

Example: Thermocouple cable type K







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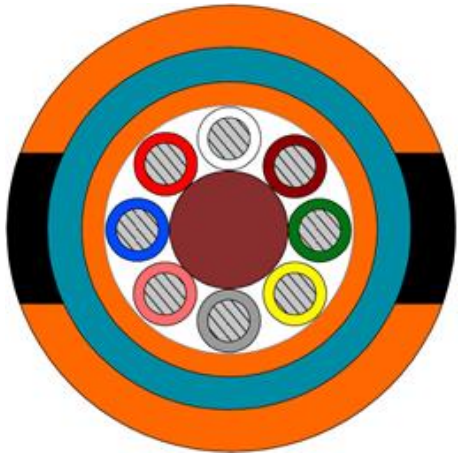
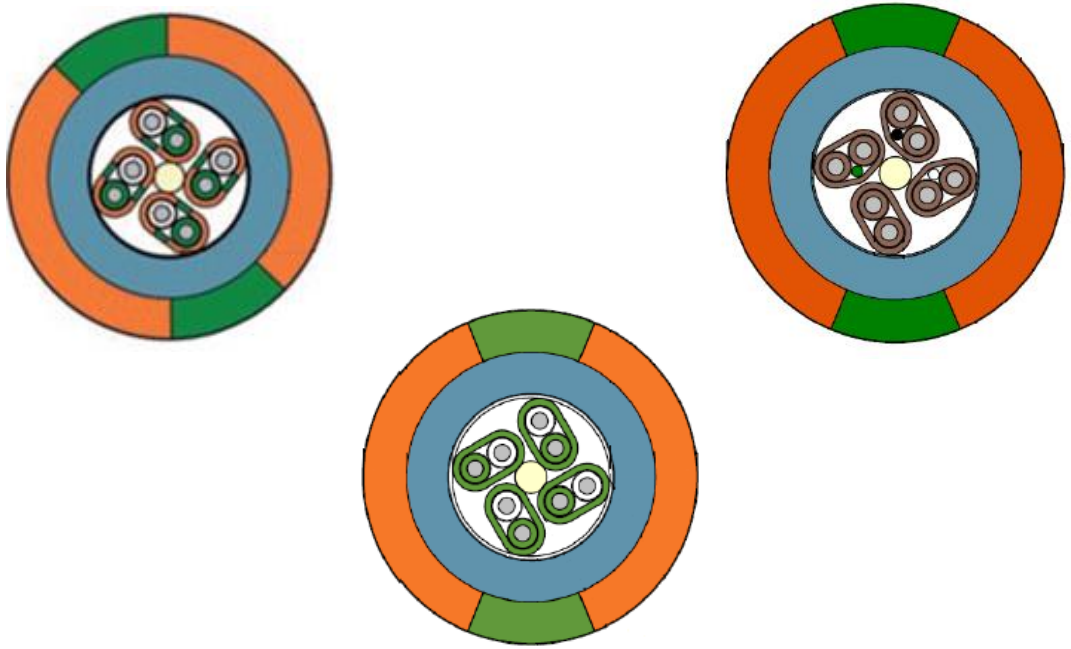
HV-safe Sensor Cables

Typical 8-wire sensor cable

- Good ratio between outer protective sheath, warning inner sheath, pair or bundle sheath and strands
- Still sufficiently thin and flexible
  - Outer sheath 1,000 V safe to touch



