
Chassis, Control Systems and Equipment

1 Introduction

Recent years have seen increasing social demands to reduce the environmental impact of vehicles while also enhancing safety. Automakers are locked into continuous competition to develop fuel efficient and active safety technologies. The main vehicles newly launched in 2014 are shown in Table 1 (1)(2).

In addition to specifically environmentally friendly vehicles, such as hybrid, plug-in hybrid, and electric vehicles (HVs, PHVs, and EVs), the first commercially available fuel cell vehicle (FCV) was also launched in 2014. Since FCVs require dedicated parts such as high-pressure hydrogen tanks, the development of chassis that are applicable to these new vehicle packages will be necessary. At the same time, the adoption of new technologies to conventional engine vehicles such as idling stop and energy regeneration mechanisms is increasing. The development of chassis systems such as motorized vehicle control technologies, lighter parts, and tires with rolling reduction were actively promoted in 2014.

Automakers are announcing various active safety technologies such as automatic braking and lane departure prevention control to help mitigate collision damage. These systems are made possible by electronically controlled chassis components, and such technologies are greatly evolving. Active safety technologies are being adopted in luxury vehicles as well as a growing number of compact class vehicles including mini-vehicles. This trend is only expected to continue. In addition, the development of automated driving technology, which forms the basis of advanced active safety technology, is progressing, and automatic driving tests on public roads are being conducted.

This article describes the chassis and vehicle movement control technology trends focusing on the new models and technology released in 2014.

2 Suspension

2.1. Base suspensions

As shown in Table 1, the suspension types of new model vehicles of 2014 do not differ greatly from recent trends.

The main types of front suspension continue to be the McPherson strut type for medium size or smaller class vehicles, and the double wishbone type for larger vehicles.

The main types of rear suspension continue to be the torsion beam type for compact and smaller vehicles, and the double wishbone or multi-link types for larger vehicles.

The front suspension of the Mercedes-Benz C-Class was changed from a McPherson strut type to a 4-link type, and the suspension type and arm position made similar to that of the E-Class and S-Class (3). Recently, the trend to develop large scale platforms with commonized parts and components to facilitate the simultaneous development of various models has accelerated. The MQB (4) from VW and TNGA (5) from Toyota are two examples.

The Toyota Mirai achieved an underfloor package for FCVs by installing two high-pressure hydrogen tanks in a conventional platform (a McPherson strut front suspension and a torsion beam rear suspension). In addition, heavy parts such as the FC stack and high-pressure hydrogen tanks were placed at low positions at the center of the vehicle to lower the center of gravity and to enhance agile cornering performance (Fig. 1).

Ford reduced the weight of the frame of the F150 by approximately 27 kg by increasing the ratio of high strength material in the frame from 23% (2013) to 78%, adopting a uniform box shape as the frame section, and improving the stamping method (6).

Tire sizes are gradually shifting to narrow widths and larger diameters, triggered by the launch of the

155/70R19 on the BMW i3 at the end of 2013. Since this tire size is an efficient way of lowering the rolling resistance of the tire to improve fuel efficiency, this trend is highly likely to accelerate with knock-on effects on the design of the wheelhouse to allow the usage of other sized tires and an increase in the turning circle of the vehicle.

2.2. Suspension controls

Following recent trends, air suspensions and electronically controlled shock absorbers were adopted mainly in high-class sedans and SUVs. However, Mercedes-Benz adopted a four-wheel air suspension (the Airmatic suspension) for the first time in the C-Class. This differs from recent trends, in which fewer models have adopted such a suspension (Fig. 2).

The aims of this suspension are probably to further improve maneuvering stability by lowering the center of gravity, and to reduce the running resistance by lowering the vehicle height according to the driving state.

Recently, more models have adopted electronically controlled shock absorbers to ensure both maneuvering stability and ride comfort. A trend of new models in 2014 is damping force control systems using magnetic fluid. Furthermore, the systems developed by each automaker change the characteristics of the air suspension and electronically controlled shock absorbers using drive mode select functions, which allows the driver to select the vehicle characteristics. The general method is to switch the characteristics of the engine, transmission, and electric power steering at the same time.

