Measuring in high-voltage environments

CSM Web Seminars

Innovative Measurement and Data Technology

From conventional to electric drive

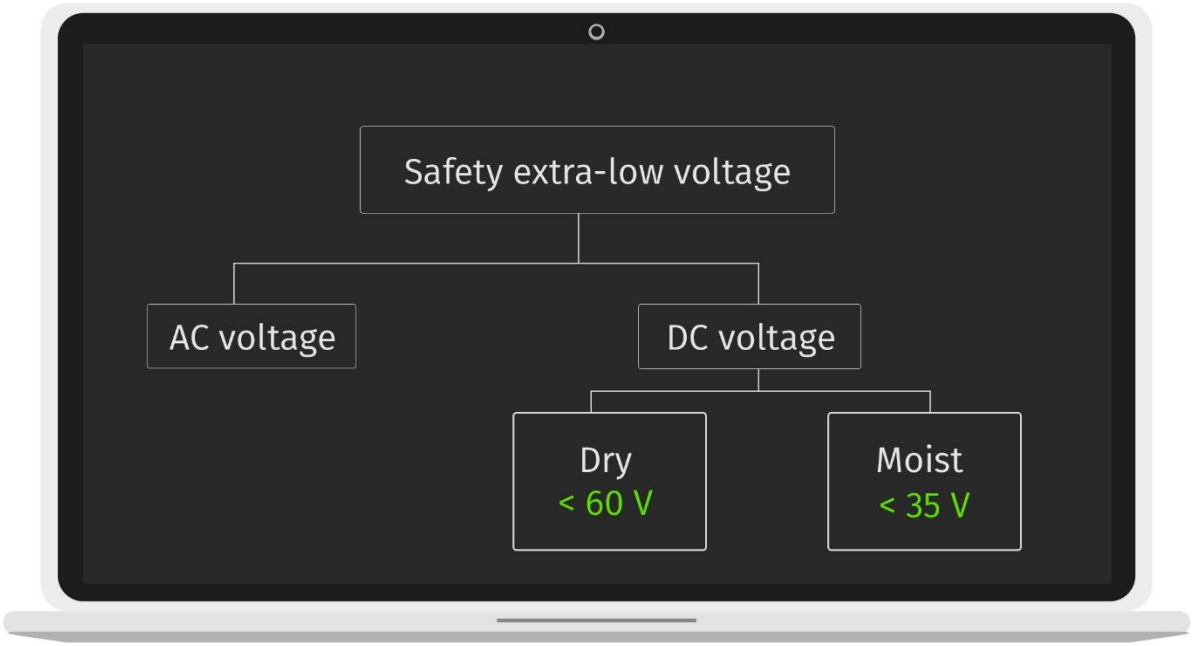
Components	Conventional vehicle	Electric vehicle
Drive	mechanical	Electric
Drive control	mechanical	Electric
Heating	mechanical	Electric
Air conditioning compressor	mechanical	Electric
Energy storage	mechanical	High-voltage battery
System voltage	12 Volt, 24 Volt	≥ 400 Volt

- 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.



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 requencies to be acquired (useful bandwidth of the measuring channels)

  Operating voltage
  - **Selection of proper, safe equipment required when > 50 V (per OSHA) of the Device Under Test**

Selection of measurement equipment must be completely re-evaluated!

"Conventional" measurement technology in the HV environment...?

Example: Temperature measurement in a HV power electronics system

Unsuitable and dangerous temperature measurement chain

Power Electronics

No strain relief

Not waterproof

Not safe to touch due to open contacts

"Standard" measuring module

Insufficient insulation
-> not HV-safe!

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!**
  - Risk to capital investment (prototype, product, measurement system
  - Danger to the user's life!!
- **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 measuring point to data acquisition

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

Uninterrupted safety from the measurement point to data acquisition!