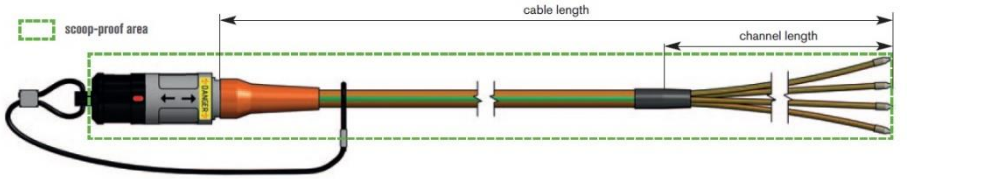
PT100 cable



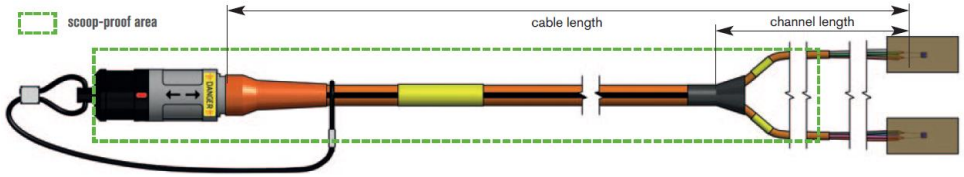
Thermo cable

A sample of SAB HV-Safe measurement cables for CSM Modules

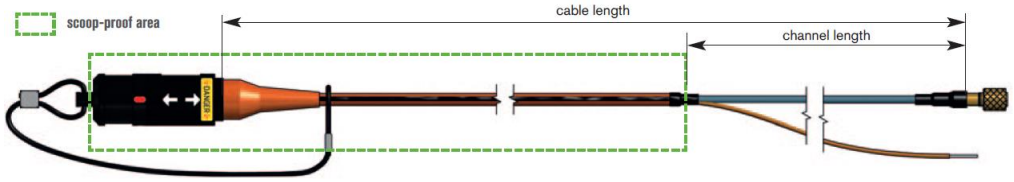
With our Partner



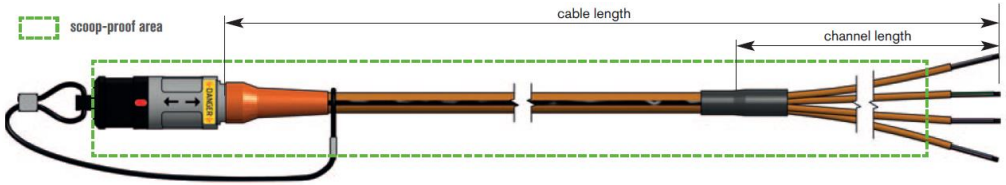
Temperature Type K



Temperature PT100/1000



Acceleration IEPE



Strain gauges

HV-safe Measurement Chain for Temperature Measurements - Step 2

Partially **unsuitable and dangerous temperature measurement chain**

No contact safety due to open contacts

Strain relief

Waterproof

HV-safe insulation

„Standard“ measurement module

Connector

A special HV-safe connector concept is required:

- Features
  - Connector system (plug, socket) type-tested according to safety st
    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 - Step 3

