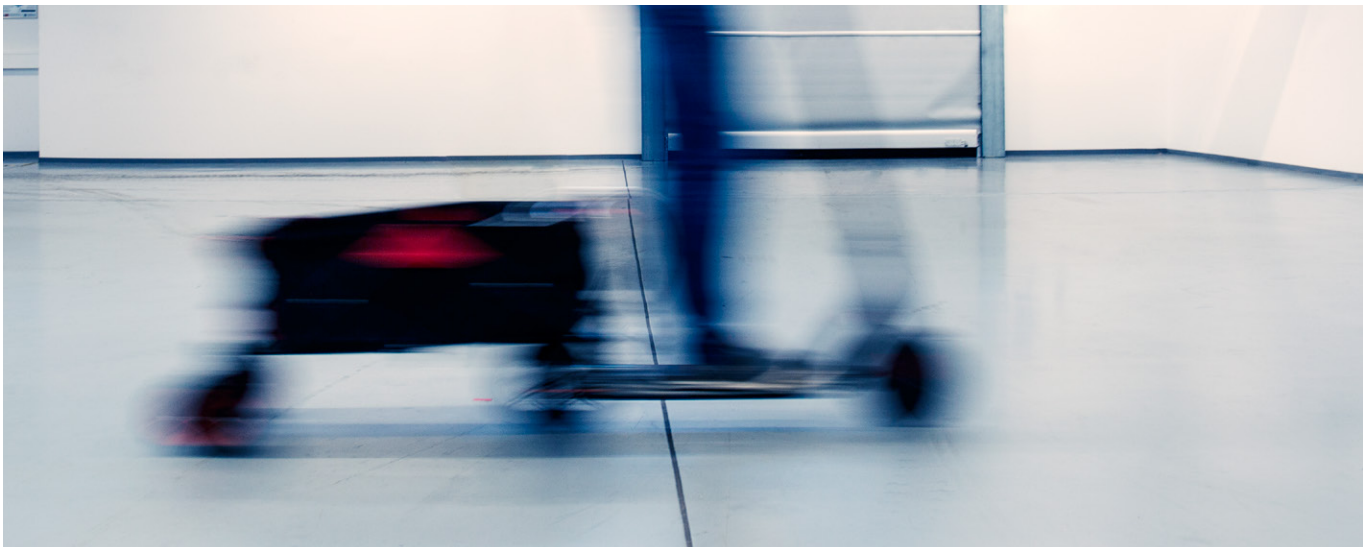


# High-Speed Power Measurement on an E-Scooter



## Current & Voltage Measurement

The optimization of the drivetrain and its components is the biggest challenge in eMobility. To achieve this optimization, high-speed measurements during drive-cycle tests are required. The objective of this use case is to show the requirement for high-speed measurements in a low-voltage vehicle network.



## Background

E-scooters (or "PLEV" - Personal Light Electric Vehicles) require optimal combination of high performance and small physical packaging of the system. In this respect, despite their low-voltage network, e-scooters and other similar vehicles, are comparable to vehicles powered by high-voltage batteries. Developers of both low-voltage and high-voltage vehicles are also using regeneration to maximize the range the vehicle will travel without external charging. All components in the drivetrain (Battery, inverter, and e-motor) must be designed optimally to maximize this regeneration and extend the range per external charge. The generation of heat is not an important factor in this

application due to the low motor power, and therefore was not measured. In other vehicle applications such as passenger cars or commercial vehicle trucks, the generation of heat and thermal management are also important factors in overall system efficiency.

This e-scooter measurement application proves that CSM's high-speed measurement modules intended for high-voltage environments can also be used effectively in low voltage electrical systems to verify vehicle performance such as the range per charge.



## Challenge

The APS-tech company ([www.aps-tech.de](http://www.aps-tech.de)) provides electric vehicle testing. One application to demonstrate their expertise in testing the performance of electric drive systems (battery, inverter, and motor) is an analysis of the commercially available e-scooter, a Xiaomi Mi M365. This PLEV is driven by a three-phase (regenerative) synchronous motor with a nominal power of 250 W (maximum output of 500 W). The battery has a maximum of 40 V and a nominal energy capacity of 7800 mAh.

The system had to measure the voltages and currents from the battery to the inverter, and from the inverter to the motor during the pre-defined drive cycle test. Changes in current and voltage of an electric drive system are based on many variables. These include the load applied to the system, the current draw, energy flow, and the inverter's switching frequency, in this case 8 kHz. The sampling rate needs to be at least 50 kHz to properly capture data at 5 – 10 times the natural frequency of the inverter in order to eliminate aliasing. A high-speed measurement system achieves this objective.

All the voltages and currents measured during the test were to be recorded locally on the e-scooter.



Fig. 1: The e-scooter during its mobile test.

