CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1 Introduction

Recently, the social demand for autonomous driving, safety performance, and environmental performance, and the introduction of new technologies and services such as CASE, have led to a once-in-a century period of profound transformation, and automakers are locked into continuous competition to develop these technologies.

Systems corresponding to level 2 autonomous driving, such as the Nissan ProPilot 2.0 and BMW Extended Traffic Jam Assistant, are becoming more advanced and common. An agreement on the framework document on autonomous driving proposed by Japan in conjunction with the U.S. and Europe (covering matters such as international guidelines for autonomous vehicles and schedule for drafting regulations was reached at the World Forum for Harmonization of Vehicle Regulations (WP.29) of the United Nations. Automatically operated devices have also been added to the devices covered under the safety regulations in Japan, and safety standards stipulating items such as the safety performance of autonomous vehicles and records of their operating state have been formulated.

In the area of safety, the international standard for collision mitigation braking systems in passenger vehicles, with stipulations that include meeting the prescribed braking requirements with respect to vehicles and pedestrians, has been established at WP.29. The Japanese Ministry of Land, Infrastructure Transport and Tourism (MLIT) has also announced policies on vehicle safety measures related to traffic safety emergency measures, and progress was made on the international standardization of brakes and the introduction of the standard in Japan.

Countries around the world have successively announced regulations and other environmental performance-related policies. In Japan, this includes new fuel economy standards stipulating a 32.4% improvement in passenger vehicle fuel efficiency in 2030 compared to 2016 values, as well as regulations on EVs and PHEVs.

This article describes the chassis and vehicle control technology trends focusing on the new models and technology released in 2019 in the context of these social trends. The main new models launched in and outside Japan in 2019 are shown separately in Table 1[1]. However, technologies such as electronic stability control (ESC) that are mandatory in various countries, and warning functions that are part of active safety technologies, have been omitted.

2 Suspension

2. 1. Base Suspensions

As shown in Table 1, the suspension types of new vehicle models in 2019 do not differ greatly from recent trends. The main types of front suspension continue to be the strut type for medium-sized or smaller vehicles, and the double wishbone type for larger vehicles. The main types of rear suspension are the torsion beam type for compact and smaller vehicles, and the multi-link type for larger vehicles.

Manufacturers have been optimizing the structure of suspension parts and replacing the materials in an effort to reduce weight reduction. One example is the Daihatsu Tanto, which uses the Daihatsu New Global Architecture (DNGA), and rationalizes the structure of chassis parts to reduce the number of parts[2]. Another example is the BMW 3 Series that adopts an aluminum alloy for the rear hub support.

Fluid stoppers that use hydraulic pressure are an example of a technology that is increasingly adopted to enhance performance. A hydraulic rebound stop damper, which mitigates shock when the rebound stroke extends to its full length and provides both a sporty dynamic performance and high level of comfort, has been adopted in the rear suspension of the BMW 3 Series mentioned earlier[3].

