DRIVETRAIN

9.0 Introduction

Drivetrain

Drivetrain is the assembly of all the components that are involved in the transmission of the power from the engine of the vehicle to its wheels.

9.1 Drivetrain configurations

The layout of the automotive drivetrain varies according to the position of the engine and the drive axle:

Drive configuration	Engine position	Driven axle
Standard rear-wheel drive	front	Rear-axle
Front-wheel drive	front. longit. or transverse	Front axle
All-wheel drive	front, occasionally rear or middle	Front-axle and rear-axle
Rear-wheel drive with rear-mounted engine	rear	Rear-axle

Note: "4Matic" is a marketing name used by some automobile companies to denote an All-Wheel-Drive vehicle.

9.2 Drivetrain elements

The elements of the drive train must perform the following functions:

- Remaining stationary even with the engine running,
- Achieving the transition from a stationary to a mobile state,
- Converting torque and rotational speed,
- Providing for forward and reverse motion,
- Compensating for wheel-speed variations in curves,
- Ensuring that the power unit remains within a range on the operating curve commensurate with minimum fuel consumption and exhaust emissions.

Stationary idle, transition to motion and interruption of the power flow are all made possible by the clutch. The clutch slips to compensate for the difference in the rotational speeds of engine and drivetrain when the vehicle is being set in motion.

When different conditions demand a change of gear, the clutch disengages the engine from the transmission while the gear shift operation takes place. With automatic transmissions, the hydrodynamic torque converter is responsible for the take-up of power.

The transmission (gearbox) modifies the engine's torque and revolution per minute to adapt them to the vehicle's momentary tractive requirements.

The overall conversion of the drivetrain is the product of the constant transmission ratio of the axle differential and the variable transmission ratio of the gearbox – assuming there are no other transmission stages involved. Gearboxes are almost always multiple fixed-ratio gearboxes though some are of the continuously variable ratio type. Gearboxes generally fall into one of two categories: manual gearboxes with spur gears, and a layshaft arrangement and load-actuated automatic transmissions with planetary gears. The transmission also allows the selection of different rotational directions for forward and reverse operation.

The differential allows laterally opposed axles and wheels to rotate at varying rates during cornering while providing uniform distribution of the driving forces. Limited-slip final drives respond to slippage at one of the wheels by limiting the differential effect, shifting additional power to the wheel at which traction is available.

Torsion dampers, hydrodynamic transmission elements, controlled-slip friction clutches or mass-suspension systems dissipate high vibration amplitudes, as well as protecting against overload and providing added ride comfort.

9.3 Power take-up elements

These are elements or systems that ensure a smooth and efficient linkage or transmission of the power generated from the engine through the drive-train. The power take up elements are the clutch and the torque converter in manual transmission and automatic transmission vehicles respectively.

9.3.1 Dry-plate friction clutch

The friction clutch consists of a pressure plate, a clutch disk – featuring bonded or riveted friction surfaces – and the second friction surface represented by the engine-mounted flywheel. The flywheel and pressure plate provide the thermal absorption required for friction operation of the clutch; flywheel and pressure plate are connected directly to the engine, while the clutch disk is mounted on the transmission's input shaft.

A spring arrangement, frequently in the form of a central spring plate, applies the force which joins the flywheel, pressure plate and clutch disk for common rotation; in this state, the clutch is engaged for positive torque transfer. To disengage the clutch (e.g., for gear shifting), a mechanically or hydraulically actuated throw-out bearing applies force to the center of the pressure plate, thereby releasing the pressure at the periphery. The clutch is controlled either with a clutch pedal or with an electro-hydraulic, electro-pneumatic or electromechanical final-control element.

