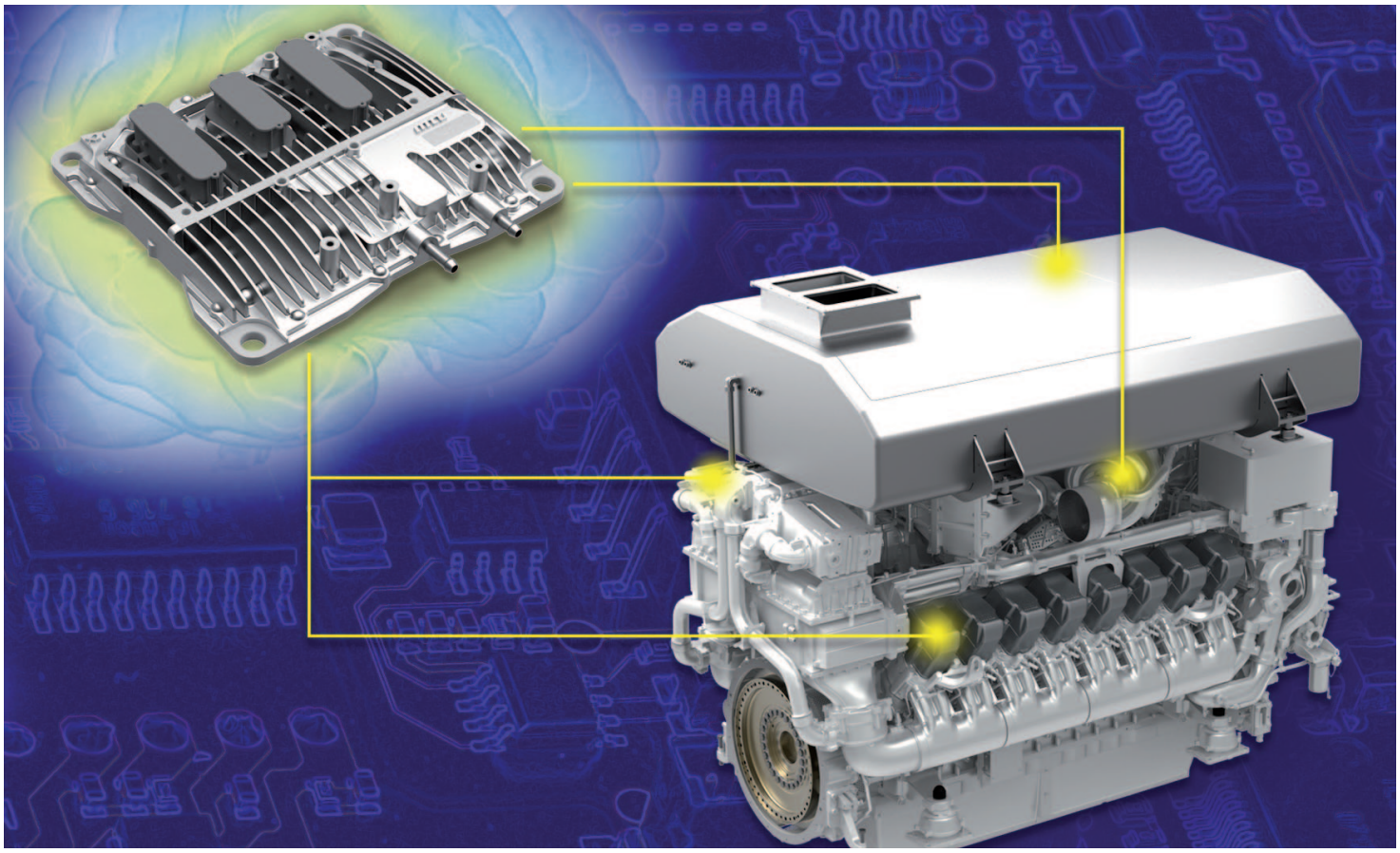
Electronic engine management: Key technology for intelligent engine control



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The brain of a modern engine is the electronic control unit. It monitors and controls all the key functions of the engine and the exhaust aftertreatment system. The control unit also acts as the interface to the vehicle's automation system. The optimum interplay of the entire drive system is the key to low pollutant emissions, low fuel consumption and high power output over the entire service life. MTU develops and manufactures this key technology in-house.

