
Chassis, Control Systems and Equipment

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1 Introduction

Increasing customer awareness of issues such as global warming and safety has become the driving force behind vehicle development in recent years. As increased fuel efficiency has become a particularly important issue, automakers have responded by launching a number of alternative vehicles such as hybrid, plug-in hybrid, and electric vehicles (HVs, PHVs, and EVs). At the same time, the adoption of fuel-saving technologies, such as idling stop and braking energy regeneration mechanisms, are also spreading in vehicles with conventional engines. Furthermore, as the sophistication and complexity of vehicle controls increases, a wide range of safety-oriented functions have been developed, a trend that is likely to continue in the future.

With this background, automakers are implementing various measures for basic chassis and vehicle control system technologies. These include the electrification of components to adapt to the growing introduction of HVs, PHVs, and EVs, the development of vehicle control technologies in line with this trend, the weight reduction of related parts, as well as the reduction of tire rolling resistance, brake drag, and so on. Obviously, the basic elements of chassis development, namely the enhancement of ride comfort, dynamic performance, noise and vibration (NV), and safety will also continue to be a focus of technological development in the future.

This article describes chassis and vehicle control system technology trends based on new vehicles (Table 1) and technologies launched in 2012.

2 Suspension

2.1. Base suspensions

As shown in Table 1, the suspension types of new vehicles launched in 2012 continued the same trends of recent years.

At the front, most vehicles up to the medium class

have adopted strut-type suspensions whereas sporty and executive-class vehicles have tended to adopt double wishbone suspensions.

At the rear, compact-class vehicles and below have adopted torsion beam suspensions, which contrasts with multi-link suspensions for medium-class vehicles and upward, and double wishbone suspensions for sporty and executive-class vehicles.

However, the Volkswagen Golf Mk7 was launched with two different rear suspensions, depending on the vehicle grade. The comfort-oriented grade uses a torsion beam rear suspension instead of the multi-link suspension used up until the Golf Mk6, whereas the higher grade model maintains the same multi-link set up as the Golf Mk6⁽⁵⁾ (Fig. 1).

In this way, automakers are continuing to improve vehicle performance by revising linkage arrangements and suspension bushing characteristics to enhance stability, controllability, and ride comfort, while maintaining the same basic suspension structures.

The new Toyota Crown features suspension arm stiffness tuning in addition to the existing spring, shock absorber, and bushing tunings (Fig. 2). The use of an open section structure for the rear suspension arms allows for flexible motion to ensure refined ride comfort. This suspension structure also features an offset rear toe control arm to optimize stiffness, thereby enhancing vehicle stability when cornering⁽⁶⁾.

The purpose of weight reduction is to improve both economic performance through higher fuel efficiency and dynamic performance through lower unsprung mass. Automakers are acting to reduce weight by changing materials, and by rationalizing part structures through integration, the reduction of wall thicknesses, and the hollowing of parts. The main approach to mass reduction through the adoption of different materials is to reduce part thicknesses by switching to high strength steel. However, the adoption of aluminum and other ma-

Table 1 Chassis and vehicle control systems of new vehicles launched in 2012⁽¹⁾⁻⁽³⁾

