Automotive Systems

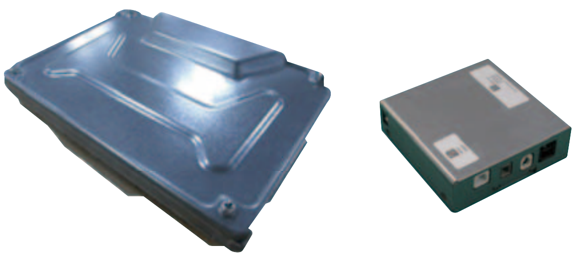
1 Autonomous Driving Unit and High-definition Map Position Unit

Since releasing an advanced driver assistance system (ADAS) unit in 2000, the Hitachi Group has released a number of information-based safety products such as stereo cameras and gateway units. In 2019, it started mass-producing an autonomous driving unit and high-definition map position unit using technologies acquired from developing autonomous driving systems.

The autonomous driving unit is configured with two central processing units (CPUs) for vehicle control and recognition, enabling a high level of safety and high-speed computing performance. The high-definition map position unit stores high-definition map data covering features such as Japan's nationwide highway network. It sends look-ahead information not visible to sensing technology to the autonomous driving unit. A satellite positioning system has been combined with a gyro sensor to develop a function that computes the vehicle position with high accuracy even in tunnels or other areas of weak satellite signal. Using another developed function, the route to the destination set in the car navigation system is converted from a route showing each road to a route showing each vehicle lane. The high-definition map position unit outputs information along with high-definition map data of the area around the vehicle to the autonomous driving unit.

Hitachi will continue to draw on its identity as a supplier of autonomous driving systems to help create safe and comfortable driving experiences driven by advances such as original Hitachi over-the-air (OTA) software updates and security technologies.

(Hitachi Automotive Systems, Ltd.)



1 Autonomous driving unit (left) and high-definition map position unit (right)

2 Risk Prediction Map Technology Assisting Autonomous Driving Functions for Local Roads

Hitachi has developed a risk prediction map technology for autonomous driving and driving assistance applications. It enables risk avoidance by predicting collision risks in the vehicle's surroundings.

Autonomous driving technologies have so far been designed for relatively simple driving behaviors such as highway travel in a constant lane, making them unable to handle complex vehicle surroundings such as local roads. Technologies for complex vehicle surroundings need to anticipate safety conditions several seconds in advance by using information detected by sensors to predict changes in the behavior of moving objects, and by considering risks in blind spots undetectable to sensors.

To predict conditions on the planned trajectory several seconds in advance, the technology needs to search the optimum trajectory in the three dimensions of time and space (planar X- and Y-coordinates, and time t). But searching in three dimensions is known to usually have a massive computation cost. For any future arrival point of the vehicle (X, Y) and its anticipated arrival time (T), the developed technology finds the collision risk and represents it as a risk prediction map projected into two dimensions. By seeking a trajectory that traverses only safe regions in the risk prediction map, the technology can provide a risk-avoiding trajectory that foresees future hazards. Even in processors for onboard use, the technology can predict risks in real time up to 5 seconds in advance, and enables autonomous driving with natural risk avoidance.

(Hitachi Automotive Systems, Ltd.)

3D: three dimensional 2D: two dimensional

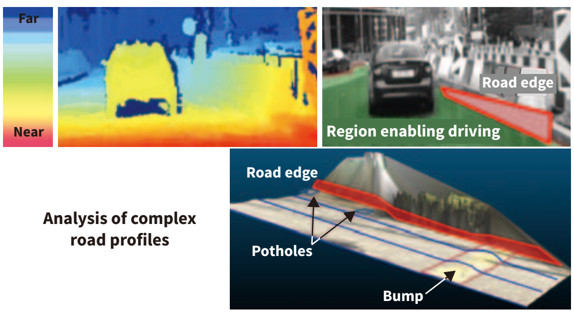
2 Risk prediction map generation (left), and autonomous driving using the risk prediction map to avoid a parked vehicle (right)

3 Preview Semi-active Suspension Using Stereo Camera-based Road Profile Recognition Technology

The rise of preventive safety functions is making the automotive market take a closer look at functions designed to increase safety and convenience. One such function attracting interest is technology that provides appropriate suspension control in response to unevenly shaped road surfaces with the bumps and potholes common overseas. Stereo cameras have features that make them effective at recognizing unevenly shaped road surfaces. Their distance measurement performance increases in proportion to decreasing range. They can also infer large distant obstacles such as vehicles and people, along with precise road edge and profiles such as nearby level differences of a few centimeters.

