High-Voltage Safe Strain Measurement in HV Batteries

HV Measurement of Mechanical Stress

The housings of HV batteries are on the one hand a structural element in the bodies of electric and hybrid vehicles, and on the other hand they contribute significantly to the safety of the vehicle passengers. For optimal material design, the structural loads inside and outside the battery housing must be measured. The following example explains how this can be done easily and safely with strain gauges and special STG measurement modules.

Background

As the primary energy storage device, high-voltage batteries are a central element in electric vehicles. For smooth operation and to ensure safety for the system and passengers, not only the electronic components of the HV battery have to be optimized, but also the battery housing and its structures. The battery housing protects the battery from environmental influences such as dust, dirt and moisture, thus ensuring proper functioning. Battery housings are often made of steel, aluminum, plastic or a combination of these materials. In order not to make the entire battery any heavier than necessary, the housing should be designed to be light and compact without compromising the safety aspects. At the same time, the structure of the housing has to withstand a number of different stresses:

- Inside the HV battery, the battery cells expand during charging processes and depending on the state of charge and age. The resulting forces act on structures of the housing, such as struts between the battery modules. These struts have to absorb the occurring forces and continue to provide rigidity and support for the housing and the components in the housing.
- On the outside, mechanical forces resulting from driving dynamics in particular affect the vehicle frame. Depending on how the HV battery is installed, it is either a separate component or an integral part of the vehicle frame. As a result, torsions of the frame are also have an impact on the battery housing.

The structure of the battery housing has to withstand these loads at any time. It must not break under any circumstances, as this could affect thesafety of the vehicle passengers.

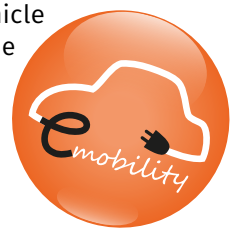
For optimal material design and the analysis of the housing structure, mechanical strains and stresses inside and outside the battery housing must be measured. The following example shows how these measurements are made using strain gauges inside the battery housing and on the outside of it.

The measurement points within the housing are arranged as follows:

- 4 single strain gauges are applied to struts between battery modules to detect material strain.
- 3 strain gauge rosettes (0°, 45°, 90°) are attached to the inside of the housing base and side walls to determine the material stress from the individual strains.

Additional strain gauges are applied to the outside of the housing:

- 10 single strain gauges attached to the points where the battery housing is fixed to the vehicle frame to measure strains and loads on the suspensions.
- 3 strain gauge rosettes (0°, 45°, 90°) mounted at critical points of the battery housing construction to determine the material stress here as well.



