CSM HV DTemp Measurement System

Digital Temperature Measurement with up to 512 Measurement Points

Innovative Measurement and Data Technology

HV DTemp Measurement System

Up to 512 Sensors Connected via a Single Measurement Bus

The CSM HV DTemp measurement system was developed for the spatially precise and digital thus interferencefree acquisition of up to 512 temperature measurement points within confined HV environments. Only one high-voltage safe cable has to be led out of the HV environment to the HV DTemp-P Central Unit.

The digital temperature sensors are tiny, robust, and highly accurate. This makes the HV DTemp measurement system especially suitable for the use in HV batteries.

Optimal thermal management is crucial for the performance, safety, and durability of HV batteries. This requires precise information about the temperature distribution and thermo-dynamics within the battery, all the way down to cell level. For this, measurement data from hundreds of measurement points within the battery system is needed. Especially on the cell level, the precise identification of each sensor is important.

With the HV DTemp measurement system you are able to:

- Accurately verify and optimize temperature models of HV batteries, improving the design and performance of Battery Management Systems (BMS)
- Investigate fast-charging problems, cell aging, cooling concept, behavior during regeneration effects simultaneously at cell, module, and battery level
- Validate and enhance simulation models with empirical data
- Determine and evaluate temperature hotspots dependent on various operating conditions
- Carry out safety analyses on the spread of fires and their containment by appropriate measures within the battery design

Highlights

- Measurement accuracy of the entire system: ±0.1 °C to ±0.25 °C
- Efficient acquisition of up to 512 temperature measurement points via a single control unit
- Only one connection cable from the HV environment to the CAN bus central unit
- Miniaturized, highly accurate, robust, components inside HV environment
- Very low space requirement for IC temperature sensors, controller and cabling inside the battery
- Lowest possible influence on the object under test
- Sensor arrangement flexibly adaptable to the object under test, precisely positionable and clearly identifiable, e.g. via IC sensors on ultra-thin flexible circuit
- Accurate temperature measurement in places where it was previously not possible due to lack of space
- HV-safe for equipment and users up to 1,000 V RMS

Space Requirement

When using conventional HV-safe temperature measurement technologies, based on thermocouples or PT100 sensors, each sensor requires its own cable connection for the transmission of its analog voltage values. Additionally, PT100 sensors also require their own power supply. With a high number of necessary measurement points comes a high number of sensor cables.

This influences the temperature behavior within the battery. All these cables must also be routed to the outside through openings in the battery housing in a way that is HV-safe and does not allow moisture to penetrate the battery.

The Integrated Circuit temperature sensors (IC Sensors) of the HV DTemp measurementsystem measure the temperatures and transfer their measured values directly as digital signals. This not only eliminates the need for many cables inside the battery, but it also means that one single small cable gland suffices as an opening in the battery housing for the single digital measurement bus cable.

Due to the small space requirement of all components, the HV DTemp measurement system can also be installed in confined spaces and sophisticated temperature measurements on different cell types can be performed. In addition, only one central unit outside the HV environment is required to control up to 512 measurement points.

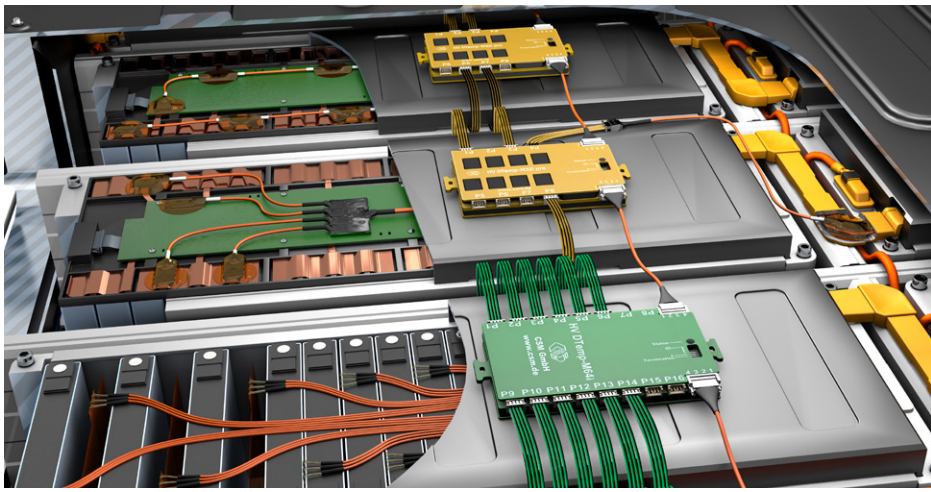


Fig. 1: Even in the confined spaces of HV batteries, the components of the measurement system can be installed.

Flexible Installation of the Sensors

Hundreds of measurement points are required for the precise analysis of the thermal behavior of battery systems. Measurements with conventional temperature sensors, such as thermocouples or PT100 / PT1000 sensors, require the extremely time-consuming application of hundreds of sensors and the routing of the necessary sensor cables.

In addition, the repeated exact positioning of the sensors on measurement points calculated in simulations on several battery cells is only possible to a limited extent.

With IC sensors positioned on ultra-thin flexible circuits, such measurements are set up quickly and precisely: The positions of the sensors can be transferred exactly to the flexible circuit, and machine production means that the arrangement can be reproduced as often as required. Afterwards, the ultra-thin flexible circuit only have to be positioned between the battery cells.

For temperature measurements on busbars, electronics and other components, various variants for the grouping of individual sensors facilitate individual adaptation to the measurement task.

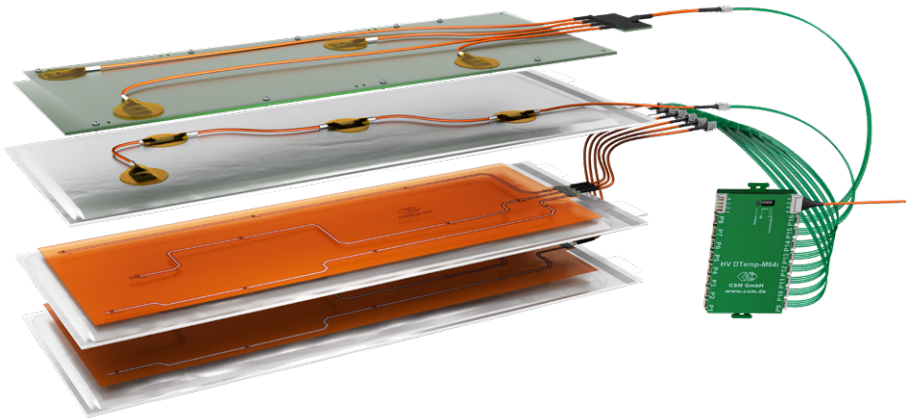


Fig. 2: Various wiring options are available for the installation of the HV DTemp IC sensors - so measurements can be taken at any point.

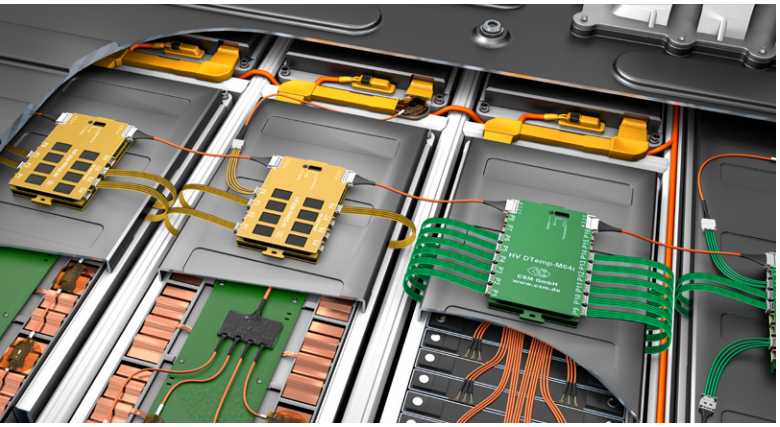


Fig. 3: The measurement data is transmitted digitized.

Interference Immunity

Long cables behave like antennas and catch interfering signals. Especially with thermoelectric voltages in the mV range, there is a great danger that the measurement signals are corrupted by a time variant offset value.

Interferences on measurement cables do not change the value of measurements which are already digitized. The worst case is that interfering high-energy pulses can briefly interrupt the data transmission. The HV DTemp measurement system detects and corrects this automatically. This ensures that the measured values are transmitted unaltered at all times.

