

Mechanical Transmission

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Chapter 1

Transmission (Mechanics)

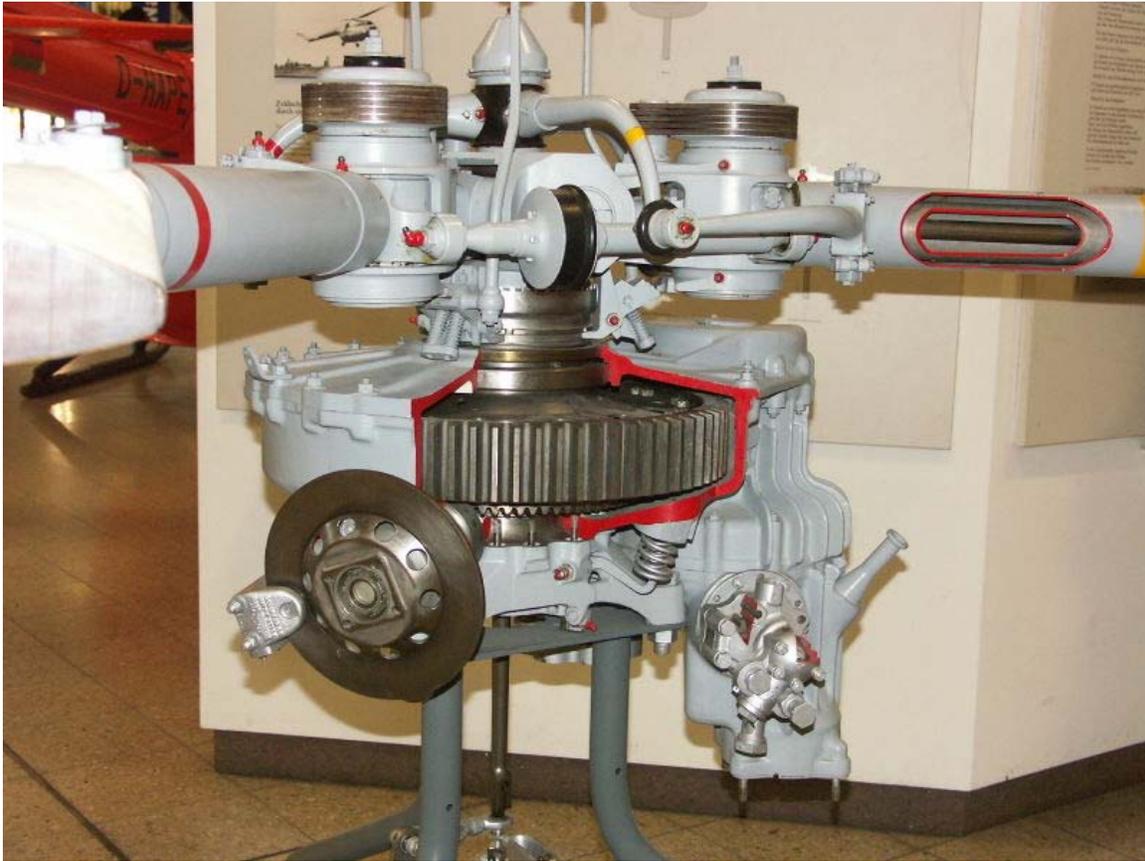
A **transmission** or **gearbox** provides speed and torque conversions from a rotating power source to another device using gear ratios. In British English the term transmission refers to the whole drive train, including gearbox, clutch, prop shaft (for rear-wheel drive), differential and final drive shafts. In American English, however, the distinction is made that a gearbox is any device which converts speed and torque, whereas a transmission is a type of gearbox that can be "shifted" to dynamically change the speed:torque ratio, such as in a vehicle. The most common use is in motor vehicles, where the transmission adapts the output of the internal combustion engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process. Transmissions are also used on pedal bicycles, fixed machines, and anywhere else rotational speed and torque needs to be adapted.

Often, a transmission will have multiple gear ratios (or simply "gears"), with the ability to switch between them as speed varies. This switching may be done manually (by the operator), or automatically. Directional (forward and reverse) control may also be provided. Single-ratio transmissions also exist, which simply change the speed and torque (and sometimes direction) of motor output.

In motor vehicle applications, the transmission will generally be connected to the crankshaft of the engine. The output of the transmission is transmitted via driveshaft to one or more differentials, which in turn drive the wheels. While a differential may also provide gear reduction, its primary purpose is to change the direction of rotation.