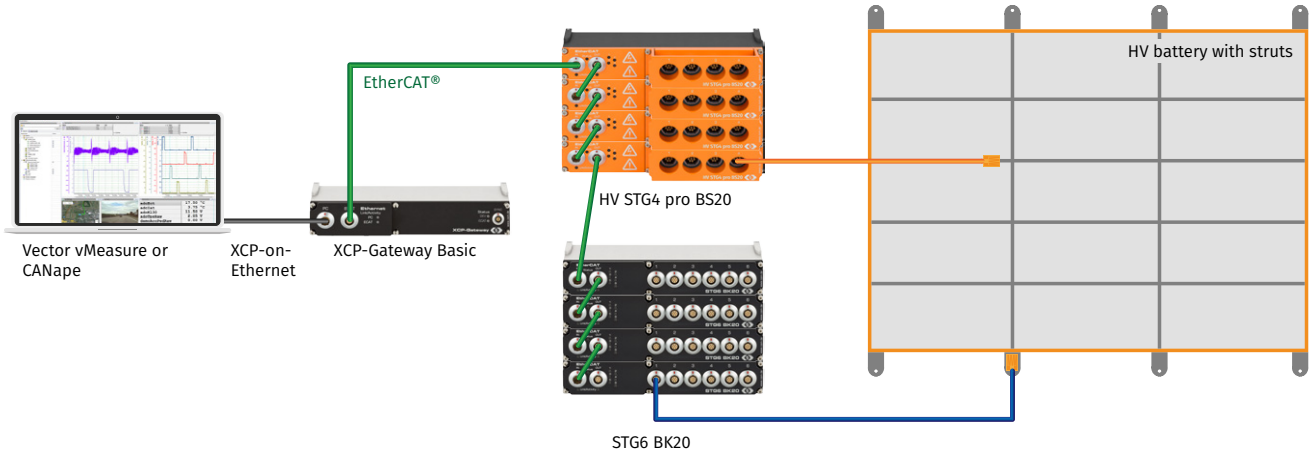
Challenge

The loads are to be measured while driving, which means that the required measurement technology has to be HV-safe (for measurements inside the HV battery) as well as compact and robust (for installation in the vehicle).

In order to be able to analyze even small mechanical stresses accurately, it should be possible to adapt the measuring range to the material properties (aluminum, steel, plastic) and the expected size (e.g. ±1,000 µm/m). The measuring range as well as the supply voltage should be adjustable in the measurement module even after installation of the strain gauges in order to be able to record strain values which are smaller or higher than initially expected. And this without an additional calibration of the strain value. The sampling rate must be selected according to the requirements and the type of load (e.g. 2,000 Hz). Time synchronicity of the individual data channels is essential. If required, an additional software filter should be activated, in this example 200 Hz (Butterworth filter).

The measurement system used should also allow an easy integration of further measurement technology in order to record temperatures, accelerations within the HV battery as well as data from the vehicle control units, if required, and to be able to correlate the data.

The CSM Measurement Solution



The required measurement technology can be found in the components of the E-Mobility Basic Measurement System (first expansion stage of the **Vector CSM E-Mobility Measurement System**).

Inside the battery housing, the strain gauges are applied as half and full bridges. The strain gauge data is acquired by HV-safe **HV STG4 pro BS20** strain gauge measurement modules. With special HV-safe sensor cables, strain gauges designed for the low-voltage range can also be used safely in the HV environment. This facilitates the application, as it is possible to use known sensors. 4 strain gauges are connected to each module. If a later change of the measuring ranges or the supply voltage should be required, this can be done without the need of further calibration or conversion, since the data acquisition is ratiometric. This means, the measured quantity µm/m set in the module can be kept without having to correct this by recalibration or recalculation - the specified measuring range (µm/m) always gives a correct strain value. The bridge supply is adjustable in 4 levels and can optionally be switched off:

- 1 V, 2,5 V, 5 V, 10 V – per channel max. 42 mA

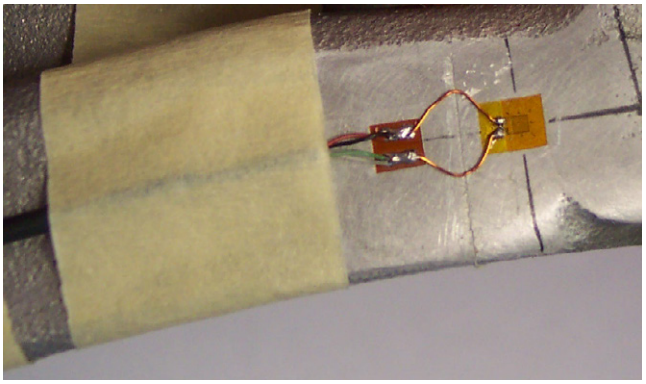


Fig. 1: Strain gauge on the outside of the housing

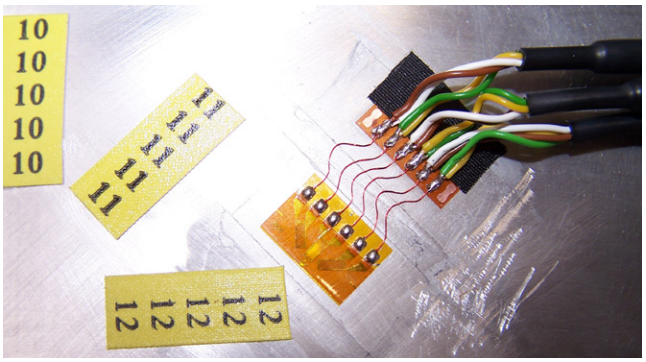


Fig. 2: Strain gauge as rosette on the outside of the battery housing

Since the strain gauges attached to the outside of the battery housing are not located in the HV environment, no special safety measures have to be taken with regard to the measurement technology. It is thus possible to use the classic STG6 BK20 strain gauge measurement modules. The strain gauges are set up as quarter, half or full bridges.