Market	Manufacturer/brand	Model	Category	Drivetrain types (IS: includes idle stop system)	Drivetrain layouts	Suspension type Front/Rear (): suspension of AWD layout	Steering	Vehicle control systems
Japan	Honda	N-ONE	Mini-vehicle	Gasoline (IS)	FF/AWD	Strut/torsion beam (De Dion)	EPS	ABS with EBD, Vehicle Stability Assist, Hill-start Assist function
	Lexus	GS	Executive	HV, gasoline	FR/AWD	Double wishbone/multi-link	EPS	Variable Gear Ratio Steering (VGRS), Adaptive Variable Suspension system (AVS), Vehicle Dynamics Integrated Management (VDIM), Lexus Dynamic Handling system, ABS (with EBD) + Vehicle Stability Control + Traction Control, Brake Assist, Hill-start Assist Control, Electronically Controlled Brake (ECB), Pre-collision Safety System
	Mazda	CX-5	SUV	Gasoline, diesel (IS)	FF/AWD	Strut/multi-link	EPS	EBD, ABS, Brake Assist, Dynamic Stability Control System, Traction Control System, Smart City Brake Support, Acceleration Control for AT, Hill Launch Assist
		Atenza	Medium	Gasoline, diesel (IS, regeneration)	FF/AWD	Strut/multi-link	EPS	EBD, ABS, Brake Assist, Dynamic Stability Control System, Traction Control System, Smart City Brake Support, Acceleration Control for AT, Radar Cruise Control, Lane Departure Warning System, Hill Launch Assist
	Mitsubishi	Mirage	Small	Gasoline (IS, regeneration)	FF	Strut/torsion beam	EPS	ABS, EBD, Brake Assist, ASC, Hill Start Assist
		Outlander	SUV	Gasoline (IS)	FF/AWD	Strut/multi-link	EPS	ABS, EBD, Brake Assist, s-AWC, Active Yaw Control, Active Stability Control, e-Assist (Forward Collision Mitigation System + Lane Departure Warning system + Adaptive Cruise Control system), Hill Start Assist
	Nissan	Cima	Luxury	HV	FR	Double wishbone/multi-link	EHPS	Drive Mode Selector, double-piston shock absorbers, ABS, EBD, Vehicle Dynamics Control, TCS, Lane Departure Prevention, Lane Departure Warning, Forward Collision Warning, Intelligent Brake Assist
		NV350 Caravan	Minivan	Gasoline, diesel	FR/AWD	Double wishbone/leaf rigid	HPS	ABS + Brake Assist
		Note	Compact	Gasoline (IS)	FF/AWD	Strut/torsion beam	EPS	ABS, EBD, Vehicle Dynamics Control, TCS, Brake Assist, e-4WD
		Latio	Compact	Gasoline (IS)	FF	Strut/torsion beam	EPS	ABS, EBD, Vehicle Dynamics Control, TCS, Brake Assist
		Sylphy	Medium	Gasoline	FF	Strut/torsion beam	EPS	ABS, EBD, Vehicle Dynamics Control, TCS, Brake Assist
	Subaru	BRZ	Sporty	Gasoline	FR	Strut/double wishbone	EPS	ABS, EBD, Vehicle Dynamics Control
		XV	SUV	Gasoline (IS)	AWD	Strut/double wishbone	EPS	ABS, EBD, Vehicle Dynamics Control, Pre-Collision Braking, Pre-Collision Brake Assist, Pre-Collision Throttle Management, Brake Assist, Adaptive Cruise Control with all-speed range tracking function, Hill Start Assist, Lane Sway Warning, Lane Departure Warning, Brake Override
		Forester	SUV	Gasoline (IS)	AWD	Strut/double wishbone	EPS	ABS, EBD, SI-DRIVE, Vehicle Dynamics Control, Pre-Collision Braking, Pre-Collision Brake Assist, Pre-Collision Throttle Management, Brake Assist, Adaptive Cruise control with all-speed range tracking function, Hill Start Assist, Lane Sway Warning, Lane Departure Warning, Brake Override
	Suzuki	Wagon R	Mini-vehicle	Gasoline (IS, regeneration)	FF/AWD	Strut/trailing-link	EPS	ABS, EBD, Hill Hold Control, Brake Assist
	Toyota	Prius PHV	Compact	PHV	FF	Strut/torsion beam	EPS	EBD, ABS, Brake Assist, Steering-assisted Vehicle Stability Control, Traction Control, Radar Cruise Control (with brake control), Hill-start Assist Control
		86	Sporty	Gasoline	FR	Strut/double wishbone	EPS	EBD, ABS, Vehicle Stability Control
		Corolla Axio Corolla Fielder	Compact	Gasoline (IS)	FF/AWD	Strut/torsion beam	EPS	EBD, ABS, Brake Assist, Vehicle Stability Control, Traction Control, Active Torque Control 4WD
		Porte/Spade	Small	Gasoline (IS)	FF/AWD	Strut/torsion beam	EPS	EBD, ABS, Brake Assist, Vehicle Stability Control, Traction Control, Active Torque Control 4WD
		Auris	Compact	Gasoline (IS)	FR/AWD	Strut/torsion beam Strut/multi-link (Strut/multi-link)	EPS	EBD, ABS, EBD, ABS, Brake Assist, Vehicle Stability Control, Traction Control, Hill-start Assist Control, Active Torque Control 4WD
Crown		Executive	HV, gasoline	FR/AWD	Double wishbone/multi-link	EPS	VDIM (ABS with EBD, VSC, TRC, EPS + active steering integrated control), AVS+NAVI, AI-AVS, NAVI AI-SHIFT, Radar Cruise Control (with brake control), Hill-start Assist Control, Electronically Controlled Brake, Pre-collision Safety System (millimeter wave radar type)	

