CHASSIS, CONTROL SYSTEMS AND EQUIPMENT

1 Introduction

In addition to the chronic shortage of semiconductor supply caused by the COVID-19 pandemic, the steep rise in resource prices due to the Ukraine crisis and the reduced or suspended production stemming from component supply restrictions imposed by the lockdown in China resulted in another year of insufficient automobile supply. Under such severe circumstances, automakers remain engaged in research and development on automated driving, environmental performance, and safety performance.

In the area of automated driving, passenger vehicles featuring automated driving Level 1 AD/ADAS functions are becoming increasingly common as those functions are installed in more and more vehicles. The number of vehicles equipped with Level 2 functions is also increasing. In Japan, the revised *Road Traffic Act* defined Level 4 automated driving as a special automated operation in April 2023, permitting services on public roads upon obtaining the authorization of the Public Safety Commission. This is expected to expand initiatives targeting Level 4 in the future. Public road field tests are also being actively carried out in North America, China, and Europe.

With respect to environmental performance, the Japanese government has set a policy of 100% electrification by 2035, and other countries have established policies to achieve carbon neutrality by 2050. Automobile manufacturers are developing electrification technologies and battery electric vehicles (BEVs). In China, notably, national policy has led new energy vehicles (NEVs) sales to exceed 25% of the 2022 nationwide sales, and the competition is intensifying. In Europe, the European Parliament and the Council of the European Union have agreed to the European Commission proposal to achieve zero emissions for all new vehicles by 2035. In addition, a draft Euro 7 standard proposed in November 2022 will add brake particle and wear regulations in July 2025.

In terms of safety performance, collision damage mitigation braking systems have been mandatory for new models in Japan since November 2021, and will become mandatory for existing vehicles as of December 2025. Automakers are working to address the various evaluation methods added in the assessments (e.g., NCAP) in countries around the world.

This article describes chassis and vehicle control technology trends, focusing on the new models and technologies released in 2022. The main new models launched in and outside Japan in 2022 are shown separately in Table 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 in new models follow recent trends. For the front suspension, the McPherson strut type remains common in many vehicles, while the double wishbone type continues to be used in medium or larger vehicle classes. For the rear suspension, the torsion beam type is found in compact class vehicles, while the double wishbone or multi-link types is often adopted in the medium or higher class vehicles. The Mazda CX-60 uses the double wishbone type for the front suspension and the multilink type for the rear suspension to align the working axles of the front and rear suspensions, enabling the spring tops to bounce, and reducing occupant head movement.

The 5-link multilink type suspension is increasing used in vehicles equipped with high-torque motors and vehicles with rear-wheel steering, particularly in Europe, where the number of BEVs is rising. The Toyota Crown Crossover uses a rear-wheel steering device called Dynamic Rear Steering, which improves not only maneu-

