CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1 Introduction

Recently, the social demand to reduce the environmental impact of vehicles while also enhancing safety has been increasing. In addition, as the transition to an era of automatic driving is becoming a real possibility creating rising expectations, automakers are locked into continuous competition to develop these technologies.

Regarding environmental performance, as internal combustion engine (ICE) vehicles are being complemented with the spread of hybrid vehicles (HVs) and plug-in hybrid vehicles (PHEVs), electric vehicles (EVs) and fuel cell vehicles (FCVs) are also making headway into the market as the necessary infrastructure becomes established. Nissan has released the NOTE e-Power as a new form of electric vehicle. Instead of relying on an external charging system, this vehicle is installed with a system that can only refuel the engine dedicated power generation. In addition, the user can experience EV driving with a feel similar to that of driving a gasoline-powered vehicle. Honda has released its second-generation FCV. CFRP was used to reduce the weight of the hydrogen tank. Amidst calls for improved fuel economy and an extended cruising range, technologies to reduce weight and rolling resistance are being developed for the chassis.

Active safety assessments carried out by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) regarding collision mitigation braking systems, lane deviation warning, and rear view information, started in 2014. Partially in response to the move toward making these systems mandatory on new models, active safety technology was installed in all new models released in Japan in 2016, including mini-vehicles.

Automated driving is being developed as a specific application of future active safety technology. Targets for the 2020 Tokyo Olympic Games have been set for the intelligent transportation systems (ITS) concept involving the integration of the public and private sectors, and development is expected to accelerate further.

This article describes the chassis and vehicle control technology trends focusing on the new models and technology released in 2016. The main new models launched in and outside Japan in 2016 are shown separately in Table 1[1][2]. Technologies such as 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 models in 2016 follow recent trends and present nothing new.

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.

Due to automakers adopting large-scale platforms, there is a continuing trend of standardizing suspension types of rear suspensions. The TNGA-based Toyota C-HR, like the Prius, has switched to a multi-link rear suspension (Fig. 1). Trailing is used to optimize the wheel trajectory, increased longitudinal compliance steer improves ride comfort, and increased lateral force steer enhances stability[3]. The Honda CR-V that likewise reformed its platform has followed the same path as the Civic launched in 2015 and also adopted a multi-link rear suspension. Other compact and smaller vehicles still use torsion beam axle (TBA) suspensions.

With respect to weight reduction, the Subaru Impreza, built on the Subaru global platform, has adopted aluminum front and rear hub carriers and raised environmental performance, reducing unsprung weight in an effort to improve maneuverability and ride comfort.

2. 2. Suspension controls

Suspension control elements include springs, shock absorbers and stabilizers. There were no notable changes in control devices, but in line with recent trends, air sus-

