Measurements of the Mechanical Load of a Solar-powered Passenger Car Test Vehicle

Measurement of Mechanical Stress

Along with the shift from combustion engine drives to electromobility, the question arises of where the electricity will come from to run e-motors in vehicles in the future. One idea: solar panels integrated into the vehicle to charge the battery. For this purpose, a fleet of solar-powered test vehicles has been developed as part of Sono Motors' Sion program. CSM accompanied the integration of the necessary measurement technology for acquiring the mechanical loads and the electrical power of the powertrain for one of the vehicles.

Fig. 1: Solar-powered Sion (Sono Motors GmbH).

Background

Sono Motors, a company based in Munich, Germany, manufactures solar modules that can be installed in the body of passenger cars or trucks either during production or as “aftermarket”. The electricity generated by the solar cells can be used directly to charge the battery in e-vehicles - making not only driving but also charging emission-free to a significant extent.

With its own passenger car, the concept should be implemented holistically. For the construction of a new passenger car, the values from previous calculations for the dimensioning of the drive components and the battery, as well as the overall design had to be checked within the framework of the performance analysis and the durability.

It should also be independently checked whether the output values of the installed control units match the measured data. The requirement: To integrate a measurement setup in the vehicle that synchronously acquires the various measurement data from the components and at the same time is suitable for use in rough road tests. For this reason, one of the test vehicles was completely equipped with measurement technology from CSM.[1]

Challenge

"How does the vehicle behave while driving?" and "What forces affect the individual components?" are just some of the questions that precede measurements of mechanical stress.

In addition the measurement equipment needing to be robust, it was essential that the various types and multiple channels of measurement data be acquired simultaneously. Only in this way can accurate decisions be made about how the test vehicle behaves under different requirements - and about how the physical components and control software must be designed.

The evaluation of operational stability, in other words the achievement of the planned durability of the materials, requires that acting forces (vibrations, torsion and acceleration) are measured on components such as the vehicle frame and battery assembly.

»Since we wanted to build a completely new vehicle concept for the Sion program, we first had to plan a comprehensive vehicle testing program. In addition to many measurement points for mechanical loads and temperatures in the entire vehicle, High voltage safe measurement of current and voltage was also particularly relevant on the drive side«, reports Peter Kummer, Test Engineer for the Powertrain division at Sono Motors.

For a measurement project of this scale, which includes several hundred measurement channels and numerous measured variables, data recording must also function safely and reliably while the vehicle is in motion. A data logger that records and stores the results is additionally required for this.

[1] Unfortunately, the project had to be terminated in spring 2023. At the time of this report, no more tests with the vehicle have been performed.