Partially **unsuitable and dangerous temperature measurement chain**

HV-safe measurement on www.csm.de

Strain relief

Contact safety

Waterproof

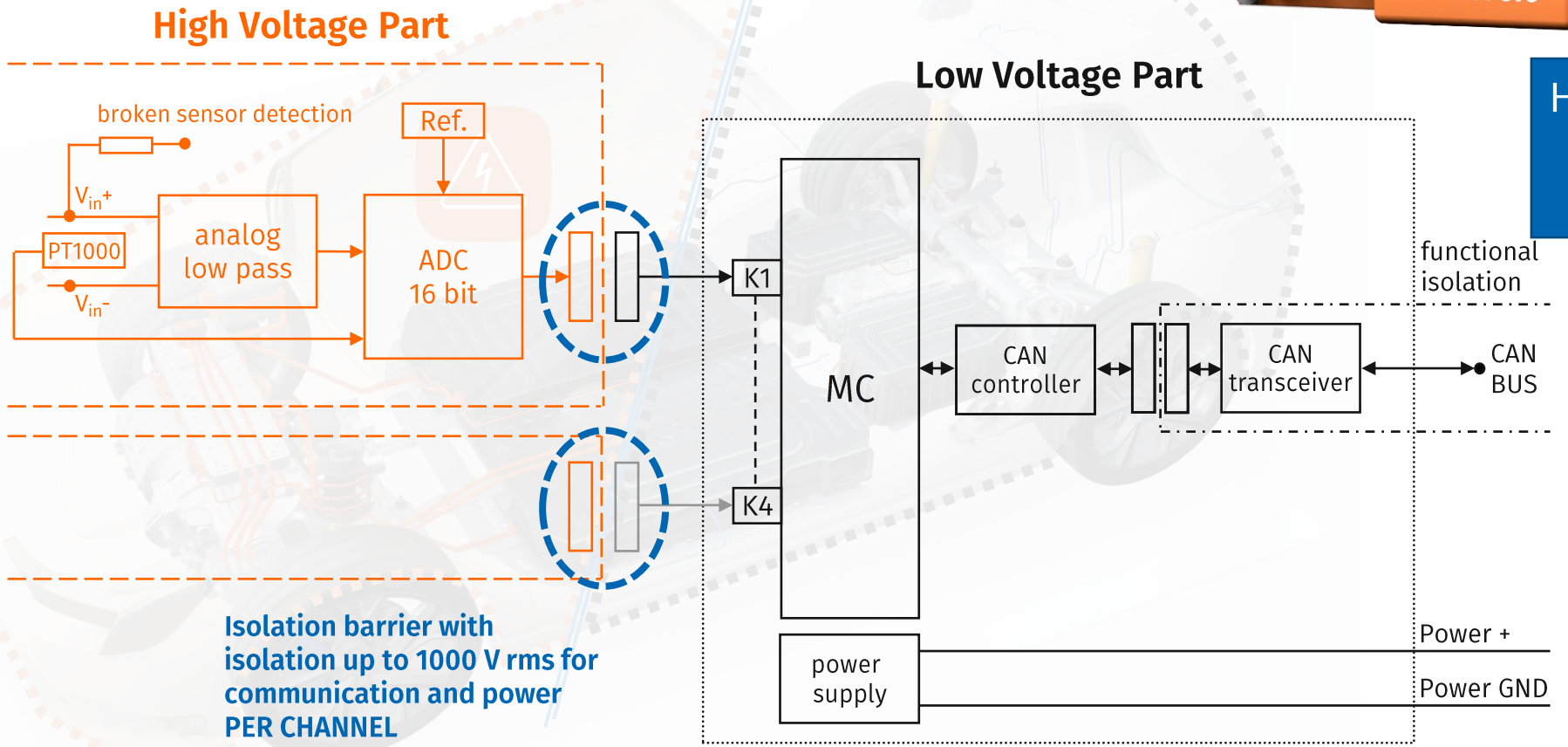
HV-safe insulation

„Standard“ measurement module

HV Isolation Inside Measurement Modules

Example: CSM HV TH4 evo measurement module

HV measurement modules on www.csm.de



Definition „Isolation“ according to EN 61010-1

- **Basic isolation**

  Isolation of harmful active assemblies as basic protection

  Remark: A basic isolation may also serve for functional purposes.

- **Additional isolation**

  Independed isolation, which is additionally applied to the basic isolation to provide protections against electric shock in case of failure of the basic isolation.

- **Double isolation**

  insulation, which consists of basic isolation and additional isolation

- **Reinforced isolation**

  Isolation, that provides an amount of protection, which is not below a protection provided by a double isolation

Remark: REINFORCED ISOLATION may constist of several layers, that cannot by individually tested as ADDITIONAL or BASIC ISOLATION.