Table 1 Chassis and Vehicle Control Systems of New Vehicles Launched in 2019

Market	Manufac-turer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/ Rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Suzuki	Hustler	HEV	FF/AWD	MacPherson strut/ torsion beam (isolated trailing link)	Grip Control/Hill Descent Control/Dual Camera Brake Support/False Start Prevention Function/Lane Departure Prevention Function/Lane Departure Warning Function/Weaving Alert/Preceding Vehicle Start Notification Function/Adaptive Cruise Control/Back-up Brake Support/ Rear False Start Prevention/Emergency Stop Signal/Hill Hold Control
	Daihatsu	Tanto	ICE	FF/AWD	MacPherson strut/ Torsion beam (3-link)	Smart Assist (Crash-avoidance Support Braking Function/Lane Departure Warning Function/Lane Departure Preventive Control Function/Erroneous Start Prevention Function with Brake Control (Forward, Reverse)/Preceding Vehicle Start Notification Function)/Adaptive Cruise Control (ACC) with Full-speed Following Function/Lane Keeping Control (LKC)/Hill Hold System
		Rocky	ICE	FF/AWD	MacPherson strut/ Torsion beam	Smart Assist (Crash-avoidance Support Braking Function/Lane Departure Warning Function/Lane Departure Preventive Control Function/Erroneous Start Prevention Function with Brake Control (Forward, Reverse)/Preceding Vehicle Start Notification Function)/ Adaptive Cruise Control (ACC) with Full-speed Following Function/ Lane Keeping Control (LKC)/Hill Hold System
	Honda	N-WGN	ICE	FF/AWD	MacPherson/Axle (De Dion)	Honda Sensing (Collision Mitigation Braking System (CMBS), Erroneous Start Prevention, Pedestrian Collision Mitigation Steering System, Lead Car Departure Notification System, Road Departure Mitigation System/Adaptive Cruise Control (ACC) with Low-Speed Follow/Lane Keeping Assist System (LKAS), Rear Erroneous Start Prevention)/Automatic Brake Hold/Agile Handling Assist
	Mazda	Mazda3	ICE/HEV	FF/AWD	MacPherson strut/ Torsion beam	Smart Brake Support (SBS)/Smart Brake Support [Reverse] (SBSR)/ Smart Brake Support [Rear Crossing] (SBS-RC)/Acceleration Control for AT [Forward/Reverse]/Mazda Radar Cruise Control (MRCC)/ Lane Keep Assist System (LAS)/Cruising & Traffic Support (CTS)/ Lane Departure Warning System (LDWS)/Hill Launch Assist (HLA)/ G-Vectoring Control Plus (GVC Plus)
		CX-30	ICE/HEV	FF/AWD	MacPherson strut/ Torsion beam	Smart Brake Support (SBS)/Smart Brake Support [Reverse] (SBSR)/ Smart Brake Support [Rear Crossing] (SBS-RC)/Acceleration Control for AT [Forward/Reverse]/Mazda Radar Cruise Control (MRCC)/ Lane Keep Assist System (LAS)/Cruising & Traffic Support (CTS)/ Lane Departure Warning System (LDWS)/Hill Launch Assist (HLA)/ G-Vectoring Control Plus (GVC Plus)
	Mitsubishi	eK Wagon/eK X	ICE	FF/AWD	Strut/Torsion beam (Torque arm 3-link)	e-Assist (Forward Collision Mitigation system (FCM)/Emergency assist for pedal misapplication/Lane Departure Warning (LDW) & Lane Departure Prevention (LDP))/MI-PILOT (Adaptive Cruise Control (ACC)/Lane Keep Assist (LKA))/Hill Start Assist (HSA)
	Nissan	Skyline	ICE/HEV	FR/AWD	Double wishbone/ Multi-link	Direct Adaptive Steering/Active Lane Control/ProPilot 2.0/Intelligent Emergency Braking/Intelligent Cruise Control/Intelligent pedal (following distance keeping assist system)/Intelligent LI (lane departure prevention assist system)/Lane Departure Warning (LDW)/Intelligent BSI (back collision prevention assist system)/Intelligent BUI (backup collision intervention system)/Intelligent Dynamic Suspension (electronically-controlled shock absorber)/Emergency Assist for Pedal Misapplication
	Toyota	Rav4	ICE/HEV	FF/AWD	MacPherson strut/ Double wishbone	Toyota Safety Sense (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection [day and/or night] and with Cyclist Detection [day]/millimeter wave radar and monocular camera), Lane Tracing Assist (LTA), Radar cruise control (with all-speed tracking function))/Advance Car Start Notification function (TMN)/Rear Cross-Traffic Braking [Parking Support Brake (rear crossing vehicles)]/Downhill Assist Control/Hill-Start Assist Control
		Supra	ICE	Front right	MacPherson strut/ Multi-link	Active variable suspension system (AVS)/Pre-collision Safety (Collision Avoidance Assist Type with Pedestrian Detection [day] and with Cyclist Detection [day]/Millimeter wave radar and monocular camera)/Lane Departure Alert (with Steer Assist)/Radar cruise control (with all-speed tracking function)/Hill-Start Assist Control
	Audi	Q8	ICE	AWD	Wishbone/Wishbone	Adaptive air suspension/Adaptive drive assist/Emergency assist/Active lane assist/Audi pre sense city/Turn assist/Hold assist/All-wheel steering
		A8	ICE/MHEV	AWD	Wishbone/Wishbone	Predictive active suspension/Audi pre sense rear/Adaptive drive assist/Active lane assist/Audi pre sense city/Turn assist/Hold assist/ Dynamic all-wheel steering
	BMW	3 Series	ICE/PHEV	FR/AWD	Double-joint spring strut/5-link rear suspension	CBC/Cornering Brake Control/Active Cruise Control (with Stop & Go function)/Steering and lane control assistant/Lane Departure Warning (Lane departure warning system)/Active side collision protection/Collision avoidance and collision mitigation brakes (with accident avoidance assistant)/Rear collision warning function/Extended Traffic Jam Assistant/Emergency stop assistant
		Z4	ICE	Front right	Double-joint spring strut/5-link rear suspension	CBC/Cornering Brake Control/Active Cruise Control (with Stop & Go function)/Lane Departure Warning (Lane departure warning system)/Collision avoidance and collision mitigation brakes/Rear collision warning function

