Springer Vieweg

ATZ extra

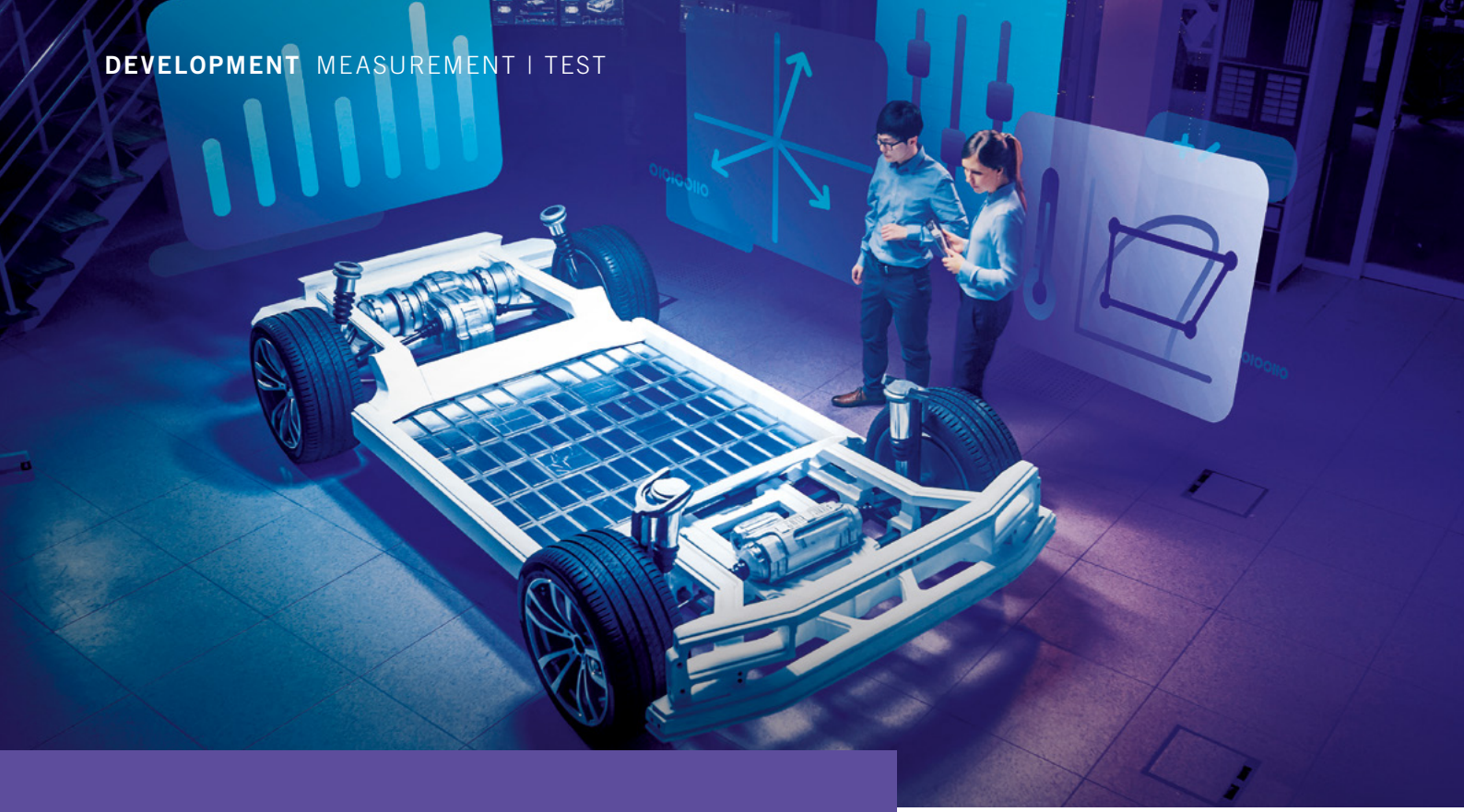
Article from ATZelectronics
worldwide 09-10/2026



Range, Performance, Driving Experience:

Smart Calibration for EV Systems

ETAS



© depositphotos I Gorodenkoff I Etas

Optimized Calibration for High-Performance E-Drives

Developing electric drives is a balancing act. Engineers must maximize range, service life, and driving dynamics without compromising on cost or functional safety. The key lies in holistic system optimization. Etas demonstrates how intelligent measurement and calibration of the battery, powertrain, and thermal management enhance both efficiency and the driving experience.