Table 1 Chassis and vehicle control systems of new vehicles launched in 2016

Market	Manufacturer/ brand	Name of vehicle model	Category	Drivetrain type	Drive system	Suspension type Front/Rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Suzuki	Ignis	Compact	MHEV	FWD/AWD	Strut/TBA (3 link)	Dual Camera Brake Support (Automatic Braking Function, False Start Preventive Function/Hill Descent Control/Grip Control, Hill Hold Control)
		Baleno	Lower-Medium	ICE	FWD	Strut/TBA	Radar Brake Support II (Automatic Braking Function), Hill Hold Control
	Subaru	Impreza	Medium	ICE	FWD/AWD	Strut/Multi-Link	EPB/EyeSight ver. 3 (Pre-collision Braking System, Cruise Control with Full-speed Following Mode, Active Lane Keep Pre-collision Throttle Management, Pre-collision Throttle Management when Reversing), Active Torque Vectoring, Vehicle Dynamics Control range
	Daihatsu	Boon	Compact	ICE	FWD/AWD	(3 link)	Smart Assist II (Crash-avoidance Support Braking Function, False Start Preventive Control Function (Forward/Rear)), Hill Hold System
		Hijet Caddie	Mini-vehicles	ICE	FWD/AWD	(3 link)	Smart Assist II (Crash-avoidance Support Braking Function, False Start Preventive Control Function (Forward/Rear)), Hill Hold System
		Thor	Mini-vehicles	ICE	FWD/AWD	(3 link)	Smart Assist II (Crash-avoidance Support Braking Function, False Start Preventive Control Function (Forward/Rear)), Hill Hold System
	Toyota	C-HR	SUV	ICE/HEV	FWD/AWD	Strut/Multi-Link	EPB, Toyota Safety Sense P, (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection), Lane Departure Alert (with Steering Control)), Radar Cruise Control (with Brake Control/Full-speed Following Function), S-VSC (Steering-assisted Vehicle Stability Control), Hill Start Assist Control
		Prius PHV	Compact	PHEV	FWD	Strut/Multi-Link	Toyota Safety Sense P, (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection), Lane Departure Alert (with Steering Control)), Radar Cruise Control (with Brake Control/Full-speed Following Function), S-VSC (Steering-assisted Vehicle Stability Control), Hill Start Assist Control
	Nissan	Serena	Minivan	ICE	FWD/AWD	Strut/TBA (Multi-Link)	ProPilot, Intelligent Parking Assist, Intelligent Emergency Braking, Lane Departure Prevention Assist System, Emergency Assist for Pedal Misapplication, Hill Start Assist
		Note e-Power	Compact	REV	FWD	Strut/TBA	Intelligent Emergency Braking, Emergency Assist for Pedal Misapplication
	Honda	Clarity Fuel Cell	Medium	FCV	FWD	Strut/Multi-Link	Honda Sensing (Collision Mitigation Braking System, Pedestrian Collision Mitigation Steering System, Adaptive Cruise Control, Lane Keeping Assist System, Road Departure Mitigation System, False Start Preventive Function), Hill Start Assist Function
		Freed	Minivan	ICE/HEV	FWD/AWD	Strut/TBA	Honda Sensing (Collision Mitigation Braking System, Pedestrian Collision Mitigation Steering System, Adaptive Cruise Control, Lane Keeping Assist System, Road Departure Mitigation System, False Start Preventive Function), Hill Start Assist Function
Outside Japan	Acura	CDX	SUV	ICE	FF/AWD	Strut/TBA	EPB/Control Damper/Agile Handling Assist/Automatic Brake Hold
		NSX	Sports	HEV	M・AWD	DW/Multi-Link	EPB/Active Magnetorheological Dampers/Brake Assist/Sport Hybrid SH-AWD/Integrated Dynamics System/Agile Handling Assist /Automatic Brake Hold
	Aston Martin	DB11	Luxury Sports	ICE	FR	DW/Multi-Link	EPB/Adaptive Damping System/Emergency Brake Assist/Positive Torque Control/Dynamic Torque Vectoring/Launch Control
	Audi	Q2	SUV	ICE	FF/AWD	Strut/Multi-Link	Dynamic suspension/Emergency Braking/Active Lane Assist/Multi-collision brake assist/Adaptive Cruise Control
	BMW	5 Series	Upper Middle	ICE / PHEV	FR	DW/Multi-Link	EPB/Variable Damper Control/Active Roll Stabilization/Integral Active Steering/Active Cruise Control/xDrive/Remote Control Parking function
	Mercedes-Benz	E-Class	Upper Middle	ICE	FR/AWD	DW/Multi-Link	EPB/Air Body Control/Active Brake Assist /Active Emergency Stop Assist/Distance Pilot DISTRONIC & Steering Pilot/DISTRONIC PLUS/Active Lane Change Assist/Parking Pilot/Active Lane Keeping Assist/Parking Pilot/Evasive Steering Assist Function
	Bugatti	Chiron	Sports	ICE	M・AWD	DW/DW	Adaptive Shock Absorbers/Chassis Height Control
	Chevrolet	Malibu	Medium	ICE	FF	Strut/Multi-Link	EPB/Low Speed Forward Automatic Braking/Lane Keep Assist/Semi-Automatic Parking Assist/Adaptive Cruise Control
		Bolt EV	Compact	EV	FF	Strut/TBA	EPB/Low Speed Forward Automatic Braking/Lane Keep Assist/Semi-Automatic Parking Assist
	Chrysler	Pacifica	Minivan	ICE/HEV	FF	Strut/Multi-Link	Active Braking/Lane Keep Assist/Parallel and Perpendicular Park Assist/Adaptive Cruise Control
	Citroën	C3	Compact	ICE	FF	Strut/TBA	Emergency Braking Assistance/Hill Start Assist function