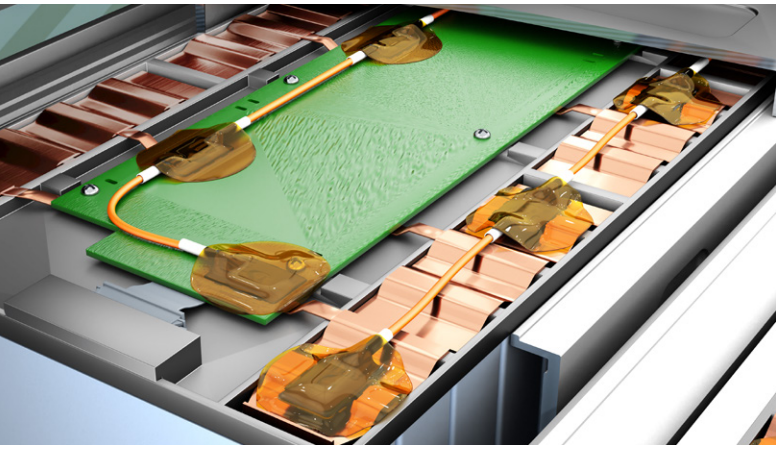


Fig. 4: The temperature values are immediately digitized in the IC temperature sensor. This means that the measurement accuracy of the sensor is identical with the measurement accuracy of the entire measurement chain.

Measurement Accuracy

The measurement accuracy of the IC temperature sensors is between ±0.1 °C and ±0.25 °C in the temperature measurement range from -40 °C to +125 °C. This is also the measurement accuracy of the entire measurement chain!

When using analog temperature sensors, the accuracy with which a temperature is measured is the sum of the measurement accuracies of the sensor, the potential interference in the cable, and the measure ment accuracy of the measurement device. With PT100 / PT1000 sensors, a measurement accuracy of the entire measurement chain between ±0.3 °C and ±0.5 °C is achieved using high-precision CSM HV PT measurement modules. With thermocouples, this measurement uncertainty is significantly higher.

HV Safety

As for all measurements in a high-voltage environment, the safety of users and systems must be ensured by appropriate measures.

The HV DTemp measurement system meets these requirements according to DIN EN 61010-2010 for an operating voltage up to 1,000 V RMS.

The HV DTemp IC Sensor cables offer contact protection and, depending on the application, isolated controllers with galvanic isolation are used. This ensures safety in the HV environment.

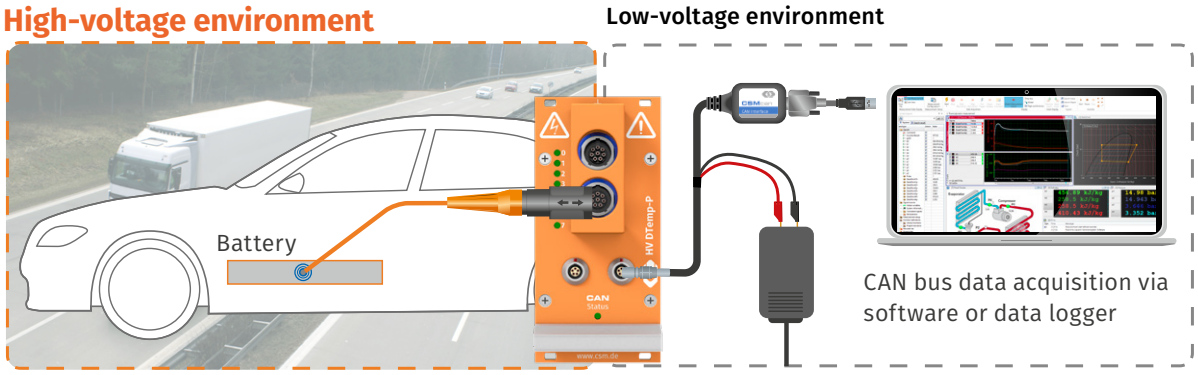


Fig. 5: Safe transition from the high-voltage to the low-voltage environment.

The Measurement System

The measurement system consists of three components: HV DTemp IC Sensors, HV DTemp Controllers and the HV DTemp-P Central Unit. The components and variants are assembled specifically for each application. This allows flexible adaptation to the challenges of the measurement task.

HV DTemp IC Sensors

The IC Sensors are soldered onto an ultra-thin flexible circuit and measure the temperature point on their bottom surface. The special structure of this flexible circuit ensures that there is very good conductive heat transfer from the object under test; with simultaneous electrical isolation. In addition, they are mechanically robust and can be pressed between battery cells.

- IC temperature sensor dimensions (W×H×D): approx. 1.5 mm × 0.5 mm × 1 mm
- Measurement range: -40 °C to + 125 °C
- Internal resolution: 16 Bit

The flexibility of the ultra-thin flexible circuit allows installation on all battery cell types (including round cells) and components in the HV battery.

For additional protection, the IC Sensors (including the connection cables) can be encapsulated.

The HV DTemp IC Sensors are based on the above IC temperature sensor technology and are available as standard in the following variants:

Single Sensors

A single sensor with one single cable can be directly connected to a HV DTemp-Mx Controller. The cable is connected to the flexible circuit via four soldering points. This single sensor option is ideal for measurement on a power busbar or other single-point locations.

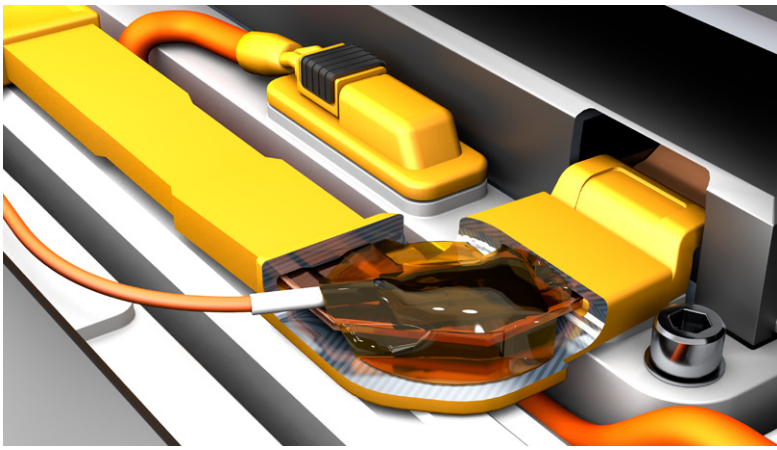
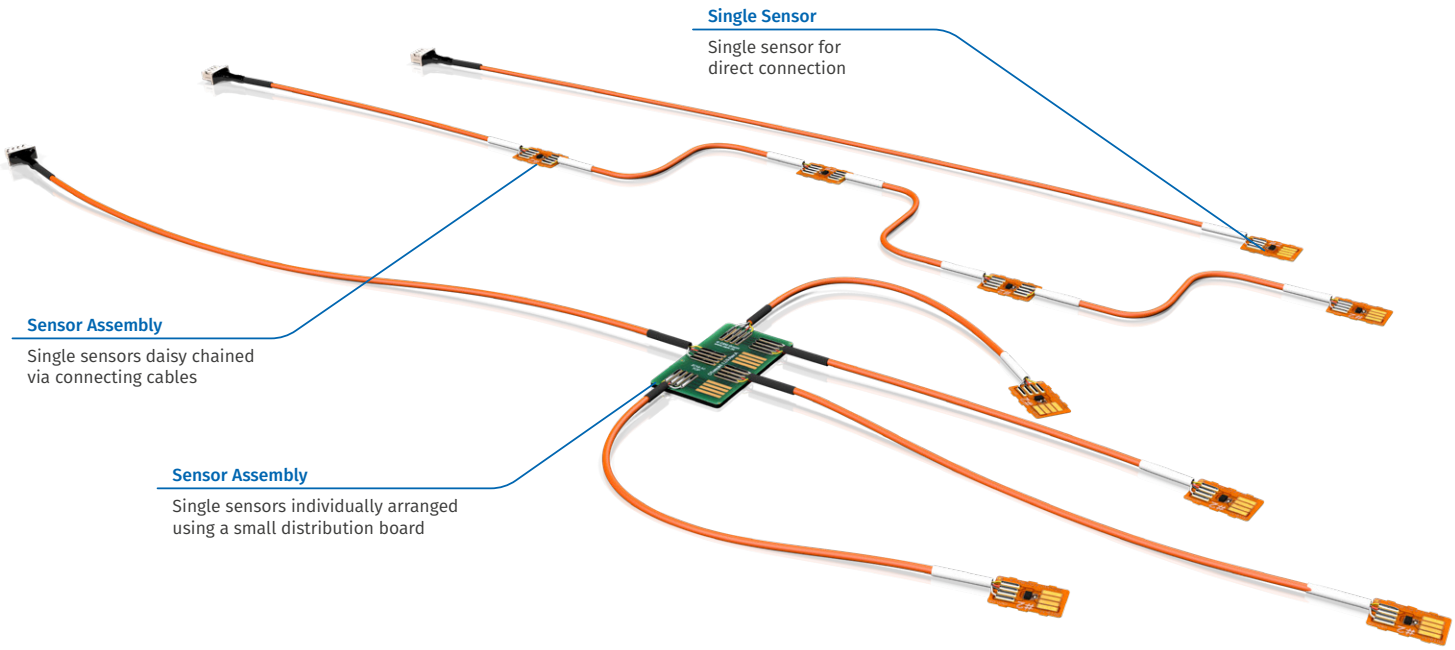


Fig. 6: Single sensor installed for temperature measurement on a busbar.



