
CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1. Introduction

As social expectations concerning autonomous driving, safety, and environmental performance are intensifying, the circumstances affecting automobiles are becoming increasingly sophisticated and complex.

Systems corresponding to Level 2 autonomous driving, which provide steering assistance to stay in the lane while maintaining an appropriate distance from the preceding vehicle or run at a set speed when in the lead, are becoming more common. They include the Nissan ProPilot, Volvo Pilot Assist, and Mercedes-Benz Intelligent Drive. Autonomous driving technologies to change lanes automatically on expressways, as well as to handle multiple lanes and general roads, including intersections, are being developed for eventual commercialization.

In the area of safety, almost all new models entering the market qualify as a Safety Support Car or Safety Support Car S, the safe driving support vehicles the government has made efforts to raise awareness about and spread through public-private partnerships since 2014. Such safety systems are now taken for granted.

Responses to environmental concerns include England and France announcing that they will prohibit the sales of new gasoline and diesel vehicles by 2040, and China introducing regulations for new energy vehicle (NEVs)—electric vehicles (EVs), plug-in hybrid vehicles (PHEVs), and fuel cell vehicles (FCVs). These regulations mandate the manufacturing and sale of a set quota of NEVs among all vehicles produced and sold starting in 2019. The majority of electric-powered vehicles in Japan are hybrid electric vehicles (HEVs) or plug-in hybrid vehicles (PHEVs), and all automakers have announced plans to introduce electric vehicles. Technologies to extend the cruising range on a full charge, which is key to the spread of such vehicles, are being actively developed.

Against this social backdrop, automakers are competing intensely in research and development aimed at re-

sponding to the demand for higher levels of technological advances related to the chassis, not only for standalone steering or brake control, but also for their integrated control, decreasing rolling resistance, and reducing weight.

This article describes the chassis and vehicle control technology trends with a focus on the new models and technology released in 2018. The main new models launched in and outside Japan in 2018 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

Table 1 shows the suspension types for new models launched in 2018. Recent trends in suspension types were maintained and presented 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. The Suzuki Jimny uses a three-link rigid axle front suspension to achieve high levels of performance on rough roads⁽²⁾. The newly developed TNGA front platform in the Toyota Crown uses a multi-link, double-joint structure with a total of four upper and lower arms that achieves linear handling by ensuring high rigidity against lateral force when cornering⁽³⁾.

The main types of rear suspension continue to be the torsion beam (TB) type for compact and smaller vehicles, and the multi-link type for larger vehicles. The Toyota Crown has a multi-link rear suspension that divides the upper arm in two⁽³⁾. The use of shock absorbers with amplitude sensing on the Honda CR-V and Clarity PHEV⁽⁴⁾, and of newly developed shock absorbers optimized for friction and damping characteristics at ultra-low speeds on the Toyota Corolla Sport are examples of efforts to

