Superbike Success from the Electronics Lab

As an official partner to BMW Motorrad Motorsport, BMW's motorcycle motorsports division, dSPACE has brought the Superbike World Championship circuits into the lab.

The BMW motorcycle motorsports team is in the fast lane. Since 2009, BMW Motorrad has been competing in the Superbike World Championship, and with success. After safety, racing's number one priority, reliability is a major issue – especially in the engine controls for racing machines. BMW Motorrad relies on dSPACE to validate the quality of their completely self-developed electronic control units.

Motorsports Center of Excellence

Even though BMW Motorrad looks back on 87 years of racing tradition, in the Superbike World Championship the company is a newcomer. The BMW team stood at the World Superbike starting-line for the first time in 2009, with the S 1000 RR racing machine. In Stephanskirchen near Rosenheim in Upper Bavaria, Germany, BMW and alpha Racing jointly set up a motorsports center of excellence to further develop the racebike. BMW development engineers are responsible for ensuring that the S 1000 RR competes well in the World Superbike class.

Electronics Development at BMW Motorrad

Electronics development is one of BMW's core competencies in the field of motorsports. The self-developed engine control, the RSM5 (Racing Sport Engine Control, 5th Generation), plays a major role in the Superbike project. From selecting the processors and components to designing circuit boards and programming low- and high-level functions, all the work steps are performed at BMW Motorrad. This enables the team to respond quickly and flexibly to new requirements imposed by the test tracks and race

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BMW rider Ruben Xaus deep in concentration with racing engineer Wolfgang Martens shortly before the race in Portimão, Portugal.

Milestones

in BMW Motorrad's 87 Years of History

Chief designer Max Friz developed BMW's first motorcycle, the R 32, in **1923**.

In **1933**, Ernst Henne's team brought home the European Offroad Championship title on 33-HP, R16-type Boxer machines in Wales. Offroad races were used to try out innovations. Both telescopic forks and the first BMW rear-wheel suspension passed the acid test of six-day events before being installed in production models.

In **1937**, Ernst Henne achieved a world speed record of 216.75 km/h. The record was unbroken for 14 years and brought BMW worldwide respect as a motorbike manufacturer.

In **1963**, the BMW competition machines made a technological breakthrough with their new chassis, whose ride stability set new standards on US highways. It was later integrated into the 5-Series in **1969**.

BMW's first Superbike success came in Daytona, USA, in **1976**. The American Steve McLaughlin won the AMA Superbike event in an exciting photo finish against his team colleague.

The R 100 RS launched by BMW in **1984** was the world's first production motorcycle with a full fairing. The development work had focused on aerodynamic aspects and on protecting the rider from the wind and the weather.

Frenchman Hubert Auriol, nicknamed "the African" because of his navigation talent, won the Paris-Dakar desert rally, the toughest rally in the world, for BMW in **1981** and **1983**.

In **1988** BMW was the first manufacturer in the world to market an electronic, hydraulic antilock braking system (ABS) for motorcycles.

At INTERMOT **2004**, BMW presented the K 1200 S, their first transversely mounted four-cylinder engine. Its 167 HP (123 kW) took BMW Motorrad into new power dimensions.

The team first competed in the Superbike World Championship in the first race in Phillip Island, Australia, in **2009**. The BMW S 1000 RR production machine has innovative features such as a 2.5 kg lightweight racing ABS and dynamic traction control that permits slip depending on the lean angle.

In **2010**, BMW riders Troy Corser and Ruben Xaus were among the first ten at the Superbike event in Portimão. Troy Corser took 4th place at the race in Valencia, BMW Motorrad's best World Superbike class result to date. More exciting races on legendary race tracks such as the Nürburgring and the circuit in Imola will follow.

Daytona

Last check on the superbike before the race. Even BMW pilot Troy Corser gets a bit nervous.

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tracks. For example, over 14 software versions were created and driven for the 28 worldwide Superbike races on the 14 days of the 2009 season.