WRITTEN BY



Dipl.-Ing. (BA) Klaus Grabmaier
is Technical Architect Measurement & Calibration at Etas GmbH in Stuttgart (Germany).



Dr. Mike Wolter
is Solution Manager Measurement & Calibration at Etas GmbH in Stuttgart (Germany).

There is no doubt that electric mobility is finally on the rise. While proper drive system calibration generally provides, regardless of its propulsion concept, a significant leap in quality for any vehicle, this applies to Electric Vehicles (EVs) to a very high degree. Electric drive systems confront development with complex interactions and conflicting objectives. The pursuit of maximum range and performance must be reconciled with the demands for low weight, long service life, high operational reliability, and manageable development and hardware costs. At the same time, optimizing the electric drive through an adapted measurement and calibration strategy promises automobile manufacturers tangible competitive advantages. These include improved performance at lower costs, but also an improved user experience, from driving comfort to a reliably accurate remaining range indicator.

Electric drives are complex, interconnected systems with components that are closely linked and influence each other. Optimizing individual

components is therefore an important intermediate step, but the real potential lies in holistic integration and coordination of the subsystems. Ideally, the end result is a perfectly coordinated interplay of the three core systems, high-voltage battery, electric powertrain and thermal management.

HIGH-VOLTAGE BATTERY SYSTEM

The high-voltage battery system is not only the heart of modern electric vehicles, but also their main cost driver. It essentially consists of battery cells, supporting peripherals, and the Battery Management System (BMS) as the central control unit. The system's performance depends significantly on its State of Charge (SoC), the State of Health (SoH) and the operating temperature.

For development engineers, the challenge lies in finding the sweet spot for the battery system between maximum performance, a long lifespan, and high operational reliability. Optimization is achieved through an iterative measurement and calibration process. This process begins with the precise, real-time acquisition of individual cell voltages, currents, and temperatures throughout the entire battery pack. Dedicated measurement and analysis tools (for example Etas Inca and MDA) allow the vast amount of diverse data to be processed and correlated in such a way that critical conditions, such as overload of individual battery cells, and especially cell imbalance and the efficiency of the balancing process, become visible, **FIGURE 1**.

MINIMIZING IMBALANCE

The insights gained in this way then form the basis for targeted fine-tuning of the BMS algorithms, where protective functions are specifically optimized and the accuracy in calculating SoC and SoH is further improved. Methods such as Coulomb counting and Kalman filters are also playing an increasingly important role. These are particularly relevant for the now commonly used Lithium Ferro-Phosphate (LFP) cells, whose state of charge can hardly be reliably determined via cell voltage alone.

For the automobile manufacturer, this is a worthwhile endeavor, because only by precisely determining the SoC of each individual cell and minimizing imbalances can the full potential of the battery system be exploited. The result is greater range, extended lifespan, and superior vehicle performance. Such a precisely calibrated system allows for more efficient battery designs and thus reduces costs.