HV-safe Measurement Chain for Temperature Measurements

Safe temperature measurement chain

Contact safety

Strain relief

Waterproof

HV-safe insulation

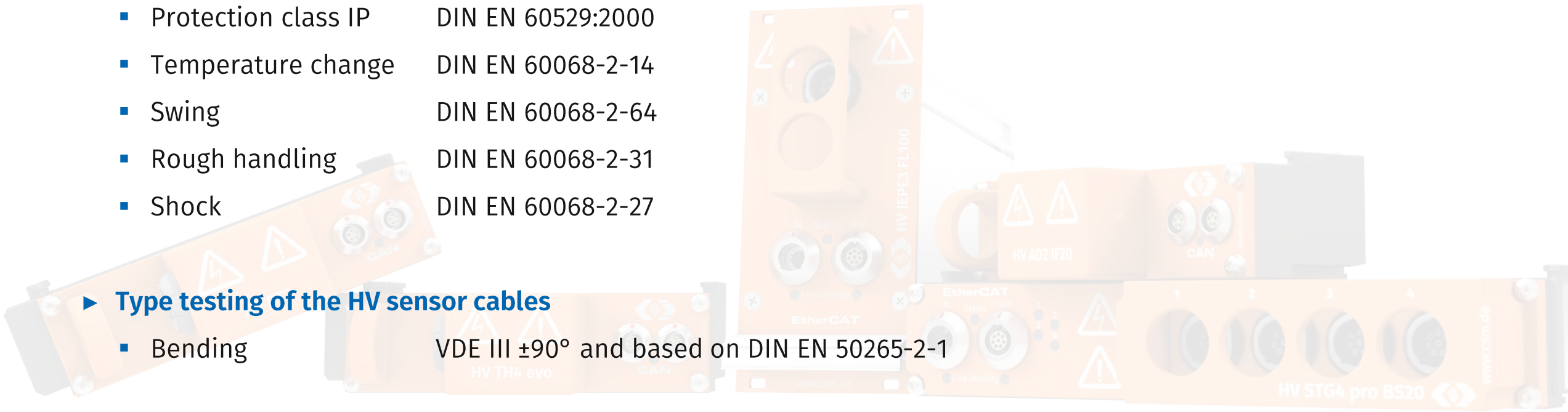
HV-safe measurement module

Measurement Technology Safety Concept – One-Off Type Tests

- **Type testing of the complete system (measurement module together with sensor cable)**
  - Safety — IEC 61010-1 and IEC 61010-2-030
  - EMV (CE) — DIN EN 61326-1

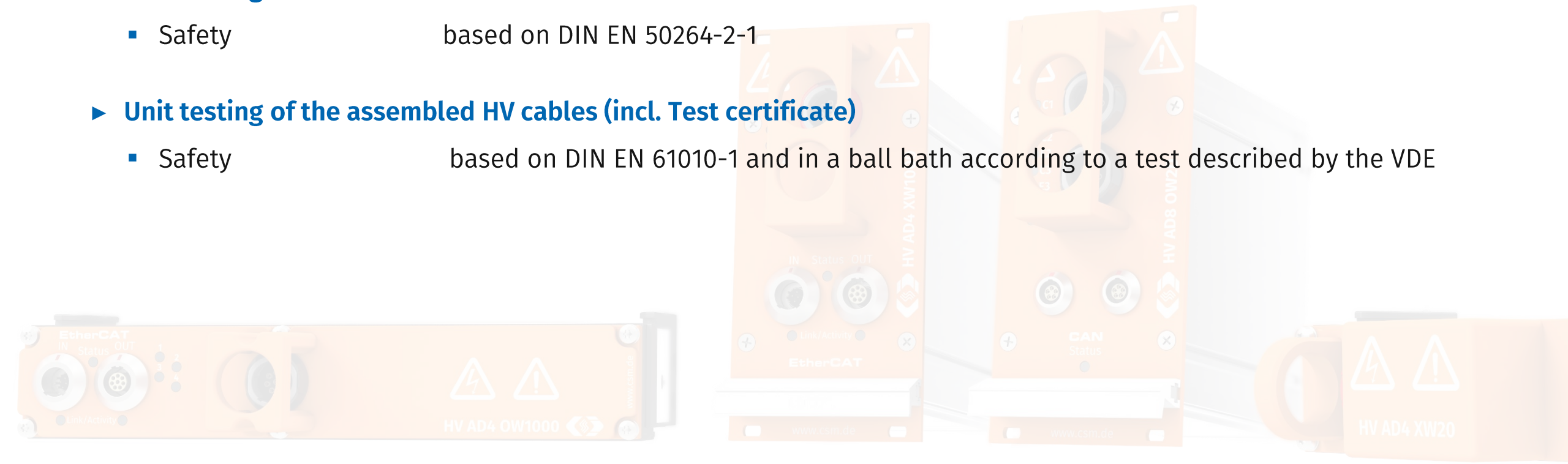
- **Type testing of measurement modules**
  - Protection class IP — DIN EN 60529:2000
  - Temperature change — DIN EN 60068-2-14
  - Swing — DIN EN 60068-2-64
  - Rough handling — DIN EN 60068-2-31
  - Shock — DIN EN 60068-2-27