A safe and comfortable ride can be achieved by using high-density 3D point sets from stereo cameras along with the original images to recognize the road edge and profile in advance, and provide preview suspension control tailored to the 3D shape of the travel path. At Consumer Electronics Show 2019, Hitachi used a test vehicle that used working cameras together with a semi-active suspension to demonstrate a method of improving ride comfort and decreasing impacts while driving a vehicle.

(Hitachi Automotive Systems, Ltd.)



3 Travel path shape analysis using high-density 3D point sets

4 Fail Operational Steering System with Dual-CPU Configuration

In the development of advanced safe driving technologies such as autonomous driving, the importance of fail operational functions that keep the system operating even if a failure occurs is increasing. In power steering, which provides vehicle lateral motion, the complete loss of assist should be avoided in the event of a failure. The market demand for risk reduction through redundancy is growing.

In order to meet this demand, the mass-produced electric power steering system (EPS) adopts a redundant configuration for major electric components such as dual CPUs, and complies with ASIL-D in the functional safety standard ISO26262. The fail operational function has been improved significantly, such that the system can provide assist force of up to 50% continuously during fail operation. Moreover, the failure rate of sudden loss of assist has been reduced to less than 100 FIT.

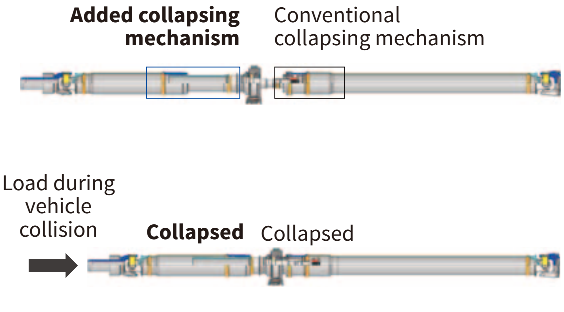
4 Fail operational belt drive EPS

In the future, Hitachi intends to continue developing next-generation models aimed at further reducing the failure rate (less than 10 FIT), improving the maximum assist force during fail operation, and implementing OTA wireless software updating and security functions for connected cars.
(Hitachi Automotive Systems, Ltd.)

5 Improving Collision Safety by Adding Propeller Shaft Mechanism that Collapses During Collisions

Hitachi has created a propeller shaft that improves vehicle collision safety by collapsing more than twice as much as conventional types under low impact loads. The propeller shaft is the drive shaft on a vehicle that conveys the engine rotation and torque to the rear wheels. Propeller shafts that act like rigid supports during a collision prevent the vehicle's crumple zones from absorbing shocks and have other properties that impede features designed to reduce the severity of occupant injury.

Propeller shafts have traditionally had a collapsing mechanism to combat this problem. Hitachi has added to it with a mechanism of interlocking splines that keeps the propeller shaft fixed and unmoving during vehicle travel, and collapses only during a collision. By optimizing the interlocking dimension and improving precision, the splines reduce the load that collapses the propeller shaft as a way to reduce the severity of occupant injuries. O-rings are used to seal the spline section for protection, and a structure that reduces O-ring encroachment into the spline section during a collision is used to reduce the collapsing load.
(Hitachi Automotive Systems, Ltd.)