ELECTRIC POWERTRAIN

Hardly less important for the performance of the EV is the electric powertrain. Consisting of electric motor(s), power electronics, and transmission, it converts electrical energy into propulsion. Its efficiency, however, is not a fixed value, but depends heavily on the speed and the requested torque. The challenge lies in operating the powertrain in its most efficient range as often as possible across the vehicle's entire operating spectrum. If two motors are installed, the operating strategy allows the motors, with their different characteristics, to be used selectively

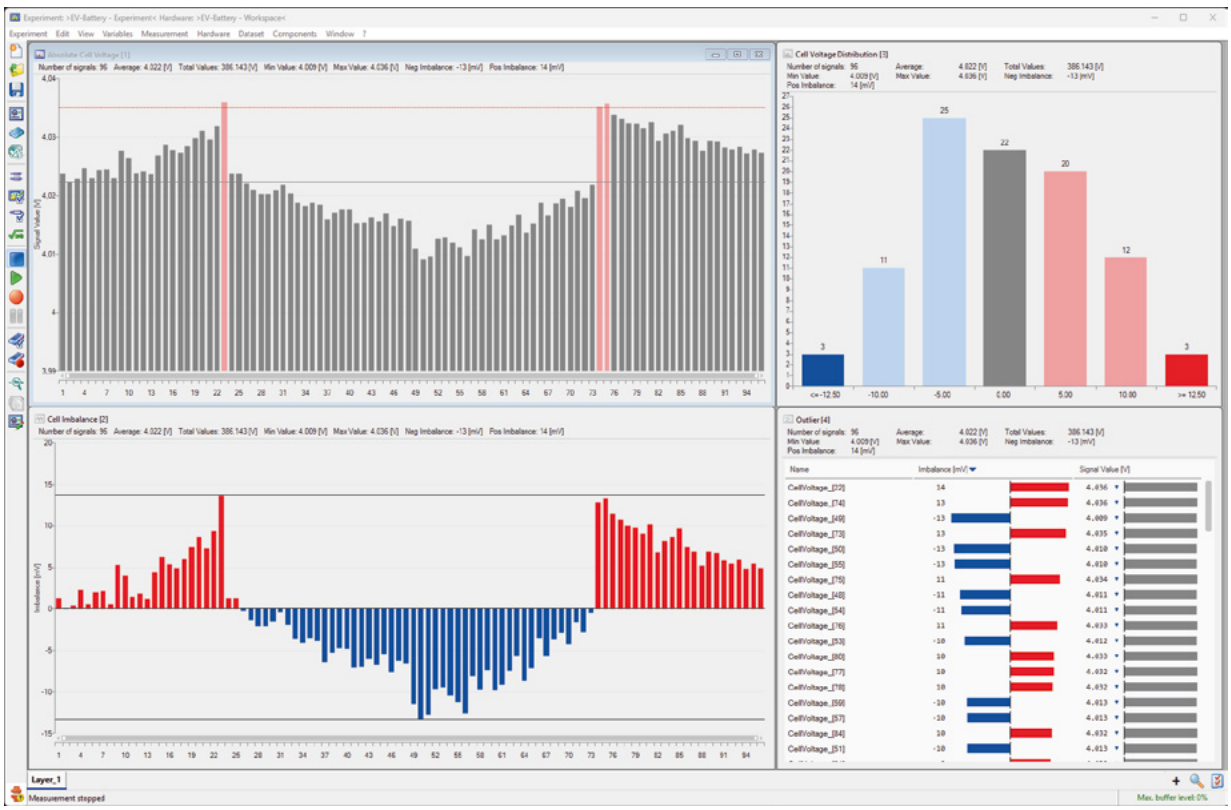


FIGURE 1 Acquisition and analysis of real-time data on individual cell voltages, currents, and temperatures reveal critical conditions, cell imbalance, and the efficiency of the balancing process (screenshot) (© Etas)

to achieve maximum efficiency. For the best possible configuration, electrical performance data such as high-voltage currents and voltages at the inverter are first recorded and combined with vehicle data from the control units and networks during real-world driving and on the test bench. The subsequent data analysis and modeling reveal inefficiencies and allows for the generation of detailed efficiency and loss maps for the respective motor-inverter unit, **FIGURE 2**.

