Hydrogen in the Tank: Analyzing Many Measured Values in One System

Fuel Cell Drive

When people talk about hydrogen-powered vehicles, they usually mean a fuel cell drive. This generates the electricity required to drive the electric motor directly in the vehicle from the hydrogen tank. Although the chemical reaction occurs with just a few substances, certain conditions must be met for an ideal result. These include the temperature as well as the quality of the reaction components supplied. Comprehensive measurements – some of them requiring high-voltage safety – must be carried out to ensure that the fuel cell drive can be operated as efficiently and safely as possible.

Conventional e-mobility not suitable everywhere

The transition to electrified mobility is considered one of the main measures for more environmentally friendly transportation of people and goods. In most cases, the electric motor is powered by electrical energy stored in a battery. However, this concept reaches its limits in certain contexts - for example, when the range provided from a single battery charge is not sufficient or when there is no possibility of charging the battery as often is the case for larger loads across longer distances. This is often the situation for goods logistics, public transport, maritime and aviation applications. Therefore, there is an increasing shift to fuel cell-powered mobility.

The battery installed in the powertrain is comparatively much smaller and lighter, since it is not the primary energy source but is instead an intermediate storage unit. This design ensures that the fuel cell can continuously produce electricity and thus operate efficiently for the long term, while at the same time allowing dynamic driving.

Different technology, different challenges

As the fuel cell stack in the vehicle generates the electricity required to drive the electric motor directly from the chemical reaction of hydrogen and (atmospheric) oxygen, more extensive tests must be carried out than for conventional battery-powered electric vehicles. For an ideal supply of electricity to the vehicle, the energy from the chemical reaction must be optimally utilized in a wide variety of driving situations and under changing environmental conditions. In addition to the temperature of the hydrogen and the supplied air, the humidity, pressure and flow rate also play an important role. By precisely measuring these variables, it is possible to investigate whether the components for adapting the air and hydrogen are functioning as desired or to determine how much the values may deviate before the fuel cell drive can no longer be operated properly. Also, some of the measurements must be performed in a high-voltage safe manner due to the high system voltages of electric drives.

Complex components require many measurements

The fuel cell drive is a technically complex system with many components. In this example, the focus will be on the metrological investigation of the fuel cell system. Like the chemical reaction, a distinction is made between the part of the system that supplies hydrogen and the other part supplying the air: The components of the hydrogen path are also called the anode path, those of the air path the cathode path. An additional combined cooling and heating system ensures ideal temperatures for the reaction components, while in the electrical path the energy generated is passed on to the drive or directly to the electric motor, or even to the buffer battery.