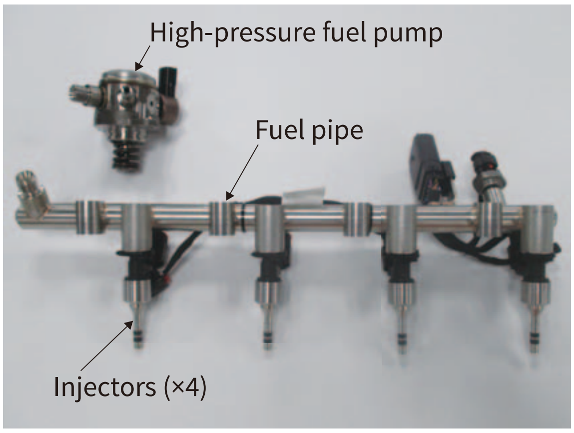
5 Propeller shaft with added collapsing mechanism

6 Fuel Supply Subsystem for 35 MPa Direct Injection Engine

Today's direct fuel-injection engines are being designed to support higher fuel injection pressures to comply with the tougher emissions regulations being enacted worldwide. While these higher pressures promote fuel atomization and reduce emissions, they create challenges such as reducing noise and increasing the speed and precision of injection quantity control.

By developing a pre-stroke mechanism and creating a high-speed on-off valve, Hitachi has developed an injector set that supports a fuel injection pressure of 35 MPa. A minimum injection quantity of 2.0 mg per shot has been achieved by applying a valve close detection control. Developing a nozzle shape that prevents fuel from adhering to the orifice surface has also achieved a reduction in emissions particulate number (PN) generation to 80% lower than the Euro 6c regulatory value.

The high-pressure fuel pump's internal volume was reduced, making a 50% reduction of compression loss over the previous model, while a low-noise electromagnetic valve and discharge valve that reduce the previous noise level by 3 dB have been developed. A unique internal layout also enables one of the smallest sizes in the industry (48 mm), improving engine installation ease.
(Hitachi Automotive Systems, Ltd.)

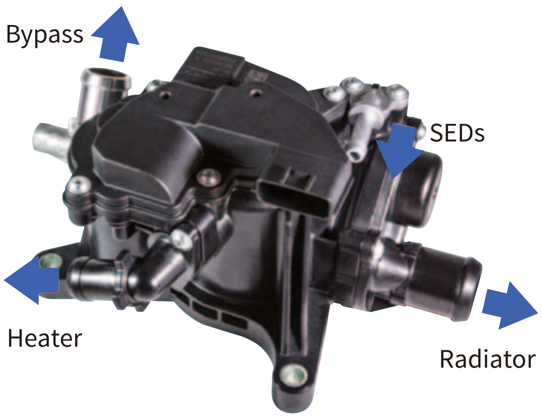


6 Fuel supply subsystem for 35 MPa direct injection engine

7 Development of Channel Switching Control Valve

While electric vehicle (EV) development is making progress in and around the developed world, today's increasingly strict CO_2 emission regulations continue

to create a market need for improvements in the fuel efficiency of internal combustion engines (ICEs). The multi-waterway control valve (MCV) is a valve for switching cooling water channels that Hitachi Automotive Systems has developed to improve fuel efficiency. It works by promoting early combustion chamber warm-up and reducing mechanical friction. It achieves these benefits by switching the cooling water channels in response to the driving conditions (engine speed, load, water temperature, and outside air temperature), to control the temperature of each unit (thermal management). The use of a double worm mechanism layout with smaller actuators enables MCV installation in current engine layouts, and has resulted in a new order. Hitachi Automotive Systems is planning to study the proposed use of MCV in combination with cooling systems that can improve fuel efficiency through thermal management in ICEs, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) and EVs.
(Hitachi Automotive Systems, Ltd.)



SEDs: small electric devices

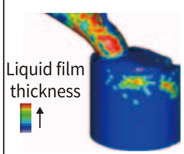
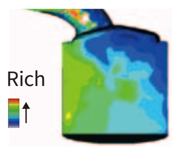
7 MCV's cooling water channels and switching pattern

8 Simulation-based Spray Design for Port Injection Injectors

Twin port fuel injection (twin PFI) is being used in a growing number of fuel systems for light and small automobiles to satisfy demands for low fuel consumption, emissions, and cost. Hitachi Automotive Systems has been mass-producing multi-swirl port injection injectors for twin PFI systems since November 2013.