Table 1 Chassis and vehicle control systems of new vehicles launched in 2016 (cont.)

Market	Manufacturer/brand	Name of vehicle model	Category	Drivetrain type	Drive system	Suspension type Front/Rear ( ): suspension for AWD layout	Vehicle control systems
Outside Japan	Citroën	E-Méhari	Compact	EV	FF	Strut/TBA	
	Ford	Ka+	Compact			Strut/TBA	Hill Start Assist
	Honda	CR-V	SUV	ICE	FF/AWD	Strut/Multi-Link	EPB/Collision Mitigation Braking System/Lane Keeping Assist System /Road Departure Mitigation System /Adaptive Cruise Control
	Hyundai	Ioniq	Medium	HEV/PHEV/EV	FF	Strut/Multi-Link	Autonomous Emergency Braking/Lane Keeping Assist System/Smart Cruise Control/Hill-start Assist Control
	Jaguar	F-Pace	SUV	ICE	AWD	DW/Integral Link	EPB/Autonomous Emergency Braking/Torque Vectoring/Lane Keep Assist/Adaptive Cruise Control
	Maserati	Levante	SUV	ICE	FF/AWD	Strut/Multi-Link	EPB/Air Adaptive Suspensions/Electronically Variable Active-Damping Suspension System/Brake Assistance System/Adaptive Cruise Control/Hill Descent Control/Hill holder
	Infiniti	QX30	SUV	ICE	FF/AWD	Strut/Multi-Link	Forward Emergency Braking/Vehicle Dynamic Control
		Q60	Medium	ICE	FR/AWD	DW/Multi-Link	Continuously variable electronically controlled shock absorbers/Forward Emergency Braking/Active Lane Control
	Opel	Mokka X	SUV	ICE	FF/AWD	Strut/TBA	Hill start assist
	Peugeot	3008	SUV	ICE	FF	Strut/TBA	EPB/Emergency Braking Assistance/Adaptive Cruise Control/Lane Keeping Technologies/Advanced Grip Control/Hill Assist Descent Control/Hill Start Assist
	Porsche	Panamera	Sports	ICE/HEV	FR/AWD	DW/Multi-Link	Adaptive air suspension/Porsche Dynamic Chassis Control/Porsche Torque Vectoring Plus/Porsche Dynamic Chassis Control/Porsche Stability Management/Porsche Active Suspension Management/Power steering Plus
	Renault	Scénic	MPV	ICE	FWD	Strut/TBA	EPB/Active Emergency Braking System/Lane Keeping Assist/Hands Free Parking/Adaptive Cruise Control
		Koleos	SUV	ICE	FF	Strut/Multi-Link	EPB/Advanced emergency braking system/Hill Start Assist
	Skoda	Kodiaq	SUV	ICE	AWD	Strut/Multi-Link	Adaptive Dampers/Dynamic Chassis Control/Multi-Collision Brake

Fig. 1 Toyota Double Wishbone Rear Suspension (The figure shows the suspension of the Prius[4])

pension and electronically controlled shock absorbers were adopted mainly in high-class sedans and SUVs.

The Mercedes-Benz E-Class is equipped with an air body control suspension. The vehicle height automatically lowers during high speed cruising, which improves handling performance, aerodynamic characteristics and fuel efficiency. A constant handling performance is achieved by a self-leveling function, which compensates for vehicle body posture changes resulting from differences in the number of occupants[5].