Engine control center

Legislators all over the world are specifying increasingly tougher emissions limits for diesel engines. To comply with the requirements, emissions from the drive system are constantly being reduced. As the engine's brain, the engine management system (see Figure 1) controls key systems such as fuel injection, turbocharging and exhaust gas recirculation (EGR) that affect engine consumption and emission levels as well as performance. This means that the electronic engine management system is one of MTU's key technologies for developing engines that comply with the increasingly tougher emissions stan-

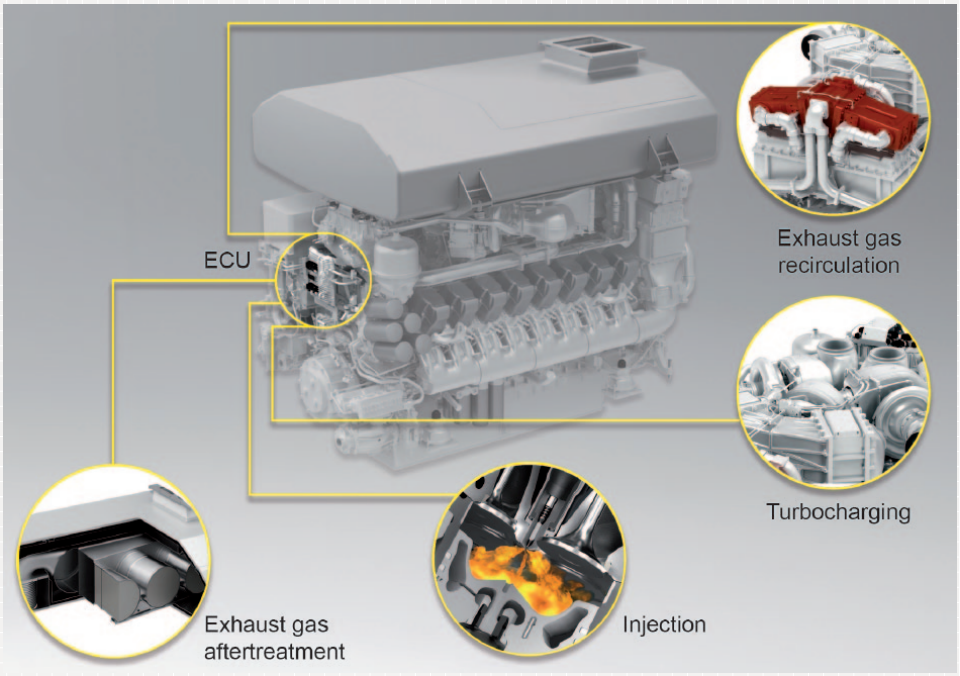


Fig. 1: **Rail engine 16V 4000 RX4 with ECU as "nervous system"**
As brain of the engine the ECU engine management system enables the precise interaction between key engine systems including the key technologies injection, turbocharging, exhaust gas recirculation or diesel particulate filter that affect engine consumption and emission levels as well as performance.

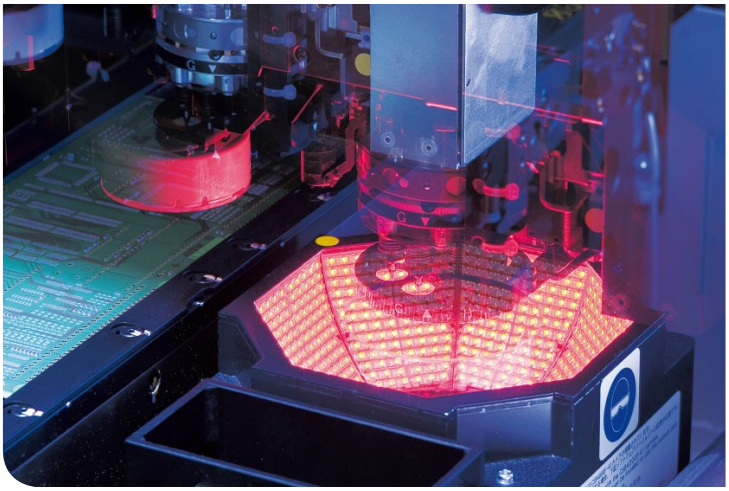
dards. MTU's own proprietary Engine Control Unit (ECU) controls engine functions extremely precisely so that the formation of harmful emissions is greatly reduced by internal engine modifications to the combustion process. For very stringent emission limits, MTU combines these measures with exhaust treatment systems that also remove emissions from the exhaust gas, such as the SCR system (Selective Catalytic Reduction) or the diesel particulate filter (DPF).