Table 1 Chassis and Vehicle Control Systems of New Vehicles Launched in 2018

Market	Manufacturer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/Rear (): suspension for AWD layout	Vehicle control systems
Japan	Suzuki	Super Carry	ICE	FR/AWD	Strut/Leaf spring	False Start Preventive Function/Rear False Start Preventive Function
		Jimny/Jimny Sierra	ICE	AWD	3-link rigid axle coil spring (front and rear)	Dual Sensor Brake Support/False Start Prevention Function (in 4-speed AT models)/Lane Departure Warning Function/Weaving Alert/Hill Hold Control/Hill Descent Control/Brake LSD Traction Control (4 WD-L)
		Spacia Gear	ICE	FF/AWD	Strut/torsion beam (2 WD), Isolated trailing link (ITL) (4 WD)	Dual Sensor Brake Support/False Start Prevention Function/Weaving Alert/Preceding Vehicle Start Notification Function/Back-up Brake Support/Rear False Start Prevention/Hill Hold Control
	Subaru	Forester	ICE	AWD	Strut independent suspension/Double wishbone independent suspension	Active Torque Split AWD (electronically controlled AWD)/EyeSight Core Technology/EyeSight Safety Plus (driver assistance)/Driver Monitoring System/EyeSight Safety Plus (expanded visual field)/Side View Monitor/Active Torque Vectoring/Auto Vehicle Hold
	Toyota	Century	ICE	FR	Multi-link/multi-link	Drive Mode Select/Electronically controlled air suspension with AVS function/NAVI AI-AVS/Electric Parking Brake & Brake Hold/Active Noise Control/Toyota Safety Sense (pre-collision system (millimeter wave radar and monocular camera), lane departure warning (with a steering control function), radar cruise control)/Hill-Start Assist Control/Emergency Braking Signal
		Crown	ICE	Front-engine RWD/4 WD	Multi-link/multi-link	Drive Mode Select/Electric Parking Brake & Brake Hold/AVS/NAVI AI-AVS/Toyota Safety Sense (pre-collision system (millimeter wave radar and monocular camera), lane tracing assist, radar cruise control, road sign assist)/Hill-Start Assist Control/Emergency Braking Signal
		Corolla Sport	ICE	Front engine FWD/4 WD	Strut/double wishbone	Drive Mode Select/Electric Parking Brake/AVS/Active Torque Control AWD (4 WD only)/ACA/Hill-Start Assist Control/Emergency Braking Signal/Toyota Safety Sense (pre-collision system (millimeter wave radar and monocular camera), lane tracing assist, radar cruise control, road sign assist)/Parking Support Brake
	Honda	N-Van	ICE	Front engine FWD/4 WD	FWD vehicles: MacPherson/axle type 4 WD vehicles: MacPherson/de Dion	Honda Sensing
		CR-V	ICE/HEV	Front engine FWD/4 WD	MacPherson/Multi-link	Honda Sensing/Agile Handling Assist/Amplitude-Sensing Dampers/Variable Gear Ratio (VGR) steering
		Clarity	PHEV	FF	MacPherson/Multi-link (wishbone)	Honda Sensing/Agile Handling Assist/Motion Adaptive EPS/Amplitude-Sensing Dampers
Insight		HEV	FF	MacPherson/Multi-link	Honda Sensing/Agile Handling Assist	
Mitsubishi	Eclipse Cross	ICE	FF/AWD	MacPherson strut/Multi-link	S-AWC/Active Yaw Control (AYC)/Forward Collision Mitigation System (FCM)/Lane Departure Warning (LDW)/radar cruise control system (ACC)/False Start Prevention Function (forward and rear)/rear vehicle warning (with lane change assist function) (BSW/LCA)/vehicle backup warning system (RCTA)/Hill-Start Assist (HSA)/Electric Parking Brake/Brake Auto Hold	
Lexus	ES	HEV	FWD	MacPherson strut (with stabilizer)/Double wishbone (with stabilizer)	Active Cornering Assist (ACA)/Active Noise Control/Electronically Controlled Brakes (ECB)/Hill-Start Assist Control/Brake Assist/Drive-Start Control/Tire Pressure Warning Display (also shown on the multi-information display)/EV Drive Mode Switch/Lexus Safety System+/Blind Spot Monitor (BSM)/Parking Support Brake (PKSB)/Back Guide Monitor/Panoramic View Monitor	
	UX	HEV	FWD/AWD	MacPherson strut (with stabilizer)/Double wishbone (with stabilizer)	Performance Rod (front)/Active Cornering Assist (ACA)/Active Noise Control/Electronically Controlled Brakes (ECB)/Hill-Start Assist Control/Sequential Shifting/Brake Assist/Drive-Start Control/Emergency Brake Signal/Tire Pressure Monitoring System (with warning on multi-information display)/Lexus Safety System+/Blind Spot Monitor (BSM)/Parking Support Brake (PKSB)/Panoramic View Monitor/ITS Connect	
Mercedes	A-Class	ICE	Front	Strut/Torsion	ASR/BAS/Crosswind Assist/Adaptive Brake/Adaptive Brake Light/Attention Assist/Parking Assist with Reversing Camera/Tire Pressure Monitoring System/Cruise Control and Variable Speed Limiter/Active Distance Assist DISTRONIC/PRE-SAFE/PRE-SAFE Plus/PRE-SAFE Sound/Emergency Avoidance Assist System/ Congestion Emergency Braking/Active Blind Spot Assist/Active Lane Keeping Assist/Active Steering Assist/Parktronic/Active Parking Assist	

Table 1 Chassis and vehicle control systems of new vehicles launched in 2018 (cont.)