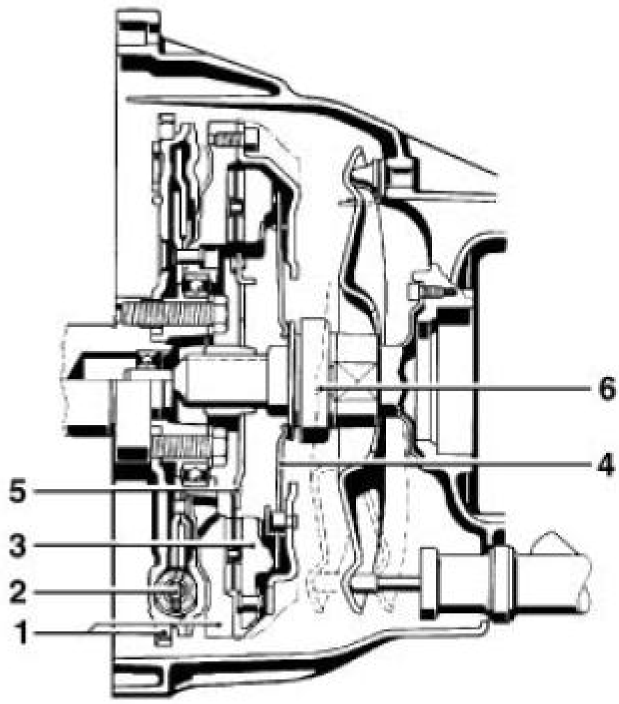


Figure 9.1: Clutch with dual-mass flywheel

1 Dual-mass flywheel, 2 Flexible element, 3 Pressure plate, 4 Spring plate, 5 Friction plate, 6 Thrust bearing.

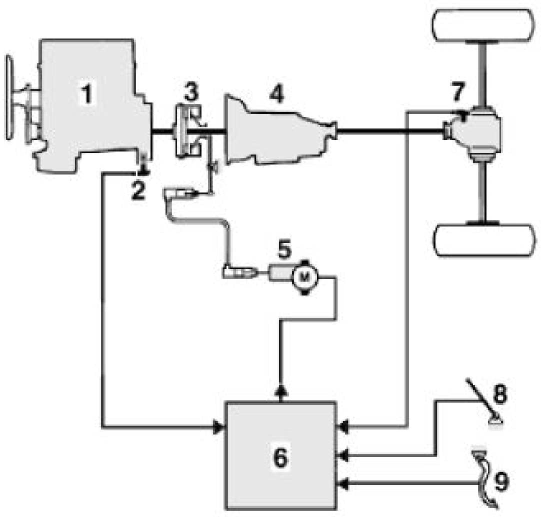


Figure 9.2: Automatic clutch, limited to clutch actuation

1 Engine, 2 Engine min^{-1} sensor, 3 Clutch, 4 Transmission, 5 Servomotor, 6 ECU, 7 Speed sensor, 8 Accelerator pedal, 9 Clutch pedal.

9.3.2 Wet-plate friction clutch

The wet-plate friction clutch has the advantage over the dry-plate version that its thermal performance is better as oil can be passed through to assist heat dissipation. However, its drag losses when disengaged are considerably higher than with a dry clutch. Use in combination with synchromesh gearboxes presents problems due to the increased synchronous load when changing gear. The wet clutch was introduced as a standard component on continuously variable car transmissions. It has space-saving advantages particularly when one or more friction-drive gear-shift components (multiplate clutch or clutch stop) that are present in any case can also be used for the power take-up process.

9.3.3 Hydrodynamic torque converter

The hydrodynamic torque converter consists of the impeller which is the driving component, the turbine which is the driven component and the stator which assists the torque converter function. The torque converter is filled with oil and transmits the engine torque by means of the viscosity of the oil. It compensates for the speed difference between the engine and the other drive-train components and is therefore ideally suited to a power take-up function. An impeller converts the mechanical energy into fluid energy; and a second transformation, back into mechanical energy, takes place at the blades within the turbine.

A stator located between impeller and turbine diverts the hydraulic oil back to the input side of the impeller. This raises the torque beyond the initial engine output as exerted at the impeller.

Maximum torque multiplication is achieved at $\nu = 0$, i.e., with the turbine at stall speed. Further increases in turbine speed are accompanied by a virtually linear drop in multiplication until a torque ratio of 1:1 is reached at the coupling point. Above this point the stator, which is housing-mounted with a one-way clutch, freewheels in the flow.

