

Automotive Systems

1 G-Vectoring Control

New technology based on Hitachi Automotive Systems, Ltd.'s G-Vectoring vehicle motion control technologies was developed by Mazda Motor Corporation, and is being introduced in all Mazda models starting with the updated Mazda Axela released in July 2016.

Mazda developed the advanced G-Vectoring control (GVC) technology by pursuing application-focused development on the basis of Hitachi Automotive Systems' G-Vectoring control algorithm. Its key feature of enabling dynamic coordination in both the car's lateral and longitudinal acceleration forces makes it the world's first control system capable of ensuring smooth and efficient vehicle motion by optimizing the vertical load on the four wheels. Hitachi Automotive Systems and Mazda started collaborating in 2010, and achieved mass production of this technology through industry-university cooperation with Kanagawa Institute of Technology.

The GVC developed by Mazda is the company's first step forward in the company's new-generation vehicle control technologies initiative known as SKYACTIV*-VEHICLE DYNAMICS and as such is expected to stimulate future market growth as a new-concept

control technology that uses the engine to enhance chassis performance.

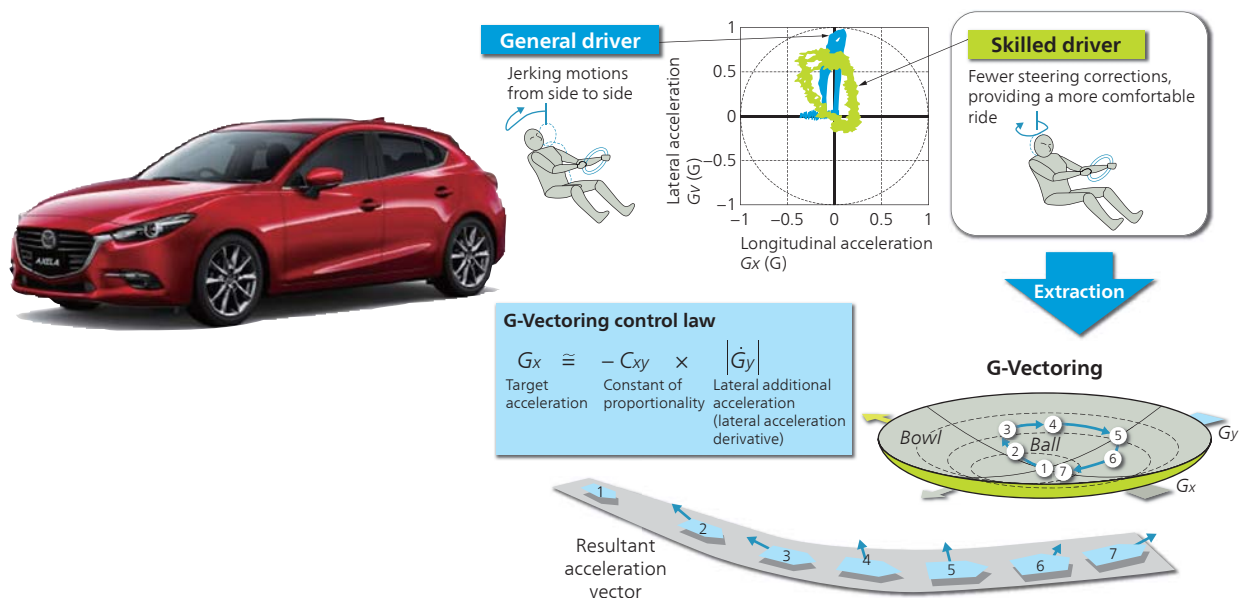
Hitachi is committed to continuing strengthening development of automotive equipment systems with the potential to improve car safety and comfort, and to help carmakers build even more appealing cars. (Hitachi Automotive Systems, Ltd.)

*See "Trademarks" on page 162.