Separation of high voltage environment and 12/24 volt network

On-vehicle Requirement (ISO 6449-3:2018)

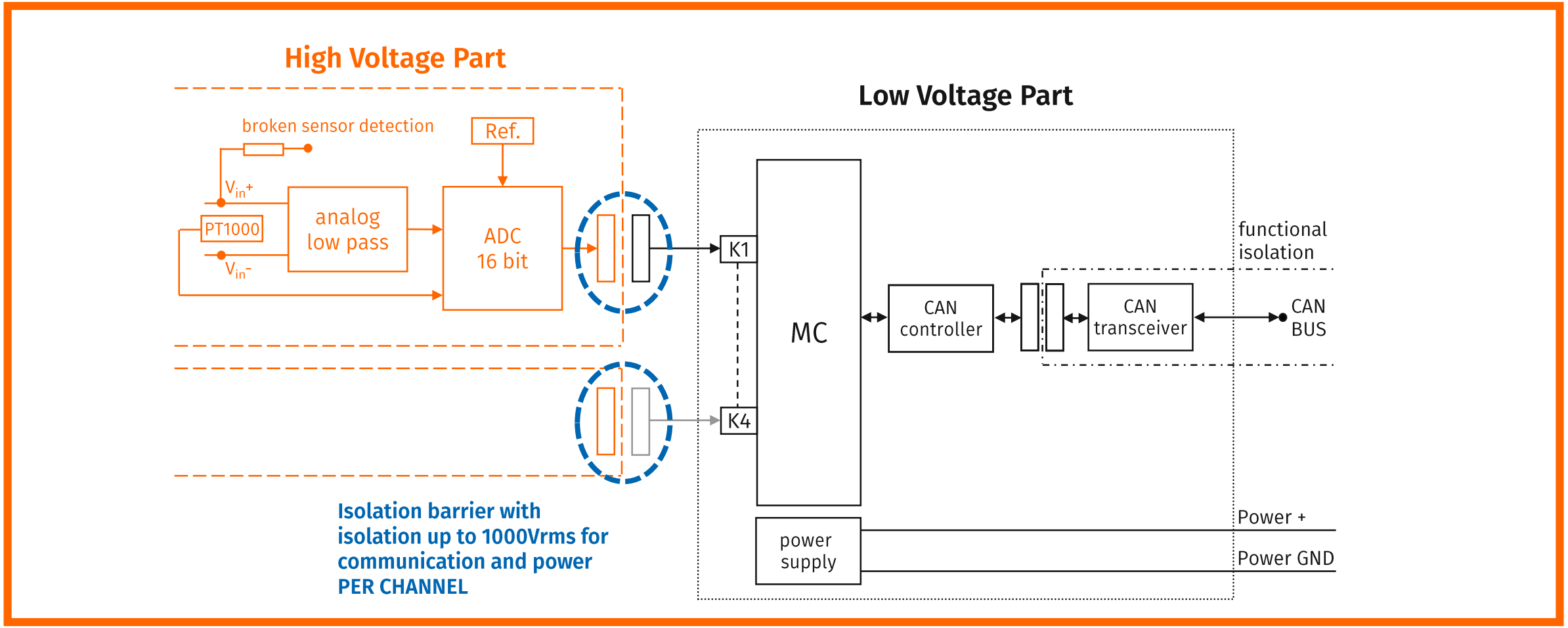
Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety

Galvanic isolation between the HV electrical propulsion system and the 12 V auxiliary electrical

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

HV Isolation inside Measurement Modules

Example: of the CSM HV TH4 evo thermo measuring module



Insulation Definitions
According to IEC 61010-1 (ANSI/UL 61010-1)

- **Basic insulation**

  Insulation of hazardous active parts as basic protection

  Note: Basic insulation may also serve for functional purposes.

- **Additional insulation**

  Independent insulation applied in addition to the basic insulation to provide protection against electric shock in case of failure of the basic insulation.

