

# Drivetrain

## 1 Introduction

Facing growing demands to help address environmental concerns, automakers are researching, developing, and launching a wide range of drivetrains for gasoline, diesel, hybrid, electric, and fuel cell vehicles. The drivetrains described in this article have been developed with a focus on further enhancing drive efficiency and control to help satisfy customer demands for vehicle fuel economy and dynamic performance. Looking at the patent trends of the automotive industry in the five fields of driving force, navigation systems, steering operation, safety, and entertainment, the highest number of patent applications since the global financial crisis between 2009 and 2013 were related to driving force (including engine design, transmissions, alternative driving force systems, and driving force transmission systems). These applications far outnumbered those in the other four fields. Based on this analysis, driving force transmission systems (i.e., drivetrains) are likely to remain a key technical field in the future. This article outlines the latest drivetrain technologies focusing on environmental and dynamic performance technology.

## 2 Manual Transmission (MT) Trends

### 2.1. Adoption of 5-speed MT with auxiliary transmission in the Daihatsu Hijet

Multi-speed automatic transmissions (ATs) and continuously variable transmissions (CVTs) with auxiliary transmissions are being adopted to increase ratio coverage. This trend has also spread to MTs, and the two-wheel drive Daihatsu Hijet now comes with a 5-speed MT with an auxiliary transmission (Fig. 2). In addition to a high-g geared rear differential, this auxiliary transmission enables the driver to switch between high and low modes. High mode reduces fuel consumption and low mode ensures dynamic performance when the truck is loaded down or driving on mountainous roads.

## 3 Automatic Transmission (AT) Trends

### 3.1. Second generation ZF 8-speed AT

The BMW 530 has adopted the second generation ZF 8-speed AT (Fig. 3). This transmission reduces the speed of the engine through a wider ratio coverage (increased from 7.0 to 7.8) and lower rotational variations at low engine speeds due to the combination of twin and pendulum dampers.

### 3.2. Third-generation Aisin AW AT series

Aisin AW has launched its third-generation AT series, including a 6-speed AT with a ratio coverage of 6.64 and an 8-speed AT with a ratio coverage of 7.8 (Fig. 4), combined with a modular design that achieves wide-reaching part commonization and common configurations. This