Top Priority: Reliability

Electrics and electronics make a bike not only fast, but also reliable. “To finish first, first you have to finish.”: The BMW racebike team embraced this motto and chose to use a dSPACE Simulator Full-Size as a hardware-in-the-loop system to test the ECUs, including running automated tests under dSPACE AutomationDesk (Figure 1). The simulator primarily performs three main tasks:

- Automated quality assurance of ECU hardware
- Automated, individual ECU calibration
- High-level software development with the aid of a complete vehicle model

> “BMW Motorrad’s development philosophy is to find problems before they reach the test track or even the race track.”
>
> *Ralf Schmidt, BMW Motorrad*

Automated Quality Assurance

To put the RSM5 engine control on the track absolutely reliably and to reproduce it easily for small production runs, the quality of the ECUs must be validated by automatic testing. Errors in the electronics are not acceptable, because any possibility of failure on the race track or test track must be excluded.
After each hardware and software change, the ECUs undergo a test program lasting almost two hours on the dSPACE HIL test bench. The inputs for the tests are simulated on the simulator, and the outputs such as ignition and injection signals are read back via the simulator. These signals are then compared with the calculated values of the ECU that the simulator sends to the ECU via the ASAM MCD-3 interface. The permitted deviations are evaluated, and then documented and archived in a test log of over 100 pages. If a channel is above a predefined deviation limit, the entire ECU is taken apart completely in an intensive test to hunt down the cause and fix the error. This approach is the only way to ensure the quality of the hardware and software reliably and continuously, and has given the systems their extremely high standard.

Automated, Individual ECU Calibration

Because only very small quantities of the ECUs are produced, production tolerances can occur, for example, in the gain and offset values on some analog input channels. To eliminate these deviations, the simulator performs automated measurements on each ECU. This is done with AutomationDesk, where a test protocol is implemented to apply specific signal voltages to each individual input channel on the ECU. Each voltage value is transferred from the ECU to the simulator via the ASAM MCD-3 interface, and the deviation is logged. Then an individual binary calibration file is automatically created with MATLAB® and written to the ECU’s flash memory.

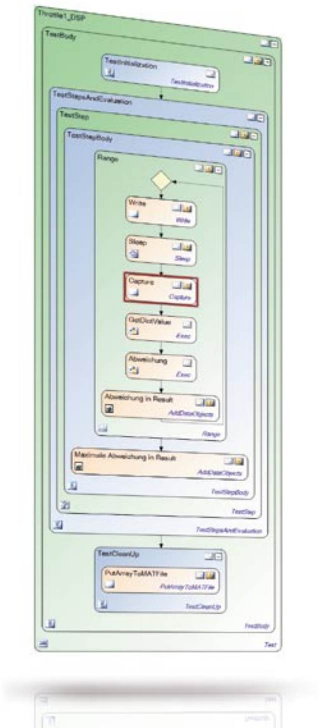

Figure 1: AutomationDesk provides a graphical user interface for creating and modifying test projects and test sequences.

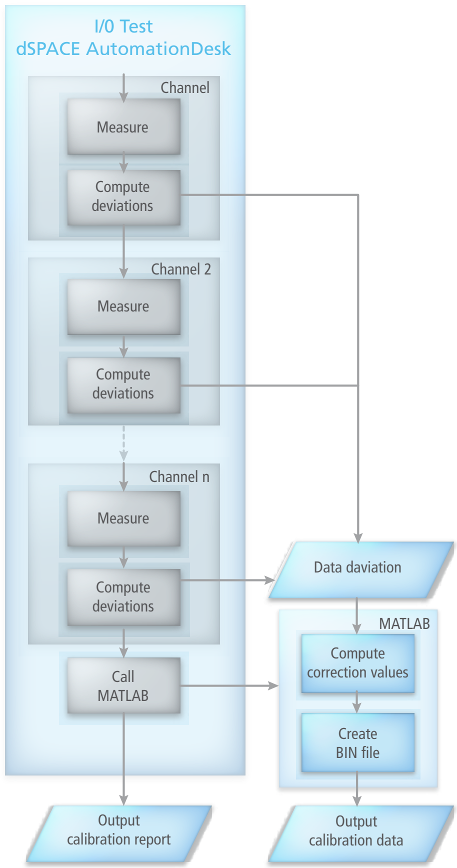

Figure 2: Finding the correction values with the ECU calibration system consisting of flexible hardware and scalable software for measurement, calibration and diagnostics tasks.

Laboratory test on BMW Motorrad Motorsport's RSM5 engine ECU with the dSPACE HIL test bench.