- **Double insulation**

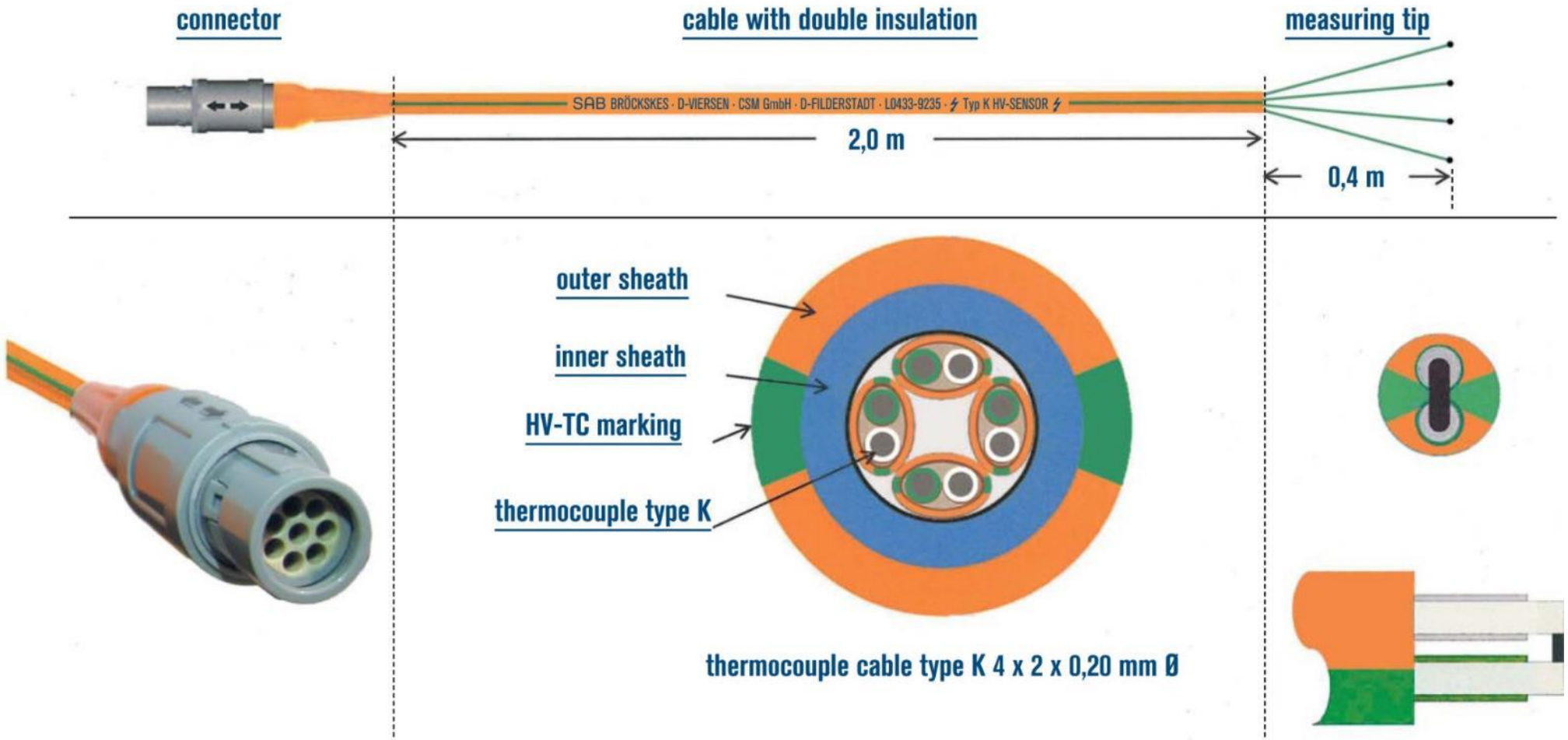
  Insulation consisting of the basic insulation and the additional insulation.