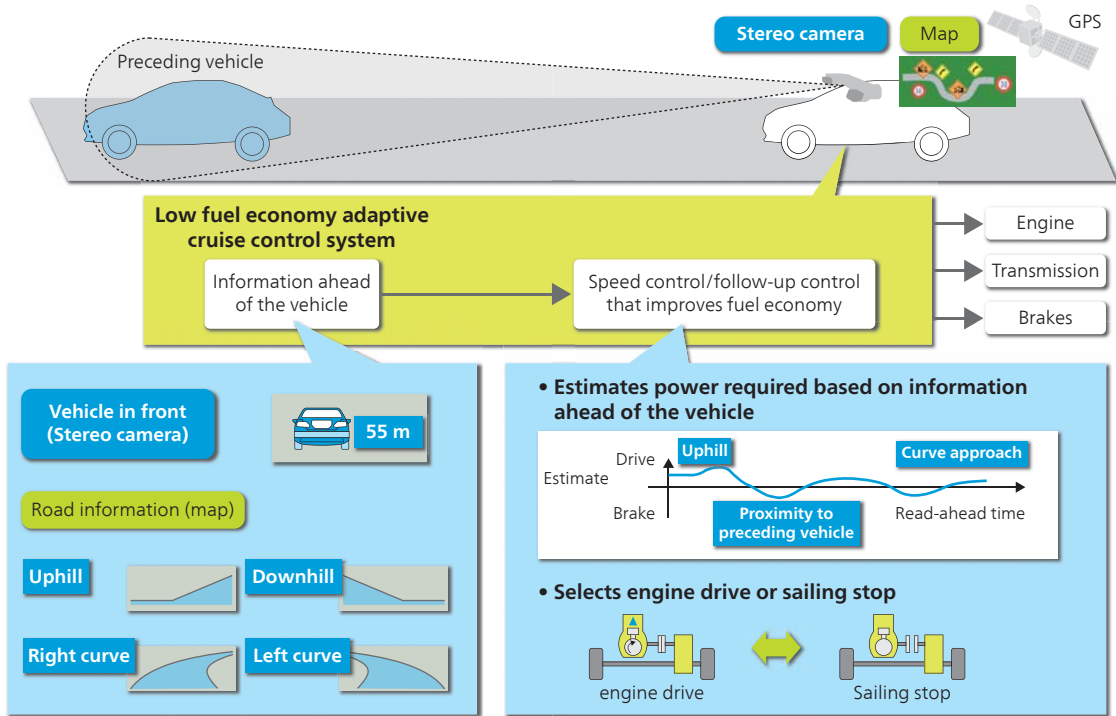
2 Preview-sailing-stop Technology

In recent years, demand for improvement in real-world fuel economy has increased, creating expectations of improvement in the efficiency of the powertrain, which includes the engine and transmission, and powertrain control based on driving conditions, such as eco drive.

As part of development of advanced driver assistance systems that balance the four objectives of safety, comfort, environment and time, the Hitachi Group has developed technology that reads the situation ahead of the vehicle from outside-world information and improves fuel economy through powertrain control based on read-ahead information. The technology known as preview-sailing-stop technology calculates