Functions in the ECU software use this calibration data to compensate for component tolerances in each individual ECU. Even BMW Motorrad's two professional riders Troy Corser and Ruben Xaus noticed the resulting quality boost and gave very positive feedback on the identical reproduction of the ECUs (figure 2).

Developing a Complete Vehicle Model

At the end of 2009, work started on developing a special vehicle dynamics model for the racing version of the BMW S 1000 RR in MATLAB/Simulink®, initially focusing on the vehicle's longitudinal dynamics. The objective is to generate a representation of a real vehicle that is as realistic as possible to simulate complex control functions, such as traction control, launch control and wheelie control, in the laboratory. The development laboratory in Stephanskirchen gives the team ideal conditions for this. The center brings together the know-how of experts from the engine and chassis fields, and also from the alpha Racing team, who all provide input for a representation of a real vehicle that is accurate in every detail. This saves a lot of time and money that would otherwise be spent on items such as track time, i.e., on renting the race track, staff and equipment.

The Race Track in the Lab

With the numerous test runs made by the S 1000 RR and the 28 races in the 2009 World Superbike season, the powerful data logger integrated into the RSM5 engine control ECU captured an enormous volume of recorded data, which can now be used as stimuli for the vehicle's newly developed model:

- Throttle grip
- Steering angle setting
- Hydraulic pressure of front- and rear-wheel brakes
- Gear position
- Force on the gear shift lever
- Start button
- Emergency stop switch

The first laboratory experiments showed that the model values calculated for the longitudinal dynamics are virtually identical with the real values in the racebike. The simulation covered legendary circuits such as Nürburgring, Monza and Valencia, which are all venues for the Superbike World Championship and therefore available as a data collection for simulation with the dSPACE simulator.

The Challenge of Lateral Dynamics

Lateral dynamics are the most difficult block in the vehicle model. The vehicle dynamics of a single-track vehicle are extremely complex due to constantly changing tire contact force caused by the bike rider shifting weight. Only a precise model of the vehicle's center of mass location can represent these dynamics. For example, during

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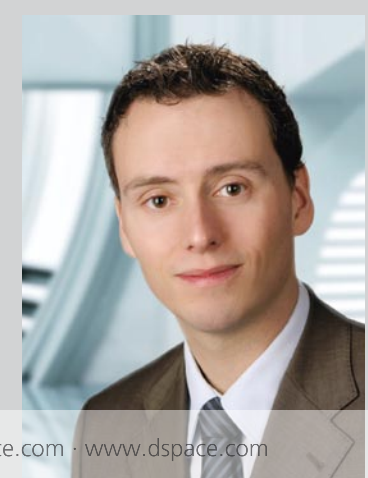

Superbike S 1000 RR – Technical Data:

Engine displacement:	999 cm^3, four-stroke, four-cylinder, liquid cooling
Transmission:	6 gears
Power:	> 200 HP at >14,000 min^{-1}
Bore x stroke:	80 x 49.7 mm
Compression ratio:	14:1
Dry weight:	162 kg
Front-wheel suspension:	Öhlins upside-down telescopic fork, ø 43 mm
Rear-wheel suspension:	Öhlins TTX

> "Automated ECU quality assurance has become indispensible at BMW Motorrad, because the two attributes of complete reliability and identical reproduction of ECU controls are absolutely essential."

Ralf Schmidt, BMW Motorrad

acceleration the rider moves his or her body weight forward to counteract the rising front wheel, known as a wheelie. During tight cornering, the steering angle causes the vehicle to lean into the turn by up to 65 degrees. The tire contact force and the resultant possible force transmission of the engine depend to a very high degree on the rider's weight shifts. The aim is therefore to create a realistic model of these actions to ensure the BMW team's continued success in the World Superbike class.

Looking Forward to World Superbike 2010

BMW riders Ruben Xaus and Troy Corser aim to deliver constant results in the 2010 season. Their team has set itself the goal of improving the electrics and electronics in the S 1000 RR and also the simulation models as a major contribution towards the S 1000 RR's success in the Superbike World Championship. ■

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Superbike rider Ruben Xaus and racing engineer Wolfgang Martens feel good about the S 1000 RR's performance.