All measurement modules are connected to an **XCP-Gateway**. The XCP-Gateway synchronizes the ECAT (EtherCAT®) data and forwards it to the DAQ.

Further measurement modules can also be easily connected via the XCP-Gateway in order to acquire additional measurement data. For example, the temperatures inside the battery cells can be measured as a reference value for the expansion of the battery cells using the **HV DTemp measurement system**.In this case, the temperature data is transmitted on to the XCP-Gateway via CAN, packetized in the gateway and sent to the DAQ together with the ECAT data.

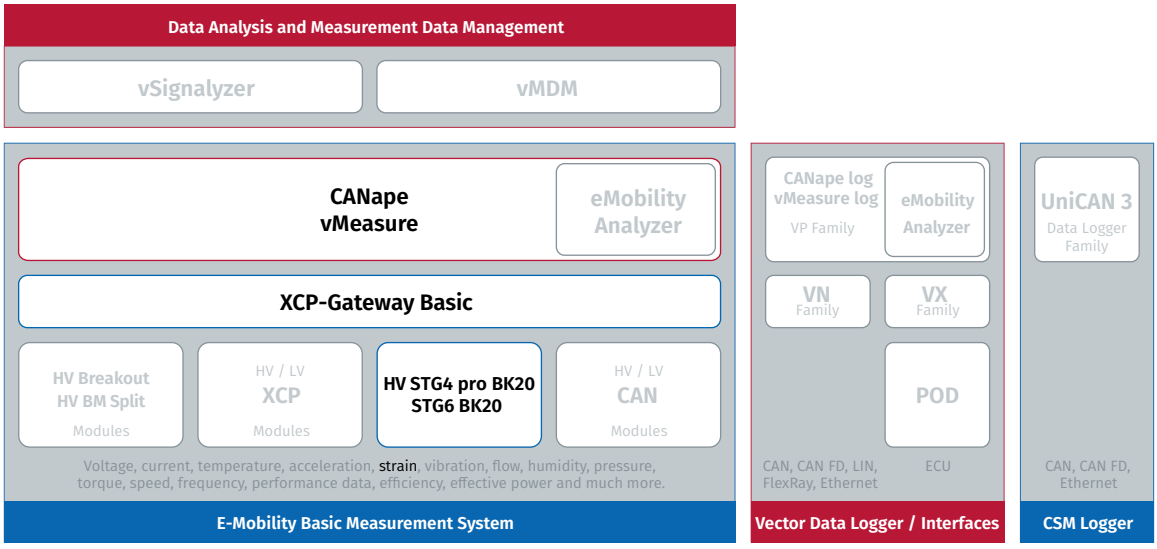


Fig. 3: The HV-safe strain measurement in HV batteries in the systematics of the Vector CSM E-Mobility Measurement System

Benefits

With the measurement technology used, the mechanical stresses inside and outside the battery housing can be measured precisely even while driving. The measurement modules used are very compact in design and robust so that they can be installed close to the measurement point.

Via the XCP-Gateway, the data of all measurement modules are acquired with high precision and allow a precise analysis of the mechanical stress. Further measurement data can be easily recorded and included in the analysis.

Featured Products

HV STG4 pro BS20

The measurement module for HV-safe strain gauge measurements is suitable for decentralized use under demanding conditions in the high-voltage environment: robust, extremely compact and with four time-synchronous strain gauge inputs. The extended input voltage range enables precise measurements from very small to very large signal voltages.

STG6 BK20 (ECAT STGMM 6)

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.

XCP-Gateway-Serie

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
178, rue des Frères Lumière • Immeuble Alliance – Entrée A
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)
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