1 Mazda Axela Sport with GVC (left) and G-Vectoring concept (right)



GPS: global positioning system

2 Overview of low fuel economy adaptive cruise control system using outside-world information

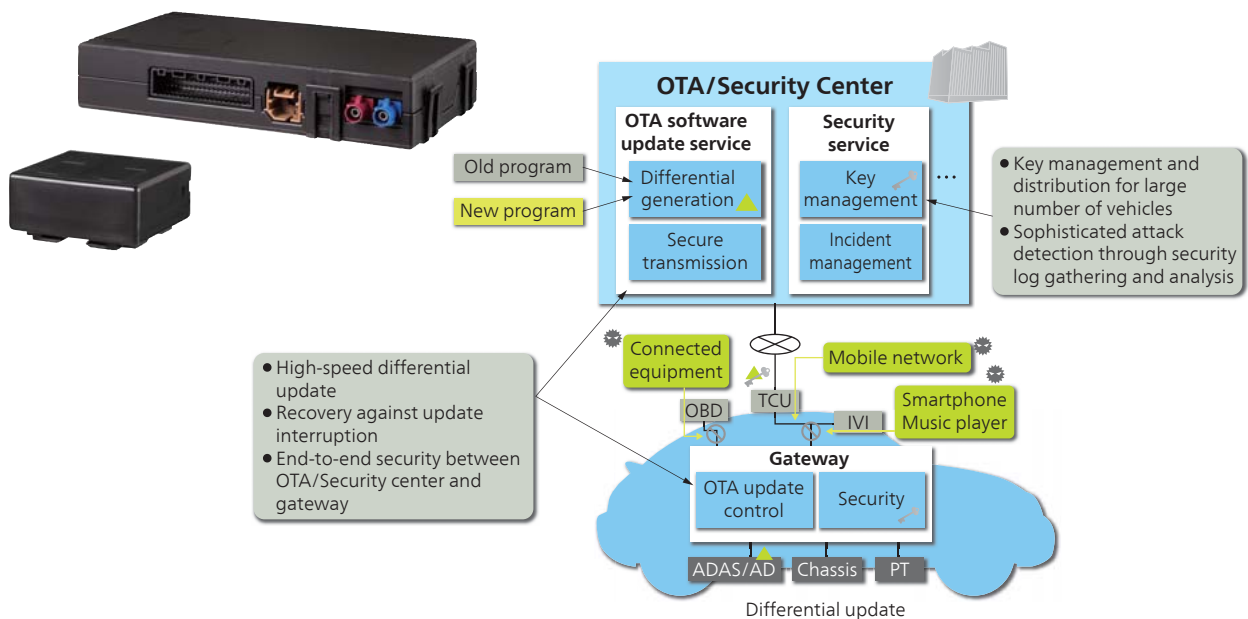
speed and distance relative to the preceding vehicle using a stereo camera and at the same time acquires the gradient and curvature of the road ahead from map information, thus estimating required output and automatically stopping the engine if output is judged unnecessary. Hitachi has also developed a low fuel economy adaptive cruise control (ACC) system that combines preview-sailing-stop technology and conventional ACC. This new system is an effective way of

conferring the added value of improvement in fuel economy on driver assistance and automated driving systems.

(Hitachi Automotive Systems, Ltd.)

3 Center and In-vehicle Gateway Technologies for OTA Software Update and Security

With the increase of connected cars and enhanced



OBD: on-board diagnostics, IVI: in-vehicle infotainment, AD: autonomous driving, PT: powertrain

3 Exterior images of TCU (top), gateway (bottom), and overview of OTA software update and security management through OTA/Security center and gateway

connectivity between vehicles and the outside world such as servers and transport infrastructure, the Hitachi Group has developed over-the-air (OTA) software update and security management technologies. The OTA software update technology improves the quality and added value of vehicles throughout the vehicle life cycle and the security management technology protects the control system domain from security threats.

These technologies will be provided as a total system, including an in-vehicle gateway and OTA/Security center services. The OTA software update technology achieves high speed and reliable updates using such technologies as differential update, which reduces the amount of communication data, and fault recovery method, which completes or restores the update even if it fails or is interrupted. The security management technology ensures security through encryption of the data and mutual authentication between the OTA/Security center and the gateway. The technology also includes key management and incident management functions.

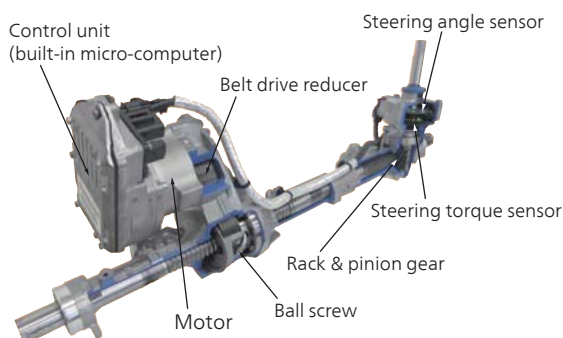
As the Hitachi Group possesses every technological element, ranging from the OTA/Security center to a telematics control unit (TCU) for wireless communication and vehicle electronic control units (ECUs) such as the gateway, Hitachi can offer the total system in a one-stop manner.