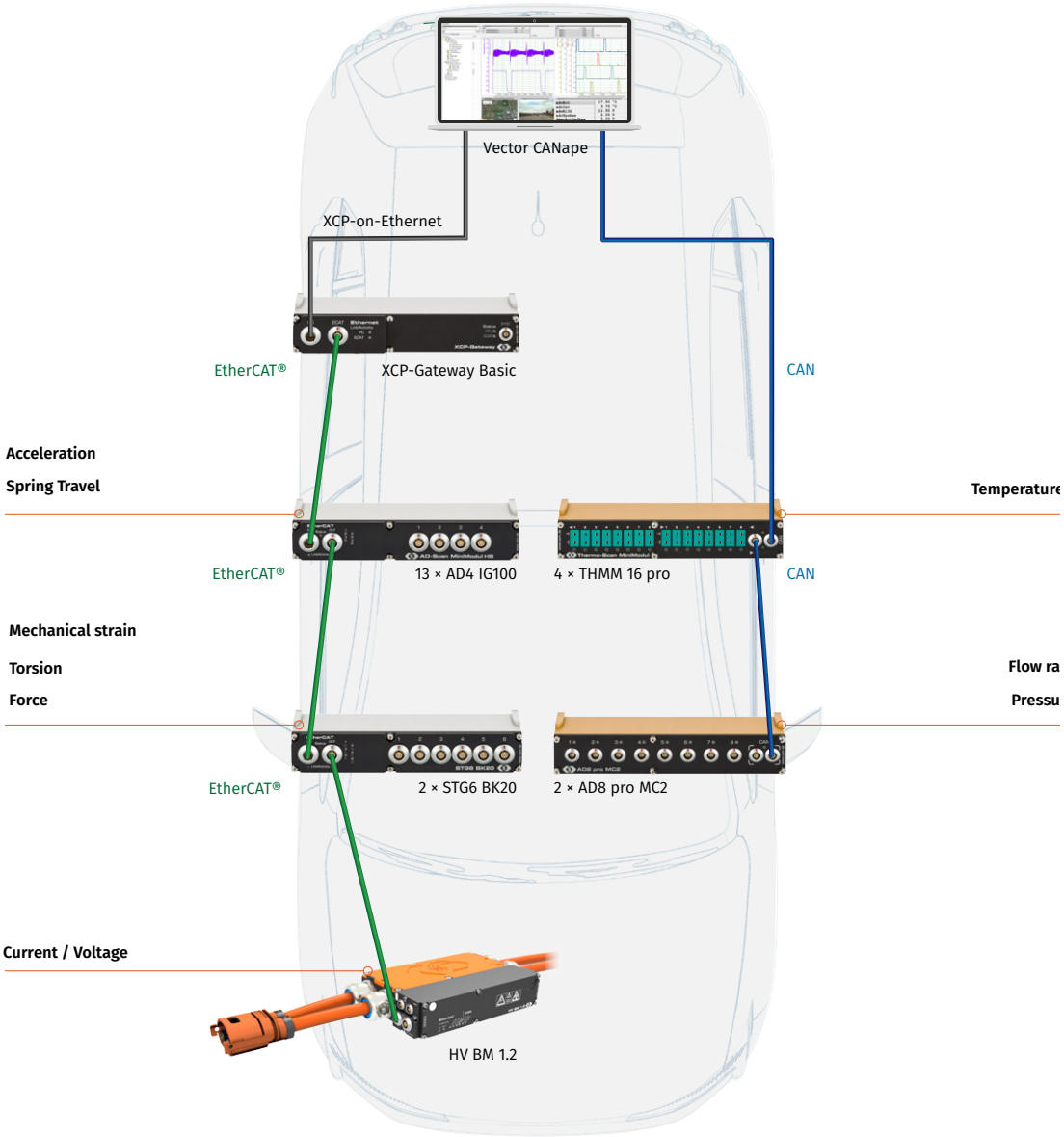
The CSM Measurement Solution

Components of the Vector CSM E-Mobility Measurement System were used to equip the test vehicle.

To be able to comprehensively acquire and analyze all signals, a measurement setup with more than 200 measurement channels was necessary.

The following values were acquired:

- acceleration at the axle and suspension,
- vibration and torsion on the frame and battery,
- torsion at the drive shafts,
- suspension travel at the shock absorbers,
- current and voltage in the electric drive train,
- pressure and flow in the cooling system,
- and temperatures in the entire vehicle.