- **Reinforced insulation**

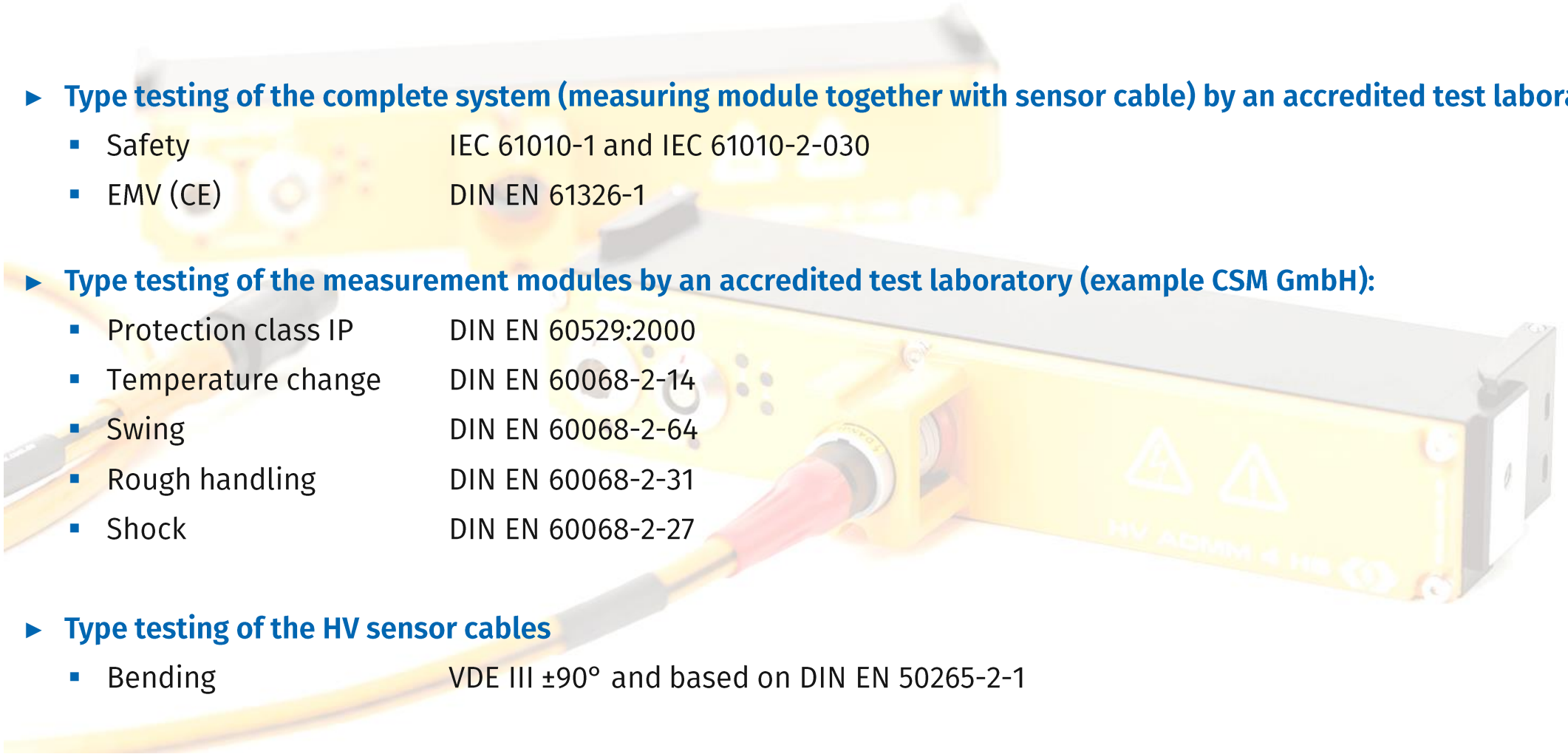
  Insulation that provides protection against electric shock no less than protection provided by double insulation.

  Note: Reinforced INSULATION may be composed of several layers which cannot be tested individually as ADDITIONAL INSULATION or BASE INSULATION.