Electronics development and production at MTU

Around 300 staff in development, production and project planning at MTU work on tailor-made electronics solutions for engines and their automation systems. MTU develops the hardware and software for its engines in-house and also carries out production itself. By doing so, MTU can ensure a long-term product lifespan of up to 30 years for electronic compo-nents. A particular challenge in this respect is the production lifecycle of bought in components such as microprocessors, which is generally much shorter than the production lifecycle of the engine control modules. As early as the ECU's design concept stage, therefore, MTU chooses processor families that will continue to be able for a long period. If necessary, to ensure long-term availability, MTU also sets up a second supplier for electronic components. If components for control systems of older engines are no longer available, there is the possibility of adapting an ECU of the current generation to the engine concerned. In such cases, however, the engine management software has to be reconfigured for the drive system and the application.

MTU system modules

MTU's engine controllers are designed as modular systems. That means that new functions can be quickly and flexibly integrated into the existing hardware and software platforms. The modular system also offers advantages for engine maintenance, since electronic engine diagnosis can be carried out quickly and efficiently for all MTU controller generations using just one service tool. In the development of engine management systems, MTU generally pursues the objective of producing as few hardware and software versions as possible. Five controllers in total cover all current MTU engine series – from the classic Series 396, 538, 956 and 1163 engines to the current Series 1600, 2000, 4000 and 8000 engines (see Figure 2). MTU launched its first electronic engine controller module to reduce engine fuel consumption and increase performance back in 1982. This was followed in the 1990s by the MDEC (MTU Diesel Engine Control), which controlled diesel engines with either unit-pump fuel injection or the common rail system, which was still quite new at the time. In 2004, there followed the ECU 7 for the Series 2000 and 4000 engines, which is designated ADEC (Advanced Diesel Engine Control). The universal controller is suitable for use with all cylinder configurations from V8 to V20 and for all drive applications. The ECU 8, a special version followed in 2008 for the Series 1600 engines.



From development to production, MTU electronic products come from a single source. The highly sophisticated electronic components are manufactured in the company's in-house production section. Each control unit contains several thousand components.

Controllers for future emissions

To be able to meet the requirements of even stricter exhaust emissions legislation, MTU expanded its modular system in 2011 with the addition of the ECU 9, which also is designated ADEC. The new controller is based on the proven ECU 8 platform and uses the same processor family and software architecture. The improvements featured in the ECU 9 primarily include new control functions and additional sensors and actuators for turbocharging and exhaust gas recirculation. As a result, the engine's combustion process can be configured for even lower emissions. However, the additional sensors and valve actuators increase the requirements for more communications with the engine management system.

To cope with the increasingly complex networking of individual engine systems in future, MTU implemented a design change for the ECU 9. Unlike the design of previous systems, individual sections of the control unit, such as the area for engine function, are now encapsulated. Interfaces with the application's automation system have also been separated and standardized. This means that the engine can be easily integrated in the various customer applications via a standardized J1939 interface. The development time for the ECU 9 hardware to first-time field use was just ten months, with the soft-ware for the new functions requiring only twelve months to produce and to be integrated into the existing software structure of the ECU 7. Due to the very short development times, MTU is able to make sure that the engine management system is always state of the art.