Table 1 Chassis and vehicle control systems of new vehicles launched in 2012 (Cont.)⁽¹⁾⁻⁽³⁾

Market	Manufacturer/brand	Model	Category	Drivetrain types (IS: includes idle stop system)	Drivetrain layouts	Suspension type Front/Rear (): suspension of AWD layout	Steering	Vehicle control systems
Outside Japan (launched in the home country of each auto-maker)	Aston Martin	Vanquish	Sporty	Gasoline	FR	Double wishbone/double wishbone	EPS	Adaptive Damping System, Dynamic Stability Control, ABS & EBD, Brake Assist, Traction Control
	Audi	A3	Compact	Gasoline, diesel (IS)	FF/AWD	Strut/multi-link	EPS	ABS, Electronic Differential lock System, ESC, Hold Assist, Driver Assist Parking System, Active Lane Assist, Adaptive Cruise Control,
	BMW	BMW 3 Series	Medium	HV, gasoline, diesel (IS)	FR/AWD	Strut/multi-link	EPS	ABS, Dynamic Traction Control, Dynamic Stability Control, Cornering Brake Control, driver assistance, Active Cruise Control (with Stop & Go function), approach control warning (with brake activation), Park Distance Control, Driving Experience Control
	Cadillac	ATS	Medium	Gasoline	FR	Strut/multi-link	EPS	ABS, StabiliTrak (vehicle stability enhancement system), Adaptive Cruise Control, Automatic Collision Preparation (applying brakes when an imminent collision is detected), Automatic Braking (brake application to lessen severity of impact), Driver Shift Control, performance suspension (Magnetic Ride Control (magnetic fluid damping force control system)), Traction Control, Brake Assist, Hill Start, Auto Dry Brakes, Forward Collision Alert, Lane Departure Warning
	Chevrolet	Malibu	Medium	Gasoline (IS)	FF HV	Strut/multi-link	EPS	ABS, Brake Assist, Cornering Brake Control, Rear Park Assist, Stability Control System, Forward Collision Alert, Lane Departure Warning
	Dodge	Dart	Medium	Gasoline	FF	Strut/multi-link	EPS	ABS, Brake Assist, Electronic Stability Control, Hill Start assist, brake lock differential, All-Speed Traction Control, Electronic Roll Mitigation
	Hyundai	Santa Fe	SUV	Gasoline, diesel	FF/AWD	Strut/multi-link	EPS	ABS, EBD, Brake Assist, Vehicle Stability Management system, Electric Stability Control, Traction Control System, Downhill Brake Control, Hill-start Assist Control, Driver Selectable Steering Mode
	Mercedes Benz	A Class	Compact	Gasoline, diesel (IS)	FF	Strut/multi-link	EPS	ABS, Acceleration Skid Control, Brake Assist, Adaptive Brake Hold function, Hill Start Assist, Active Parking Assist
		SL Class	Sporty	Gasoline (IS)	FR	Multi-link/multi-link	EPS	ABS, Brake Assist, PRE-SAFE brake, Active Lane Keeping Assist, Active Blind Spot Assist, DISTRONIC PLUS, Electronic Stability Program, Active Damping System
		GL Class	Large SUV	Gasoline	AWD	Double wishbone/multi-link	EPS	Electronic Traction System, Airmatic suspension, Adaptive Damping System, Electronic Stability Program, Cross-Wind Stabilization, Active Curve System, adaptive braking technology, Trailer Stability Assist
	Opel	Mokka	SUV	Gasoline (IS)	FF/AWD	Strut/torsion beam	EPS	ABS, EBD, Electronic Stability Control, Traction Control, Hill Start Assist, Hill Descent Control system,
	Peugeot	208	Small	Gasoline, diesel	FF	Strut/torsion beam	EPS	EBD, ABS, Brake Assist, Electronics Stability Control
	Porsche	Boxster	Sporty	Gasoline (IS), coasting	MR	Strut/strut	EPS	Dynamic transmission mount, Porsche Torque Vectoring, Porsche Active Suspension Management, Porsche Stability Management system
	Renault	Clio	Compact	Gasoline, diesel	FF	Strut/torsion beam	EPS	EBD, ABS, Brake Assist, Electronic Stability Control (with traction and understeer control)
	VW	Passat Alltrack	Medium crossover	Gasoline, diesel (IS, regeneration)	AWD	Strut/multi-link	EPS	Pre-crash braking system, Electronic Stabilization Program, ABS, EBD, Hydraulic Brake Assist, Adaptive Cruise Control, Hill Descent Assist
Golf		Compact	Gasoline, diesel, variable displacement, coasting	FF/AWD	Strut/torsion beam Strut/multi-link (Strut/multi-link)	EPS	Electronic Stabilization Program, driver steering recommendation, ABS, EBD, Hydraulic Brake Assist, Lane Assist, pre-crash braking system, multi-collision brake system, Adaptive Cruise Control, Electronic Differential Lock	
Volvo		V40	Compact	Gasoline, diesel	FF	Strut/multi-link	EPS	Adaptive Cruise Control, Collision Warning with full auto brake and pedestrian and cyclist detection, Driver Alert Control, City Safety, Dynamic Stability and Traction Control, Lane Keeping Aid, Hydraulic Brake Assist, Ready Alert Brake, ABS, EBD