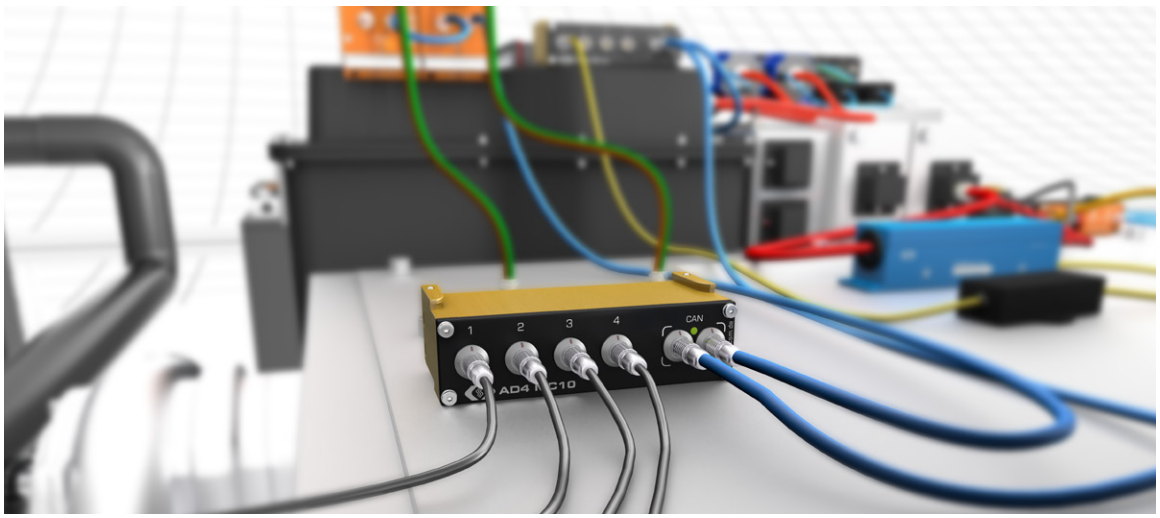
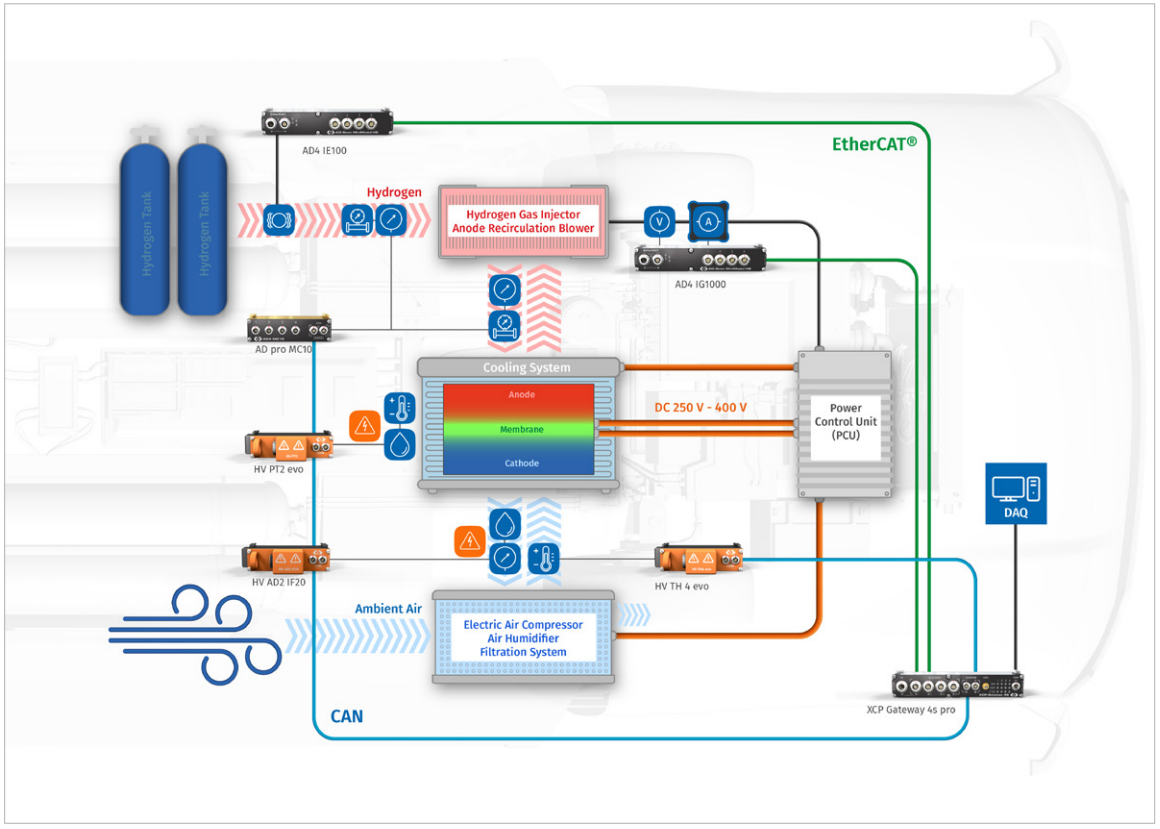


Fig. 1: AD measurement module for acquiring pressure and flow in the anode path.

How should the hydrogen ideally reach the system?