- **Type testing of the HV sensor cables**
  - Bending — VDE III ±90° and based on DIN EN 50265-2-1



Measurement Safety Concept – Tests for Each Measurement Module

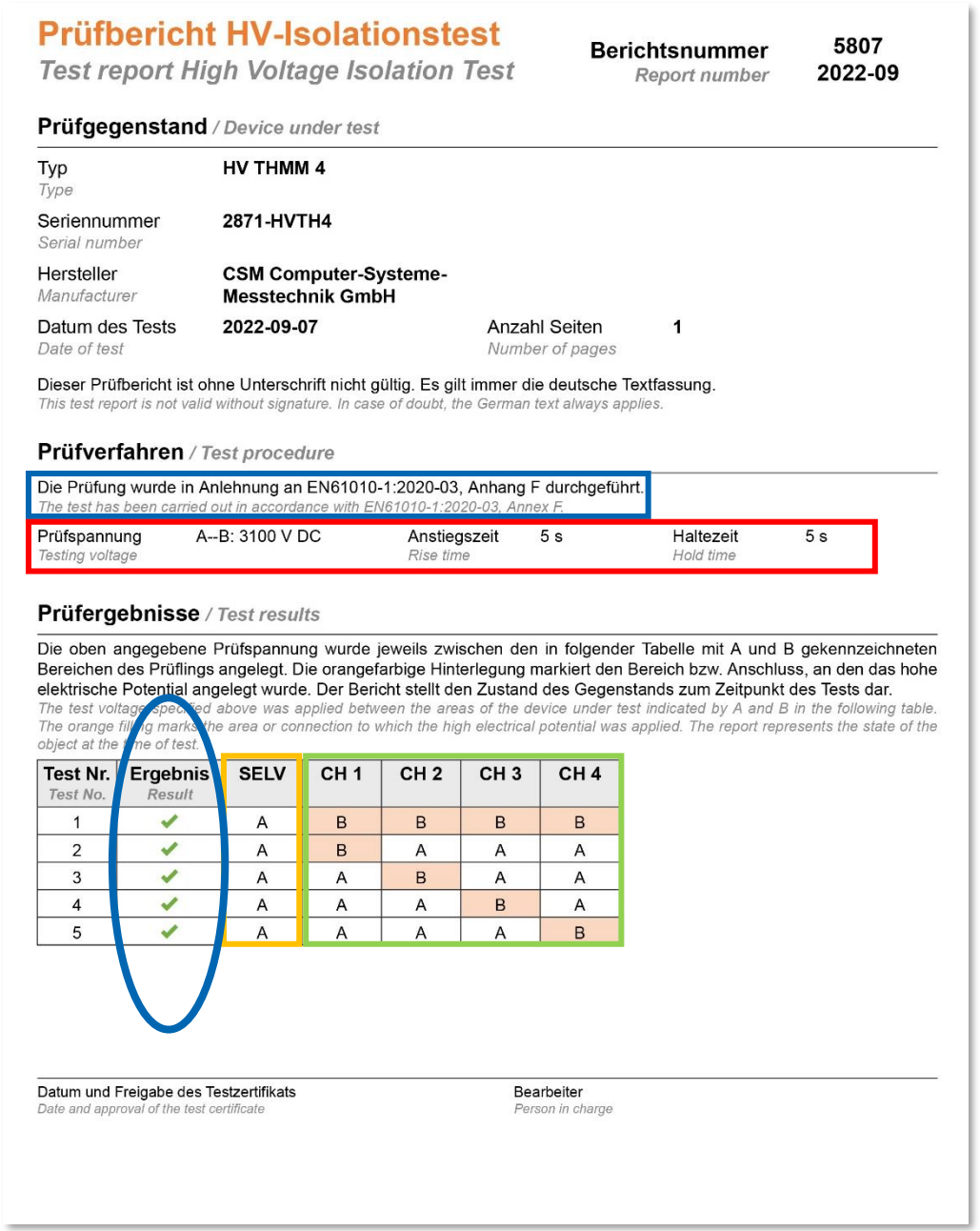
- **Unit testing of the measurement modules (incl. Test certificate)**
  - Safety based on DIN EN 61010-1:2020-03, Appendix F
- **Unit testing of the HV cables**
  - Safety based on DIN EN 50264-2-1
- **Unit testing of the assembled HV cables (incl. Test certificate)**
  - Safety based on DIN EN 61010-1 and in a ball bath according to a test described by the VDE