Table 1 Chassis and vehicle control systems of new vehicles launched in 2019 (cont.)

Market	Manufac-turer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/ Rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Peugeot	508 /508 SW	ICE	FF	MacPherson strut/ Multi-link	Active Safety Brake (collision mitigation brake)/Lane keeping assist/ Active cruise control (with stop & go function)/Lane Positioning Assist/Active Blind Spot Monitoring System/Active suspension
Outside Japan	BMW	X2	ICE	FF/AWD	Single-joint spring strut/Multi-link	Lane Departure Warning [Lane departure warning system]/Frontal Collision Warning function/Collision avoidance and collision mitigation brakes/Active Cruise Control (with Stop & Go function)
	DS	DS 3 Crossback	ICE	FF	MacPherson strut/ Torsion beam	Active Safety Brakes (collision mitigation brakes)/Lane keeping assist/DS Drive Assist (Active Cruise Control/Traffic jam assist/Lane positioning keep)/Active Blind Spot Monitor/Hill Start Assistance
	Mercedes-Benz	GLE	ICE/MHEV	4 WD	Double wishbone/ Multi-link	Adaptive distance assist DISTRONIC (with automatic restart function)/Active Braking Assist (with pedestrian/running out/oncoming vehicle in right-turn detecting function)/PRE-SAFE/PRE-SAFE PLUS (Rear-end collision warning system with damage mitigation brake)/ Congestion Emergency Braking/Active Blind Spot Assist (with warning function when getting out of vehicle)/Active Lane Keeping Assist/Active Steering Assist/Active Lane Change Assist/Active Emergency Stop Assist/Emergency Avoidance Assist System/Downhill Speed Regulation (DSR)/AIRMATIC air suspension system
	Porsche	Cayenne Coupé	ICE/PHEV	AWD	Multi-link/Multi-link	Collision and brake assist/Lane Keeping Assist/Adaptive cruise control/Porsche 4 D Chassis Control/Porsche Dynamic Chassis Control (PDCC)/Adaptive air suspension including Porsche Active Suspension Management (PASM)/Rear-axle steering
	Volkswagen	Golf	ICE	FF/AWD	MacPherson /Multi-link	Auto emergency braking Front Assist with pedestrian and cyclist monitoring/Anti-Slip Regulation (ASR)/Automatic Post-Collision Braking System/Electronic Differential Lock (XDS+)/Adaptive cruise control (ACC)/Lane Assist & Traffic Jam Assist/Travel Assist
	Honda	Passport	ICE	FF/AWD	MacPherson Strut/ Multi-Link	Honda SENSING (Collision Mitigation Braking System (CMBS)/Road Departure Mitigation System (RDM)/Adaptive Cruise Control (ACC)/ Lane Keeping Assist System(LKAS)/Lane Departure Warning (LDW))
	Ford	Escape	ICE/HEV/ PHEV	FF/AWD	MacPherson strut/ double lateral link semi-trailing arms	Pre-Collision Assist with Automatic Emergency Braking (AEB)/Curve Control/Adaptive Cruise Control with Stop-and-Go and Lane Centering/Lane-Keeping System/Evasive Steering Assist
		Explorer	ICE/HEV	FR/AWD	MacPherson strut/ Multi-link	Hill Descent Control, Trailer sway control/AdvanceTrac with Roll Stability Control/Pre-Collision Assist with Automatic Emergency Braking (AEB)/Lane-Keeping System/Evasive Steering Assist/Intelligent Adaptive Cruise Control/Reverse Brake Assist