In terms of technology that will make electronically-controlled shock absorbers more widespread, the Acura CDX eliminates dedicated electronically-controlled shock absorber sensors such as the stroke or G sensors, by estimating the suspension stroke state quantity from the difference between the existing wheel speed sensor and speed sensor CAN signals, facilitating the introduction of the system. There have also been studies on similar technologies[6] carried out by other automakers.

3 Steering

Electric power steering (EPS) was originally adopted as a technology to improve fuel efficiency. However, its conventional auxiliary functions of electrically assisting driver steering effort have, in conjunction with the increasing need for safety driving support, been shifting to functional requirements to more actively support steering functions, and EPS is expected to meet more advanced requirements.

Along with the recent rapid advancement of technologies for advanced driver assistance systems (ADAS) and autonomous driving (AD) by car and parts manufacturers, EPS is becoming a promising and essential system in

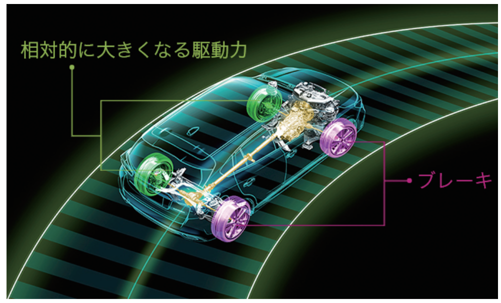

Fig. 2 Subaru Impreza Active Torque Vectoring[7]

terms of upcoming advances in automation and electrification.

The mainstream systems are column assist EPS in compact or smaller vehicles, and rack assist EPS in medium or larger vehicles. The adoption of dual pinion EPS, as well as belt drive EPS, which is adapted to high output levels, is increasing.

Addressing reliability design in the unlikely event of malfunction, particularly for heavier vehicles, is being emphasized as high output power EPS is becoming more prevalent. Recently, vehicles with systems featuring redundancy in the assist motors are being launched. The adoption of EPS systems with redundant designs can be expected to increase due to the requirements for both the reliability design of the EPS assist function and of the system reliability design imposed by automation. Further advances are expected in steering functions that use these systems in the ADAS and AD fields, including lane departure prevention control, lane centering functions, active cruise control, and automatic parking functions.

4 Brakes

As various countries have made electronic stability control (ESC) mandatory, the application of new added value technology for this system has been increasing.

The active torque vectoring installed in the Subaru Impreza acts as a mechanism that further enhances emergency evasive maneuvering performance through a relative increase in drive power on the outer ring side achieved by adding braking force to the inner ring side during cornering to enhance cornering performance (Fig. 2).

Among other examples of applied technologies, it is no exaggeration to say that the Hill-Start Assist function, which has been installed in most of the new models launched in Japan, including mini-vehicles, has become a generalized technology.

The installation of an electronic parking brake (EPB) has become more widespread, particularly in medium-sized or larger vehicles and SUVs. In Japan, this system was adopted by the Subaru Impreza and Toyota CH-R in 2016.

The types of regenerative-friction brake coordination systems in HEVs, PHEVs and EVs include electric hydraulic brakes boosted using the hydraulic pressure accumulated in the motor, an electric servo mechanism that boosts the master cylinder via the motor and ball screw, and a system that replaces reliance on the engine negative pressure with an electric vacuum pump combined with a conventional brake system. The Honda Freed is equipped with an electric servo system as well as a brake pedal with a link mechanism, which provides a more natural braking feel[8].