Measurement Technology Safety Concept

A HV Isolation test certificate must be included in the scope of delivery for each measurement module.

- Norm EN 61010-1:2020
- Test of flashover strength between potentials on HV measuring device
  - All measurement channels against each other
  - All measurement channels against housing (SELV)
- **Test specification:**
  - 3100 V DC Testing voltage
  - 5 s Rise time
  - 5 s Hold time



Prüfbericht HV-Isolationstest
Test report High Voltage Isolation Test

Berichtsnummer *Report number* 5807 2022-09

Prüfgegenstand / *Device under test*

Typ *Type*	**HV THMM 4**
Seriennummer *Serial number*	**2871-HVTH4**
Hersteller *Manufacturer*	**CSM Computer-Systeme-Messtechnik GmbH**
Datum des Tests *Date of test*	**2022-09-07**
Anzahl Seiten *Number of pages*	**1**

Dieser Prüfbericht ist ohne Unterschrift nicht gültig. Es gilt immer die deutsche Textfassung.
This test report is not valid without signature. In case of doubt, the German text always applies.

Prüfverfahren / *Test procedure*

Die Prüfung wurde in Anlehnung an EN61010-1:2020-03, Anhang F durchgeführt.
The test has been carried out in accordance with EN61010-1:2020-03, Annex F.

Prüfspannung *Testing voltage*	A--B: 3100 V DC	Anstiegszeit *Rise time*	5 s	Haltezeit *Hold time*	5 s

Prüfergebnisse / *Test results*

Die oben angegebene Prüfspannung wurde jeweils zwischen den in folgender Tabelle mit A und B gekennzeichneten Bereichen des Prüflings angelegt. Die orangefarbige Hinterlegung markiert den Bereich bzw. Anschluss, an den das hohe elektrische Potential angelegt wurde. Der Bericht stellt den Zustand des Gegenstands zum Zeitpunkt des Tests dar.
The test voltage specified above was applied between the areas of the device under test indicated by A and B in the following table. The orange filling marks the area or connection to which the high electrical potential was applied. The report represents the state of the object at the time of test.

Test Nr. *Test No.*	Ergebnis *Result*	SELV	CH 1	CH 2	CH 3	CH 4
1	✔	A	B	B	B	B
2	✔	A	B	A	A	A
3	✔	A	A	B	A	A
4	✔	A	A	A	B	A
5	✔	A	A	A	A	B