The power calculated from the voltage and current was to be sent wirelessly to a remote display for real-time presentation of the data to the engineer(s).

With a small PLEV, the measurement system had to be lightweight and compact to avoid interfering with the operator performing the test.

Without these requirements being met (accurate and fast measurement of voltage and current, power calculation, and wireless communication from a compact system) the testing of the electrical drive system of the e-scooter could not be accomplished.



## The CSM Measurement Solution

APS-Tech ([www.aps-tech.de](http://www.aps-tech.de)) chose a high-speed measurement system from CSM. The system is comprised of breakout modules to measure the voltage and currents in the electric drivetrain, along with an on-board mini-computer from Vector Informatik with vMeasure exp software to calculate power.

The Breakout Modules were originally developed by CSM for use in High Voltage (HV) electric vehicles that also require high-speed data sampling of current and voltage, but certainly work well in low voltage applications as demonstrated by this use-case. CSM's High-Voltage Breakout Module (HV BM) measures current and voltage at a data rate up to 1 MHz per channel. It measures current by using a calibrated and temperature compensated shunt. Voltage is also measured within the breakout module. The module maintains the synchronicity of the

two signals to within 1  $\mu$ s. Thus, instantaneous power is calculated and is an output from the HV BM.

Due to their direct installation in the power supply cables, the breakout modules can be easily inserted into the vehicle drivetrain and offer enormous space and weight advantages.

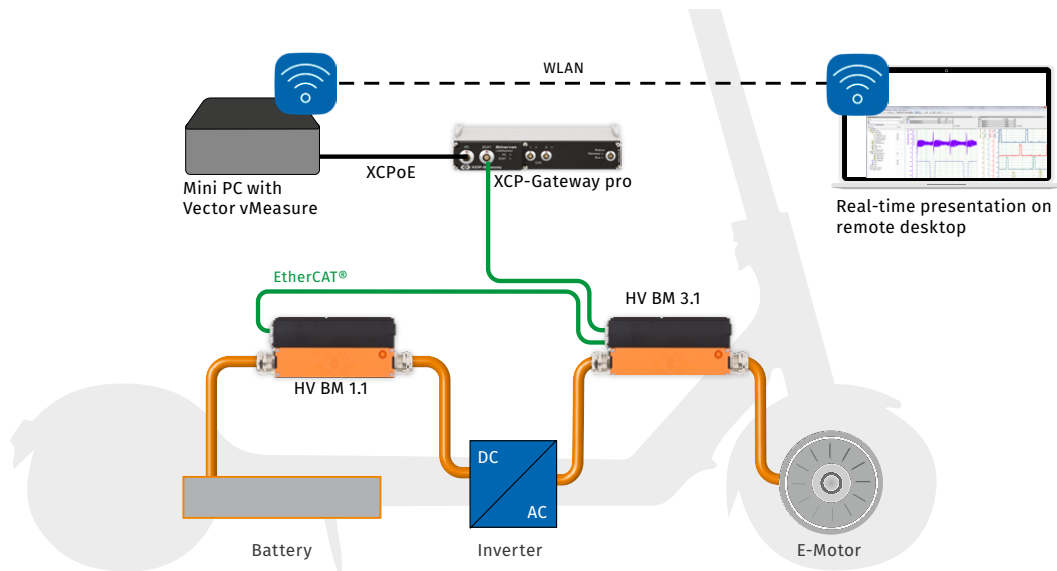


Fig. 2: The measurement setup

As shown in Fig. 2, one module (**HV BM 1.1**) is inline between the battery and the inverter, measuring single-phase current and voltage with a data rate up to 1 MHz. Another module (**HV BM 3.1**) allows the three-phase AC measurement of current and voltage with a data rate of up to 500 kHz per channel.

The measurement network is EtherCAT®, which uses a distributed clock mechanism via ethernet to maintain synchronicity of the data. Most DAQ software systems receive high-speed data via XCP-on-Ethernet from single devices (usually ECU's). Therefore, CSM offers **XCP-Gateways** to collect the time synchronized data and convert it from EtherCAT® to XCP-on-Ethernet. In this e-scooter application, this gateway receives the high-speed measurement data from the Breakout Modules on the EtherCAT® network and provides it to the Vector vMeasure software via mini-PC. In testing the e-scooter, a Mini PC loaded with vMeasure software including the **eMobilityAnalyzer** package from Vector was part of the configuration. The Mini PC was installed with its own battery so that it did not draw power from the e-scooter.

The calculation of the desired measured values in this Mini PC ensures reliable data capture. It prevents any data loss due to a wireless network disconnection. The data transmitted wirelessly from the Mini PC to the remote display is only the calculated values (not the entire data set) and thus reduces the amount of data to be transferred wirelessly.