Market	Manufacturer/brand	Name of vehicle model	Drivetrain type	Drive system	Suspension type Front/Rear (): suspension for AWD layout	Vehicle control systems
	Mercedes	C-Class	ICE	RWD/4 WD		BAS/Crosswind Assist/Adaptive Brake/Adaptive Brake Light/Attention Assist/Parking Assist with Reversing Camera/Active Distance Assist DISTRONIC/Active Steering Assist/Active Lane Changing Assist/Active Emergency Stop Assist/Active Brake Assist/PRE-SAFE/PRE-SAFE Plus/PRE-SAFE Sound/Emergency Avoidance Assist System/ Congestion Emergency Braking/Active Blind Spot Assist/Active Lane Keeping Assist/CPA/4 ESP/3-stage ESP/Parktronic/Active Parking Assist/Tire Pressure Monitoring System/Agility Control Suspension/Sport Suspension/Air Body Control Suspension
	DS	DS 7 Crossback	ICE	FWD	MacPherson strut/Multi-link	DS Active Scan Suspension/Electric Parking Brake/Hill Start Assistance/Active Safety Brakes (collision mitigation brakes)/DS Connected Pilot (with traffic jam support and lane positioning assist)/Active Cruise Control (with braking support)/Active Blind Spot Monitor/Traffic Sign Information/Tire Pressure Warning Lamp
	Alfa Romeo	Stelvio	ICE	AWD	Double wishbone/multi-link	Adaptive Cruise Control (ACC) (with Stop & Go function)/Alfa DNA Drive Mode System/FSD Rear Shock Absorbers/Forward Collision Warning (FCW)/Lane Departure Warning (LDW)/Blind Spot Monitor (BSM)/Rear Cross Path Detection (RCPD)/Hill Descent Control (HDC)/Integrated Brake System (IBS)/Alfa Steering Torque/Tire Pressure Monitoring System (TPMS)
Outside Japan	Honda	Accord	ICE/HEV	FWD	MacPherson Strut/Multi-Link Rear	Electric Parking Brake with Automatic Brake Hold/Eco Assist™ System/Active Noise Cancellation™(ANC)/Hill Start Assist/Adaptive Damper System/Brake Assist/Tire Pressure Monitoring System (TPMS) /Honda Sensing® feature
	Toyota	Rav4	ICE/HEV	FWD/AWD	Independent MacPherson strut with stabilizer bar and hydraulic shock absorbers/Trailing wishbone style multi-link rearsuspension	Toyota Safety Sense™ 2.0 (TSS2.0) -Pre-Collision System with Pedestrian Detection (PCSw/PD) (with low light pedestrian detection and daytime cyclist detection)/Lane Departure Alert with Steering Assist (LDAw/SA) (with road edge detection and Sway Warning System)/Full-Speed Range Dynamic Radar Cruise Control (DRCC) /Road Sign Assist (RSA), and Lane Tracing Assist (LTA) /Star Safety System™-includes Enhanced Vehicle Stability Control (VSC) / Electronic Brake-force Distribution (EBD) /Brake Assist (BA) /Smart Stop Technology (SST) /Blind Spot Monitor (BSM) with Rear Cross-Traffic Alert (RCTA) /Intelligent Clearance Sonar (ICS) with Rear Cross-Traffic Braking (RCTB)
	BMW	X5	ICE	AWD	DOUBLE-WISHBONE/FIVE-LINK	Adaptive two-axle air suspension/Brake Energy Regeneration/Brake Force Display/Cruise control with braking function/Integrated brake system/Park Distance Control (PDC), front and rear/Parking Assistant/Tyre pressure monitoring
	Jaguar	XF	ICE	RWD/AWD	Double Wishbone/Integral Link	8-speed Electronic Automatic/Hill Launch Assist/Jaguar Drive Control/Torque Vectoring/Electric Parking Brake (EPB) /Cruise Control with Automatic Speed Limiter/Lane Departure Warning (LDW) /Emergency Brake Assist
	Hyundai	Kona	ICE	Front engine FWD/4 WD	Independent MacPherson strut with coil springs/Coupled torsion beam axle	Vehicle Stability Management/Tire Pressure Monitoring System (TPMS) with individual tire indicator/Blind-Spot Collision Warning/ Lane Change Assist/Rear Cross-Traffic Collision Warning/Lane Keeping Assist/Forward Collision-Avoidance Assist/Pedestrian Detection

refine basic technologies to balance handling performance and ride comfort.