In the hydrogen/anode pathway, the conditions of the hydrogen supply to the system are examined. This includes the pressure, the flow rate and, as a result, the quantity of liquid hydrogen over the period under consideration. This is measured using suitable sensors in the supply line from the tank to the circulation blower and at the dosing valve. The measured values are recorded with an AD measurement module and transmitted via CAN bus. The pressure and flow sensors are supplied with the appropriate sensor supply voltage directly from the AD measurement module eliminating the need for a separate power supply for the sensors. The power consumption of the circulation fan is measured using an LEM sensor package and another ECAT AD module.

Thanks to its high cut-off frequency of up to 200 kilohertz, the LEM current transformer is also suitable for reliably detecting possible high-frequency interference in the vehicle electrical system – with a very high measurement accuracy. The ECAT AD measurement module provides the correspondingly high sampling frequency of up to 1 MHz per channel. IEPE accelerometers and an ECAT AD module for data acquisition are installed at this point to determine the mechanical loads caused by vibrations in the hydrogen supply line in real operation. Here too, the CSM solution provides the special sensor supply for IEPE accelerometers and the high bandwidth required for the measurements. Both measured values are transmitted via EtherCAT®.



High-voltage safe measurement in the cathode path

In the air or cathode path, corresponding components such as the electric air compressor are usually operated with high-voltage voltage. To protect users and devices, the necessary measurements must be taken using HV-safe measurement technology. Ideal air conditions for the chemical reaction are essential, especially when it comes to the performance of the fuel cell. Therefore, the air pressure and humidity are measured with HV AD modules and analog pressure and humidity sensors, and the temperature of the air is measured with thermocouples (type K) and HV TH modules. The HV measurement modules, which are specially designed for use with high system voltages, provide the sensor supply voltages for the sensors – just like their standard variants – but also galvanically isolate both the supply voltage and the measurement signals. This means that standard sensors can be used safely in a high-voltage environment. For the power consumption of the electric air compressor, current and voltage are recorded directly with the HV Split Breakout Modules and transmitted via EtherCAT®. The compact sensor modules of the HV BM-Split use the precise shunt method to measure the current and are also designed for measuring working voltages of up to 1,000 volts.

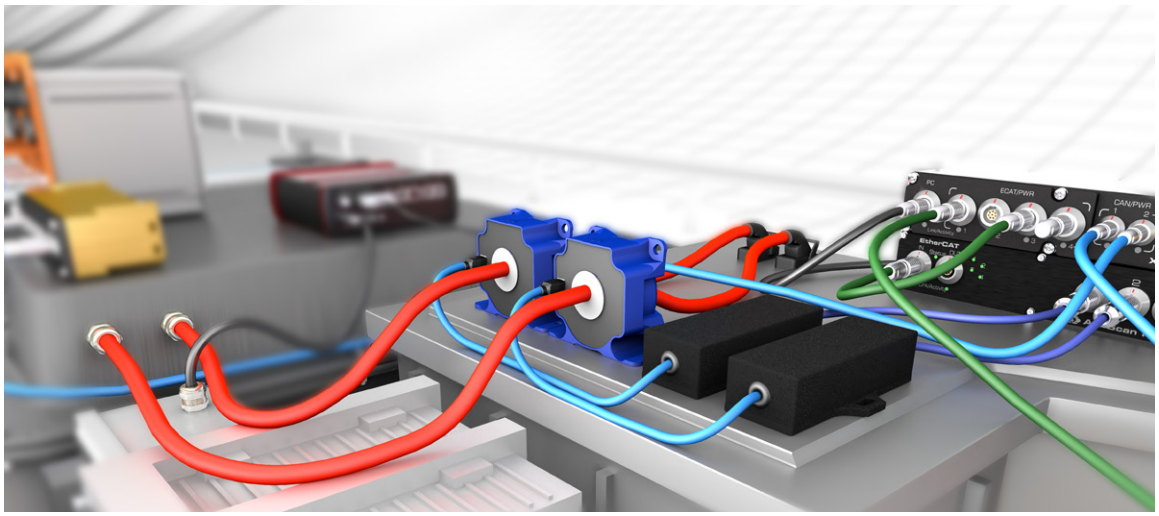


Fig. 2: LEM sensor packages and ECAT AD measurement modules are used to measure currents at various units in the supply system.