Sensor Assembly

Up to 4 single sensors can be connected together to form a sensor assembly. All are connected to a HV DTemp-Mx Controller.

The sensors are either daisy chained via connecting cables or connected via a small distribution board.

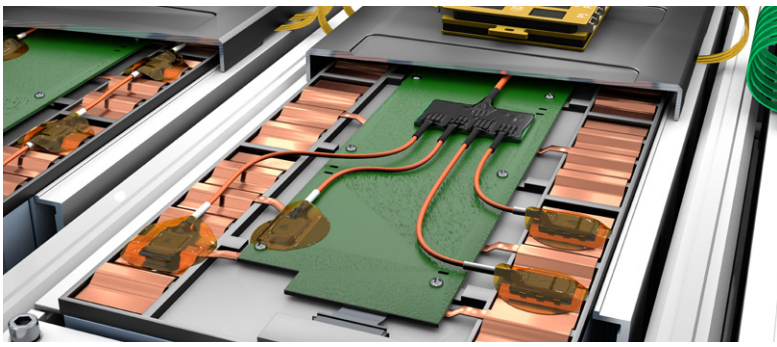


Fig. 7: Sensor assembly connected via a small distribution board.

Connection Cables IC Sensors

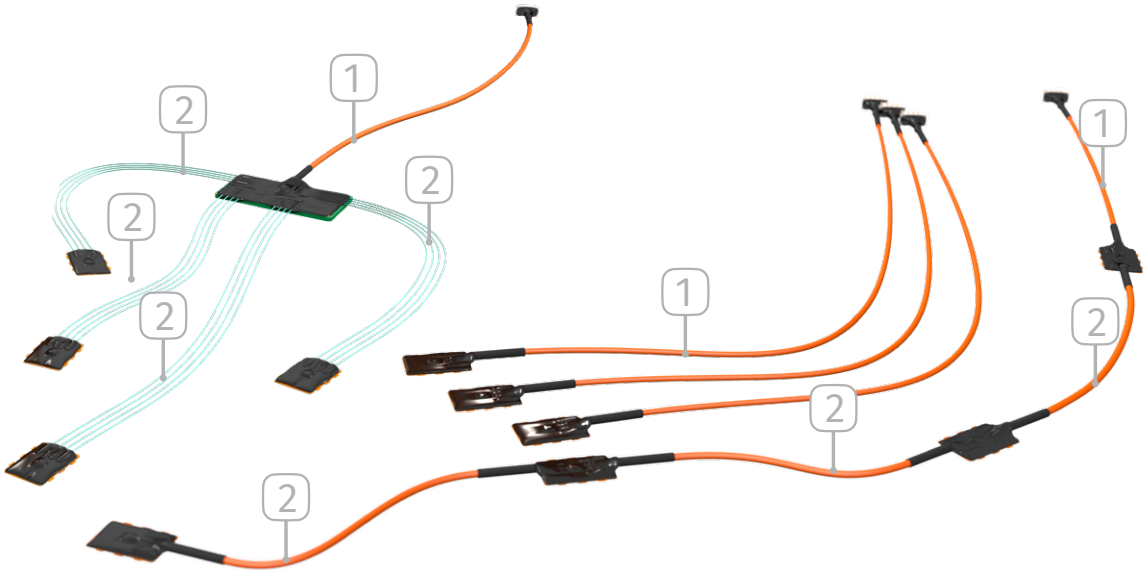


Fig. 8: Sensor cables for connecting single sensors and sensor assemblies.

Connection cables with different cable diameters are available for connecting the single sensors to sensor assemblies and for connection to HV DTemp Controllers. Thus, the appropriate cable can be selected depending on the required robustness. The cable lengths are manufactured specifically for each application.

All variants of the connection cables ensure contact safety at operating voltages up to 1,000 V RMS.

1. Cable for connection to HV DTemp Controller

- Cable diameter: 2.8 ±0.3 mm

2. Cables for connection of Sensor Assemblies

There are two cable variants for connection of single sensors via the distribution board or for daisy chaining:

- Connection via a connection cable with a cable diameter of 1.6 ±0.3 mm

- Connection via four separate, single-core connection cables with a cable diameter of 0.42 ±0.05 mm each

Ultra-thin Flexible Circuit

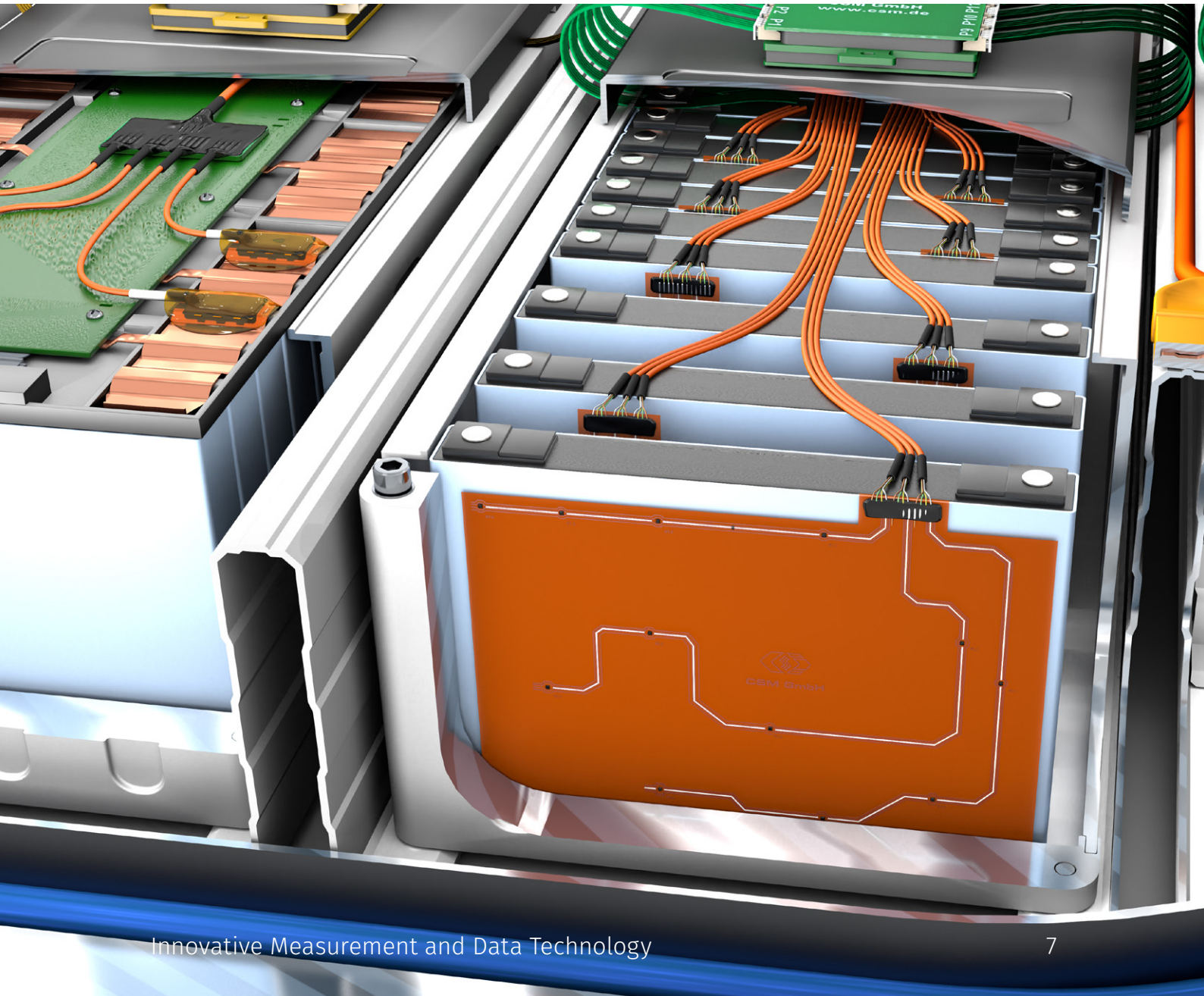
Many IC sensors can be precisely positioned on an ultra-thin flexible circuit and connected via conductor tracks. The size and shape of the flexible circuit as well as the exact arrangement of the sensors are defined by the individual customer requirements.

The precise positions of the sensors on the ultra-thin flexible circuit ensure that the desired target points of the temperature measurement are hit exactly, and at the same time the measurements are reproducible.

The ultra-thin flexible circuits are therefore ideally suited for repeatable placement between battery cells to determine temperature profiles.

Fig. 9: IC sensors on ultra-thin flexible circuit as strips for temperature measurement between round cells.

- Many sensors can be arranged on the smallest area
- The position of each sensor is exactly defined



HV DTemp-Mx Controller

The HV DTemp-Mx Controller provides the addressing and power supply for the IC Sensors. For the connection of semiconductor temperature sensors the Controller M-series was introduced.

The Controllers have 8 or 16 port inputs. Depending on the Controller type, up to four sensors can beconnected per port, thus a total of 64 sensors per controller. Special sensor connection cables are used for convenient connection of the IC Sensors.