3 Steering

The adoption of electronic power steering (EPS) has become common, and automakers are using different assist systems from the standpoints of output, layout, and cost. Mainstream systems are column assist for compact or smaller vehicles, and rack assist for medium or larger vehicles. However, some automakers have adopted pinion assist for compact vehicles and a dual pinion type for compact to medium sized vehicles. In addition, the general trend is to decrease the overall steering gear ratio to improve handling properties and agility.

Another trend for steering control technology is to adopt controls that compensate for mechanical properties (such as inertia and friction), while also improving comfort. For example, VW has adopted a control that assists the necessary steering force for constant cross

winds and transverse gradients, and a control that stabilizes the steering angle against kickback when driving straight on rough roads (4). In addition, the Acura RLX and TLX have a right and left individual toe angle control system in the rear suspension as a new steering system configuration. This technology enables high turning performance and braking stability in various driving scenarios by setting the optimum toe angle (7).

In contrast, BMW and Mercedes-Benz are aiming to balance handling properties with straight line stability by extending the adoption of variable gear systems, in which the gear ratio of the rack and pinion differ depending on the steering angle as a measure to improve mechanical steering performance (8).

Recently, the adoption of EPS is extending to vehicles with large axle loads such as SUVs. Along with the trend to reduce the steering gear ratio, these systems are also likely to increase the necessary assist force. Accordingly, it will be necessary to consider necessary measures in the event of an accident (9).

4 Brakes

The mandatory adoption of electronic stability control (ESC) is expanding globally and the application of automatic collision damage mitigation brakes is also increasing. The adoption of automatic braking, which is particularly effective for reducing collision damage at low speeds, has spread rapidly to compact and mini-vehicles. In the future, as the development of higher performance systems is anticipated, the adoption of sensors such as radars and cameras as well as brake controls such as adaptive cruise control (ACC), which was mainly adopted in luxury vehicles as a convenient function, are expected to enter wider use. As the adoption of ESC pressurization functions are actively spreading, the operation range of these functions as motion control systems is also increasing. For example, Honda has adopted a control that applies the brakes so slightly that the driver does not notice to the inner wheels when the steering angle wheel is increased and to the outer wheels when the steering wheel angle is returned. Such control improves responsiveness and convergence performance (10). Further improvement of performance in accordance with the expansion of braking functions, such as the responsiveness for enhancing collision avoidance performance, durability for the larger operation ranges and frequency, and quieter operation will be required.

Table 1 Chassis and vehicle control systems of new vehicles launched in 2013⁽¹⁾⁽²⁾