In the "category" section above, the vehicles are categorized based on vehicle length. The categorization may be different from that defined by the manufacturer. Drivetrain layout abbreviations) FF: front-engine, front-wheel drive, AWD: all-wheel drive, FR: front-engine, rear-wheel drive, HV: hybrid vehicle, MR: mid-engine, rear-wheel drive



(a) Torsion beam



(b) Multi-link

Fig. 1 VW Golf Mk7 rear suspension options⁽⁴⁾

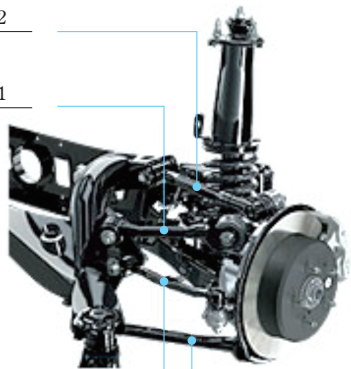
[Rear suspension]

Upper arm No. 2

Open section

Upper arm No. 1

Open section



Toe control arm

Offset type

Lower arm No. 1

Open section

Fig. 2 Rear suspension of the Toyota Crown⁽⁶⁾

materials with a lower specific gravity is also taking place. Although some aluminum suspension parts are being adopted, this is not an active trend since steel still provides superior cost performance.

2.2. Suspension controls

The key suspension control elements are springs, shock absorbers, and stabilizers. There is also a continuing trend to adopt air suspensions and electronically con-

trolled suspensions mainly on SUVs and luxury sedans to simultaneously improve ride comfort, stability, and controllability. The Mercedes-Benz GL-Class SUV uses its Airmatic suspension to maintain the same ride height regardless of the number of occupants or load through electronically controlled air springs and a self-leveling function. The Mercedes Adaptive Damping System automatically adjusts the damping characteristics of the shock absorbers to achieve a comfortable ride⁽⁷⁾.

The Lexus GS series has adopted electronically controlled shock absorbers in the VDIM system that integrates the control of the engine, brakes, steering, and so on⁽⁶⁾. For each vehicle in the series, VDIM performs optimum control of spring and damping forces in accordance with constantly changing driving and road conditions as well as driving styles to enable excellent stability, controllability, and ride comfort.

3 Steering

In recent years, electric power steering (EPS) has been adopted on a fast growing number of European as well as Japanese models to help improve fuel efficiency and to respond to increasing needs for driver support systems compatible with HVs, PHVs, and EVs. EPS is equipped on virtually all the new 2012 models in Table 1. Up to compact class vehicles, the main type of EPS is the column-assist type that is relatively lower in cost and easier to layout. For medium-class vehicles and above, automakers have adopted steering rack-assist type EPS that can provide higher output directly to the steering rack bar.