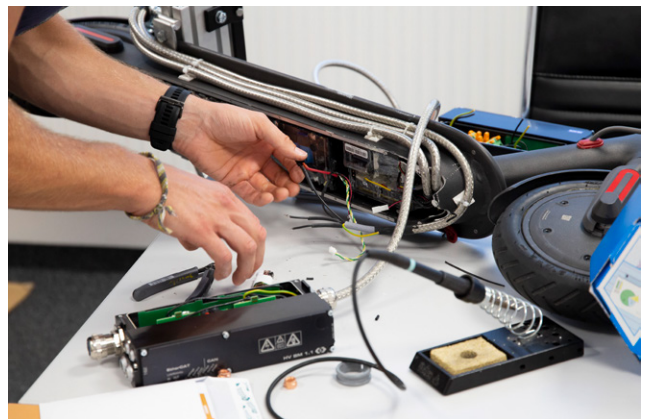


Fig. 3: The HV BM 1.1 is being installed into the cables between the battery and inverter.



Fig. 4: The data can be accessed and viewed directly via WLAN during measurement.

For example, Fig. 6 shows the comparison of calculated power of the battery and the inverter. The entire data set can be retrieved from the Mini PC by other means after the test.

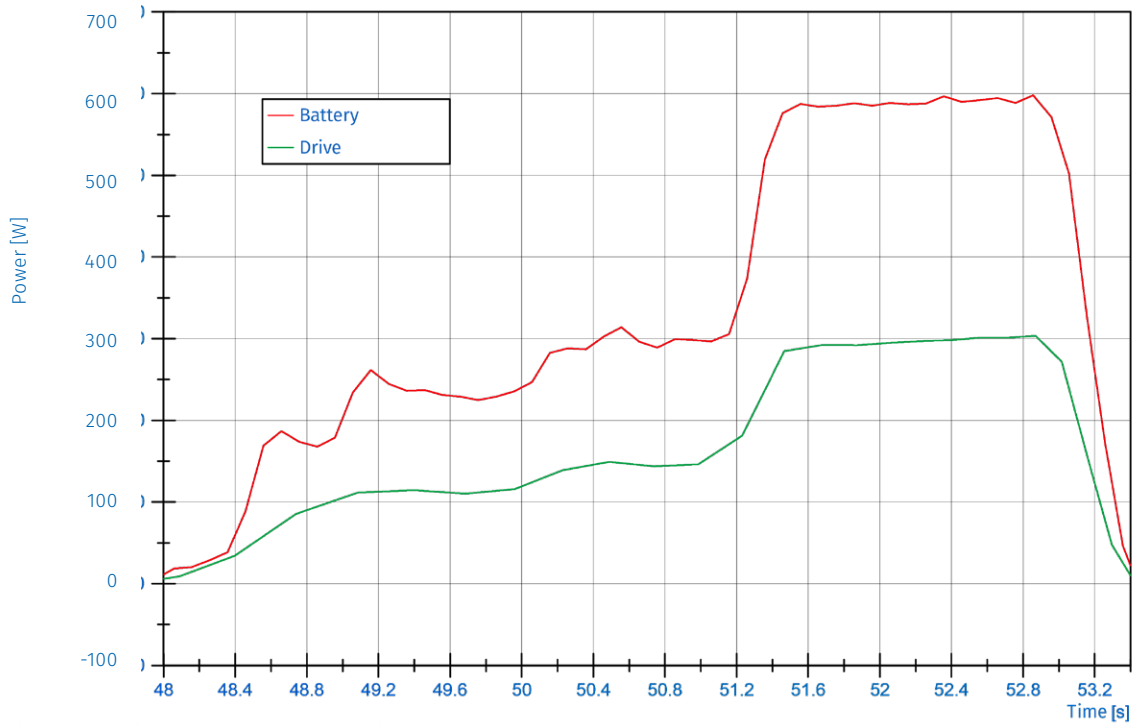


Fig. 5: Comparison of battery power and inverter power.