Just as for direct fuel injection engines, PFI engines also need spray design that has been optimized to the individual engine. The Hitachi's Research & Development Group has developed simulations that analyze the engine's internal fuel spray behavior, air-flow, and air-fuel mixture to determine the specification requirements of the optimum spray to propose to customers.

To create a spray proposal in time for the demanding deadline of a recent development project, Hitachi Automotive Systems designed the spray by working with the customer and making extensive use of simulations right from the start of development. A number of requirements created the need for this approach: Shortening the development cycle for design, prototyping and demonstration testing on actual equipment was a mandatory requirement. A good balance was needed between the differing spray requirements for improving engine knock and improving combustion in the partial region. The engine intake port shape (injector mounting positions) and other design elements also needed to be optimized. The multi-swirl port injection injectors resulting from the project satisfied the customer's requirements during fuel efficiency testing on actual equipment done by the customer, and helped Hitachi win the order.
(Hitachi Automotive Systems, Ltd.)

Fuel droplet behavior	Adhering fuel quantities	Vaporized fuel quantities
		

Spray analysis was used to reduce the quantity of adhering fuel on parts such as the intake ports, and to improve the homogeneity of the air-fuel mixture in the cylinders. The analysis findings enabled the optimum injector spray specification requirements and intake port shape to be determined.

8 Simulation-based spray design for port injection injectors

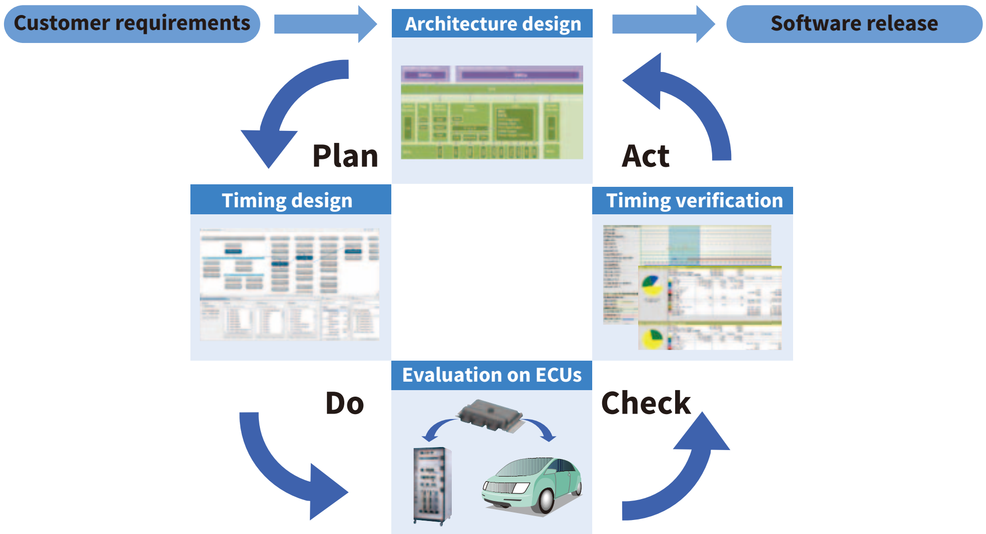
9 Reforming Software Development Processes for Onboard Control Software

Electronic control units (ECUs) need to provide a good balance between cost (hardware specifications) and performance (functionalities and capabilities) as dictated by the car-manufacturer's requirements (the customer requirements). For example, it has been challenging to create software architecture that provides functional safety, real-time operation, guarantees data consistency/coherency, and multicore-based load distribution when hardware resources such as memory and CPU processing time are limited.

Hitachi Automotive Systems promotes development processes that efficiently optimize multicore software architecture. These processes use the plan-do-check-act (PDCA) cycle to repeat four steps based on the customer requirements—(1) architecture design, (2) timing design, (3) evaluation on ECUs, and (4) timing verification. The analysis tools and measurement data used in these development processes for evaluation on actual equipment are shared by Hitachi and the customer, enabling early detection and handling of the timing problems that often occur at the end of the development phase.

Hitachi Automotive Systems is planning to work on automating these development processes to enable further improvements in customer value.

(Hitachi Automotive Systems, Ltd.)



9 Reforming the software development processes for onboard control software