These characteristic maps form the basis for the final calibration of the powertrain. First via Software-in-the-Loop (SiL) and Hardware-in-the-Loop (HiL) simulation and then in the vehicle, the parameters of the control unit software are adjusted so that determinants, such as torque distribution and recuperation in the powertrain, interact perfectly. The focus is not only on maximum efficiency, but also on a successful alignment with the driving experience. Transitions, such as engaging a second axle or switching from regenerative to mechanical braking, must be smooth and imperceptible to the driver.

INTELLIGENT TORQUE SPLITTING

In all-wheel drive or multi-motor systems, the greatest potential for efficiency lies in the intelligent distribution of drive torque, or torque splitting. The key to this is the Vehicle Control Unit (VCU), which, as the central drive coordinator, calculates the optimal torque distribution in real time for every driver request, thus minimizing the overall system losses. The previously measured efficiency maps for each individual motor-inverter unit serve as the data basis for this calculation. The torque splitting algorithm in the VCU must be calibrated so that it distributes the required torque to the motors as efficiently as possible based on these maps. The strategy is to completely deactivate one axle whenever the driving situation allows, thereby reducing the motors' baseline energy consumption, which is independent of torque. This targeted switching on and off of the motors, especially during partial load driving, significantly reduces energy consumption and consequently maximizes range. However, this efficiency gain must not diminish the driving experience: the blending of the multi-motor system's engine torque must ensure a smooth driving feel without compromising safety.

PREDICTIVE THERMAL MANAGEMENT

Another crucial factor for the efficiency of the electric drive is the optimization of thermal management. Due to the high efficiency of modern electric motors, very little usable waste heat is available while driving. Consequently, almost all the energy for heating and cooling of the battery and vehicle interior must be drawn from the traction battery, which directly reduces the range. Therefore, thermal management must balance the competing thermal demands with the lowest possible energy consumption in all weather conditions and without compromising performance or comfort. For example, the high-voltage battery is actively cooled via the air conditioning system, thus directly competing with the cabin's climate control. Conversely, the drive motors are sometimes put into a special operating mode in which they deliberately generate high losses, which are then used to heat the battery and the interior. The path to proper thermal management therefore involves a detailed analysis of the thermal energy flows and the thermodynamic process of the refrigerant circuit. However, the subsequent calibration should not only establish the optimal balance within the thermal system but also consider its integration with the powertrain.

Furthermore, significant potential lies in the predictive control of the thermal system through the intelligent use of navigation and vehicle data. For example, the battery can be preconditioned to its optimal temperature of up to 60 °C before a planned fast-charging process, considering factors such as driving profile, topography, ambient temperature, and the expected power output of the charging station. Such a forward-looking control system not only maximizes charging power but also increases the efficiency and lifespan of the electric drive overall.

RESOLUTION OF CONFLICTING OBJECTIVES AND EFFICIENT DATA MANAGEMENT

The specific optimization of the traction battery, powertrain, and thermal man-

FIGURE 2 Calibration of the motor-inverter unit in the powertrain: analysis of the measurement data reveals inefficiencies and enables optimization of the overall system in terms of efficiency and driving comfort (© Etas)