2. 2. Suspension Controls

No notable changes were observed in suspension control devices, and the recent trend of adopting electronically controlled suspension, mainly in high-priced luxury vehicles, continued. The use of the information obtained from the various sensors applied in advanced driver assistance systems (ADAS) is expected to increase the adoption of electronically controlled suspensions offering appealing added value. The higher voltages of vehicle powertrain systems are leading to control based on the use of high output motors in suspension control systems. More specifically, the Audi A8 is equipped with a mechanism called predictive active suspension. This mechanism achieves a stable cornering posture and ideal ride comfort by continuously predicting the road surface conditions and driving states based on the same vehicle information used in the cameras, laser scanners, and millimeter-wave radars of ADAS, and optimally controlling the vehicle height and damping characteristics. Upon predicting a potential side collision, the system uses the 48 V high power drive unit to instantly raise the vehicle height, thereby mitigating the impact on occupants and increasing passive safety(4).

Furthermore, control that takes SUV-specific uses into account has also been introduced. The Mercedes-Benz GLE is equipped with an active suspension system called E-Active Body Control that achieves comfortable ride comfort and sportiness by independently controlling the air spring and damping force to each wheel. In addition, this system improves rough road performance in off-road situations characteristic of SUVs through, for example, a function that improves traction by driving an electric pump using a high voltage power supply and moving the suspension up and down several times when the vehicle is stuck in a sand dune or other terrain(5).

In conjunction with advances in active control technologies, manufactures are also developing semi-active control technologies that not require a dedicated sensor for shock absorbers, and real-world applications are expected to grow in the future.

3 Steering

Electric power steering (EPS) was first adopted in light-duty vehicles to improve fuel efficiency, and has been expanding to medium-duty and larger vehicles. At the same time, EPS has become an essential component for improving ADAS and autonomous driving technologies, and has therefore started to make see adoption in commercial and other vehicles.

The use of steer-by-wire systems and other fully by-wire systems without a mechanical link is expected to grow to both further vehicle technological advances and improve in-vehicle comfort during travel.

Supplementary electronic control other than the basic power assist initiated by EPS have been actively used to address various vehicle-based requirements. However, from the viewpoint a person driving the vehicle, excessive control system intervention will make steering unnatural, and the importance of the mechanical area is being given a second look. This is expected to become a key point in differentiation by OEMs and EPS manufacturers based on the approach they take to steering feel and how they balance it with cost reductions.

Moreover, in addition to improved operability for various devices, driving position is becoming increasingly important in realizing accurate driver operation and providing safe and secure driving. Although only tilt steering had been mainstream in conventional compact and smaller vehicles, tilt & telescopic steering has been adopted in compact and mini-vehicles such as the Honda N-WGN, Fit, and Shuttle[6], the Toyota Yaris[7], and the Suzuki Swift[8]. The number of vehicles offering an optimal driving position for various drivers is increasing.

4 Brakes

Demands place on braking systems are changing as safety and environmental needs increase, recently launched new models have systems that use various electronic control technologies.

With the tailwind of regulations based on the global goal of reaching zero traffic accident fatalities, autonomous emergency braking (AEB) systems are becoming more widespread and achieving higher performance. In addition, the number of models with level 2 automated driving functions achieving simultaneous longitudinal speed control and steering control at the same time is increasing. These functions can be achieved by conventional braking systems that consist of vacuum booster and ESC, and are expected to expand to even more models in the future. For level 3 autonomous driving, however, raising the safety standards that braking systems must satisfy is considered necessary. For example, realizing functions using a different structure—known as redundancy—in the event of a partial failure in the braking system, is considered crucial, and parts manufacturers are also proposing various systems.

On the environmental front, the electrification of the powertrain seen in HEVs, PHEVs, and EVs, as well as expanded application of regenerative braking is advancing in light of the growing need to reduceCO_2. Compared to a few years ago, electronic control technologies such as electric negative pressure pump, electric booster, and electric hydraulic brake-by-wire are increasingly being added to braking systems to adapt them to these powertrains. Numerous vehicles equipped with a brake-by wire system consisting of a single unit that detects driver intent, generates hydraulic pressure, and adjusts that pressure have been released, particularly in the last few years. The superior responsiveness of such systems compared to conventional systems relying on a vacuum booster and ESC, and the mechanical independence of the fluid pressure generation source from the driver pedal operation, allow a higher degree of freedom in the control of inputs and outputs. This makes it a promising system for applications involving cooperative control with systems other than the brakes, such as driving support systems and regenerative braking systems, and its expansion to other models is anticipated.