Safety within the HV Sensor Cables



Measurement technology safety concept - one-off type tests
according DIN (standard by German Institute for Standardization)



- **Type testing of the complete system (measuring module together with sensor cable) by an accredited test laboratory**
  - Safety — IEC 61010-1 and IEC 61010-2-030
  - EMV (CE) — DIN EN 61326-1
- **Type testing of the measurement modules by an accredited test laboratory (example CSM GmbH):**
  - 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 - routine tests for EACH CSM Module

- **Unit testing of the measuring modules (incl. test certificate)**
  - Safety following DIN EN 61010-1:2010, F.4
- **Unit testing of the HV cables**
  - Safety following DIN EN 50264-2-1
- **Unit testing of the assembled HV cables (incl. test certificate)**
  - Safety in a ball bath according to a test described by the VDE

Measurement technology safety concept

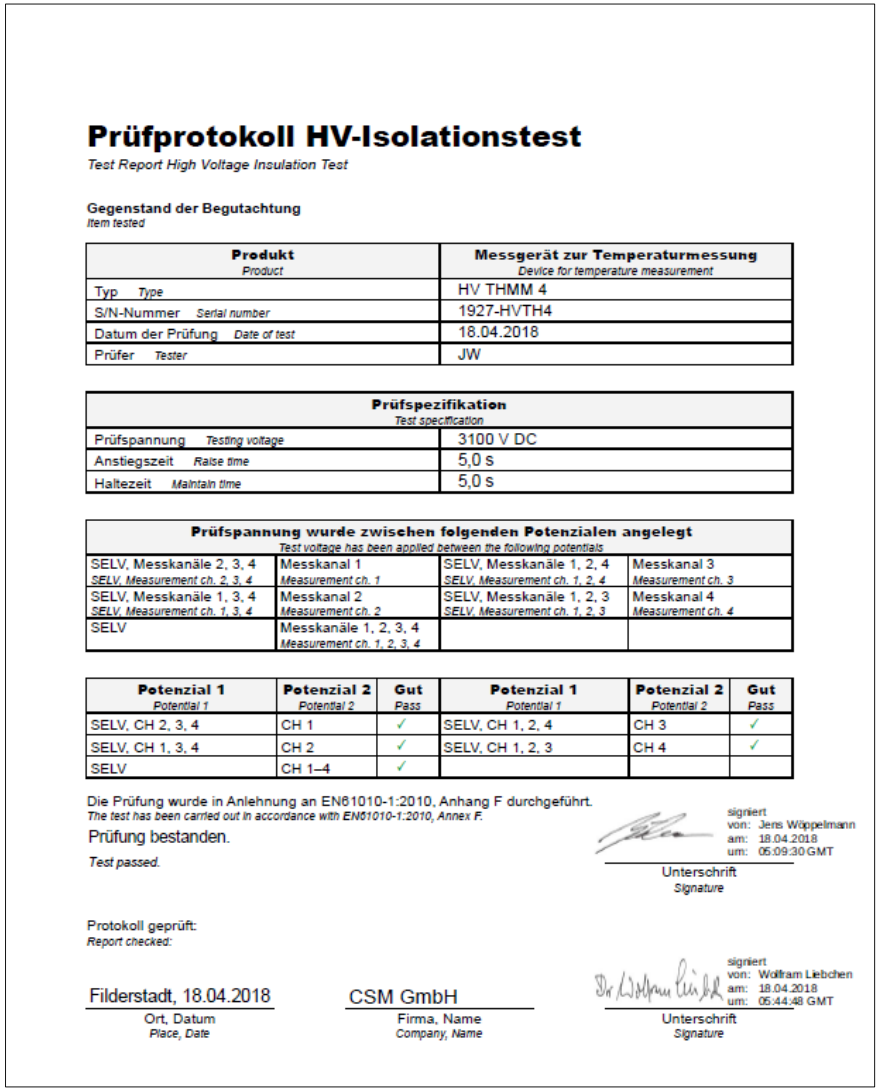
The routine test is performed in accordance with the EN 61010-1:2010 standard.