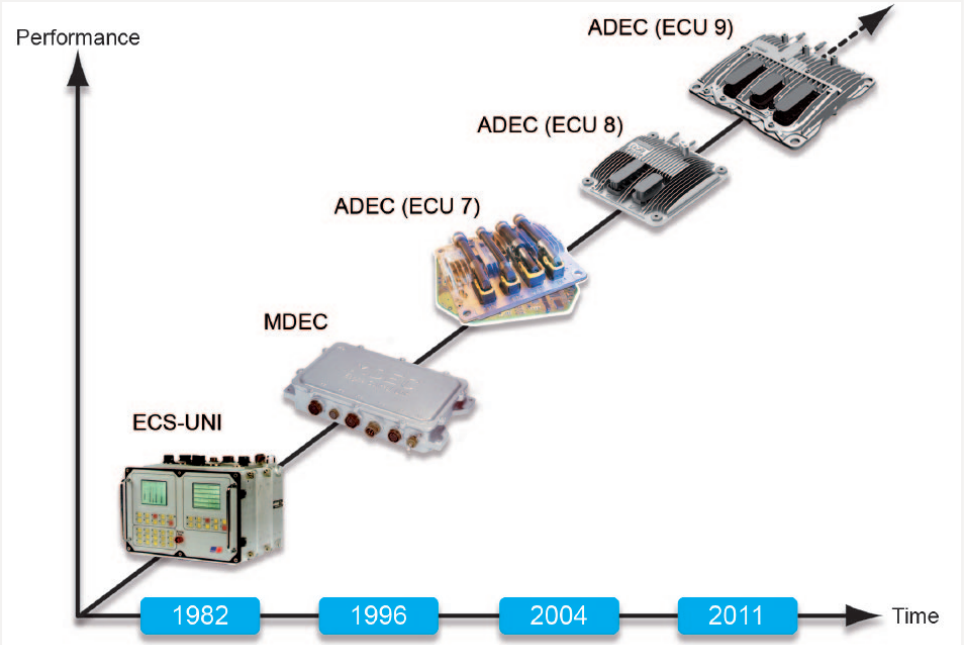


Fig. 2: **Overview of the development stages of the engine management system since 1992**
MTU launched its first electronic engine controller module to reduce engine fuel consumption and increase performance back in 1982. In 1996 it was followed by the MDEC (MTU Diesel Engine Control). In 2004, there followed the ECU 7 for the Series 2000 and 4000 engines, which is designated ADEC (Advanced Diesel Engine Control). The ECU 8, a special version, followed in 2008 for the Series 1600 engines. Three years later, MTU launched the ECU 9, which also is designated ADEC.

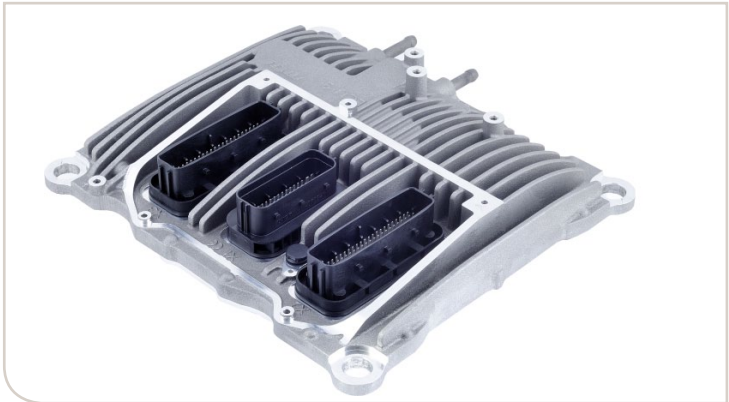
Long-term stability of the engine functions

To ensure that MTU engines remain as economical, clean and powerful over their entire service lives as they are when new, MTU consistently incorporates closed-loop control circuits in the engine management system whenever possible. This enables the system to compare the readings obtained from the sensors with the target settings for optimum engine performance. If any deviation occurs due to interference, the engine controller constantly brings the actual readings in line with the required settings by means of actuators. The sensors then monitor the effect of the adjustments made by the actuator on their readings. That makes the engines stable in terms of fuel consumption, emissions and performance over the entire lifespan, since the engine management system ensures that compensation is made for any changes resulting from wear and tear and environmental conditions. In the case of state-of-the-art control systems such as those currently used in cars and commercial vehicles, for example, signs of aging which occur in individual engines at a given operating point cannot be compensated for and the control functions gradually become inaccurate in the course of the engine's service life. The reason is that the actuators are adjusted with no feedback from the sensors on the basis of a predefined data map that has been produced for the engine during engine trials.

The fuel injectors of the common rail injection system are the key actuators for metering fuel delivery. They are therefore required to meet extremely stringent requirements in terms of accuracy. To further improve the long-term stability of the fuel injection system, MTU has integrated specific mechanisms into the ECU to compensate for injector wear. The system records how frequently the fuel injection valves are activated when the engine is in operation. The engine management system then uses this information to calculate an aging value that is taken into account when controlling valve operation.

Safety-critical applications

For applications which demand the highest standards of availability and reliability, such as emergency power generation in nuclear power plants for example, MTU has developed special products based on existing controller families. These



The ECU is an electronic engine control unit that is responsible for the monitoring and control of all engine functions. MTU has named the current generation, the ECU 9, ADEC: Advanced Diesel Engine Control.