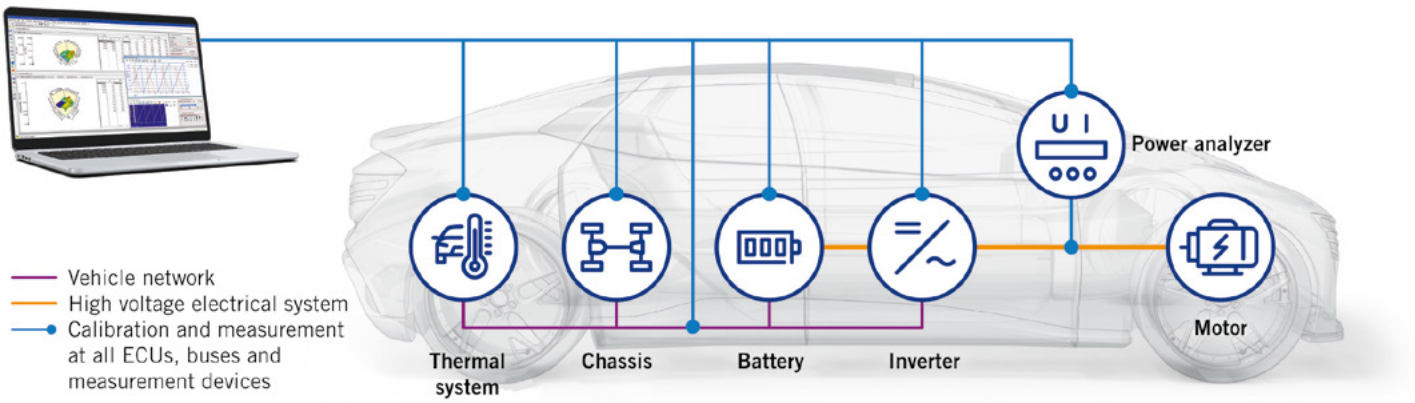


FIGURE 3 To optimize the overall system, the system parameters are calibrated using measurement data from the control units of all domains, network communication, and analog measurement data from the high-voltage system (© Etas)

agement is a fundamental prerequisite. However, the comprehensive harmonization of these individual disciplines not only holds significant potential but is also functionally necessary. This is because the trade-off between component efficiency and service life on the one hand, and driving dynamics and comfort on the other, remains a constant challenge for EVs during operation. The core task of final vehicle calibration is therefore to resolve this conflict through hierarchical control architectures, **FIGURE 3**. This means that while an operating strategy designed for maximum efficiency forms the basis, in certain situations it can be overridden by higher-level functions. For example, driving dynamics, controlled by the Electronic Stability Program (ESP), always takes precedence in critical moments. Similarly, comfort can override component lifespan, such as when high power is released despite a low battery charge or a cold battery. Driving modes like "Eco," "Comfort," or "Sport" allow the driver to influence this prioritization. The result is an intelligent vehicle that most of the time operates with high efficiency but provides maximum stability and performance instantly when needed.

A key factor in the complex coordination of the entire electric drive system is efficient data management. The enormous amounts of data from test drives and dynamometer runs require a robust infrastructure. Building a central data storage in the cloud, serving as a Single Source Of Truth (SSOT) for all measurement data, is a crucial success factor. Such a platform (for example, a toolchain consisting of EATB, Data Operator, and Ascmo from Etas) breaks down data silos, enables global and collaborative work by development teams, and creates the conditions for analysis supported by artificial intelligence, modeling and fast, effective calibration.

SUMMARY AND OUTLOOK

The modern electric drive is more than the sum of its parts. The art of smart calibration therefore not only coordinates the interplay of all components in the battery system, powertrain, and thermal management, but also harmonizes these three core systems. Only by striking the best possible balance between range, battery life, cost, and driving dynamics can an electric vehicle be developed that offers both high efficiency and an excellent driving experience. The present and future of electromobility are characterized by fierce competition, high-cost pressure, and the need for careful resource use. In such an environment, an intelligent, data-driven calibration strategy evolves from a mere development step into a strategic success factor.

IMPRINT:
Special Edition 2026 in cooperation with ETAS GmbH, Robert-Bosch-Straße 1, 44803 Bochum; Springer Fachmedien Wiesbaden GmbH, Postfach 1546, 65173 Wiesbaden, Amtsgericht Wiesbaden, HRB 9754, USt-IdNr. DE81148419

MANAGING DIRECTORS:
Stefanie Burgmaier I Andreas Funk I Alexandra Dambeck

PROJECT MANAGEMENT: Anja Trabusch

COVER PHOTO:
© depositphotos I Gorodenkoff I Etas

ETAS

Let's kickstart future mobility



Empowering Tomorrow's Automotive Software

www.etas.com