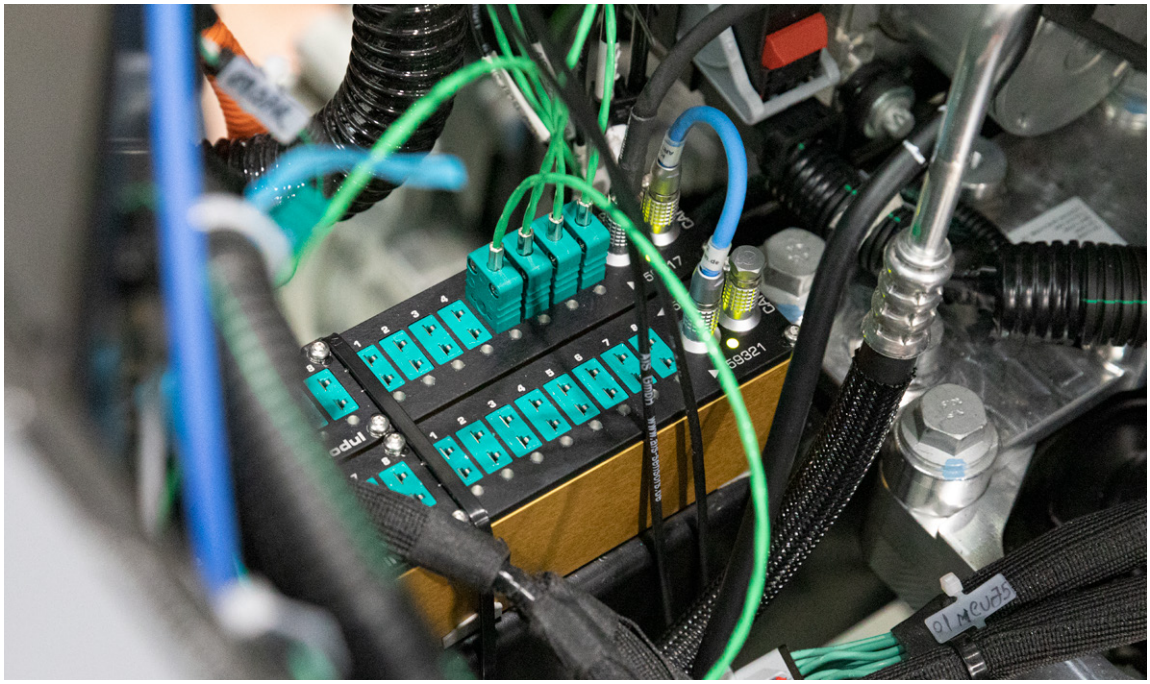


Fig. 2: In the vehicle compartment, but also on individual components, temperatures were acquired at 68 points via THMM pro thermal modules.

Measurement of mechanical loads

Accelerometers, each measuring one axis, were attached to the wheel suspension and the frame. They record the movements of the components during driving.

For the measurement of torsion of the battery and the frame, strain gauges were attached. From the data obtained, it was possible to deduce how large the forces acting at these points are.

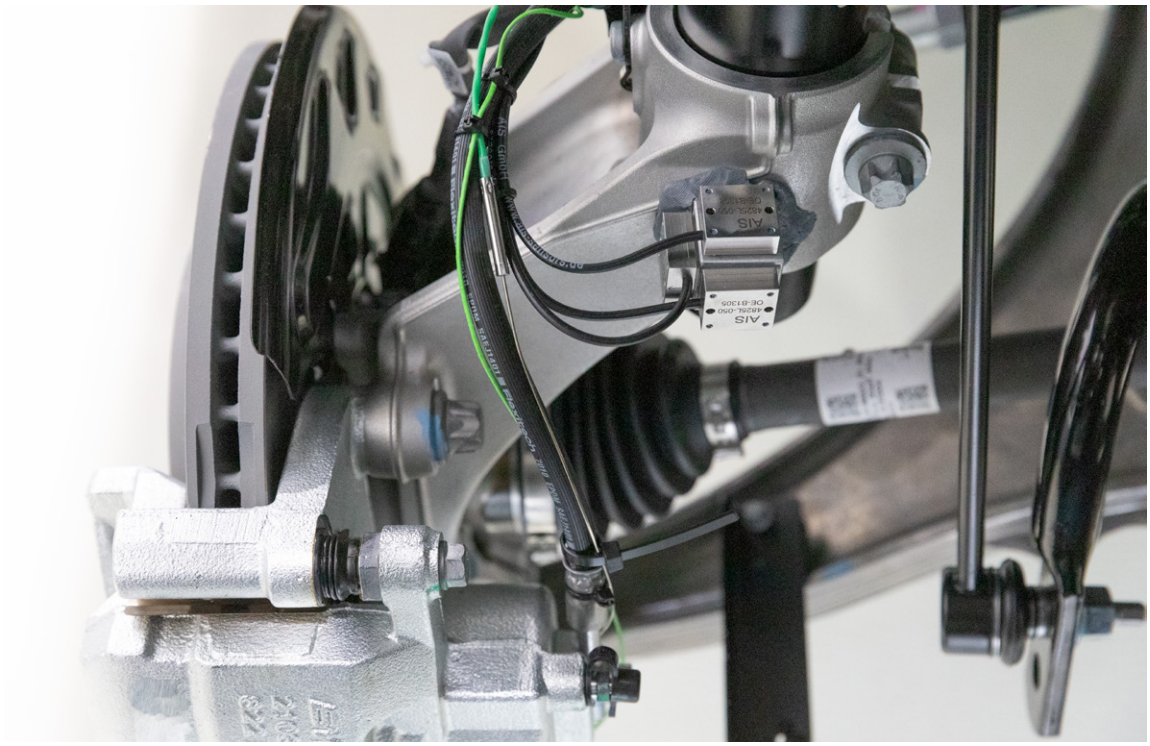


Fig. 3: Three uniaxial acceleration sensors record the movements of the wheel suspension in the x-, y-, and z-directions.

The sensor data of the strain gauges were transmitted via **STG6 ECAT modules** on an EtherCAT® network. The modules directly output the correct physical values, which eliminates the need for subsequent conversion. They also feature a ratiometric measuring principle that records the values in relation to the supply voltage - this simplifies scaling. In addition, the modules are characterized by low-noise behavior and thus enable nearly interference-free measured values.

AD4 ECAT modules were used for the accelerometers; here, the data transmission was carried out with EtherCAT®, too.

The very robust and compact IP67 rated housings of both STG6 and AD4 module types enable distributed use in road tests.