| Market | Manufacturer/ brand | Model | Category | Drivetrain types (ISS includes idle stop system) | Drivetrain layouts | Suspension type Front/Rear (): suspension for AWD layout | Steering | Vehicle control systems |
|---------|------------------------|----------------|-----------------|--|-----------------------|---|---|---|
| Japan | Daihatsu | Copen | Mini-vehicle | Gasoline ISS | FWD | Strut/torsion beam | EPS | Vehicle Stability Control (VSC), Traction Control (TRC), Brake Override System, Emergency Stop Signal |
| | | Wake | Mini-vehicle | Gasoline ISS | FWD/ AWD | Strut/torsion beam (3-link) | EPS | Vehicle Stability Control (VSC), Traction Control (TRC), Crash-avoidance braking function at low speed range, Erroneous start prevention function, Preceding vehicle departure reporting function |
| | | Move | Mini-vehicle | Gasoline ISS | FWD/ AWD | Strut/torsion beam (3-link) | EPS | Crash-avoidance braking function in low speed range, Erroneous start prevention function (reverse), Erroneous start prevention function, Preceding vehicle departure reporting function |
| | Honda | N-BOX SLASH | Mini-vehicle | Gasoline ISS | FWD/ AWD | Strut/torsion beam (De Dion) | EPS | EPB, Vehicle Stability Assist (VSA), City-Brake Active System (Collision Mitigation Brakes, False Start Prevention Function), Hill-start Assist function, Emergency Stop Signal |
| | | Grace | Medium | HV | FWD/ AWD | Strut/torsion beam (De Dion) | EPS | Vehicle Stability Assist (VSA), City-Brake Active System (Collision Mitigation Brakes, False Start Prevention Function), Hill-start Assist function, Emergency Stop Signal |
| | Lexus | NX | SUV | Gasoline ISS/ HEV | FWD/ AWD | Strut/double wishbone | EPS | EPB, NAVI AI-Adaptive Variable Suspension system (AVS), Blind Spot Monitor (BSM), Pre-Collision System, Lane Departure Alert, Drive-Start Control |
| | | RC | Sporty | Gasoline HEV | RWD | Double wishbone/ multi-link | EPS | ECB, Lexus Dynamic Handling system (LDH), NAVI AI-Adaptive Variable Suspension system (AVS), VDIM, Blind Spot Monitor (BSM), Rear Crossing Traffic Alert (RCTA), Pre-Collision System, Lane Departure Alert |
| | Mazda | Demio | Compact | Gasoline/ diesel ISS | FWD/ AWD | Strut/torsion beam | EPS | ABS, Brake Assist, Traction Control System (TCS), Dynamic Stability Control system (DSC), Hill Launch Assist, Lane Departure Warning System, Smart City Brake Support, Cruise Control |
| | Mitsubishi | ek space | Mini-vehicle | Gasoline ISS | FWD/ AWD | Strut/3-link | EPS | ABS, EBD, Active Stability Control (ASC), Hill Start Assist, brake assist, e-Assist (Forward Collision Mitigation System in low speed range, erroneous start prevention function) |
| | Nissan | Skyline | Medium | Gasoline ISS/ HEV | RWD/ AWD | Double wishbone/ multi-link | EPS | Electro-Hydraulic power steering system (vehicle speed sensitive type), Direct Adaptive Steering, ABS, EBD, Brake Assist, Intelligent pedal (Distance Control Assist), Vehicle Dynamic Control (VDC), Hill Start Assist, DRIVING ASSISTANCE (extension of drive mode select), Active Lane Control, Emergency Brake, Intelligent Cruise Control, back collision prevention assist system (BCI), back vehicle detection warning (BSW), Lane Departure Prevention (LDP), Lane Departure Warning (LDW), Backup Collision Intervention (BCI) |
| | | Tiana | Medium | Gasoline | FWD | Strut/multi-link | EPS | ABS, EBD, Active Trace Control, Vehicle Dynamic Control (VDC), Brake Assist, Emergency Brake, drive mode select, cruise control, Emergency assist for pedal misapplication |
| | | Dayz Roox | Mini-vehicle | Gasoline ISS | FWD/ AWD | Strut/3-link | EPS | ABS, EBD, Brake Assist, Vehicle Dynamic Control (VDC), Hill Start Assist, Emergency Brake, Emergency assist for pedal misapplication |
| e-NV200 | | Van | EV | FWD | Strut/leaf rigid | EPS | Regenerative braking system, ABS, EBD, Vehicle Dynamic Control (VDC), Hill Start Assist | |
| Subaru | Levorg | Medium | Gasoline ISS | AWD | Strut/double wishbone | EPS | EPB, EyeSight Ver.3 Active Lane Keep, Hill Start Assist, Pre-collision Braking System, Pre-collision Throttle Management, Pre-collision Throttle Management when reversing, EBD, ABS, Vehicle Dynamics Control (VDC), Active Torque Vectoring, Brake Assist, Brake Override, Active torque split AWD, Variable torque distribution (VTD)-AWD, ACC | |
| | WRX | Medium | Gasoline | AWD | Strut/double wishbone | EPS | EPB, EyeSight Ver.3 Active Lane Keep, Hill Start Assist, Pre-collision Braking System, Pre-collision Throttle Management, Pre-collision Throttle Management when reversing, EBD, ABS, Multi-mode Vehicle Dynamics Control (VDC), Active Torque Vectoring, Brake Assist, Brake Override, Variable torque distribution (VTD)-AWD | |
| | Legacy B4 | Medium | Gasoline ISS | AWD | Strut/double wishbone | EPS | EPB, EyeSight Ver.3 Active Lane Keep, Hill Start Assist, Pre-collision Braking System, Pre-collision Throttle Management, Pre-collision Throttle Management when reversing, EBD, ABS, Vehicle Dynamics Control (VDC), Active Torque Vectoring, Active torque split AWD, ACC | |