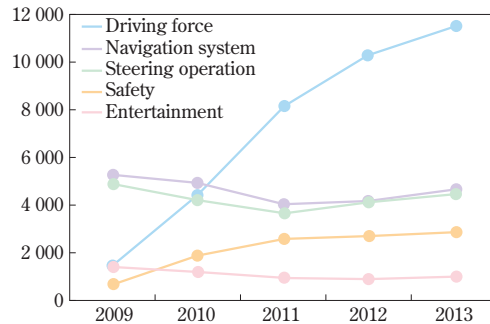


Fig. 1 Number of annual automotive patent applications in each field

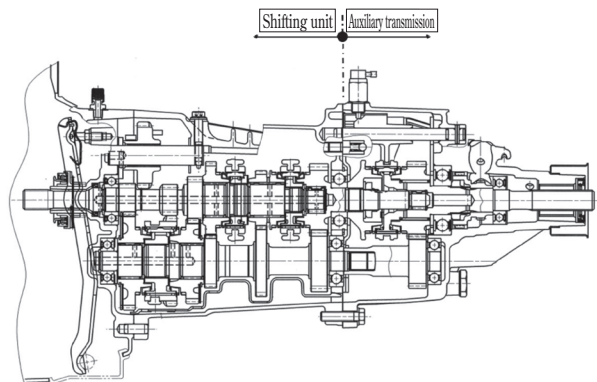


Fig. 2 5-speed MT with auxiliary transmission in the Daihatsu Hijet

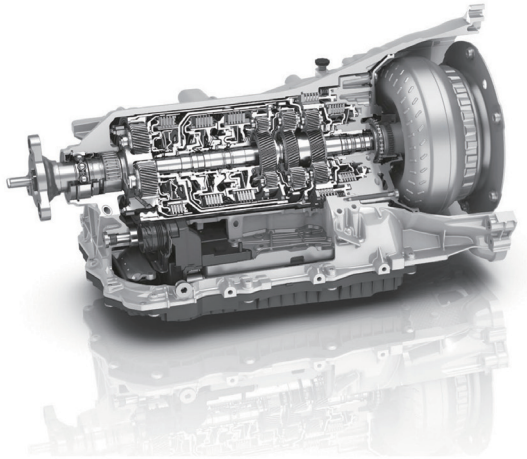


Fig. 3 Second generation ZF 8-speed AT

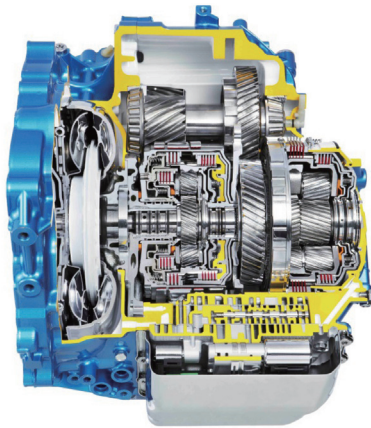


Fig. 4 Third-generation Aisin AW 8-speed AT

series features various enhancements such as a lower oil pump discharge volume, lower AT loss torque due to improved friction materials, and the adoption of a super long travel damper that reduces damper stiffness by 60% compared to the second generation AT. These enhancements help to improve fuel economy by enlarging the size of the lock up region. In addition, new linear solenoids were also adopted, featuring a new control logic and faster hydraulic response at the start of shifting and the like by reducing torque. These measures shorten the shifting response time, creating a direct shift feeling and helping to achieve both fuel efficient and dynamic driving performance.

### 3.3. Adoption of 4-speed AT in the Daihatsu Hijet

The new 4-speed AT in the Daihatsu Hijet carries over the existing gear train and adds an electronically controlled FR 4-speed AT for greater cost performance. The hydraulic control system was newly designed to im-

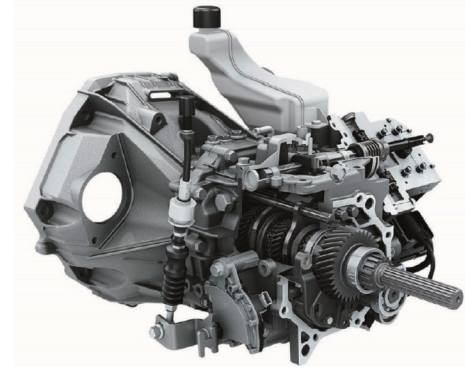


Fig. 5 Suzuki Carry AMT

prove fuel economy and shift speed performance.

### 3.4. Sharing of drivetrain components between companies

Several companies have started sharing the same AT hardware to increase production volume. The 7-speed AT installed in Mercedes Benz vehicles is also used in the Infiniti Q50. However, even though each company uses the same hardware, the components are differentiated by the mountability requirements of each vehicle, as well as the calibration with the engine and transmission.

### 3.5. Adoption of 8-speed dual clutch transmission (DCT) in the Acura TLX

Acura has installed an 8-speed DCT with torque converter in the TLX.

The length of the transmission was reduced by adopting a gear array structure with common driven gears, a double shaft structure featuring an inner shaft directly connected to the clutch and an outer shaft provided with a gear speed selection shift configuration, and an extremely flat torque converter with high-performance dampers. The arrangement of each shaft in the compact single clutch and the arrangement of the drive gears in the shift structure reduce inertia compared to similar parts and also reduce the necessary load. In addition, a hydraulic pressure servo piston was adopted for the action of the shift fork to improve response.

### 3.6. Adoption of automated manual transmission (AMT) in the Suzuki Carry

The Auto Gear Shift function (Fig. 5) installed in the Suzuki Carry and Alto is a first for Suzuki Motor Corporation. Cooperative control between the transmission and the engine ensures optimum shift change timings as well as a smooth shift feeling with little shift shock.