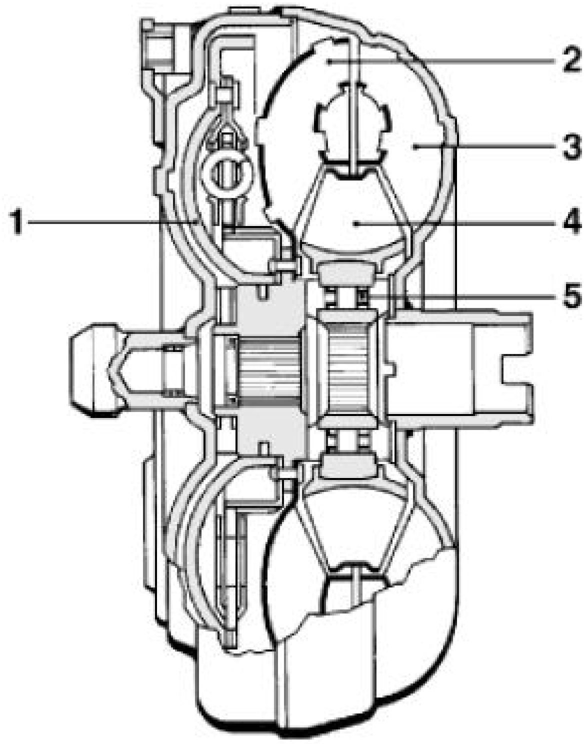


Figure 9.3: Hydrodynamic converter with lockup clutch

1 Lockup clutch, 2 Turbine, 3 Impeller, 4 Stator, 5 One-way clutch.

The hydrodynamic torque converter is a fully automatic infinitely variable transmission with virtually zero-wear characteristics; it eliminates vibration peaks and absorbs vibration highly effectively. However, its conversion range and efficiency, particularly at high levels of slip, are not sufficient for motor-vehicle applications so that the torque converter can only be usefully employed in combination with multi-speed or continuously variable gearboxes.

9.3.3.1 Converter lockup clutch

In order to improve efficiency, the impeller and turbine can be locked together by a converter lockup clutch once power take-up is complete. The converter lockup clutch consists of a plunger with friction surface, which is connected to the turbine hub. The transmission's valve body regulates the direction in which the fluid flows through the converter to regulate coupling engagement.

The converter lockup clutch normally requires additional means of vibration absorption such as:

- A torsion damper,
- Controlled-slip operation of the converter lockup clutch at critical vibration levels or
- Both of the above in combination.

9.4 Multi-speed gearbox

Multi-speed gearboxes have become the established means of power transmission in motor vehicles. Good efficiency characteristics dependent upon the number of gears and engine torque characteristics, satisfactory to good adaptation to the traction hyperbola and easily mastered technology are the essential reasons for its success.

Gear shifting on multi-speed gearboxes is performed using either disengagement of power transmission (positively interlocking mechanism) or under load by a friction mechanism. The first group includes manual and semi-automatic gearboxes while the second group encompasses automatic transmissions.

The manually-shifted transmissions installed in passenger cars and in most heavy vehicles are dual-shaft units with main and countershaft (layshaft, idler gears). Transmissions in heavy commercial vehicles sometimes incorporate two or even three countershafts. In such cases, special design features are required in order to ensure that power is evenly distributed to all countershafts.

Automatic transmissions for cars and commercial vehicles are, in the majority of cases, planetary gear transmissions and only in rare cases are countershaft designs used. The planetary gears generally take the form of a planetary-gear link mechanism. They frequently involve the use of Ravigneaux or Simpson planetary gears.

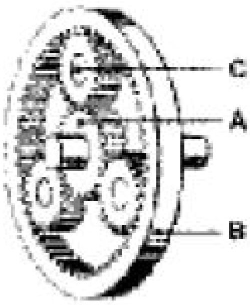
9.4.1 Planetary-gear sets

The basic planetary-gear set consists of the sun gear, internal ring gear and the planet gears with carrier. Each element can act as input or output gear, or may be held stationary. The coaxial layout of the three elements makes this type of unit ideal for use with friction clutches and brake bands, which are employed for selective engagement or fixing of individual elements. The engagement pattern can be changed – and a different conversion ratio selected – without interrupting torque flow; this capability is of particular significance in automatic transmissions.