Table 1 Chassis and vehicle control systems of new vehicles launched in 2013 (continued)

| Market | Manufacturer/ brand | Model | Category | Drivetrain types (ISS includes idle stop system) | Drivetrain layouts | Suspension type Front/Rear (; suspension for AWD layout) | Steering | Vehicle control systems |
|---|------------------------|---------------------------|--------------|--|-----------------------|--|----------|--|
| Japan | Subaru | Legacy Outback | SUV | Gasoline ISS | AWD | Strut/double wishbone | EPS | EPB, EyeSight Ver.3 Active Lane Keep, X-Mode (with Hill Descent Control), Hill Start Assist, Pre-collision Braking System, Pre-collision Throttle Management, Pre-collision Throttle Management when reversing, EBD, ABS, Multi-mode Vehicle Dynamics Control (VDC), Active Torque Vectoring |
| | Suzuki | Hustler | Mini-vehicle | Gasoline ISS/ regeneration | FWD/ AWD | Strut/trailing link | EPS | False start prevention function, Electronic Stability Program (ESP), Hill Hold Control, ABS, Electronic Brake force Distribution (EBD) with brake assist, Radar brake support |
| | | Alto | Mini-vehicle | Gasoline ISS/ regeneration | FWD/ AWD | Strut/torsion | EPS | False start prevention function, Electronic Stability Program (ESP), Hill Hold Control, ABS, Electronic Brake force Distribution (EBD) with brake assist, Radar brake support |
| | Toyota | Noah/Voxy | MPV | Gasoline ISS/ HEV | FWD/ AWD | Strut/torsion beam | EPS | ECB, S-VSC with Active Torque Control AWD System, ABS, EBD with Brake Assist, Hill-start Assist Control, Cruise Control |
| | | Esquire | MPV | Gasoline ISS/ HEV | FWD/ AWD | Strut/torsion beam | EPS | ECB, S-VSC with Active Torque Control AWD System, ABS, EBD with Brake Assist, Hill-start Assist Control, Cruise Control |
| | | Mirai | Medium | Fuel cell | FWD | Strut/torsion beam | EPS | ECB, S-VSC, ABS, EBD, with Brake Assist, Hill-start Assist Control, Cruise Control, Lane Departure Alert, Pre-collision Safety System |
| Outside Japan (launched in the home country of each automaker) | Acura | RLX | Medium | Gasoline HEV | FWD/ AWD | Double wishbone/multi-link | EPS | Precision All-Wheel Steer (P-AWS), ABS, EBD, Hill start assist, Automatic Brake Hold, Vehicle Stability Assist (VSA) with traction control (TRC), Motion adaptive steering, Agile Handling Assist (AHA), Lane Keeping Assist System, ACC, Collision Mitigation Braking System, Road Departure Mitigation System |
| | | TLX | Medium | Gasoline | FWD/ AWD | Strut/4-link | EPS | Precision All-Wheel Steer (P-AWS), ABS, EBD, Hill start assist, Automatic Brake Hold, Vehicle Stability Assist (VSA) with traction control (TRC), Motion adaptive steering, Agile Handling Assist (AHA), Super Handling All-Wheel Drive (SH-AWD), Lane Keeping Assist System, ACC, Collision Mitigation Braking System, Road Departure Mitigation System |
| | Audi | TT | Sporty | Gasoline/ diesel ISS | FWD/ AWD | Strut/4-link | EPS | Audi magnetic ride, ABS, EBD, Electronic stabilization control (ESC), Anti Slip Regulation (ASR), Hill Hold Assist, Retractable Rear Spoiler, parking system with rear sensor |
| | BMW | 2 Series Active Tourer | MPV | Gasoline ISS | FWD | Strut/multi-link | EPS | EPB, Dynamic Damper Control, Dynamic Stability Control (DSC), Collision Warning, Lane Departure Warning, Traffic Jam Assist (TJA), Head-Up Display |
| | | i8 | Medium | PHV | AWD | Double wishbone/ multi-link | EPS | EPB, Dynamic Stability Control (DSC), High Beam Assist, Collision Warning, Active Park Distance Control |
| | Cadillac | ELR | Medium | PHV | FWD | Strut/torsion beam | EPS | EPB, Continuous Damping Control (CDC), ABS, Dynamic Rear Proportioning, Brake assist, Traction Control, Lane Departure Warning, ACC, Automatic brake assist, Front & Rear Parking Assist, Forward Collision Alert |
| | | Escalade | SUV | Gasoline | AWD | Double wishbone/ 5-link rigid | EPS | EPB, Automatic load leveling, rear, Magnetic Ride Control with selectable sport mode, Surround Vision, Bird's eye view, Safety Alert Seat, Lane Departure Warning, Rear Cross-Traffic Alert, Side Blind Zone Alert, Lane Change Alert, ACC, Front and Rear Automatic Braking, Automatic Safety Belt Tightening |
| | Citroen | C1 | Small | Gasoline ISS | FWD | Strut/torsion beam | EPS | ABS, EBD, Emergency Brake Assist, Cornering Stability Control, Electronic Stability Control (ESC), Hill Start Assist, Stop and Start |
| | | C4 Cactus | Crossover | Gasoline/ diesel ISS | FWD | Strut/torsion beam | EPS | ABS, EBD, Emergency Brake Assist, Cornering Stability Control, Electronic Stability Control (ESC), Hill Start Assist, Stop and Start, Cruise Control, Reverse Parking Sensor |
| | Chrysler | 200 | Medium | Gasoline ISS | FWD/ AWD | Strut/multi-link | EPS | ABS, Electronic Stability Control (ESC), Brake Assist, EPB, Forward Collision Warning, Collision Mitigation System, ACC with Stop & Go, Lane Departure Warning, Lane Keep Assist, Blind Spot Monitor, Ultrasonic Parking Assist, Rear Cross Path Detection, Active Grille Shutter |