Table 1 Chassis and Vehicle Control Systems of New Vehicles Launched in 2022

Market	Manufacturers	Name of vehicle model	Drivetrain type	Drive system	Suspension type front/rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Daihatsu	Move Canbus	ICE	FWD/ AWD	MacPherson strut type/Torsion beam type (3-link type)	Lane Departure Preventive Control/Lane Keep Control/Cornering Trace Assist/Crash-avoidance Support/Crash-avoidance Support Braking Function (against vehicle/pedestrian [day/night])/Erroneous Start Prevention Function with Brake Control (Forward, Reverse)/Hill Hold System/Reduced Driving Burden/Parking Assist/Adaptive Cruise Control/Smart Panorama Parking Assist System (parking assistance system)/Drive-start Control
	Honda	Honda Civic e:HEV/Honda Civic Type R	HEV/ICE	FWD	Strut type type/ multi-link type	Pedestrian Collision Mitigation Steering/Lane Keeping Assist System/Road Departure Mitigation System/Agile Handling Assist/ Collision Mitigation Braking System/False Start Preventive Function/Rear False Start Preventive Function/Short Distance Collision Mitigation Braking System/Adaptive Cruise Control/Low-Speed Follow/Traffic Jam Assist (congestion driving support function)
	Lexus	LX	ICE	AWD	Double wishbone type/Tracing link axle type	AHC & AVS ／ Downhill Assist Control/Crawl Control/Pre-crash Safety (Collision Avoidance Support Type with pedestrians [day/night], cyclists [daytime] detection function/Millimeter Wave Radar + Monocular Camera System)/Lane Tracing Assist [LTA]/Radar Cruise Control/Emergency Driving Stop System/Parking Support Brake/Hill Start Assist Control/Brake Hold/Plus Support (acceleration suppression during sudden acceleration)
	Mazda	CX-60	ICE/ MHEV/ PHEV	RWD/ AWD	Double wishbone type/Multi-link type	Kinematic Posture Control (KPC)/AT false start prevention functions/Brake Assist/Hill Launch Assist/Lane-Keep Assist System/Emergency Lane Keeping Support/Smart Brake Support/Mazda Radar Cruise Control/Cruising & Traffic Support/ Emergency Driving Stop System/Hill Descent Control
	Mitsubishi	eK Cross EV	BEV	FWD	MacPherson strut type/torque arm type 3-link	MI-Pilot/MI-Pilot Parking System/Collision Mitigation Brake System/Lane Departure Prevention/Emergency Assist for Pedal Misapplication/Automatic Brake Hold
	Nissan	Nissan Sakura	BEV	FWD	MacPherson strut type/torque arm type 3-link	ProPilot/Emergency Stop Support System/ProPilot Parking/ Intelligent Emergency Braking/Intelligent LI (Lane Departure Prevention Assist System)/Emergency Assist for Pedal Misapplication/Automatic Brake Hold
		Ariya	BEV	FWD/ AWD	MacPherson strut/ multi-link type	ProPilot/ProPilot2.0/Emergency Stop Support System/ProPilot Parking/ProPilot Remote Parking System/Intelligent Emergency Braking/Intelligent LI (Lane Departure Prevention Assist System)/Emergency Assist for Pedal Misapplication/Automatic Brake Hold/Hill-start Assist/e-4 orce
		X-Trail	HEV	FWD/ AWD	MacPherson strut type/multi-link type	ProPilot/Emergency Stop Support System/ProPilot Parking/ Intelligent Emergency Braking/Intelligent LI (Lane Departure Prevention Assist System)/Emergency Assist for Pedal Misapplication/Automatic Brake Hold/Hill Start Assist/Advanced Hill Descent Control/e-4 orce
		Serena	ICE/HEV	FWD/ AWD	MacPherson strut type/torsion beam type (multi-link type)	ProPilot/ProPilot2.0/Emergency Stop Support System/ProPilot Parking/ProPilot Remote Parking System/Automatic Brake Hold/ Hill Start Assist/Intelligent Emergency Braking/Collision Avoidance Steering Assist System/Intelligent LI (Lane Departure Prevention Assist System)/Intelligent BSI (system that helps prevent rear collisions)/Emergency Assist for Pedal Misapplication
	Subaru	Solterra	EV	FWD/ AWD	Strut type/double wishbone type	Pre-crash Safety (Collision Avoidance Support Type with pedestrians [day/night], cyclists[daytime] detection function/ Millimeter Wave Radar + Monocular Camera System)/Radar Cruise Control/Lane Tracing Assist/Proactive Driving Assist/ Emergency Driving Stop System/Parking Support Brakes/Advanced Park (with remote function)/Hill Descent Control
	Toyota	bz4 X	BEV	FWD/ AWD	MacPherson strut/ Double wishbone	Pre-crash Safety (Collision Avoidance Support Type with pedestrians [day/night], cyclists [daytime] detection function/Millimeter Wave Radar + Monocular Camera System)/Lane Departure Alert [LDA] (with steering control function)/Lane Tracing Assist (LTA)/Radar Cruise Control/Emergency Driving Stop System/Proactive Driving Assist [PDA]/ Plus Support (sudden acceleration suppression system)/Advanced Park (with remote function)/Parking Support Brakes/Downhill Assist Control

Table 1 Chassis, Control Systems and Equipment of New Vehicles Launched in 2022 (cont.).