2.2. Suspension Controls

No major changes were observed in suspension control systems, and the recent trend of adopting air suspension and electronically controlled shock absorbers, mainly in high-class sedans and SUVs, continued.

The BMW X5 is equipped with a 4-wheel air suspension that provides smooth and comfortable cruising, as well as excellent driving dynamics. In addition, vehicle height is constantly adjusted to a fixed level regardless of vehicle weight, facilitating both ingress and egress and the loading and unloading of items. A switch to adjust the vehicle height is also available⁽⁶⁾.

The DS 7 Crossback from DS features a windshield-mounted camera that continuously scans the road surface ahead at high speed, recognizes irregularities in the upcoming stretch of road, and applies optimized electronic control of the damping force at the four wheels in real time to offer an always flat, pleasant ride comfort and superior quietness, as well as driving stability⁽⁶⁾. In the Toyota Crown, the adaptive variable suspension (AVS) system that adjusts damping force according to road conditions has been integrated with the navigation system, using the information provided on upcoming corners to optimally control the damping force of the shock absorbers ahead of time and provide stable cornering⁽⁶⁾.

3 Steering

In conjunction with the growing adoption of advanced driver assistance systems (ADAS) and autonomous driving (AD), electric power steering (EPS), initially adopted to improve fuel efficiency in compact vehicles, is increasingly expected to fulfill not only its original steering assist role (providing assistance with steering in response to the force applied by the driver), but also to support steering functions coordinated with components such as stability control or lane keeping assist. At the same time, even higher levels of functionality and safety are expected of EPS.

Column assist EPS was predominant in compact and medium class vehicles in the past, but other systems are increasingly being adopted in the medium class, as shown by the use of dual pinion EPS in vehicles such as the Honda CR-V and Insight⁽⁴⁾ or the Mitsubishi Delica D:5, and of belt drive EPS in the Alfa Romeo Stelvio⁽⁸⁾ and Toyota Rav4⁽³⁾, among others.

With the accelerating adoption of ADAS/AD technologies, EPS further constitutes a necessary element of fuel efficiency improvement technologies, and represents an essential system that promises to evolve even more.

In Europe, discussion on reinforcement EC 661/2009 (general safety regulation (GSR)) are underway, and the adoption of EPS in larger vehicles and commercial vehicles is becoming more common. With the increase in the number of ADAS/AD-equipped vehicles and growing adoption of EPS in large-size and commercial vehicles, The design in consideration of correspondence when trouble occurred is necessary by any chance. Therefore, EPS systems with redundant components are increasing being chosen to control changes in steering torque in the event of a malfunction. Demand for such systems is expected to rise, and AD-equipped vehicles will require sophisticated redundant designs.

4 Brakes

The installation of ESC, already mandatory on light-duty and ordinary passenger vehicles, also became mandatory for existing passenger mini-vehicles starting on February 24, 2018. It will also become mandatory for new light-duty and mini-vehicle truck models in November 2019. Anticipatory installation of ESC on those truck models has already begun, as has the installation of collision mitigation (automatic) brakes. The safe driving sup-

port vehicles (Safety Support Car/Safety Support Car S) designed with elderly drivers in mind and promoted by the government through public-private partnerships have become more widespread. In 2018, collision mitigation (automatic) brakes were installed on a mini-vehicle truck (the Daihatsu Hijet) for the first time. The collision mitigation (automatic) brakes in new models launched in 2018 recognize pedestrians, and the systems in the Subaru Forester, Toyota Crown and Corolla Sport, and the Lexus ES and UX also recognize bicycles⁽³⁾⁽⁹⁾. As with pedestrians, bicycles present a small and difficult to recognize target, and their complex movement patterns makes it hard to determine if there is a risk of collision. Moreover, bicycles move quickly, requiring rapid deceleration after the decision is made, which calls for high responsiveness by the brake system. The need for highly responsive brake systems is predicted to grow as more vehicles are equipped with bicycle collision mitigation braking systems, as well as to address various other situations at intersections.