Table 1 Chassis and vehicle control systems of new vehicles launched in 2013 (continued)

| Market | Manufacturer/brand | Model | Category | Drivetrain types (ISS: includes idle stop system) | Drivetrain layouts | Suspension type Front/Rear (: suspension for AWD layout) | Steering | Vehicle control systems |
|--|--------------------|-----------------|---------------------|---|--------------------|--|--|--|
| Outside Japan (launched in the home country of each automaker) | Chevrolet | Tahoe | SUV | Gasoline | RWD/AWD | Double wishbone/multi-link | EPS | Front/rear Park Assist, Rear Cross Traffic Alert, Side Blind Zone Alert, Cruise Control, Trailer Brake Control, |
| | Ford | Mustang | Sporty | Gasoline ISS | FWD | Strut/multi-link | EPS | ABS, EBD, Traction Control (TRC), AdvanceTrac, Emergency Brake Assist |
| | | F Series | Pickup | Gasoline ISS | FWD/AWD | Double wishbone/leaf | EPS | ABS, EBD, Traction Control (TRC), AdvanceTrac with Roll Stability Control and Curve Control, Hill Start Assist |
| | GMC | Yukon | SUV | Gasoline | RWD/AWD | Double wishbone/multi-link | EPS | Magnetic ride control, Automatic rear air level control, ABS, Brake Assist, Hill Start Assist brakes, Integrated trailer brake controller, StabiliTrak (stability control system with brake assist, includes traction control), ACC |
| | Hyundai | Sonata | Medium | Gasoline HEV | FWD | Strut/multi-link | EPS | ABS, EBD, Traction Control System, Electronic Stability Control (ESC), Brake Assist, Vehicle Stability Management, Drive Mode Select, Smart Cruise Control with Start/Stop Capability |
| | Kia | Soul EV | MPV | EV | FWD | Strut/torsion beam | EPS TCS | EPB, Flex Steer System, Hill Assist Control, Vehicle Stability Assist (VSA), ABS, Traction control (TRC), ACC |
| | Land Rover | Discovery Sport | SUV | Gasoline/diesel | FWD/AWD | Strut/multi-link | EPS | Hill Descent Control, ABS, EBD, Electronic Traction Control, Hill Start Assist, Dynamic Stability Control, EPB, Emergency Brake Assist, Roll Stability Control, Blind Spot Monitoring with Closing Vehicle Sensing alerts, Parallel Park, Parking Exit, Perpendicular Parking, Reverse Traffic Detection, Automatic emergency braking |
| | Lincoln | MKC | SUV | Gasoline | FWD/AWD | Strut/multi-link | EPS | AdvanceTrac with Roll Stability Control, EPB, ABS, Traction Control (TRC), Torque Vectoring Control, Intelligent All-Wheel Drive |
| | Mercedes-Benz | C Class | Medium | Gasoline | RWD | Double wishbone/multi-link | EPS | Agility Control suspension, Airmatic Agility Package, ABS, Radar Safety Package, Brake Assist Plus (Brake Assist Plus with Cross-Traffic Assist), Rear CPA (rear-end collision warning system with damage mitigation brake), Pre-safe Brake (with pedestrian detection), Adaptive Brake (Hold function, Hill Start Assist), CPA Plus (emergency braking), Electronic Stability Program (ESP), Cross-wind Assist, Active Parking Assist, EPB, Cruise control and Variable speed limiter |
| | Opel | Corsa | Compact | Gasoline/diesel ISS | FWD | Strut/torsion beam | EPS | ABS, EBD, Electronic Stability Program (ESP) |
| | Peugeot | 108 | Small | Gasoline ISS | FWD | Strut/torsion beam | EPS | Electronic Stability Program (ESP), EBD, ABS, Tyre pressure sensor |
| | Porsche | Macan | SUV | Gasoline ISS | AWD | 5-link/trapezoidal | EPS | Porsche Active Suspension Management, Porsche Stability Management, Porsche Hill Control, Porsche Torque Vectoring Plus, Off-Road button, Adaptive cruise control with Porsche Active Safe, Lane Change Assist, Lane Assist |
| | Renault | Twingo | Small | Gasoline ISS | RWD | Strut/De Dion | EPS | Electronic Stability Control (ESC), ABS with Brake Assist, Lane departure warning, Emergency Brake Assist, Tyre pressure sensor, Cruise control |
| | smart | fortwo | Small | Gasoline ISS | RWD | Strut/De Dion | EPS | Crosswind assist, Hill start assist, ABS, Electronic stability control (ESC) |
| | VW | Golf sports van | MPV | Gasoline/diesel ISS | FWD | Strut/4-link | EPS | Dynamic Chassis Control, ABS, Electronic stability control (ESC), Electronic parking brake, Adaptive Cruise Control, Lane Assist, Park Assist, Automatic Post-Collision Braking System |
| Passat | | Medium | Gasoline/diesel ISS | FWD/AWD | Strut/4-link | EPS | ABS, Electronic stability control (ESC), Electronic parking brake with Auto Hold function, Hill Hold Control, Trailer Assist, ACC, Driver's Assistance Pack Plus, Lane Assist, Park Assist | |