Up to eight controllers can be cascaded independently of the variants used, enabling the impressive number of 512 sensors per Central Unit.

The HV DTemp-Mx controllers are available in both isolated and non-isolated variants. Thus, depending on the requirements of the measurement task, the appropriate controller can be selected with regard to the required number of ports and desired isolation.

The controllers are so compact that they can easily be accommodated in the battery housing.

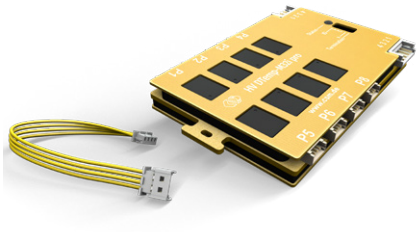
- Control and bundling of up to 64 temperature measurement points
- Cascading of up to eight controllers (independent of type)
- Measurement data rate / transmission rate: 1, 2, 5, 10, 20 Hz

HV DTemp-M64i Controller (isolated)

Temperature measurement points	up to 64
Inputs	16 digital ports for one sensor assembly each (up to 4 IC sensors)
Galvanic isolation	560 V DC
Dimensions (W × H × D)	approx. 88 mm × 10 mm × 56 mm

HV DTemp-M32i pro Controller (isolated)

Temperature measurement points	up to 32
Inputs	8 digital ports for one sensor assembly each (up to 4 IC sensors)
Galvanic isolation	1,000 V DC
Dimensions (W × H × D)	approx. 80 mm × 10 mm × 56 mm



HV DTemp-M16 Controller

Temperature measurement points	up to 16
Inputs	16 digital ports for one IC sensor each
Dimensions (W × H × D)	approx. 75 mm × 8 mm × 45 mm

HV DTemp-M64 Controller

Temperature measurement points	up to 64
Inputs	16 digital ports for one sensor assembly each (up to 4 IC sensors)
Dimensions (W × H × D)	approx. 75 mm × 8 mm × 45 mm

HV DTemp-P Central Unit

The HV DTemp-P Central Unit is the only component located outside the HV environment. The measurement data from up to 512 IC temperature sensors are transmitted via a single HV DTemp-P Cable. For this purpose, the connecting cable is fed via a cable gland into the HV battery, and connected to an HV DTemp-Mx controller. The space requirement and the impact on the housing structure are minimal.

The Central Unit has two galvanically isolated inputs for such connection cables. This allows the measurement system to be used simultaneously in two different HV environments, or additionally to measure temperatures outside a HV environment.

The HV DTemp-P Central Unit controls the entire system. The configuration and the transfer of the measurement data to the data acquisition software is done via CAN- Bus. Each measurement point is uniquely identifiable and assigned its own CAN ID. Via CAN bus, the measurement system can also be easily integrated into existing measurement setups or into the Vector CSM E-Mobility Measurement System in order to acquire other measured variables such as humidity, vibrations and energy flows in parallel.

The HV DTemp-P Central Unit is designed to be HV-safe up to 1,000 V RMS and has an operating temperature range of -40 °C to +125 °C as well as IP65 protection.

- Two galvanically isolated inputs for a total of up to eight HV DTemp-Mx controllers
- Communication via CAN interface
- Reinforced insulation up to 1,000 V DC

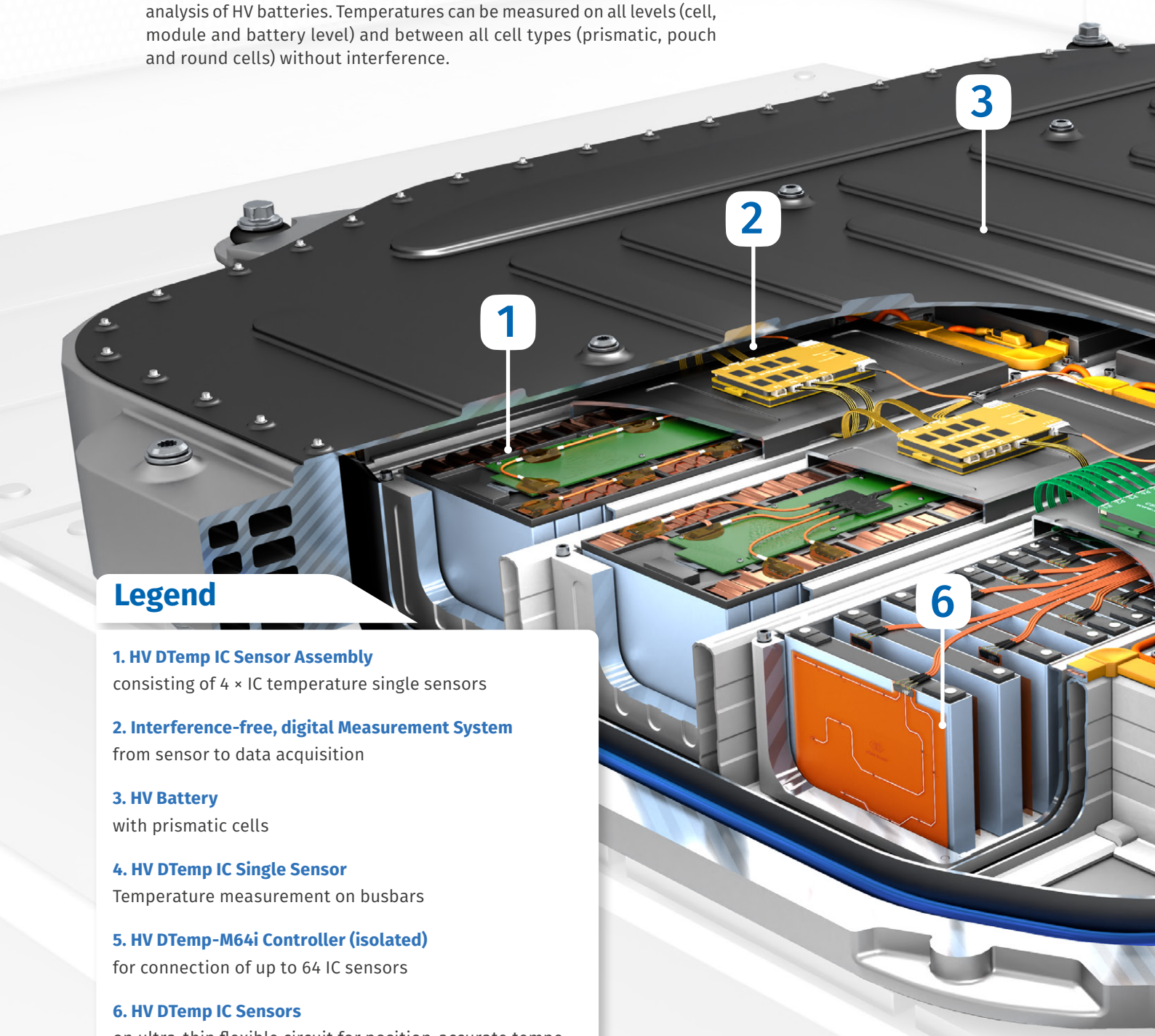
DTEMPconfig

The configuration software DTEMPconfig offers additional possibilities to individualize the measurements. Among other things, it enables:

- Selection and naming of the temperature measurement points
- Storage of comments on individual measurement points, such as position information
- Support of device firmware updates
- Output of configuration reports

System overview

The HV DTemp measurement system is suitable for the in-depth thermal analysis of HV batteries. Temperatures can be measured on all levels (cell, module and battery level) and between all cell types (prismatic, pouch and round cells) without interference.