The convenience of electric parking brakes has made them more widespread and also led to their installation as standard equipment in some mini-vehicles. Many vehicles with electric parking brakes also have a function that automatically maintains braking force after the vehicle is stopped by brakes. Examples include Auto Vehicle Hold (AVH) in the Subaru Forester⁽⁹⁾, Brake Hold in the Toyota Century, Crown, and Corolla Sport⁽³⁾, Automatic Brake Hold in the Honda CR-V, Clarity, and Insight⁽⁴⁾, Brake Auto Hold in the Mitsubishi Eclipse Cross⁽⁷⁾, and Brake Hold in the Lexus ES and UX⁽¹⁰⁾. Since they can keep the car stopped without electric power, electric parking brakes are combined with ESC or other brake control systems as a backup device provide a function that maintains braking force for long periods. The spread of electric parking brakes is anticipated to lead to greater convenience in the form of more sophisticated driver assistance functions.

5 Vehicle Controls

Many new models launched in 2018 are equipped with adaptive cruise control (ACC), and it is highlighted spreading vehicle control system. Among such systems, the field of driver assistance is expanding, as demonstrated by the installation of systems that provide assistance for driving in a lane, such as Touring Assist in the Subaru Forester⁽⁹⁾, Lane Tracing Assist in the Toyota

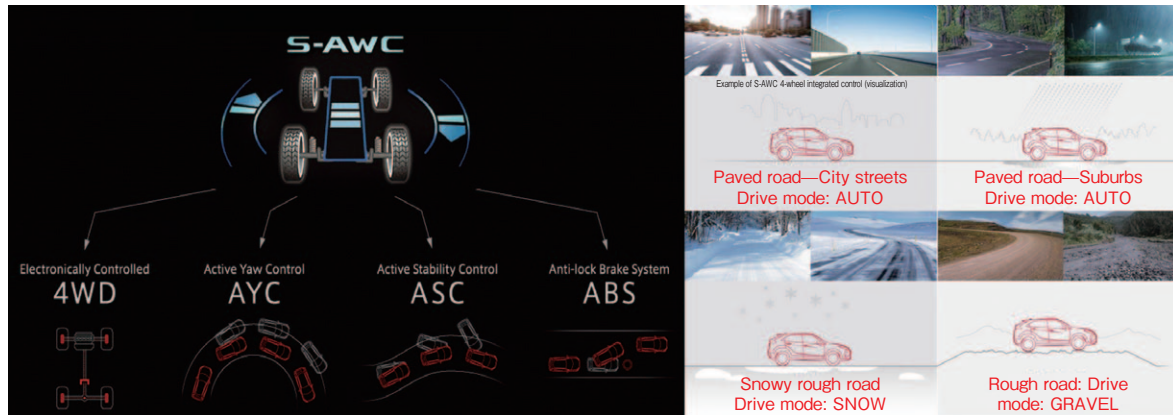


Fig. 1 S-AWC Drive Mode in Mitsubishi Eclipse Cross⁽⁷⁾

Crown and Corolla Sport⁽³⁾, Honda Sensing LKAS in the Honda CR-V, Clarity, and Insight⁽⁴⁾, and Lane Tracing Assist in the Lexus ES and UX⁽¹⁰⁾. This appears to be a ripple effect from both EPS becoming more common and the mounting of forward cameras in many vehicles stemming from the installation of pedestrian collision mitigation braking.

Functions such as X-Mode in the Subaru Forester⁽⁹⁾, Drive Mode Select on the Toyota Crown and Corolla Sport⁽³⁾, the S-AWC driving mode on the Mitsubishi Eclipse Cross (Fig. 1)⁽⁷⁾, and Drive Mode Select on the Lexus ES and UX illustrate the rise in the number of vehicles equipped with control that provides integrated switching between 4WD and brake control not only in the powertrain, but also in the steering and suspension. One probable factor behind this is the improvement in the control performance of the systems and the broadening of their range of settings. The proliferation of electronic control systems is expected to make cooperative control between systems crucial.

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