The adoption of electronic parking brakes (EPBs) is also increasing. Although these systems were mainly adopted in Europe, new models of medium size or larger vehicles and SUVs in Japan, the U.S., and Europe have adopted this as standard equipment. As the Honda N-Box Slash adopted a drum type EPB for the first time (11), this trend may develop further in the future.

Types of regenerative-friction brake coordination include systems such that use accumulative hydraulic pressure and controls using electric motors. Various systems are being developed in parallel.

5 Other Vehicle Controls

In recent years, active safety technology combining

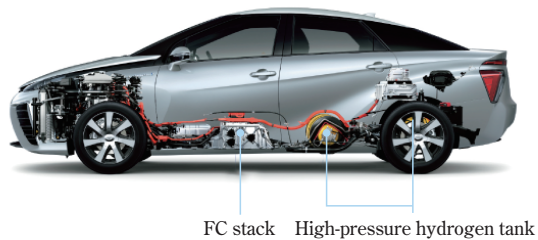


Fig. 1 Layout of hydrogen tanks and FC stack of Toyota Mirai⁽⁵⁾



Fig. 2 Mercedes-Benz C-Class Airmatic suspension⁽³⁾

recognition and chassis control technology has rapidly spread and become more sophisticated.

Subaru's EyeSight Ver. 3 (12) is equipped with a function that assists the driver's steering operation to maintain the center position in the lane. The catchphrases of the previous generation of the system, (a vehicle that does not crash) and the current system (a vehicle that stays in its lane) have attracted the attention of customers.

Google announced that the total running distance of its automated vehicles exceeded one million kilometers (13), while Audi demonstrated automated driving on a circuit (14). The steady progress of automated driving technology will push advanced active safety technology beyond its existing framework.

The development of chassis and vehicle control technologies necessary for these active safety systems is expected to become even more important in the future.

More and more vehicles such as HVs and EVs are using motor drive. For these vehicles, various motor-based vehicle motion control technologies have been proposed. As one example, the Acura RLX has adopted a technology to improve turning performance and stability by installing independently controlled motors to the left and right wheels at the rear and controlling the braking power to each wheel, regardless of the driving force at the front wheels (11).

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