In addition, as EPS becomes more widely adopted, related driver support systems such as lane departure and parking assist controls have also spread. These systems are also appearing on compact and mini-vehicles in greater numbers, which underlines the growing mainstream acceptance of these controls. Lane departure control systems include types that help the driver to keep the vehicle within the lane by constantly applying a small steering force to the steering wheel, and types that warn the driver of a potential lane departure by vibrating the steering wheel.

Nissan Motor Corporation has announced a next-generation steering technology that converts driver steering inputs into electrical signals to control tire movement, which allows independent control of the tire and steering wheel angles as well as steering torque (Fig. 3). This

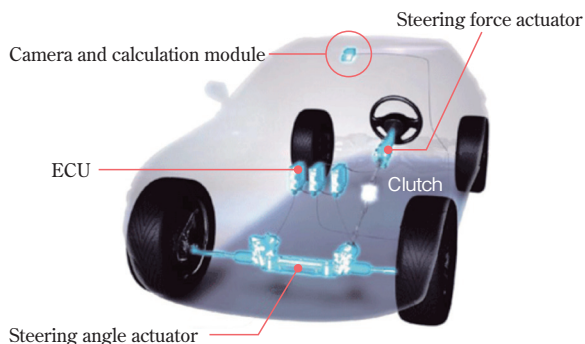


Fig. 3 Next-generation steering technology developed by Nissan Motor Corporation⁽⁸⁾

system insulates the vehicle from external disturbances and provides a more direct feel to the driver by feeding back the necessary driving information to the driver. This system also ensures reliability by using multiple ECUs to monitor the operation state. If any of the ECUs suffers a failure or error, the system can be immediately controlled by another ECU. If a total power failure occurs, a clutch engages to activate a mechanical link between the steering wheel and tires⁽⁸⁾.

4 Brakes

Many countries have begun to mandate the installation of stability Control devices (i.e., electronic stability control (ESC)). All the Japanese vehicles in Table 1 in the medium class and upward have ESC as standard equipment. Most of the models that use an idling stop mechanism to improve fuel efficiency also incorporate a braking force hold function using an ESC hydraulic brake control unit. This function prevents the vehicle from rolling backwards on a hill when the idling stop mechanism is engaged. For this reason, the proportion of vehicles equipped with ESC hydraulic brake control units is also increasing. More Japanese vehicles are being installed with functions to prevent the vehicle from rolling backwards on a hill start. The use of brake controls to provide functions with added value is likely to increase in the future. Although the conventional definition of brake controls as safety equipment remains strong, brake controls are likely to be increasingly used in convenience-oriented functions as the installation of ESC becomes obligatory. Examples of such convenience-oriented functions include electronic parking brakes with traffic jam driving support functions, and radar cruise control systems with automatic brake functions using

ESC hydraulic brake control units.

Regenerative-friction brake coordination is increasing as HVs, PHVs, and EVs become more prevalent. The development of various types of coordination systems is advancing simultaneously, including those that activate and control servo units using accumulated hydraulic pressure, and those that activate and control servo units using electrical devices. As ABS designs were narrowed down to the current type from various original formats, the same trend is also likely to occur for regenerative-friction brake coordination systems. Another proposed system directly drives the brake calipers electrically instead of via hydraulic pressure. Although this system does not require a regenerative-friction brake coordination system, major issues include developing a backup method in place of hydraulic pressure if a fault occurs.

5 Other Vehicle Controls

Radar cruise control using brake controls and collision damage mitigation brake systems are becoming more widespread. Notably, collision damage mitigation brake systems are also being installed on compact and mini-vehicles. Controls that coordinate or integrate these systems with drivetrain and steering controls are also growing. In addition, vehicle controls are likely to be developed that combine peripheral monitoring technology such as radar and cameras with navigation systems and the like.

ISO 26262, a functional safety standard titled "Road vehicles – Functional safety", was published on November 15, 2011. Various organizations in the automotive industry inside and outside Japan are working actively toward the practical adoption of this standard⁽⁹⁾. While continuing to enhance the functions of automotive electronic control systems, automakers are also likely to adopt safe design and development processes that comply with the requirements of this standard.

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