Current / voltage measurements in the HV environment

The **High Voltage Breakout Module (HV BM) 1.2** was used for the HV-safe measurements of current and voltage between the battery and the inverter directly in the HV cables.

The connection is made with ring terminals attaching the cables to shunts withing the hv-safe breakout module. Alternatively, a customer-specific connector can be provided by CSM for simplified installation.

The measured values were also transmitted using EtherCAT®, in this case enabling a time-synchronous evaluation of the data with sampling rates of up to 100 kHz.

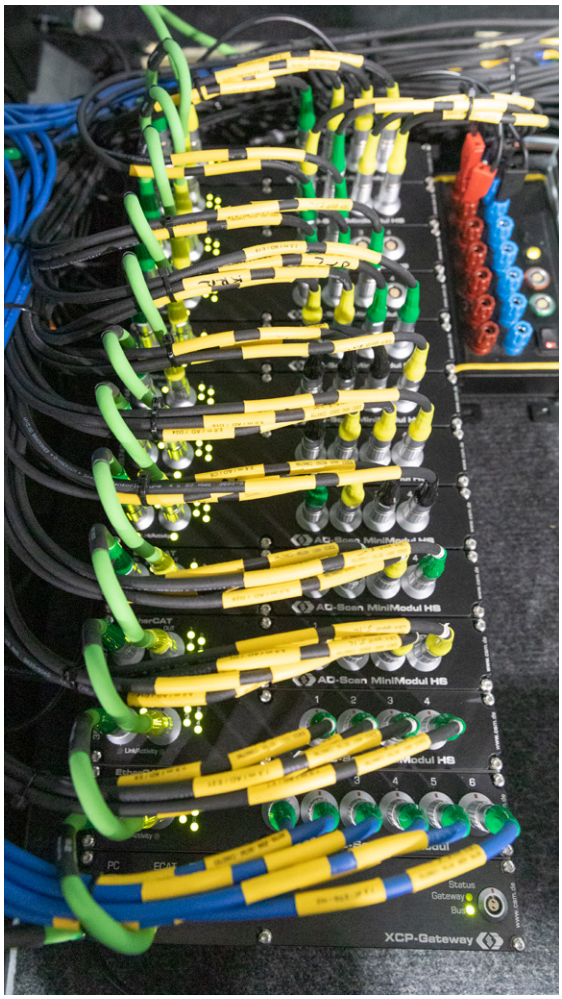


Fig. 4: Measurement data was transferred to an XCP-Gateway as an interface to the software via several STG6 ECAT and AD4 ECAT measurement modules.

Evaluation of the simultaneous measurement data

All other measured values such as temperature, flow rate, pressure and displacement were acquired via a second measurement chain using CAN and then combined with the data from the EtherCAT® measurement chain.

The **XCP-Gateway** was used as a protocol translator to XCP-on-Ethernet for evaluation with the Vector CANape software. Furthermore, the use of PTP in accordance with IEEE 1588 as a synchronization mechanism ensures the synchronicity of the measurement data.