5 Vehicle control

This section discusses driving safety support systems and automated driving technologies. The Public-Private ITS Initiatives & Roadmap 2016 specifies that, from a social perspective, Japan aims to build "the world's safest road traffic society" by 2020. With the development and spread of automated driving systems, as well as the establishment of a data infrastructure, this will be followed up with the building and maintaining of "the world's safest and smoothest road traffic society" by 2030. From an industrial perspective, Japan aims to expand the export of ITS-related vehicles and infrastructure via the collaboration of the public and private sectors. The roadmap also clearly indicates the aim of becoming a global hub of innovation regarding automated driving systems (including the preparation of data infrastructure) after 2020. Prime Minister Abe stated, "We will realize transport services and automated driving on highways via unmanned autonomous driving systems for the 2020 Tokyo

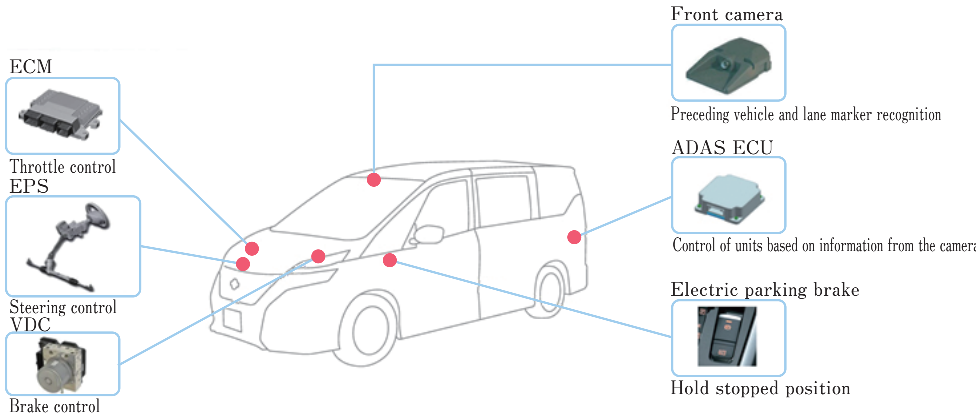

Fig. 3 Configuration of the Nissan ProPilot system[9]

Olympic and Paralympic Games. Therefore, by 2017, we will develop the required systems and infrastructure, including the implementation of demonstrations." Based on this statement, driving safety support systems and automated driving systems will be redefined, and the expected timing for the commercialization of Level 4 remote unmanned automated driving transport services in a dedicated space was reviewed to 2020, while the target for non-remote fully automated driving systems was set to 2025. With countries around engage in an industrial policies race, automakers are locked into continuous competition to develop these technologies.

Driving safety support systems and active safety technologies have spread rapidly in recent years, and are found in the models launched in 2016, including mini-vehicles. In addition to the collision mitigation braking system, lane departure alert, and rear view information systems subject to active safety performance assessments, erroneous start prevention technology and preceding vehicle start notification function have become standard functions. There are also minivans or larger vehicles that are installed with active cruise control. The Subaru Impreza equipped with EyeSight ver. 3 improves safety by performing color imaging in the stereo camera to recognize the brake lamp of the vehicle ahead[7]. In addition, the Mercedes-Benz E-Class is equipped with an emergency evasive maneuvering auxiliary system which helps the driver steer when it detects a risk of collision with pedestrians crossing the road ahead of the vehicle[5].

Nissan launched the Serena as the first model in Japan featuring automated driving. The system, called ProPilot, can (a) maintain vehicle speed when there is no preceding vehicle, (b) follow, stop and hold the stopped position when there is a preceding vehicle, (c) stay in the center of the lane (steering control) on straight lines and in corners with lane markings on both sides of the vehicle, and (d) perform automated driving during traffic jams. The system consists of a monocular camera and a dedicated ECU added to a conventional system and is made possible through cooperative control of the acceleration, steering and ESC functions (Fig. 3).

The Mercedes-Benz E-Class features Active Lane Change Assist, a system that monitors the vehicle periphery and verifies that there is no risk of collision when the turn indicator for the desired adjacent lane is turned on for two seconds or longer, and provide support for the lane change through steering assist[5].

Cameras, millimeter wave radars, laser radars, and the sensor fusion technology combines them, in addition to the use of big data, are the core technologies forming the basis of the development and evolution of artificial intelligence and are therefore actively researched in the context of automated driving technologies. Development concerning how much technological evolution can be shown at the 2020 Tokyo Olympic Games is looking promising.

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