Legend

1. HV DTemp IC Sensor Assembly
consisting of 4 × IC temperature single sensors

2. Interference-free, digital Measurement System
from sensor to data acquisition

3. HV Battery
with prismatic cells

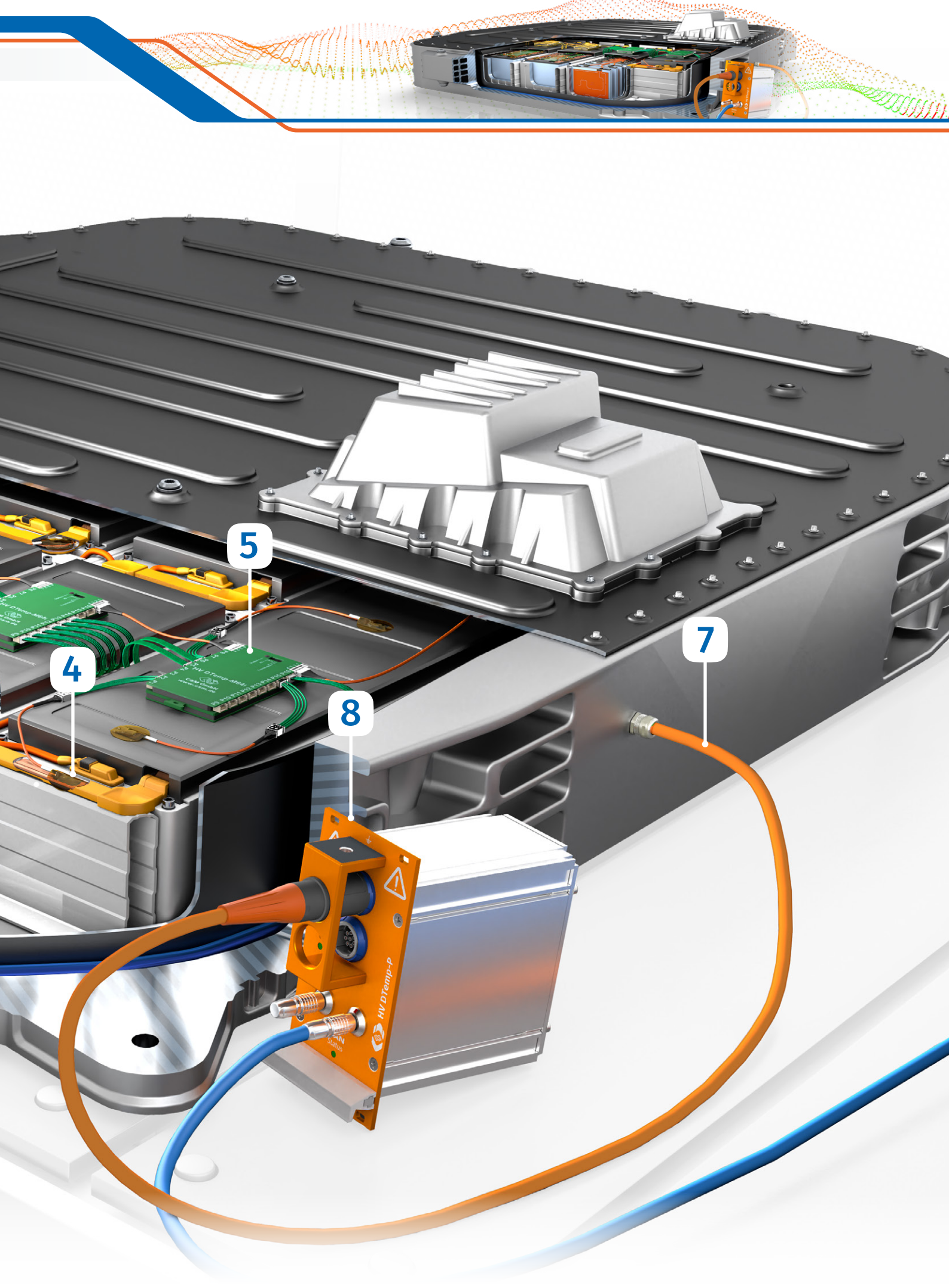
4. HV DTemp IC Single Sensor
Temperature measurement on busbars

5. HV DTemp-M64i Controller (isolated)
for connection of up to 64 IC sensors

6. HV DTemp IC Sensors
on ultra-thin flexible circuit for position-accurate temperature measurements between battery cells

7. HV-DTemp-P Cable
HV safe cable for connection of up to 512 IC temperature sensors to the central unit

8. HV DTemp-P Central Unit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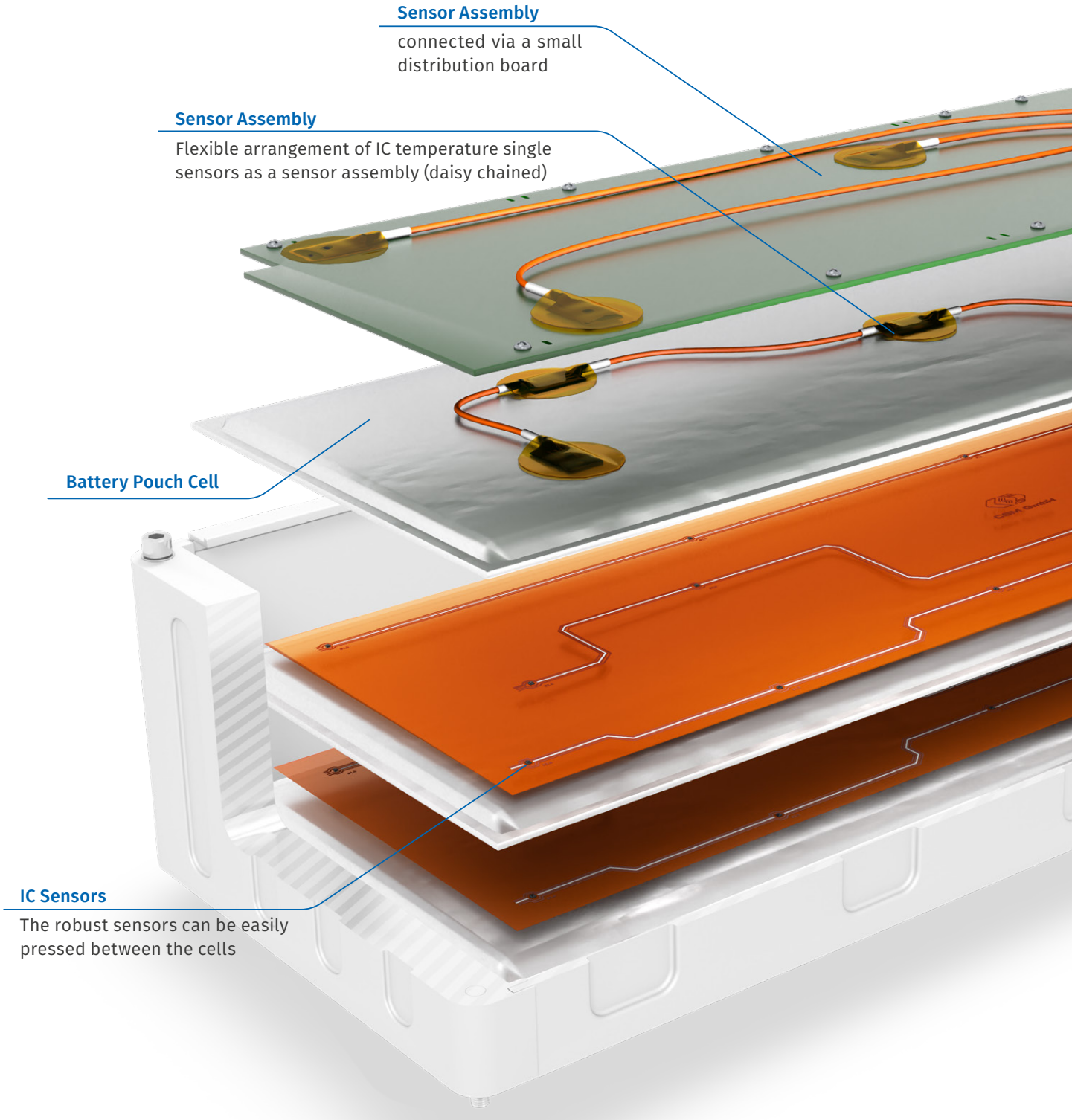
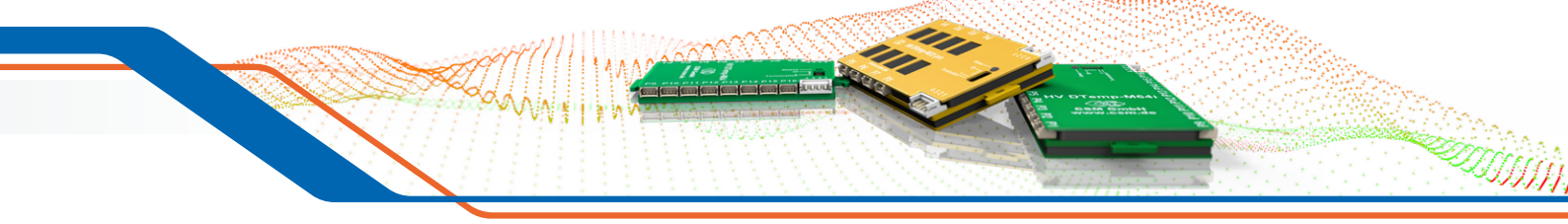
HV DTemp-P