Market	Manufacturers	Name of vehicle model	Drivetrain type	Drive system	Suspension type front/rear ( ): suspension for AWD layout	Vehicle control systems
Japan	Toyota	Crown	HEV	AWD	MacPherson strut type/multi-link type	NAVI・AI-AVS ／ E-Four (electric 4 WD) system/VDIM ／ DRS/Pre-crash Safety (Collision Avoidance Support Type with pedestrians [day/night], cyclists [daytime] detection function/Millimeter Wave Radar + Monocular Camera System)/Emergency Steering Support (with active steering function)/Lane Change Assist [LCA]/Lane Tracing Assist [LTA]/Radar Cruise Control/Driver Emergency Assist/Proactive Driving Assist [PDA]/Parking Support Brakes/Plus Support (sudden acceleration suppression system)/Advanced Park (with remote function)/Advanced Drive (support during traffic congestion)/Brake Hold
Outside Japan	Audi	e-tron GT	BEV	AWD	Wishbone type/Wishbone type	Damping control suspension/Adaptive air suspension/Progressive Steering/Adaptive Cruise Assist/Turn Assist/Audi Pre-Sense Front/Parking Assist
	BMW	7/i7	MHEV/BEV	RWD/AWD	Double wishbone type/multi-link type	Hands-Free Assist in Highway Congestion/Active Cruise Control with Stop & Go function)/Steering & Lane Control Assist/Lane Change Assist/Lane Keeping Assist (with active side collision protection)/Collision avoidance and collision mitigation brakes (with accident avoidance assistant)/Emergency Stop Assist/Dynamic Traction Control/Cornering Brake Control/Dynamic Brake Control/Park Distance Control/Parking Maneuver Assistant/Parking Assistant (tandem/parallel parking)/Reverse Assist Professional/Integrated Active Steering (front and rear wheel integrated control steering system)/4-wheel Adaptive Air Suspension
	DS	DS9	ICE/PHEV	FWD	MacPherson strut type/multi-link type	DS Active Scan Suspension/Lane-Keep Assist/Active Safety Brake (collision mitigation braking system)/DS Connected Pilot (with traffic jam assist, lane positioning assist)/Active cruise control (with brake support)/DS park pilot
	Ferrari	Purosangue	ICE	AWD	Double wishbone type/multi-link type	SSC 8.0/4 RM-S EVO/Ferrari Active Suspension/ABS EVO/HDC with grip estimation 2.0
	Mercedes-Benz	EQS	BEV	RWD/AWD	Double wishbone type/multi-link type	Rear axle steering (4.5° , 10°)/AIRMATIC/Adaptive Damping System/Active Distance Assist/Distronic/Active Steering Assist/Emergency Avoidance Assist System/Active Lane Keeping Assist/Active Lane Changing Assist/Automatic restart function/Memory Parking Assist/Remote Parking Assist/Active Parking Assist
	Renault	Arkana	MHEV/HEV	FWD	MacPherson strut type/torsion beam type	Active Emergency Brake (collision mitigation braking) with pedestrians/cyclists detection function/Adaptive Cruise Control (with Stop & Go function)/Lane centering assist (lane keeping assist system)/Lane-Keep Assist (lane departure prevention assist) /Easy Park Assist/Hill-start Assist
		Austral	MHEV/PHEV	FWD/AWD	MacPherson strut type/multi-link type	4 CONTROL advanced system, active emergency braking system, rear automatic emergency braking, lane keeping assist, emergency lane keeping assist, adaptive cruise control, active driver assist, hill start assist

verability in the low-speed range, but also responsiveness and stability in the medium and high-speed ranges. That device also coordinates with the drive mode select and VDIM to achieve optimal vehicle behavior. The use of the multi-link type, which has high compatibility with rear wheel steering device, is anticipated to continue to mitigate the increase in turning radius resulting from expanding the wheelbase to accommodate the large capacity battery mounted under the floor to meet BEV cruising range requirements.

2. 2. Suspension Controls

No notable changes were observed in the adoption of suspension control systems. Air suspensions and electronically controlled shock absorbers continue to be used primarily in high-priced vehicles, and some models adopt controls that use camera and navigation system information to modify the characteristics according to driving conditions and the road surface. The DS Automobiles DS 9 employs a preview control system that relies on the ADAS system to control the damping force of the shock absorbers on the four wheels based on road surface conditions. Further developments in automated driving are also giving rise to research on applying data science and information and communications technology to suspension control. Further research these on practical applications is expected for those promising key technologies that enhance the comfort of second tasks during automated driving.

In addition, active suspensions are used in some vehicle models. The Ferrari Purosangue uses a 48 V actuator combined with a worm gear to control an active suspension that controls the pitch and steering characteristics by dynamically modifies the center of gravity, roll stiffness, and roll center of the vehicle.