Conventional gear/belt transmissions are not the only mechanism for speed/torque adaptation. Alternative mechanisms include torque converters and power transformation (e.g., diesel-electric transmission, hydraulic drive system, etc.). Hybrid configurations also exist.

Explanation



The main gearbox of a Bristol Sycamore helicopter

Early transmissions included the right-angle drives and other gearing in windmills, horse-powered devices, and steam engines, in support of pumping, milling, and hoisting.

Most modern gearboxes are used to increase torque while reducing the speed of a prime mover output shaft (e.g. a motor crankshaft). This means that the output shaft of a gearbox will rotate at slower rate than the input shaft, and this reduction in speed will produce a mechanical advantage, causing an increase in torque. A gearbox can be setup to do the opposite and provide an increase in shaft speed with a reduction of torque. Some of the simplest gearboxes merely change the physical direction in which power is transmitted.

Many typical automobile transmissions include the ability to select one of several different gear ratios. In this case, most of the gear ratios (often simply called "gears") are used to slow down the output speed of the engine and increase torque. However, the highest gears may be "overdrive" types that increase the output speed.

Uses

Gearboxes have found use in a wide variety of different—often stationary—applications, such as wind turbines.

Transmissions are also used in agricultural, industrial, construction, mining and automotive equipment. In addition to ordinary transmission equipped with gears, such equipment makes extensive use of the hydrostatic drive and electrical adjustable-speed drives.

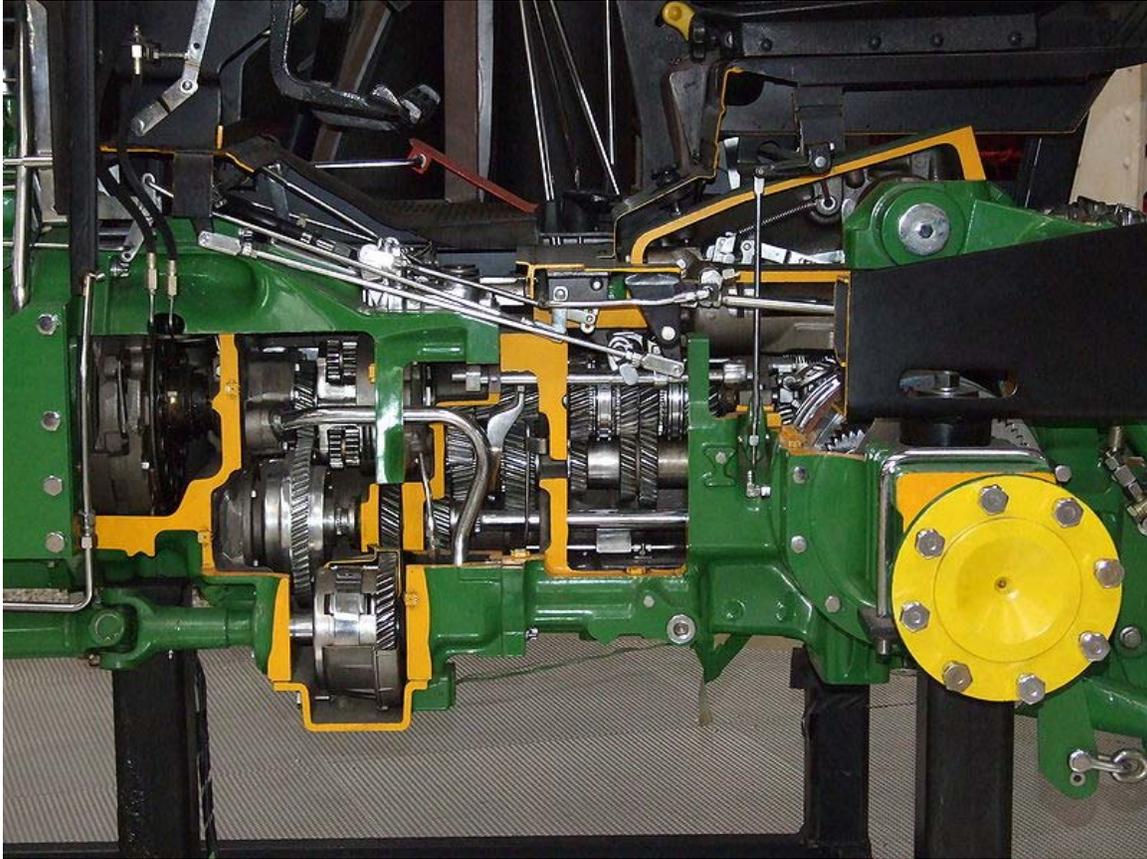
Simple

The simplest transmissions, often called gearboxes to reflect their simplicity (although complex systems are also called gearboxes in the vernacular), provide gear reduction (or, more rarely, an increase in speed), sometimes in conjunction with a right-angle change in direction of the shaft. These are often used on PTO-powered agricultural equipment, since the axial PTO shaft is at odds with the usual need for the driven shaft, which is either vertical (as with rotary mowers), or horizontally extending from one side of the implement to another (as with manure spreaders, flail mowers, and forage wagons). More complex equipment, such as silage choppers and snowblowers, have drives with outputs in more than one direction.