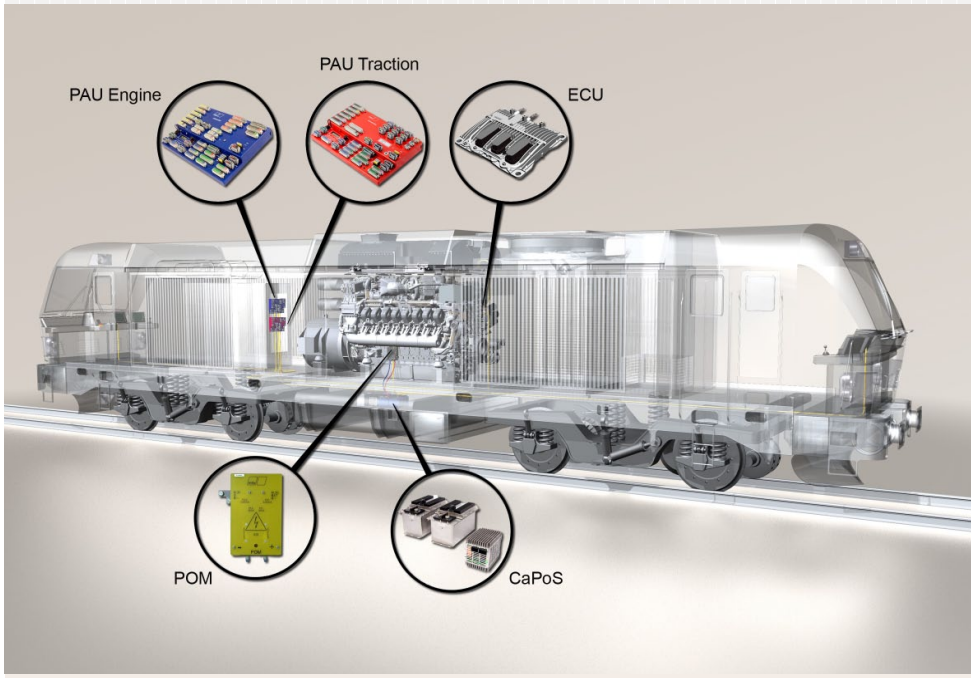
have been certified (TÜV) and audited (SPIEC for nuclear applications). Certified and expert-approved solutions are also available for oil and gas as well as rail applications.

Automation solutions

Integration of the engine management system in the automation structure has been achieved using standardized MTU interface modules. This enables drive systems to be integrated even more easily into the automation system of a given application. Here, MTU offers a modular system that enables the engine control system to be extended by adding application-specific automation solutions. For marine applications, on the one hand MTU has developed standardized automation solutions. Standardized automation solutions are likewise available for marine applications. These include the ultra-compact Blue Vision New Generation automation system introduced in 2013. The system encompass the complete Monitoring Control System (MCS) and Remote Control System (RCS) for the automation system of a vessel's entire power train from the propeller to the control stands. On the other hand, with its ship auto-mation system 'Callosum', MTU has created a modern and highly efficient modular system which can be used for customer-specific project system solutions for all types of vessels.

For rail applications, MTU supplies automation solutions for drive systems in railcars as well as in locomotives. The modular automation system 'Powerline' which has been newly developed in conjunction with Series 4000 for locomotives, integrates all of the functions required for monitoring and control of the the diesel drive plant (see Figure 3). The core electronic component of the new automation system is the Power Automation Unit (PAU Engine) which combines all of the functions in a compact unit as well as providing a secure link to the locomotive's control systems via the CAN-Open interface.

Fig. 3: **MTU Powerline automation system for locomotives**
In the rail sector, MTU has rounded out the engine management system by adding the automation package Powerline for MTU Series 4000 engines. This consists of the basic components PAU Engine, POM, ADEC (ECU 9) and CaPoS.



Engine Control Unit (ECU): The ECU is an electronic engine control unit that is responsible for the monitoring and control of all engine functions. MTU has named the current generation, the ECU 9, ADEC: Advanced Diesel Engine Control.

POM (Power Output Module): Powerline starter system.

PAU Engine (Power Automation Unit Engine): It not only controls the diesel engine, for example, but also other engine-related rail vehicle components, such as the cooling system or the electric fuel pump.

PAU Traction (Power Automation Unit Traction): MTU offers the PAU Traction automation components specifically for repowering purposes.

CaPoS (Capacitor Power System): CaPoS is a Powerline supplement providing a modern starter power supply based on capacitors instead of batteries.

Summary

As the brain of the engine, the ECU controls key engine systems that affect the engine's consumption, emissions and performance, such as fuel injection, turbocharging and exhaust gas recirculation. Increasingly stringent emission standards are placing ever greater demands on the electronic engine manage-ment system. For particularly strict emission standards, MTU launched the new ECU 9 in 2011, which further reduces the production of harmful emissions inside the engine by providing even more precise control of the combustion process.

MTU unveiled its first electronic engine controller back in 1982. Since then, the company has continued to develop and produce the entire hardware and software in-house. This ensures that MTU is able to guarantee the long-term availability of spare parts, even for older engines. With the ECU 9, MTU is offering a separate, standardized automation system interface. In addition, customers can extend the engine management system by adding application-specific automation solutions from MTU for propulsion, on-board power generation and the complete ship in the marine sector, for example, as well as for rail applications.

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