3 Steering

The adoption of electric power steering (EPS) to improve fuel efficiency started with light-duty vehicles. Since then, EPS has become indispensable to enhancing both steering feeling and automated driving support technology, and is now used not only in light- and medium-duty vehicles, but also in heavy-duty vehicles (pickup trucks/full-size SUVs). Various steering system-related driving assistance technologies were installed in new models in 2022. They include the Pedestrian Collision Mitigation Steering System (in the Honda Civic and other models), which assists with steering back toward the roadway if the vehicle deviates toward the sidewalk and there is a risk of collision with a pedestrian, the Emergency Steering Support (Active Steering Function) system (in the Lexus LX and other models) which steers the vehicle even if the driver does to help avoid a collision when there is a high possibility of hitting a pedestrian or other road user and there is sufficient space to maneuver in the lane, and the Parking Assist system (in the Nissan Serena and other models), which controls the steering wheel, accelerator, brakes, gear shifting, and even the parking brake in various parking scenarios, and not only offers the conventional white line detection, but is also automatically activated and able to assist with parking at the push of a button just by approaching the parking spot even if there are no white lines or the spot is recessed if that parking spot has been registered. Higher output assist is required to coping with the above-mentioned expansion of EPS to heavy-duty vehicles as well as the quickening of the gear ratio and the increased vehicle weight brought about by the wheelbase extension due to the electrification of vehicles. Conventionally, hydraulic power steering systems have been used instead of EPS in heavy-duty vehicles but, partly due to the electrification of the drive, the adoption of belt-drive EPS systems, which provide high-power assist, is expected to grow.

Advances in automated driving technology are also starting to change the configuration of steering systems. Those changes are predicated on a technology called steer-by-wire, which reads the driver's intent from the movement of the steering wheel, and converts that operation into an electric signal to move the wheels while providing independent control of the wheel angle, steering wheel angle, and steering force. Steer-by-wire, which has no mechanical linking between the steering wheel and the wheels, is used in the Toyota bZ4X. That vehicle also uses an unconventionally shaped steering wheel rather than a round one because setting the rotation angle of the steering wheel at about $\pm 150°$ does not require drivers to shift their grip. Steer-by-wire does not require an intermediate shaft and has the potential to provide new value in combination with upcoming technologies such as steering wheel storage technology that coordinates with automated driving, or the new steering device announced by Hitachi Astemo that removes the conventional steering wheel and expands cabin space. Automobile and EPS manufacturers are anticipated to compete in developing those technologies.

4 Brakes

On the environmental front, the addition of a brake wear particle regulation to Euro 7, proposed for enforcement in July 2025, was approved. It requires the value obtained by multiplying the amount of particles emitted from the brake by a coefficient based on the type of powertrain to be below the regulation value. In the draft submitted to the GRPE, BEVs have the smallest and most lenient coefficient, followed by hybrid systems, with ICE powertrains having the strictest coefficient. Ultimately, measures will have to comply with the coefficients approved by WP.29. In general, friction materials containing a large amount of steel are often used in models destined for Europe to satisfy the high heat resistance and braking performance requirements. Such materials are highly aggressive to the discs and generate a large amount of particles. Technical development in areas such as friction material development, changes in disc materials, and coating technology are predicted to accelerate as manufacturers state taking steps to address this issue.

Growing environmental and electrification needs are leading to more widespread use electric boosters, which do not require engine negative pressure. In addition, more and more models have been adopting brake-by-wire systems. Those system mechanically isolate the pedal operated by the driver and the source of brake fluid pressures, thereby allowing a greater degree of freedom in design than conventional brake systems. In electric vehicles equipped with a large-capacity battery, for example, the greater vehicle weight tends to increase the number of pedal strokes. However, a brake-by-wire system can provide a natural brake operation feel similar to that of an ICE vehicle. In addition, brake-by-wire systems can avoid the changes in pedal position and response found in conventional electric boosters during regenerative brake operation. These factors are predicted to lead to a continued increase in the number of models adopting a brake-by-wire system.