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

Test specification:

- 3,100 V DC Test voltage
- 5 sec Rise time
- 5 sec Holding time

- **A regular HV isolation test is required at least every 12 months!**



Prüfprotokoll HV-Isolationstest

Test Report High Voltage Insulation Test

Gegenstand der Begutachtung
Item tested

Produkt *Product*	**Messgerät zur Temperaturmessung** *Device for temperature measurement*
Typ *Type*	HV THMM 4
S/N-Nummer *Serial number*	1927-HVTH4
Datum der Prüfung *Date of test*	18.04.2018
Prüfer *Tester*	JW

Prüfspezifikation *Test specification*	
Prüfspannung *Testing voltage*	3100 V DC
Anstiegszeit *Raise time*	5,0 s
Haltezeit *Maintain time*	5,0 s

Prüfspannung wurde zwischen folgenden Potenzialen angelegt
Test voltage has been applied between the following potentials

SELV, Messkanäle 2, 3, 4 *SELV, Measurement ch. 2, 3, 4*	Messkanal 1 *Measurement ch. 1*	SELV, Messkanäle 1, 2, 4 *SELV, Measurement ch. 1, 2, 4*	Messkanal 3 *Measurement ch. 3*
SELV, Messkanäle 1, 3, 4 *SELV, Measurement ch. 1, 3, 4*	Messkanal 2 *Measurement ch. 2*	SELV, Messkanäle 1, 2, 3 *SELV, Measurement ch. 1, 2, 3*	Messkanal 4 *Measurement ch. 4*
SELV	Messkanäle 1, 2, 3, 4 *Measurement ch. 1, 2, 3, 4*		

Potenzial 1 *Potential 1*	**Potenzial 2** *Potential 2*	**Gut** *Pass*	**Potenzial 1** *Potential 1*	**Potenzial 2** *Potential 2*	**Gut** *Pass*
SELV, CH 2, 3, 4	CH 1	✓	SELV, CH 1, 2, 4	CH 3	✓
SELV, CH 1, 3, 4	CH 2	✓	SELV, CH 1, 2, 3	CH 4	✓
SELV	CH 1–4	✓			

Die Prüfung wurde in Anlehnung an EN61010-1:2010, Anhang F durchgeführt.
The test has been carried out in accordance with EN61010-1:2010, Annex F.
Prüfung bestanden.
Test passed.

signiert
von: Jens Wöppelmann
am: 18.04.2018
um: 05:09:30 GMT
Unterschrift
Signature

Protokoll geprüft:
Report checked:

Filderstadt, 18.04.2018
Ort, Datum
Place, Date

CSM GmbH
Firma, Name
Company, Name

signiert
von: Wolfram Liebchen
am: 18.04.2018
um: 05:44:48 GMT
Unterschrift
Signature

What else needs to be considered?

Norms, standards and guidelines in the use of measurement technology*

Which ones affect us specifically in the HV environment?

IEC 61010 and ANSI S82.02, CSA 22.2-1010.1, with OSHA 29 CFR 1910.303(g)(2)(i)

FMVSS 305 (USA)	U.S. Federal Motor Vehicle Safety Standard No. 305 LABORATORY TEST PROCEDURE FOR ELECTRIC POWERED VEHICLES: ELECTROLYTE SPILLAGE AND ELECTRICAL SHOCK PROTECTION
ECE-R100 (Europe)	Uniform Provisions Concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the Construction, Functional Safety and Hydrogen Emission
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

<u>Others</u>

ISO 6722, ISO 14572, IEC 61851, IEC 62196	Cables / Chargers / external power supply

***Note: There may be national specifics**

Who is allowed to do what? - Persons in the HV environment on vehicles

Example: German Regulations

- **Electrical Specialist**
  - Management and technical responsibility / monitoring / hazard assessment
- **Electrician with work under voltage**
  - Disconnect / commissioning / working on components under voltage (e.g.: batteries cannot be discharged - sensor positioning inside battery)
- **Electrician**
  - Enabling / commissioning / working on components of the enabled HV system (attaching sensors to HV lines)
- **Electrotechnical Person**
  - Wheel exchange, removal and installation of HV components under supervision and control
- **Layman**
  - Hands off...