### 3.7. Adoption of DCT in heavy-duty Volvo trucks

Volvo has adopted the world's first mass-production

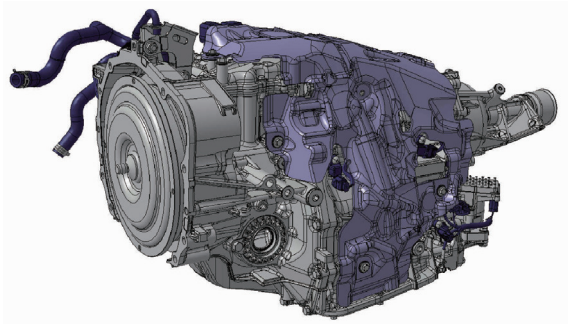
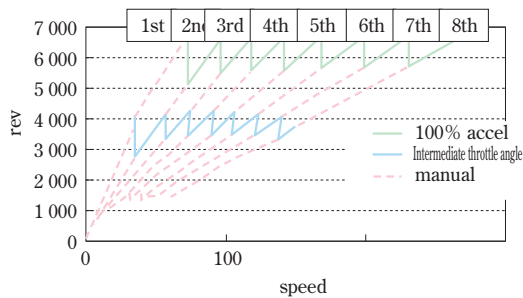
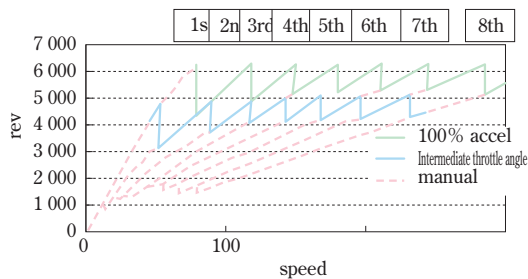


Fig. 6 Subaru Lineartronic CVT for 1.6-liter DIT



(a) LEVORG 2.0 GT DIT



(b) LGACY 2.0 GT DIT

Fig. 7 Subaru Lineartronic Sport CVT for 2.0-liter DIT

12-speed DCT its heavy-duty trucks. This DCT is based on a conventional AMT and features two newly developed input shafts and clutches, which enable shifting without losing engine torque.

## 4 Continuously Variable Transmission (CVT) Trends

### 4.1. Adoption of Lineartronic CVT in the Subaru Levorg and WRX

#### 4.1.1. Lineartronic CVT for 1.6-liter direct injection turbo (DIT) engine

This CVT adopts various fuel efficient technologies, including low-viscosity oil for the CVT and differential, a revised internal structure to reduce oil stirring resistance and low-stiffness dampers in the torque converter



Fig. 8 Nissan CVT for diesel engines

to reduce engine speed (Fig. 6).

#### 4.1.2. Lineartronic Sport CVT for 2.0-liter DIT

Combining the D and M ranges allows the driver to select the appropriate drive mode to focus on fuel economy, acceleration, or cornering performance. For example, if the driver selects the I or S mode in the D range, the transmission changes in accordance with the throttle angle. When the throttle angle is small, the transmission acts as a CVT. Then, when the throttle angle is large, the transmission acts as a stepped transmission with fixed shifting ratios (Fig. 7).

### 4.2. Adoption of diesel engine CVT in the Nissan Qashqai and X-Trail

Nissan has adopted a CVT for use with the diesel engines installed in the Qashqai and X-Trail (Fig. 8). Based on a conventional CVT, it suppresses the input torque fluctuations that commonly occur in diesel engines through an additional inertia ring. It also features improved torque converter fluid performance to ensure standing start performance before the turbocharger engages. Furthermore, in addition to the conventional D-Step control (stepped shift changes), the direct feeling of the CVT was enhanced by widening the lockup control range at start in accordance with the engine torque characteristics when the turbocharger is not in operation.

#### 4.3. Adoption of CVT in the Daihatsu Copen

The Super Active CVT has been installed in the Daihatsu Copen. This CVT allows 7-speed manual shifting using paddle shifters or a gated shifter. The 7-speed stepped transmission in the S range creates a stronger linear feeling. In addition, cooperative control between the engine and CVT suppresses shift shock and enables