Datum und Freigabe des Testzertifikats
Date and approval of the test certificate

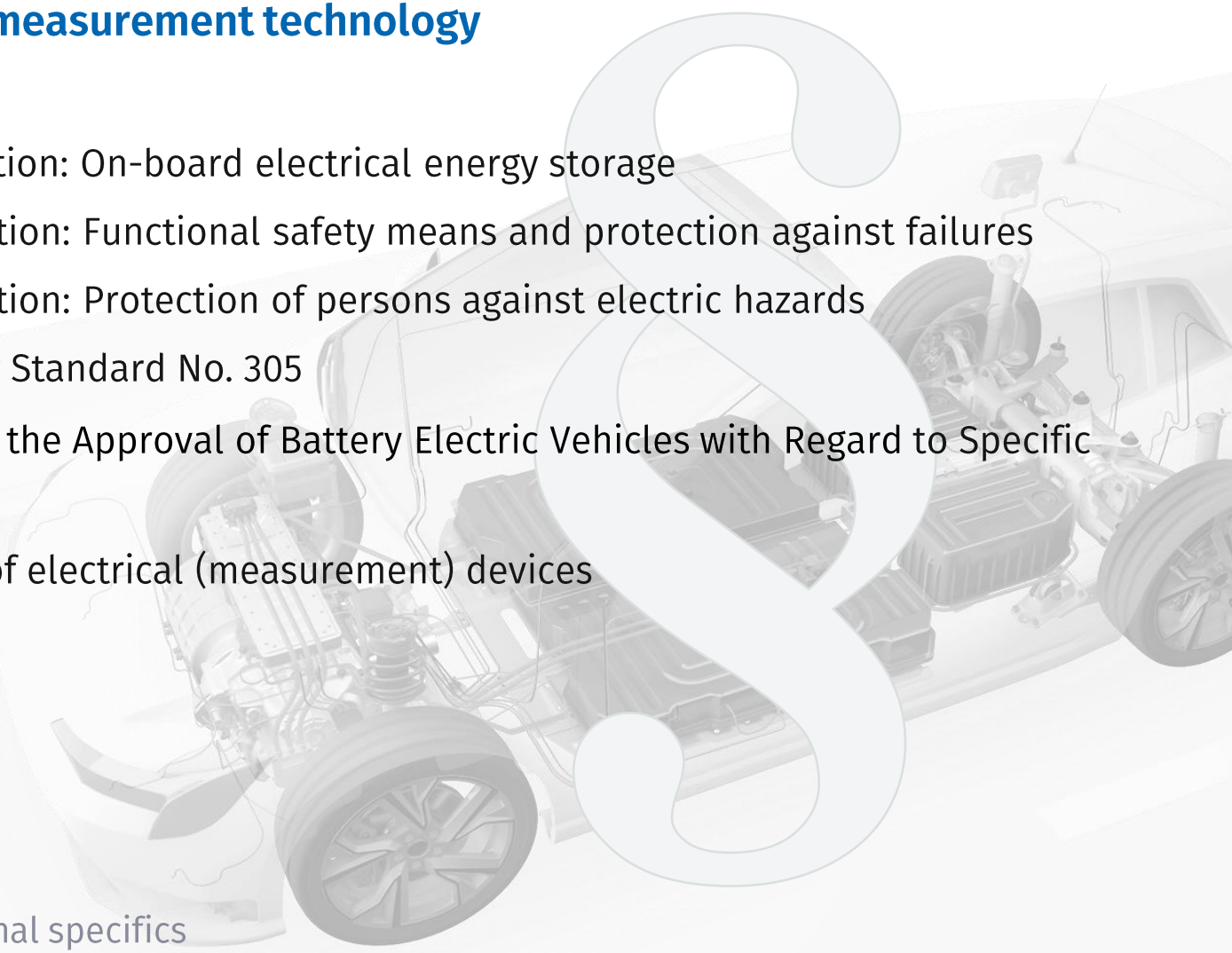
Bearbeiter
Person in charge

What else needs to be considered?

Norms, standards and guidelines in the use of measurement technology

Which ones affect work in the HV environment?

- ISO 6469-1: Electric road vehicles -Safety specification: On-board electrical energy storage
- ISO 6469-2: Electric road vehicles -Safety specification: Functional safety means and protection against failures
- ISO 6469-3: Electric road vehicles -Safety specification: Protection of persons against electric hazards
- FMVSS 305 (USA): U.S. Federal Motor Vehicle Safety Standard No. 305
- ECE R100 (Europe): Uniform Provisions Concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the Construction
- IEC 1010 (EN 61010): Definition of the basic safety of electrical (measurement) devices



Further norms (selection):

ISO 6722, ISO 14572, IEC 61851, IEC 62196, additional national specifics

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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