(Hitachi, Ltd., Hitachi Automotive Systems, Ltd. and Clarion Co., Ltd.)

4 Belt Drive Electric Power Steering

In today's environmentally regulated and energy conservation oriented society, the trend toward electric power steering is growing rapidly and, especially in recent years, the system is increasingly used in large vehicles.

Hitachi has now developed and mass produced belt



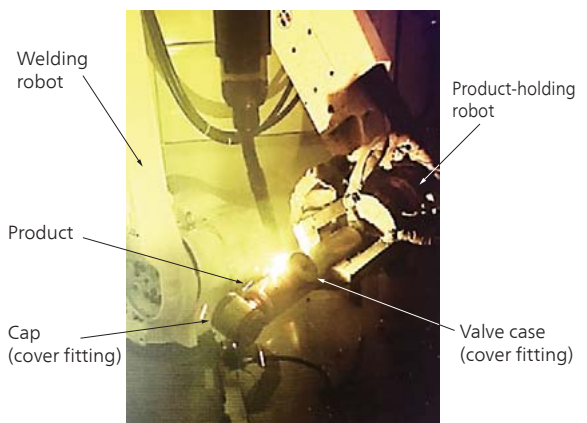
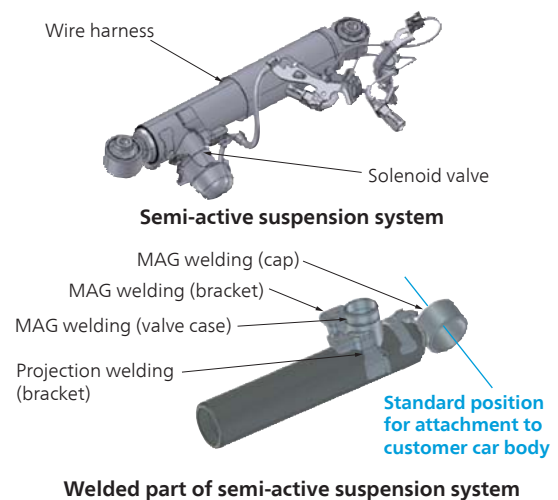
4 Belt drive electric power steering (cut model)

drive electric power steering that can be used in large vehicles. Hitachi uses a high precision ball screw that can withstand high loads as the reducer, which is the core technology of the system, and carries out submicron-level machining and precision control to reduce the operating noise. In compliance with the International Organization for Standardization (ISO) 26262 (Road vehicles – Functional Safety), Hitachi has also increased the dependability of the electrical and electronic systems by building in redundancy for all sensors and by switching from analogue to digital communication between sensors and the micro-computer.

In the future, Hitachi will develop products for autonomous cars, incorporating sensor multiplexing and system redundancy to meet new customer needs. (Hitachi Automotive Systems, Ltd.)

5 Semi-active Suspension Welding Line

Hitachi improved productivity and quality assurance for its semi-active electronically controlled suspension system, which suppresses vehicle vibrations and



5 Jigless automatic MAG welding by robot coordinated control

position changes while turning on curves, significantly improving driving comfort.

The main measures implemented are as follows.

(1) Jigless automatic metal active gas (MAG) welding by cooperative robot control

Cooperative control of three robots is adopted: the product-holding robot, the part-supplying robot and the welding robot.

(2) 100% inspection through 3D scanning

An automatic judgement/inspection machine is adopted to compare master data in 3D computer-aided design (CAD) product drawings with the shape data of the product obtained from the 3D scanner.

(3) Centralized control of products and facilities by integrated management system

A system that strictly controls the start of work, inspection and quality data for each product using CC-Link IE* is adopted.

As a result, Hitachi achieved the following results.