As several gear wheels mesh under load simultaneously, planetary-gear transmissions are very compact. They have no free bearing forces, permit high torque levels, power splitting or power combination, and feature very good efficiency levels.

Planetary-gear set with various conversion ratios
A Sun gear, B Internal ring gear, C Planet gears with carrier,
Z Number of teeth.

Basic equation for planetary-gear sets: $n_A + (Z_B / Z_A) \cdot n_B - (1 + Z_B / Z_A) \cdot n_C = 0$



In-put	Out-put	Fixed	Transmission ratio	Remarks
A	C	B	$i = 1 + Z_B / Z_A$	$2.5 \le i \le 5$
B	C	A	$i = 1 + Z_A / Z_B$	$1.25 \le i \le 1.67$
C	A	B	$i = \frac{1}{1 + Z_B / Z_A}$	$0.2 \le i \le 0.4$ overdrive
C	B	A	$i = \frac{1}{1 + Z_A / Z_B}$	$0.6 \le i \le 0.8$ overdrive
A	B	C	$i = - Z_B / Z_A$	Non-automotive with reversible direction of rotation $-0.4 \le i \le -1.5$
B	A	C	$i = - Z_A / Z_B$	Non-automotive with reversible direction of rotation $-0.25 \le i \le -0.67$

BRAKING SYSTEMS

10.0 Definitions

10.0 Braking Equipment

All the braking systems fitted to a vehicle, are to reduce its speed or bring it to a halt, or to hold the vehicle stationary if already halted.

10.1 Braking Systems

Service braking system

This includes all the elements, whose action may be modulated, allowing the driver to reduce, directly or indirectly, the speed of a vehicle during normal driving or to bring the vehicle to a halt.

Secondary braking system

This includes all the elements, whose action may be modulated, allowing the driver to reduce, directly or indirectly, the speed of a vehicle or to bring the vehicle to a halt in case of failure of the service braking system.

Parking braking system

This includes all the elements which allow the vehicle to be held stationary mechanically even on an inclined surface, and particularly in the absence of the driver.

Additional retarding braking system

All the elements that allow the driver directly or indirectly to stabilize or to reduce the speed of the vehicle, particularly on long inclines.

Automatic braking system

All the elements which automatically brakes the towed vehicle as a result of intended or accidental separation from the towing vehicle.

Antilock braking system (ABS)

An assembly of all devices within the service-braking system which provide automatic slip control (in the direction of rotation) for one or several wheels under braking conditions. The braking force at wheels featuring direct control is controlled using data provided by the wheel's own wheel-speed sensor, while indirectly controlled wheels rely on data provided by the wheel-speed sensor(s) at one or more of the other wheels. An ABS system with "Select High" control has directly and indirectly controlled wheels. With an ABS system with "Select Low" control, all wheels with speed sensors are directly controlled.

10.3 Design and Components of a Braking System

Basic components of a braking system

The braking system consists of:

- Energy supply,
- A control device
- A transmission device for controlling braking force, and for activating the engine brake, parking brake, and retarder,
- Additional equipment in the towing vehicle for braking the trailer.
- Wheel brakes.

Each of those components affects the braking forces which are decisive for slowing down the vehicle or vehicle combination.

10.4 Braking-System Applications: Legal Requirements for Vehicles

Legal regulations stipulate that the braking system on a heavy commercial vehicle will consist of:

- Service brakes,
- Secondary brakes,
- Parking brake,
- Additional retarding braking systems, and (**heavy commercial vehicle only**)
- Self-actuated braking system (**heavy commercial vehicle only**).

The service and parking brakes are equipped with separate individual control and transmission devices. The service brakes are generally applied with the foot, while the parking brake can be actuated with either hand or foot. The secondary braking system frequently shares components with the service or parking brakes. For instance, when one circuit in a dual-circuit service-braking system also functions as secondary brake, the additional retarding braking system, which acts as a supplementary, wear-free unit, is especially useful for relieving the service brakes on long downgrades. Self-actuated (automatic) braking systems apply to trailers only.