Further in the future than the aforementioned brake-by-wire systems mentioned above, electro-mechanical brake (EMB) technology, which replaces hydraulic pressure with an electric motor as the drive source that pushes the brake pistons, has been attracting attention. Manufacturers are still exploring various technical approaches, and typical examples of value specifically provided by EMBs include fluidless systems, low drag, and reduction noise such as squealing or judder. Fluidless systems, in particular, are expected to reduce the number of parts and simplify processes by eliminating the need for brake fluid and piping. Developing a four-wheel EMB that completely eliminates hydraulic circuits would remove the need for the booster and master cylinder, greatly expanding the degree of packaging freedom in the engine/motor compartment. At the same time, increased flexibility in the layout and form of the brake pedal input device will contribute to expanding the interior space around the driver's seat, and to improving designs.

5 Vehicle Controls

In 2022, many vehicles equipped with advanced functions for preventing traffic accidents and providing a comfortable driving experience were put on the market.

Looking first at active safety technologies shows that the main sensors installed in collision avoidance support braking systems are a monocular camera combined with millimeter wave radar (Mazda CX-60, Daihatsu Move Campus), or a stereo camera combined with a sonar sensor (Subaru Solterra/Toyota bZ4X). Additionally, the number of vehicles equipped with automatic braking systems capable of detecting pedestrians and bicycles at night has increased. Nissan has also announced the ground truth perception technology, a future technology that integrates next-generation lidar as well as cameras and radar. This technology accurately captures the shape of the surrounding space and objects, and instantly analyzes ever-changing situations, making it possible to perform emergency avoidance and braking operations in automated driving situations involving the risk of an accident. The development of active safety technology targeting potential accidents during automated driving is predicted to intensify.

Next, focusing on the provision of a safe and comfortable driving experience, the recent electrification trend has led to the introduction of AWD vehicles featuring improved driving stability through motor-based automaker-specific control of the longitudinal driving force distribution. Examples include the e-4orce mounted on the Nissan Ariya and X-Trail and the E-Four Advanced system in the Toyota Crown, as well as the installation of multiple drive motors on models by Audi, BMW, and other European OEMs. Two-motor AWD control offers better response than conventional mechanical AWD, and can precisely control the longitudinal driving force distribution, giving the driver a greater sense of security when driving on slippery road surfaces such as snow or wet roads. The Nissan Ariya and Note have also improved comfort by reducing the sense of rocking back and forth even during repeated starts and stops by controlling the front-rear driving force distribution and regenerative braking to limit the movement of the driver's upper body during acceleration and deceleration. Batteries are mounted on vehicles with such motor control. Among those, BEVs are increasingly given expanded wheelbases to accommodate the increased battery capacity aimed at extending the cruising range. That trend, in turn, has once again drawn interest in four-wheel steering mechanisms, which aim to improve the maneuverability, a characteristic involving a trade-off with the extended wheelbase. The Mercedes-Benz EQS, Renault Austral, Toyota Crown and other BEVs and HEVs feature such systems. In those systems, the mechanism also generates a turning in the rear wheels in response to steering input. At low speeds, the rear wheels turn in the direction opposite that of the front wheels, contributing to tighter turns when cornering and maneuverability when parking. At high speeds, the rear wheels turn in the same direction as the front wheels, contributing to improved stability. In addition, the EQS uses OTA technology to expand the maximum rear axle steering angle from 4.5 degrees to 10 degrees, and can also be purchased with a one-year license for a function that further improves vehicle maneuverability. In that respect, various functions involving control performance are expected to become part of subscription services in the future.

Toyota became the first manufacturer to use steer-by-wire technology since Nissan introduced it as a world first in 2014, installing it on the bZ4X. The steer-by-wire system contributes to improved maneuverability, stability, and comfort. In terms of steering stability, cornering offers good response because converting the movement of the steering wheel into an electric signal enables a quicker adjustment of the turning angle of the wheels than in a mechanical system. This technology can be used to reduce visual distractions such as the steering corrections during automated driving, and it also leads to giving the driver a sense of security. In addition, the system contributes to reducing unpleasant vibrations by feeding only the road surface information necessary for driving such as the force generated by the wheels when moving over a bump or during cornering, back to the steering wheel. Tesla has also announced that it will install steer-by-wire in the future, and vehicle development that capitalizes on control is anticipated to accelerate as the number of vehicles equipped with steer-by-wire increases.

As described above, control technology is applied in various scenarios, including the automated driving, to offer a safe and comfortable driving experience. In the future, functions that respond to user demands can be expected to be developed and provided in more diverse ways than ever through the use of technologies such as OTA.

References

- Mercedes-Benz website, https://www.mercedes-benz.com/