Positioning of the sensors I

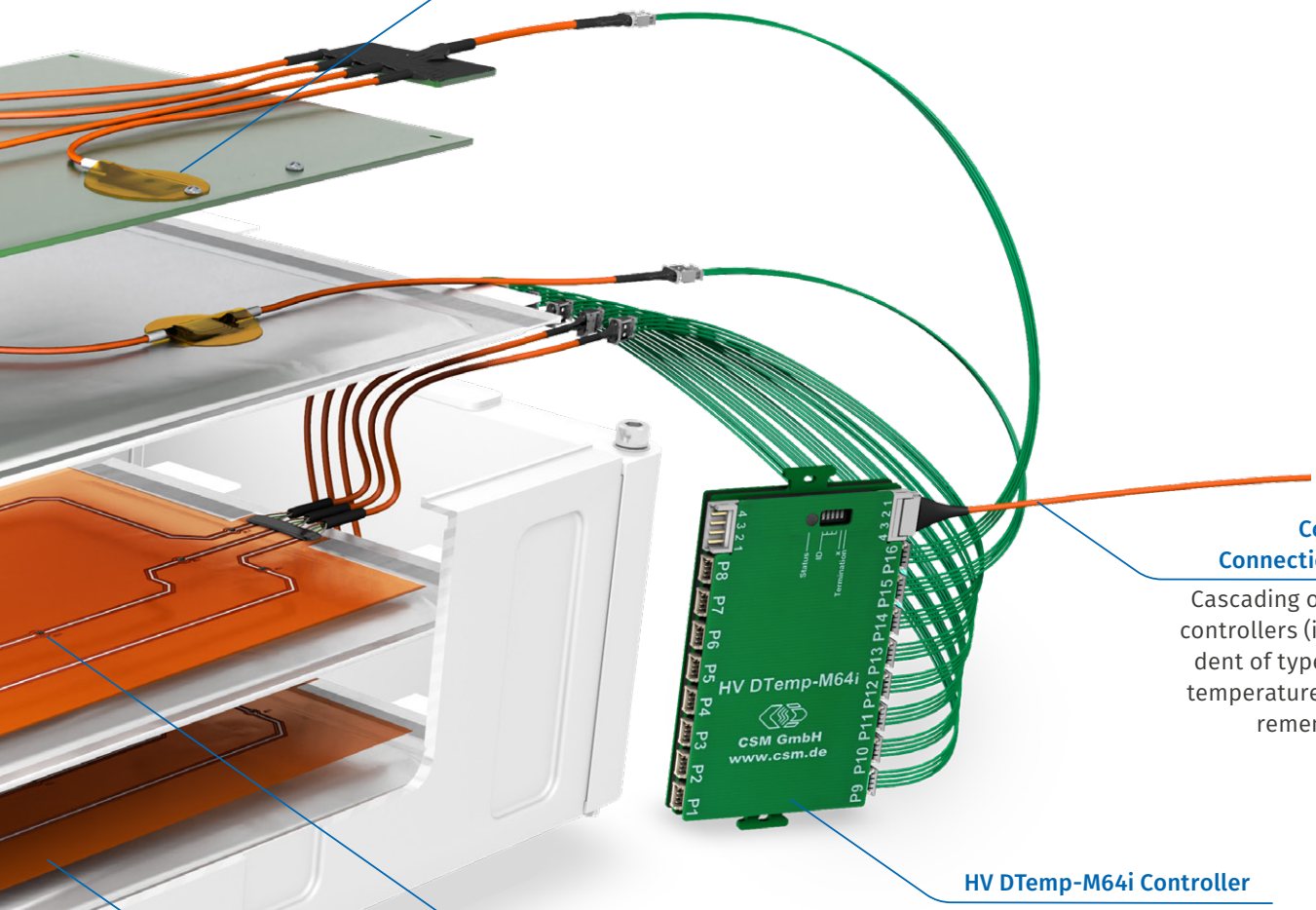
The IC sensors can be positioned and arranged project- specifically using individually designed ultra-thin flexible circuits and single sensors – enabling precise temperature measurements at all points.





Single IC Sensor

attached with Kapton film



Controller Connection Cable

Cascading of up to 8 controllers (independent of type) for 512 temperature measurement points

HV DTemp-M64i Controller

IC Sensors on ultra-thin flexible circuit

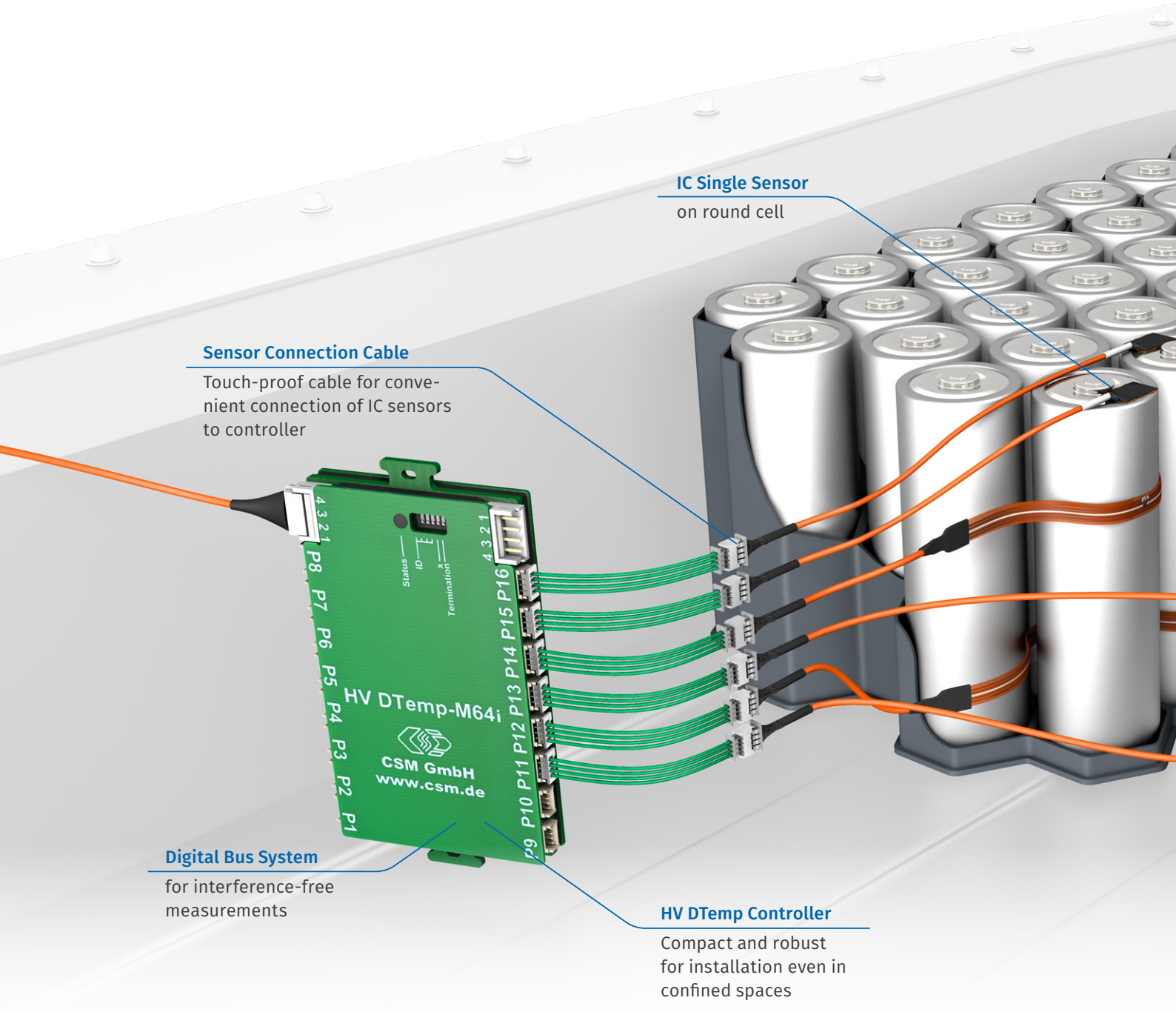
Individual arrangement of digital IC sensors (connected via traces)