10.5 Brake-Circuit Configurations

Legal regulations stipulate a dual-circuit transmission system as mandatory. There are five available options, but versions II and X have become standard in use. As the brake lines, hoses, connections, and static and dynamic seals remain at a low level of complication, the probability of failure due to leaks is comparable to that achieved with a single-circuit system. The potential response to failure of a circuit due to overheating at one wheel points up a serious weakness in the HI, LL and HH distribution patterns, where loss of both brake circuits on a wheel could lead to total brake-system failure.

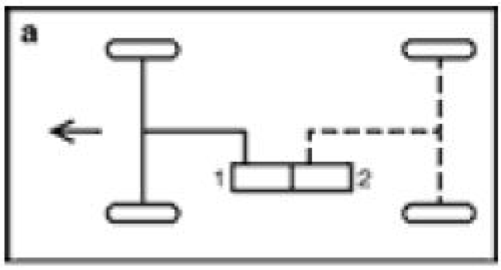
Vehicles with a forward weight bias use distribution pattern X to fulfil the regulatory requirements. The II distribution pattern is an excellent solution for vehicles with rear weight bias and mid-range and heavy commercial vehicles.

10.5.1 Brake-Circuit Configuration: Variants

1 Brake circuit 1; 2 Brake circuit 2.;

II distribution pattern

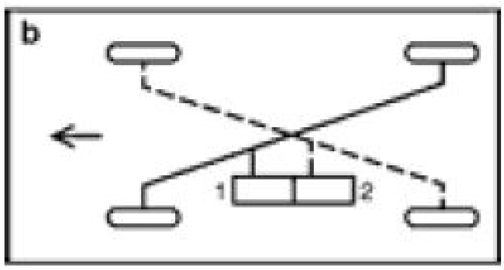
Front-axle/rear-axle split. One circuit brakes the front axle and the other the rear axle.



(a) II-distribution

X distribution pattern

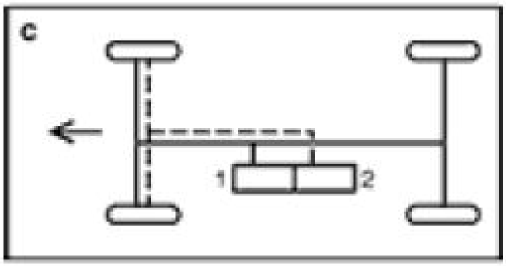
Diagonal distribution pattern. Each circuit brakes a given front wheel and the diagonally opposite rear wheel.



(b) X-distribution

HI distribution pattern

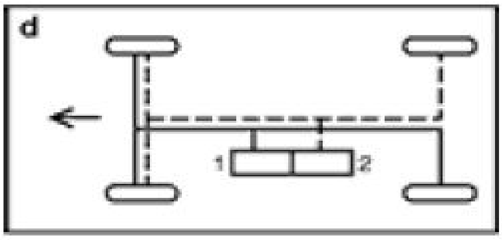
Front-axle and rear-axle/front-axle split. One circuit brakes the front and rear axles, and one circuit brakes only the front axle.



(c) HI-distribution

LL distribution pattern

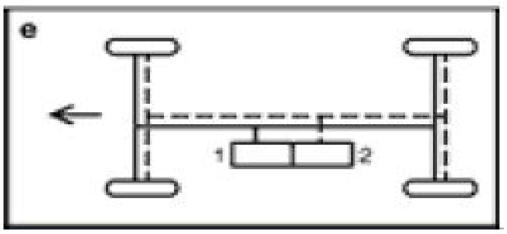
Front-axle and rear-wheel/front-axle and rear-wheel split. Each circuit brakes the front axle and one rear wheel.



(d) LL distribution

HH distribution pattern

Front-axle and rear-axle/front-axle and rear-axle split. Each circuit brakes the front axle and the rear axle.



(e) HH-distribution