Challenge to overcome: (Almost) Everything is new...

- Many vehicle components have to **be completely redeveloped**.
- On the one hand, these must be tested individually (component test), but also in interaction with other components.
- This results in **numerous test scenarios**.
- Only **limited experience** and data can be transferred from combustion engines to e-vehicles.

High-voltage safe measurement technology is required for all test areas.

-> Also for the most diverse measured variables!

Practical requirements

- **Voltage measurement** (up to 2,000 volts peak), e.g. for checking the HV battery and the vehicle electrical system
- **Current measurement** on HV potential (from quiescent current measurement to kilo-ampere range)
- **Power measurement and Analysis** (synchronous measurement of U and I and online calculation of power parameters), e.g. WLTP/SORT measurements
- **Temperature measurement** on HV potential, e.g. on HV batteries (sometimes with several hundred (!!!) measuring points in a very confined space)
- **Strain measurement** on HV battery structures
- **Acceleration measurement** on HV potential, e.g. drop test of HV components
- **Moisture measurement** in HV components
- and much more

You can find an excerpt of our experience in our application examples at www.csm.de .

The right solution for every task

Find HV-safe measurement modules on www.csm.de

Current, voltage, power	Temperatures	Strains	Standard-sensors	Acceleration







Test bench / In-Vehicle	Road test


DO NOT compromise when it comes to your safety!

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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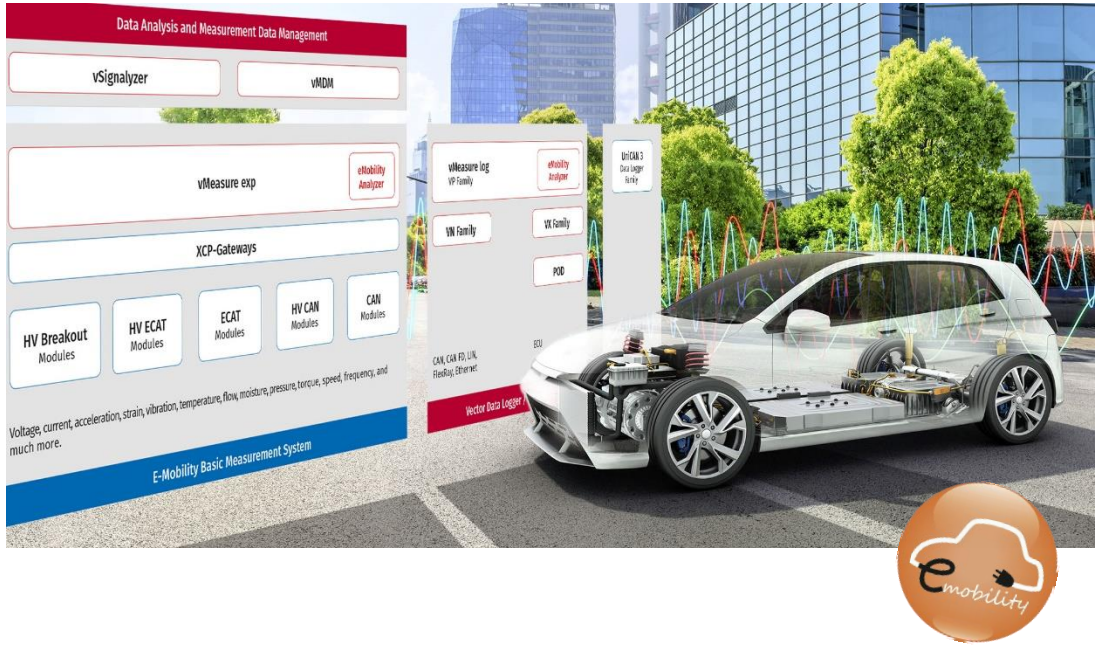

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