Look at the cooling system and electrical power of the overall system

The electrical power consumption in the cooling system is also measured in this way with additional HV Split Breakout Modules. As temperatures in the coolant must be acquired very precisely, temperature changes in the coolant are measured HV-safe at eight measurement points using PT1000 resistance sensors. The combination of high-voltage-safe and compact PT elements with fast response times and the HV PT measurement modules from CSM specially developed for PT sensors ensures high-precision temperature measurement under high-voltage conditions with an accuracy of approximately 0.3 Kelvin. To check the fluctuation of the coolant, additional measurement data from pressure sensors placed directly in the coolant is acquired with an HV AD module. An HV Breakout Module 1.2 is also used to measure current and voltage in the HV electrical path to evaluate the performance and efficiency of the drive in the further analysis.

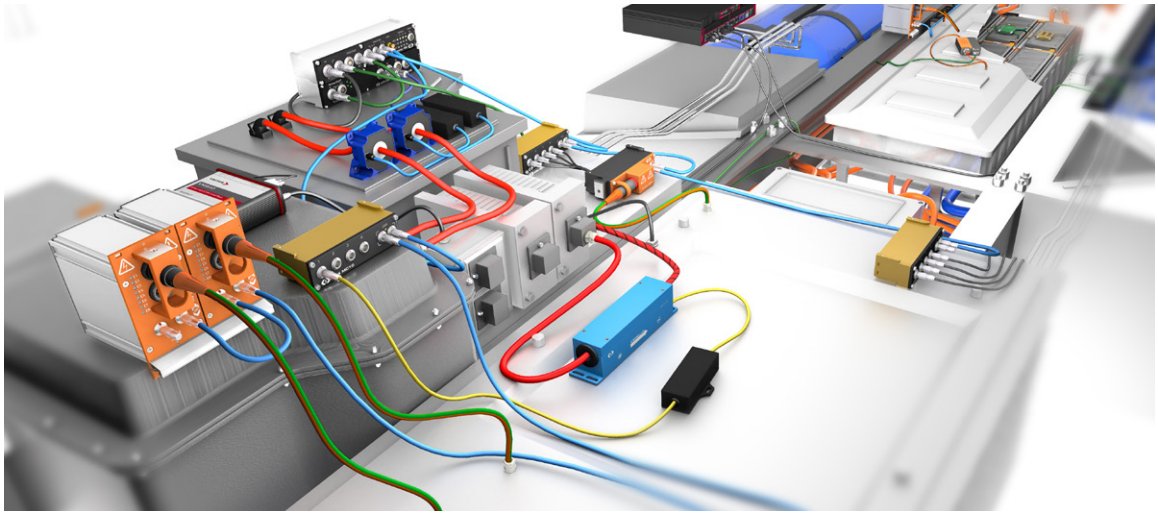


Fig. 3: With HV-safe measurement modules and sensor cables, other measured variables, such as temperature, can be acquired in a HV-safe manner.

Software for evaluation as an ideal addition

To analyze the data, the measured values from the CAN and EtherCAT® measurement chains are bundled, time-synchronized and transmitted via XCP-Gateways to a measurement computer for analysis. The XCP-Gateways act as protocol converters that can be used to channel large data streams from many measurement modules onto a time basis. In this way, all relevant measurement data is available for measurement data acquisition in a single data stream. With software solutions from the Vector CSM E-Mobility Measurement System, the measured data can be mathematically evaluated, graphically displayed and checked with regard to the respective criteria. As customized software for CAN and EtherCAT® measurement modules from CSM, vMeasure can be used to directly perform various analyses, such as calculating efficiency and other relevant variables for evaluating performance. Overall, the comprehensive data acquisition of a wide range of physical variables offers the opportunity for versatile investigations, for example to identify correlations between electrical, thermal, chemical and digital ECU data.