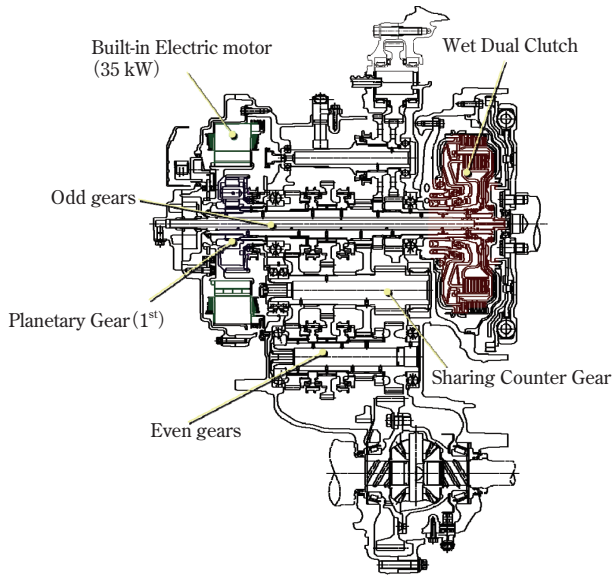


Fig. 9 Acura RLX 7-speed DCT

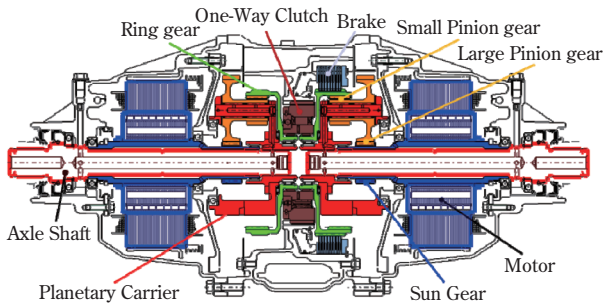


Fig. 10 Acura RLX twin motor unit

rapid shifting.

## 5 HV Drivetrain Trends

### 5.1. Adoption of Sports Hybrid SH-AWD system (7-speed DCT) in the Acura RLX

The Sports Hybrid SH-AWD system installed in the Acura RLX system is combined with a 7-speed DCT with an in-built 35 kW motor. 27 kW motors are provided at the left and right at the rear to achieve an electric four-wheel drive (4WD) system with a torque vectoring function (Fig. 10). The center portion of the system has a clutch structure. In the low and medium speed ranges, the ring gear is fixed, allowing drive, regeneration, and distribution of driving force to the left and right wheels. At high speeds, the ring gear is disengaged, helping to ensure high-speed stability through left/right driving force distribution only.

The system has three modes (EV drive mode, engine drive mode, and hybrid mode) for driving scenarios

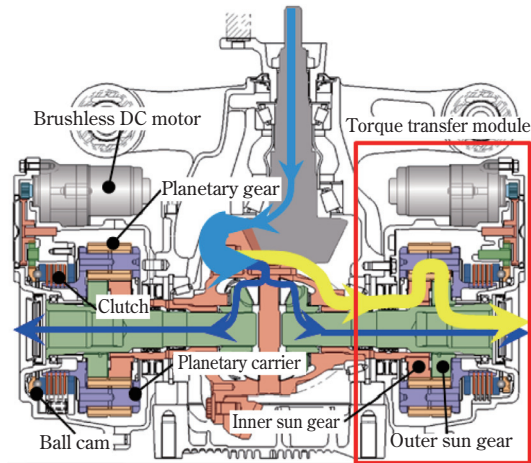


Fig. 11 Lexus RC F torque vectoring differential

such as vehicle start, high-speed cruising, and the like. Excellent dynamic performance and fuel economy are achieved by combining these modes with the three available drive systems (front-, rear-, and four-wheel drive).

## 6 4WD Device Trends

### 6.1. Adoption of part-time 4WD in the Nissan NP300 Navara

The part-time 4WD system installed in the Nissan Navara includes a new transfer case and a new final drive. These new technologies help to improve fuel economy by reducing friction and weight.

### 6.2. Adoption of multi-plate full-time 4WD in the GM Escalade

The Cadillac Escalade has replaced its center differential with a multi-plate 4WD system. This system includes a 2WD mode, an auto mode, and a 4H mode. A device is provided on the front final drive that allows the system to be disconnected in 2WD mode.

## 7 Final Drive Gear Units

### 7.1. Torque vectoring in the Lexus RC F

The front-engine, rear-wheel drive Lexus RC F has adopted a torque vectoring differential on the main driving wheels (Fig. 11). To meet a wide range of driving scenarios and driver preferences, this system includes a standard mode for everyday driving, a slalom mode for winding roads, and a track mode for circuits. The vehicle dynamics controls in this vehicle include feed-forward control of the steering angle, yaw rate feedback control, limited slip differential (LSD) control when decelerating, differential rotation control, and cooperative control

called Vehicle Dynamics Integrated Management (VDIM). These functions control the amount of torque movement to the outer or inner wheels in corners.

### **7.2. Adoption of FF-4WD system in the Jeep Renegade and Cherokee**

The FF-4WD system installed in the Jeep Renegade allows the driver to select from auto, snow, sand, mud, and rock modes in accordance with the driving conditions. It also includes 4WD low and 4WD lock modes. This system also has a rear axle disconnection function to improve performance on rough roads and fuel economy. In addition, the Cherokee has three 4WD system variations: Active Drive 1, 2, and Lock. Customers can select the desired system depending on the intended usage from a single speed type, 2-speed type, or system with a rear-

differential lock. All systems come with a disconnection function.

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