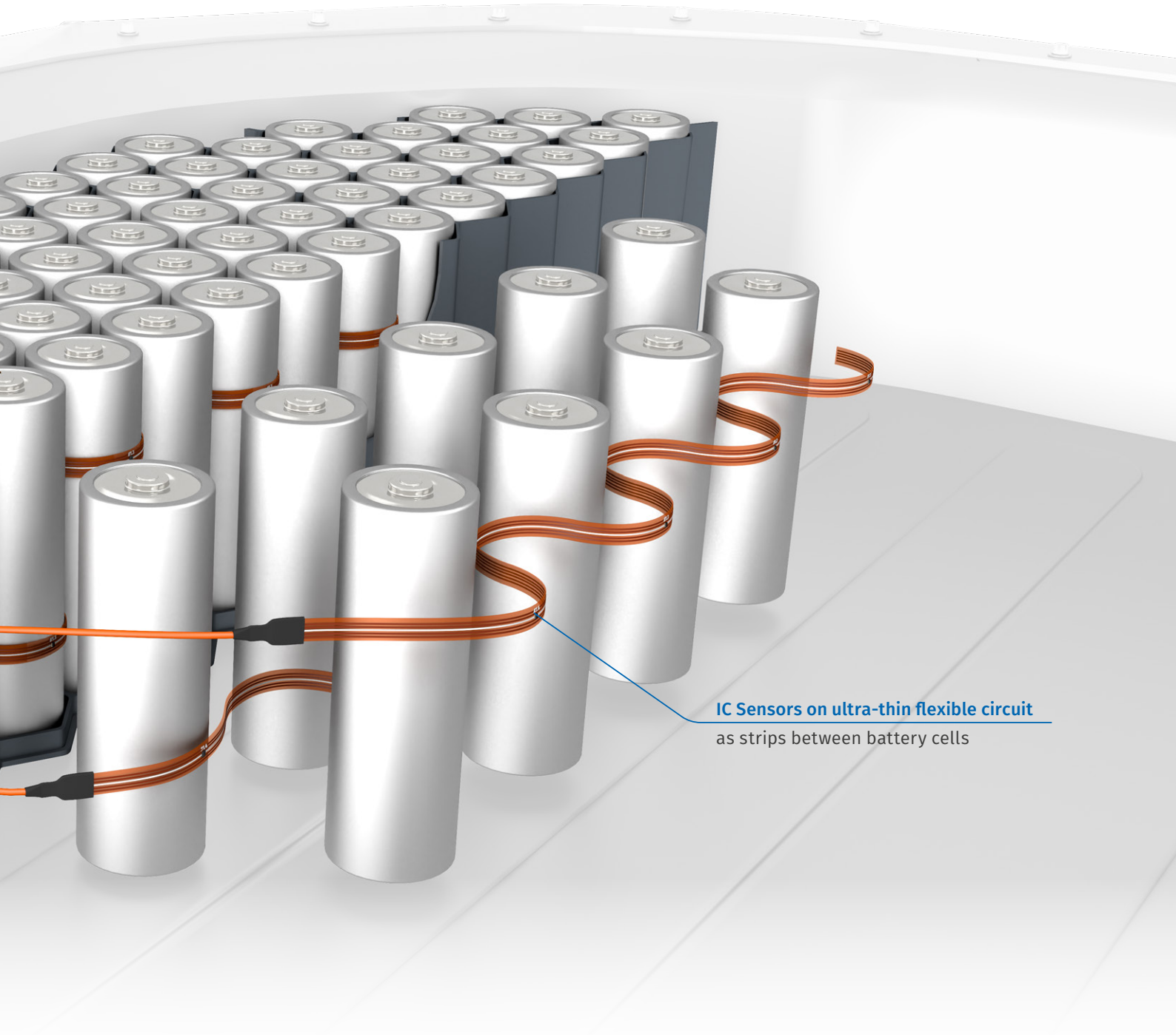
IC Sensors on ultra-thin flexible circuit

The ultra-thin flexible circuit allows exact and reproducible sensor arrangement

Positioning of the sensors II

The sensor assembly on ultra-thin flexible circuits can be adapted to different geometries according to the specific application, thus simplifying the installation of many sensors.





IC Sensors on ultra-thin flexible circuit
as strips between battery cells

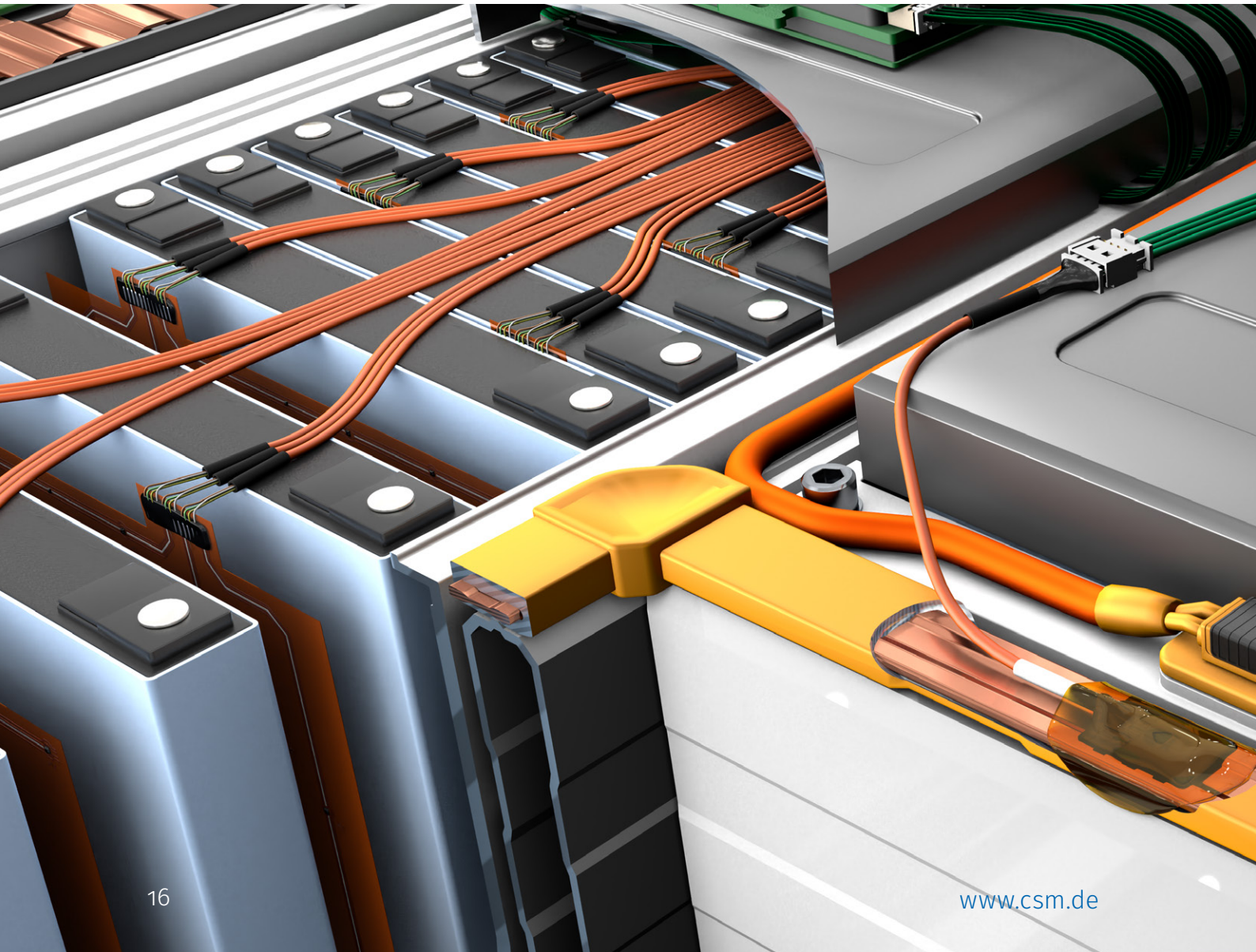
Applications

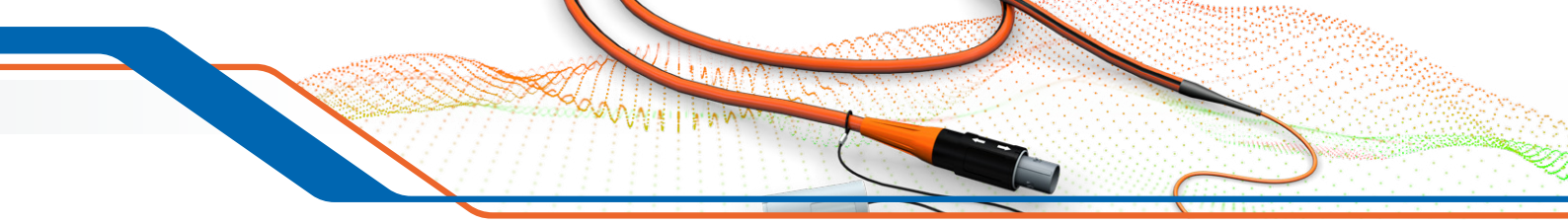
Thermal Characterization of HV Batteries

The performance of high-voltage batteries, for example lithium-ion based, is significantly influenced by temperatures due to their chemical properties. The optimal temperature range for operation for lithium-ion batteries ranges from 15 °C to 35 °C. At lower temperatures, the chemical processes in the battery are significantly slowed down, reducing energy and power capacity.

For the development of sophisticated temperature management systems, the thermal behavior of all components within the battery housing must be known. In the development phase, simulations are often used for this purpose. However, simulations often cannot describe the complex chemical processes and their effects within the battery accurately enough for all situations, so extensive measurements become necessary. Only with a precise investigation of the thermal behavior of the individual battery cell as well as the complete high-voltage battery can a precise characterization be made and simulation models validated. The analyses will enable further optimization of the battery and the temperature management system.

The entire HV DTemp measurement system meets the requirements in terms of available installation space. The sensors can be positioned between the cells, allowing precise measurement of temperature profiles at cell level. The arrangement is so flexible due to the single or group assembly that temperature paths or hot spot areas can be measured precisely depending on the requirements. The positioning of the sensors on the flexible circuit can be repeated exactly from cell to cell.