(1) Elimination of welding jigs and reduction of operators

(2) Improvement in the level of quality assurance for all products in terms of weld size, angle and loss of components

(3) Improvement in line utilization through centralized control of all production data

In the future, Hitachi will apply these technologies to other production lines besides the semi-active suspension production line, thus helping to improve productivity and the level of quality assurance.

(Hitachi Automotive Systems, Ltd.)

*See "Trademarks" on page 162.

6 Electric Parking Brake System

An increase in user awareness about vehicle safety and comfort in recent years and more widespread use of automatic brakes has led to a sudden increase in the adoption of electric parking brake (EPB) systems that increase design freedom in the interior layout, improve vehicle safety and can also be used as automatic brakes.

Hitachi Automotive Systems, Ltd. developed an EPB with a unique structure and began mass production for the Mazda CX-5 in November 2014. The same system is now being used on the Mazda CX-9 large sport utility vehicle (SUV).

Hitachi Automotive Systems plans to actively expand orders for the EPB, capitalizing on its superiority over rival products in terms of improved fuel economy, low operating current, reduced operating noise, and compact and lightweight design.



6 Electric parking brake system for Mazda CX-9

In the future, Hitachi will continue improving and developing the EPB to meet market and customer needs and help improve vehicle safety and comfort.

(Hitachi Automotive Systems, Ltd.)

7 48 V Lithium-ion Battery Pack for Mild Hybrid Electric Vehicles

Hitachi Automotive Systems, Ltd. developed a high output 48 V lithium-ion battery pack to improve the fuel efficiency of mild hybrid electric vehicles that use a battery and motor to provide power assistance when the vehicle is being driven by its internal combustion engine.

The newly developed 48 V lithium-ion battery pack is a highly integrated package that, in addition to the battery management system (BMS) board and battery cells, includes a relay and fuse. With excellent low-temperature characteristics and approximately 1.5 times the output density of Hitachi's previous battery cells, it is a highly reliable battery pack that, with its high-output prismatic lithium-ion cells. When assisting



7 48 V lithium-ion battery pack

the acceleration of a motor using a 48 V system, it delivers a fully sufficient torque performance for a maximum output of 10 kW or more and a maximum input of 13 kW or more (for 10 seconds in each case). Moreover, the compact design of the battery pack helps to increase the degree of installation freedom in the passenger compartment.

In the future, Hitachi will continue to contribute to the evolution of electric vehicles by strengthening lithium-ion batteries and electric powertrain components.

(Hitachi Automotive Systems, Ltd. and Hitachi Vehicle Energy, Ltd.)

8 Technology behind the Full Digital Sound Product Line-up

The Full Digital Sound (FDS) product line-up, which includes the Z3 digital sound processor, the Z7 speakers and the Z25W subwoofer, is the culmination of a five-year process by Clarion Co., Ltd. to develop dedicated large scale integration (LSI) for automotive grade.

The dedicated LSI for automotive grade had to meet various requirements such as sound pressure that can counter road noise while driving and resistance to automotive-specific external noise. It also had to

support 96 kHz/24 bit source audio to enable the reproduction of high resolution audio files of quality better than compact discs (CDs).

The Z3 series is equipped with ports for widely used connectors, including optical, USB and analogue connectors, and it upconverts all CD audio sources (16 bit/48 kHz) and analogue audio files to 96 kHz/24 bit, providing users with high quality music.

FDS system does not use an amplifier to amplify sound in the same way as an analogue system. The FDS system converts digital signals into sound, achieving full digital signal transfer from the digital source to the speakers. The 24 MHz high-output, high-velocity drive enables high-resolution sound reproduction, delivering a sharp, crisp sound and creating a warmth that will overturn the stiff image of digital sound. Another feature is the ability to reproduce large sound volume with low power consumption. The new LSI's power consumption is between 1/3 and 1/5 that of an analogue integrated circuit (IC). Considerable power savings can be expected with the replacement of familiar systems with FDS.

Hitachi will take this latest technological development as an opportunity to seek incorporation of this technology in more products.

(Clarion Co., Ltd.)



8 Full Digital Sound product line-up (Z3, Z7 and Z25W)