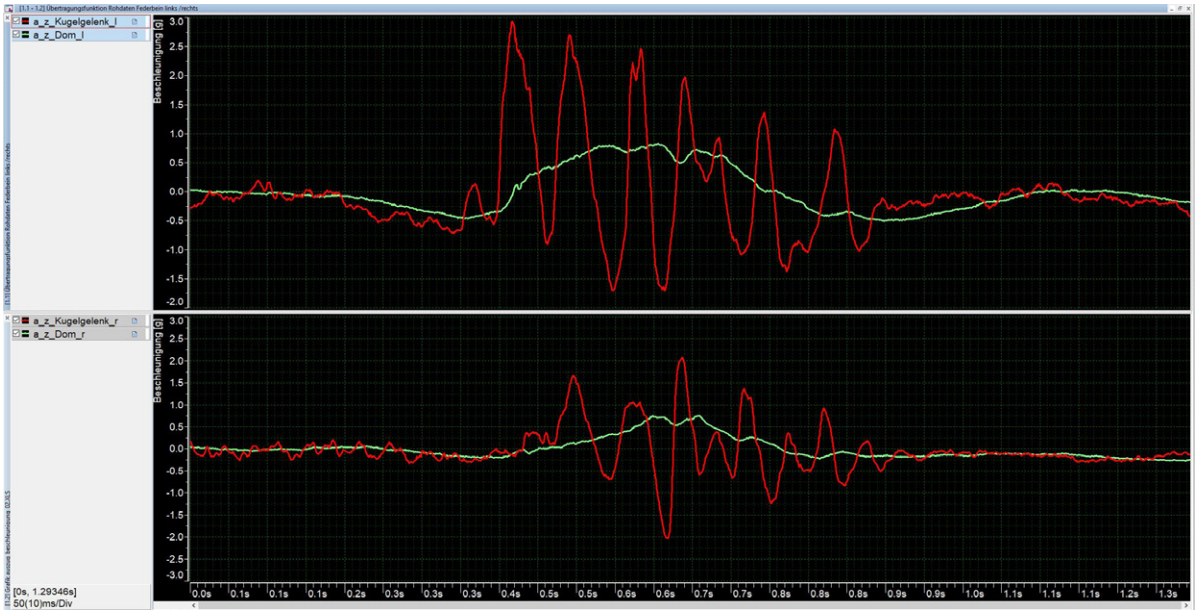


Fig. 5: Exemplary representation of the measurement data from acceleration sensors on the rear axle. The transmission factor from the spring-damper system (left and right) can be determined from the temporally correlated data.

Benefits

With the modular, distributed CSM measurement modules, a completely customized solution could be offered.

»The individual support provided by CSM during project planning and on site was particularly convincing for us. The fact that we did not have to rely on prefabricated measurement technology, but were able to work out a solution customized to our needs together with CSM, was a priority when selecting the measurement technology used for our program«, reports Alessandro Binetti, Technical Lead – Vehicle Validation and Testing at Sono Motors about the cooperation.

The measurement technology solution from a single source and the synchronicity of the data made it possible to identify possible improvements from this correlated data.

In addition to the measurement results for the individual vehicle areas and components, it was also possible to evaluate important test findings for the vehicle.

Featured Products

HV Breakout Module – Type 1.2

CSM's HV Breakout Module (BM) Type 1.2 was designed for single-phase measurements of current, voltage and power. It is ideal for measurement on large consumers such as electric motors equipped with separate HV+ and HV- cables.

The HV Breakout Module 1.2 is available in two versions for connection via cable glands or PL500 plug-in system (HV BM 1.2C).

STG6 BK20

Measuring tasks with strain gauges can be easily performed with the STG6 BK20 measurement module. With six time-synchronous strain gauge inputs for quarter-, half- and full bridges and measurement data rates from 1 Hz to 20 kHz per channel, the STG6 BK20 is also suitable for stress analyses with many points of measurement. Thanks to EtherCAT®, even large measurement networks with distances of up to 100 m between individual measurement modules can be easily set up.

AD4 ECAT MM Series – Type IG100

The AD4 IG100 measurement module is optimally suited for the most accurate analyses of high-frequency signals with measurement data rates of up to 100 kHz per channel. It offers a highly accurate, bipolar and channel-wise adjustable sensor supply from 1 to 20 V DC for a wide range of sensors.

XCP-Gateway Series

CSM's XCP-Gateway Series protocol converters were specially developed for CSM EtherCAT® measurement modules and for measurement tasks with multiple measurement channels and high measurement data rates. The XCP-Gateway is available in "Basic" and "pro" versions. The "pro" version has two CAN interfaces via which CAN-based CSM measurement modules can be connected and integrated into the XCP-on-Ethernet measurement data protocol. In the "pro" version, temperature data from the HV Breakout Modules can also be transferred directly via EtherCAT®.

Complete solutions from a single source:

CSM provides you with comprehensive complete packages consisting of measurement modules, sensors, connecting cables and software - customized to your individual needs.

Further information on our products are available on our website at www.csm.de or via e-mail sales@csm.de.

CSM GmbH Headquarters (Germany)

Raiffeisenstraße 36 • 70794 Filderstadt
+49 711-77 96 40 sales@csm.de

CSM Office Southern Europe (France, Italy)

Site d´Archamps
60, rue Douglas Engelbart • Immeuble ABC 1, Entrée A – 1er étage
74160 Archamps, France
+33 450-95 86 44 info@csm-produits.fr

CSM Products, Inc. USA (USA, Canada, Mexico)

1920 Opdyke Court, Suite 200 • Auburn Hills, MI 48326
+1 248 836-4995 sales@csmproductsinc.com

CSM (RoW)

Vector Informatik (China, Japan, Korea, India, Great Britain)
ECM AB (Sweden)
DATRON-TECHNOLOGY (Slovakia, Czech Republic)
Our partners guarantee you worldwide availability.
Feel free to contact us.

CSM GmbH Germany is certified.

ISO 9001, ISO 14001
Certified Integrated Quality and Environmental Management System
www.tuv-sud.com/ms-cert

DAkkS
Deutsche Akkreditierungsstelle
D-K-15214-01-00