5 Vehicle Controls

With respect to advanced safety technologies, the details of AEB standards and attendant obligations have been released. The installation of an AEB system that meets the performance standards will be mandatory for vehicles produced in Japan sold in or after November 2021. In addition, a certification program for systems that suppress sudden unintended acceleration due to pedal misapplication has been announced, as have the attendant performance requirements and test contents. This certification applies not just to new vehicles, but also to existing vehicles retrofitted with such as system. Moreover, guidelines for technical requirements such as those concerning intelligent speed assistance (ISA) have been formulated to promote the development of new advanced

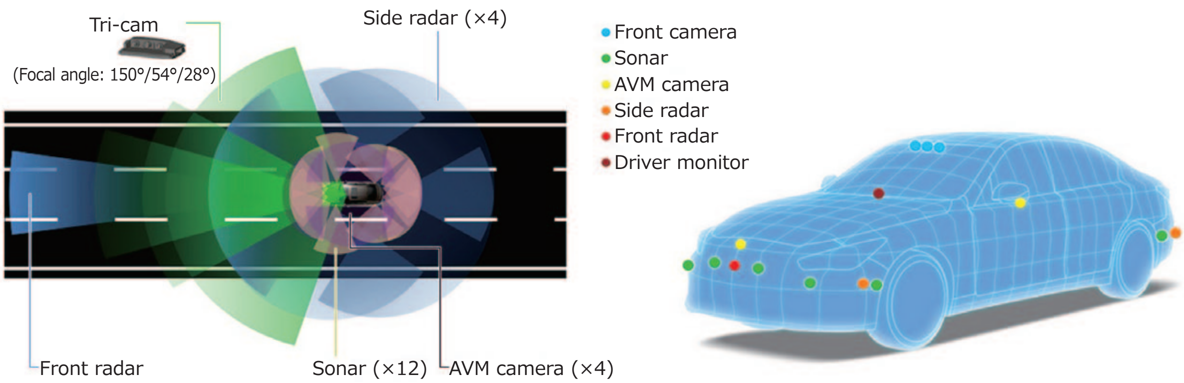

Fig. 1 360-degree Sensing of Vehicle Surroundings in Nissan ProPilot 2.0

safety technologies and to limit accidents caused by excessive speed.

The Nissan Skyline has equipped with a system called ProPilot 2.0 that enables hands-off driving. This upgrade to the original ProPilot system offering autonomous driving in a single expressway lane has become a mass-produced autonomous driving system capable of performing automatic lane changes and driving in multiple lanes. It is also the first system in the world to use high-precision map data to enable hands-off driving when cruising in a single lane on the expressway along a route entered in the navigation system. Seven cameras, including a front trinocular camera, five radars, and twelve sonars are used to detect road lane markers, signs, and surrounding vehicles. Furthermore, the 3D high definition map data complements route information with various centimeter-level highway road structure information, including slopes and line color. Tracing performance has been improved by combining various information from the 360-degree sensing of the vehicle surroundings (Fig. 1)[9].

Several BMW models have been equipped with the Extended Traffic Jam Assistant. These models are equipped with a three-camera bundle for vehicle peripheral monitoring, medium-distance detection, and long-distance detection, as well as a state-of-the-art image processor, which achieve more accurate lane keeping, predict danger at longer distances, and predict peripheral danger from a larger angle of view[3].

To realize hands-off driving, both Nissan and BMW use a trinocular camera for the front detection center. Tesla is also mass producing an autonomous driving function called Autopilot that uses a trinocular camera. Automakers are expected to adopt more stereo, trinocular, or multiple lens sensing cameras to realize even more advanced autonomous driving technologies. More stable vehicle control achieved through the use of 3D high definition map data and other higher precision surroundings and vehicle information is anticipated to lead to further improvement in autonomous driving technology performance.

References

・Daimler AG global website, https://media.daimler.com/