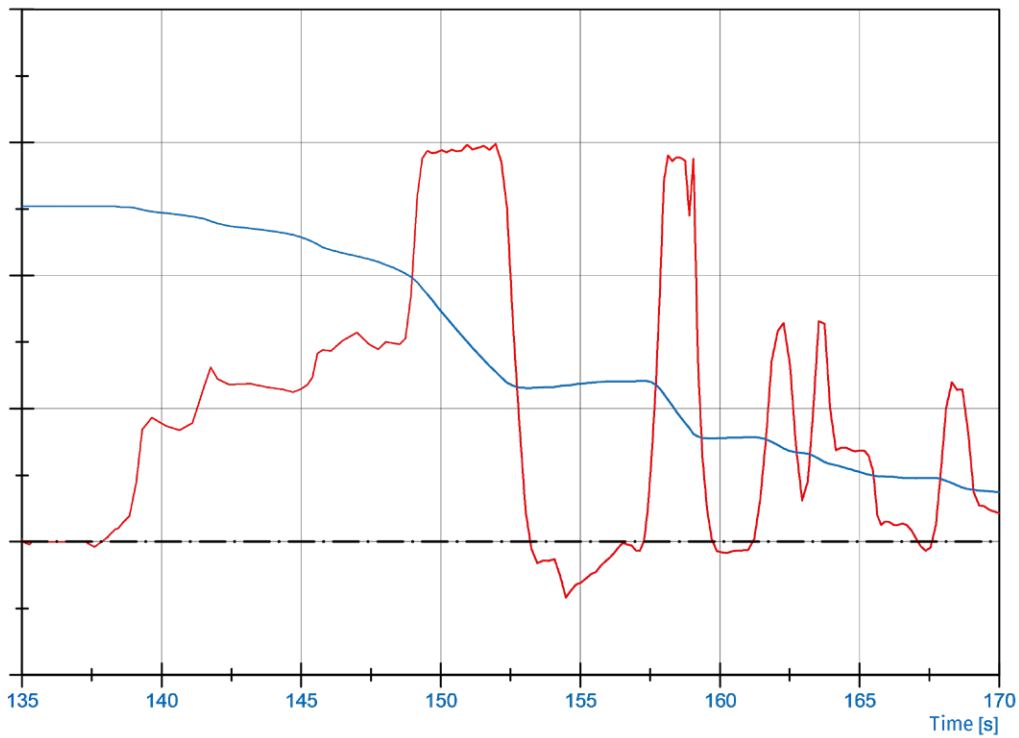


Fig. 6: The graph shows the battery charge level (blue) synchronously with the power delivery (red). While driving (power output > 0) the charge level steadily drops. During the braking process between 153 and 157 seconds, the charge goes up slightly – the effect of regeneration.

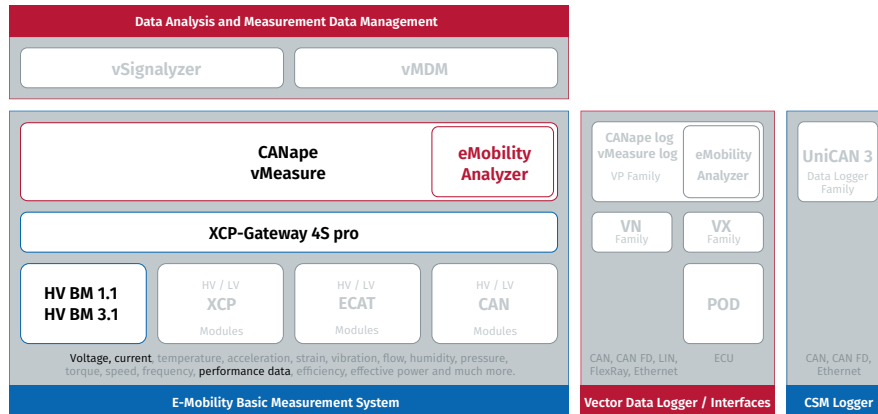


Fig. 7: The high-speed power measurement on an e-scooter in the systematics of the Vector CSM E-Mobility Measurement System



## Benefits

With the CSM measurement technology used, the requirements regarding available space and the required data rate were met. The direct installation of the HV BMs in the relevant lines also creates a compact and easy-to-install measurement setup.

Using the high-speed capability of the breakout modules and the eMobility Analyzer software, the regeneration capability of the system was also verified. In Fig. 6, the regenerative effect during braking can be clearly seen.

A parallel measurement of the heat development would have been possible with other CSM modules, such as the

CAN PT or CAN TH MiniModule. In fact, CSM's breakout modules and gateways are part of an entire offering of System Based Measurement solutions.

Through the use of CSM's measurement modules and Vector's software, the performance and range of PLEVs and high-voltage vehicles can be verified through a series of testing and continuous improvements prior to production release.



## Featured Products

### HV Breakout Module - Type 1.1

CSM's HV Breakout Module (BM) Type 1.1 is specifically designed for single-phase measurement applications on high-voltage carrying cables. It is suitable for measuring power, current and voltage on auxiliaries supplied by a single high-voltage carrying cable.



### HV Breakout Module - Typ 3.1

CSM's HV Breakout Module (BM) Type 3.1 was developed for the three-phase determination of current, voltage and power on high-voltage carrying cables with currents up to  $\pm 32$  A. One module performs three-phase measurement, therefore offering enormous cost and space advantages.



### 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](http://www.csm.de) or via e-mail [sales@csm.de](mailto:sales@csm.de).





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