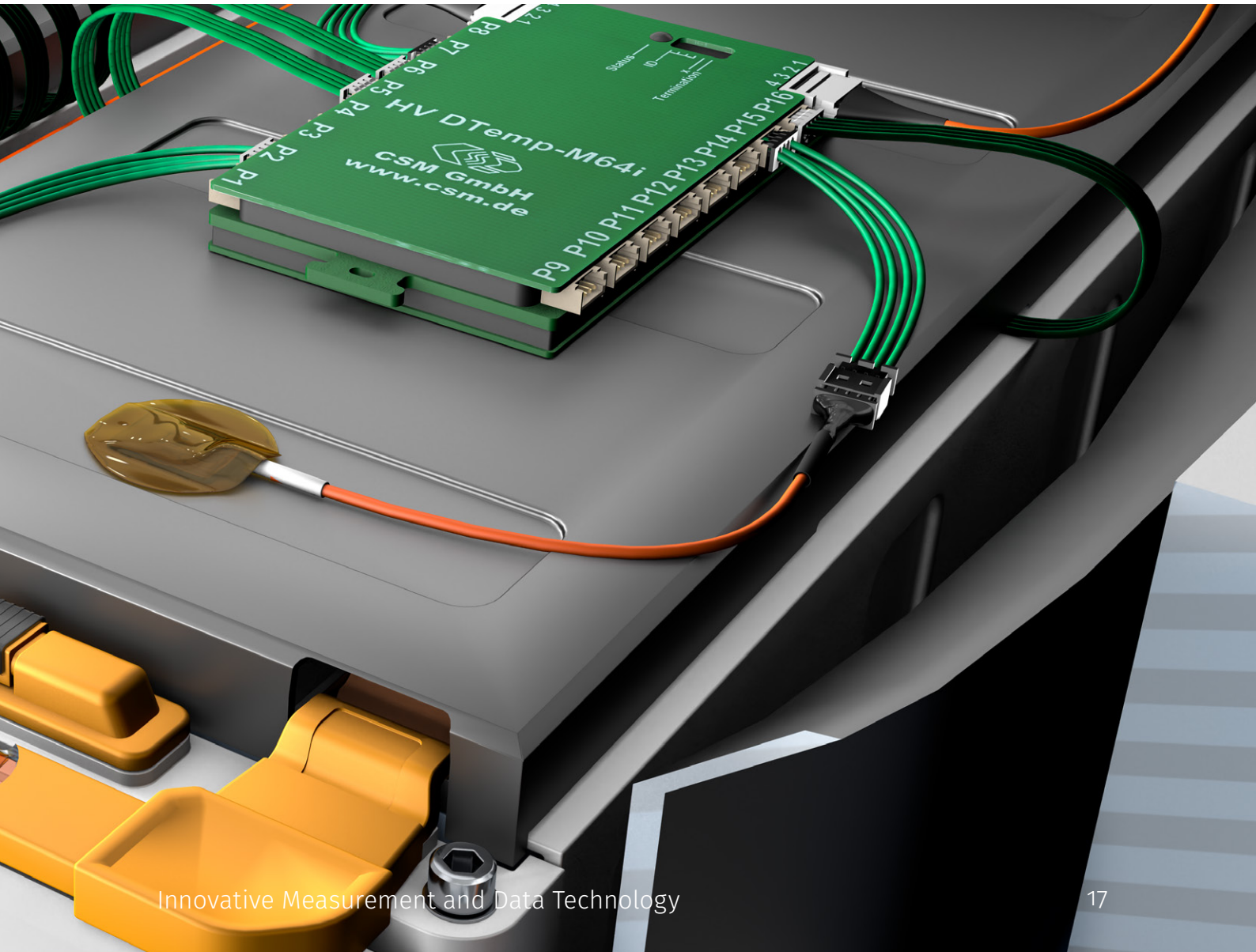


Investigation of Thermal Runaways

Thermal runaways in the HV batteries of electric and hybrid vehicles can lead to fires that are difficult to extinguish and endanger the safety of passengers. Extensive testing is required to safely design HV batteries with appropriate protection mechanisms.

Simulations can be used to calculate the potential areas for very strong heat generation (hot spots). In order for these areas to also be investigated metrologically, positionally accurate measurements are required at cell, module and pack level. This involves several hundred measurement points. The sensors and the necessary sensor cables must be manufactured very thinly in order to be able to measure under the confined space conditions.

With the HV DTemp measurement system, temperatures can be measured at all relevant points in the HV battery and instrumentation is greatly simplified. IC sensor technology on flexible circuits can be arranged with positional accuracy and reproducibility. In addition, the flexible circuits can be easily inserted during battery assembly. With accurate temperature measurements, the measures to prevent thermal runaways can be precisely verified and the safety of the vehicle and passengers is ensured.



About us

CSM Computer-Systeme-Messtechnik GmbH

CSM is a leading, highly innovative manufacturer of decentralized networked, robust measurement technology and data loggers for use in vehicles and test benches. We have been setting technological standards in this field for over 30 years. Our products are successfully used worldwide by almost all well-known manufacturers of passenger cars and commercial vehicles as well as their suppliers and service providers.

Permanent innovation and long-term satisfied customers are our guarantee for success. With our high-voltage safe measurement and breakout modules, developed for fast and synchronous measurements on electric and hybrid vehicles, we actively accompany our customers' transition to electromobility.

Together with our cooperation partner Vector Informatik, we offer harmonized solutions for measurement data acquisition and analysis based on CSM hardware and Vector software, such as the E-Mobility Measurement System: A scalable complete solution for analyzing, calibrating, testing, validating and also homologating electric and hybrid vehicles.

Measurement Technology for E-Mobility
We accompany you on the way to the future

Service & Support

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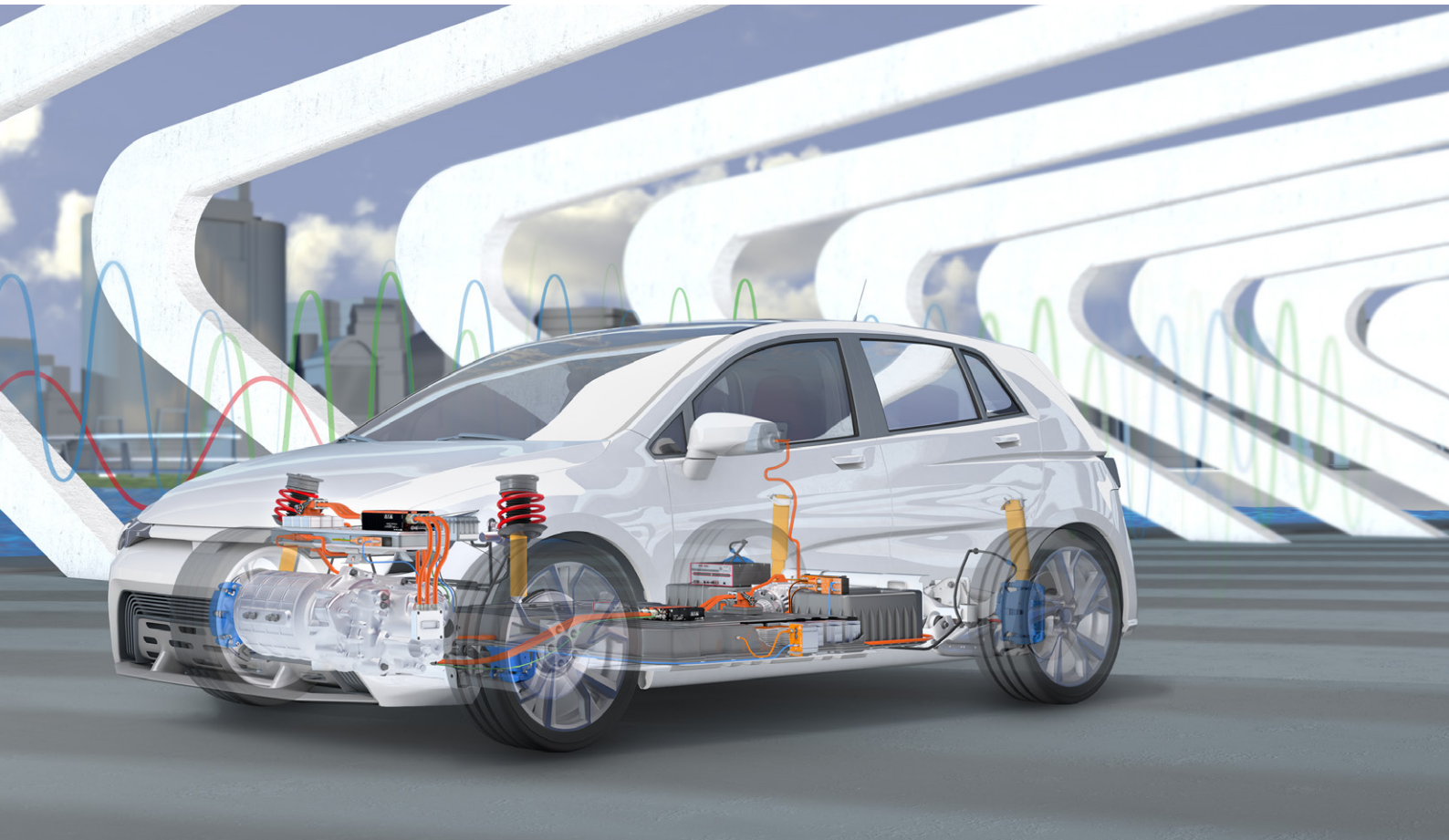

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