Scalable measurement system of hardware and software

With the measurement modules for use in low and high voltage environments, all variables relevant to the development of a fuel cell, such as temperatures, currents, voltages, flow rates, humidity and vibrations, can be acquired precisely, simultaneously and synchronized. The XCP-Gateways translate the CAN and EtherCAT® data to the standard XCP-on-Ethernet protocol. In this way, all measurement data streams with the same time reference can be evaluated with the appropriate Vector software. In addition, the hardware used is suitable for use on the test bench as well as for rough use in mobile road tests. Instead of a measurement computer, a UniCAN 3 data logger or a powerful smart logger from Vector can be integrated into the measurement setup. A metrological investigation of the electric powertrain including power and efficiency analyses with other CSM measurement modules, such as the HV Breakout modules, is also conceivable.

Featured Products

AD pro CAN MM Series

The AD pro CAN MiniModules (MM) allow a wide range of applications for the measurement of signals from sensors with analog voltage outputs (voltage, current, pressure, flow rate, etc.). A status LED for each channel makes it easy to verify proper operation. An extended scaling with 32 axis points per channel facilitates sensor linearization.

AD4 ECAT MM Series – Type OG1000

CSM's AD4 ECAT OG1000 measurement module is ideally suited for the most accurate analysis of high-frequency signals with measurement data rates of up to 1 MHz per channel. It offers a high-precision, unipolar and channel-wise adjustable sensor excitation from ±5 to ±15 V DC for a variety of sensors.

HV TH4 evo

CSM's HV TH4 evo measurement module allows safe temperature measurements with thermocouples on high-voltage components. Thanks to its compact design and reinforced insulation up to 1,000 V RMS, it is particularly suitable for distributed use in road tests.

HV AD2 evo IF20

The HV AD2 evo IF20 measurement module has been designed for the acquisition of voltage signals in high-voltage environments. With two analog measurement inputs with galvanically isolated sensor excitation, the HV AD2 evo IF20 is suitable for a wide range of applications.

HV PT Measurement Modules

CSM's HV PT measurement modules allow precise temperature measurements with PT100 and PT1000 resistance sensors in a high-voltage environment. The HV PT modules are ideal for temperature measurements in batteries, power electronics and in other components of electric and hybrid vehicles. In addition to higher measurement accuracy, PT sensors offer enhanced application options. Due to the very thin structure of foil PT sensors, it is easier to measure temperatures directly between battery cells than with thermocouples.

HV BM-Split

The HV Split-Breakout-Modules use the proven technology of the HV Breakout Modules and allow the measurement of current, voltage and power in very confined installation spaces. The components of the HV Breakout Modules have been “split” into individual sensor and measurement modules, which are connected via shielded, HV-safe sensor cables. This allows currents up to ±2,000 A (peak) and voltages up to ±2,000 V to be measured safely and precisely directly in the HV power cables and busbars.

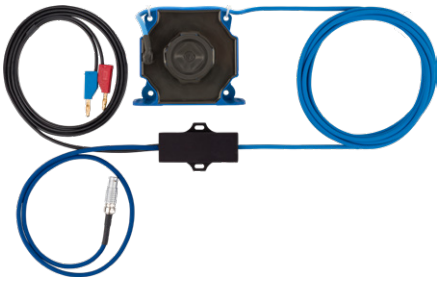
HV Breakout-Modul – Type 1.2

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).

LEM Sensor Packages

CSM's LEM Sensor Packages allow fast and synchronous current measurements. Highly dynamic current measurements (e. g., on all three phases on the inverter, as well) with a threshold frequency of up to 200 kHz in a measurement range of up to ±1,250 A can be carried out with this Sensor Package along with the EtherCAT®-based measurement modules of the AD4 ECAT Series.



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.

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19.11.2024