The gearbox in a wind turbine converts the slow, high-torque rotation of the turbine into much faster rotation of the electrical generator. These are much larger and more complicated than the PTO gearboxes in farm equipment. They weigh several tons and typically contain three stages to achieve an overall gear ratio from 40:1 to over 100:1, depending on the size of the turbine. (For aerodynamic and structural reasons, larger turbines have to turn more slowly, but the generators all have to rotate at similar speeds of several thousand rpm.) The first stage of the gearbox is usually a planetary gear, for compactness, and to distribute the enormous torque of the turbine over more teeth of the low-speed shaft. Durability of these gearboxes has been a serious problem for a long time.

Regardless of where they are used, these simple transmissions all share an important feature: the gear ratio cannot be changed during use. It is fixed at the time the transmission is constructed.

Multi-ratio systems



Tractor transmission with 16 forward and 8 backward gears

Many applications require the availability of multiple gear ratios. Often, this is to ease the starting and stopping of a mechanical system, though another important need is that of maintaining good fuel efficiency.

Automotive basics

The need for a transmission in an automobile is a consequence of the characteristics of the internal combustion engine. Engines typically operate over a range of 600 to about 7000 revolutions per minute (though this varies, and is typically less for diesel engines), while the car's wheels rotate between 0 rpm and around 1800 rpm.

Furthermore, the engine provides its highest torque outputs approximately in the middle of its range, while often the greatest torque is required when the vehicle is moving from rest or traveling slowly. Therefore, a system that transforms the engine's output so that it can supply high torque at low speeds, but also operate at highway speeds with the motor still operating within its limits, is required. Transmissions perform this transformation.

Many transmissions and gears used in automotive and truck applications are contained in a cast iron case, though more frequently aluminium is used for lower weight especially in cars. There are usually three shafts: a mainshaft, a countershaft, and an idler shaft.

The mainshaft extends outside the case in both directions: the input shaft towards the engine, and the output shaft towards the rear axle (on rear wheel drive cars- front wheel drives generally have the engine and transmission mounted transversely, the differential being part of the transmission assembly.) The shaft is suspended by the main bearings, and is split towards the input end. At the point of the split, a pilot bearing holds the shafts together. The gears and clutches ride on the mainshaft, the gears being free to turn relative to the mainshaft except when engaged by the clutches.

Types of automobile transmissions include manual, automatic or semi-automatic transmission.

Manual



A five-speed gearbox.

Manual transmission come in two basic types:

- a simple but rugged **sliding-mesh** or unsynchronized / non-synchronous system, where straight-cut spur gear sets are spinning freely, and must be synchronized by the operator matching engine revs to road speed, to avoid noisy and damaging "gear clash",

- and the now common **constant-mesh** gearboxes which can include non-synchronised, or synchronized / synchromesh systems, where diagonal cut helical (and sometimes double-helical) gear sets are constantly "meshed" together, and a dog clutch is used for changing gears. On synchromesh boxes, friction cones or "synchro-rings" are used in addition to the dog clutch.

The former type is commonly found in many forms of racing cars, older heavy-duty trucks, and some agricultural equipment.

Manual transmissions are the most common type outside North America and Australia. They are cheaper, lighter, usually give better performance, and fuel efficiency (although automatic transmissions with torque convertor lockup and advanced electronic controls can provide similar results). It is customary for new drivers to learn, and be tested, on a car with a manual gear change. In Malaysia, Denmark and Poland all cars used for testing (and because of that, virtually all those used for instruction as well) have a manual transmission. In Japan, the Philippines, Germany, Italy, Israel, the Netherlands, Belgium, New Zealand, Austria, Bulgaria, the UK, Ireland, Sweden, Estonia, France, Spain, Switzerland, the Australian states of Victoria, Western Australia and Queensland, Finland and Lithuania, a test pass using an automatic car does not entitle the driver to use a manual car on the public road; a test with a manual car is required. Manual transmissions are much more common than automatic transmissions in Asia, Africa, South America and Europe.

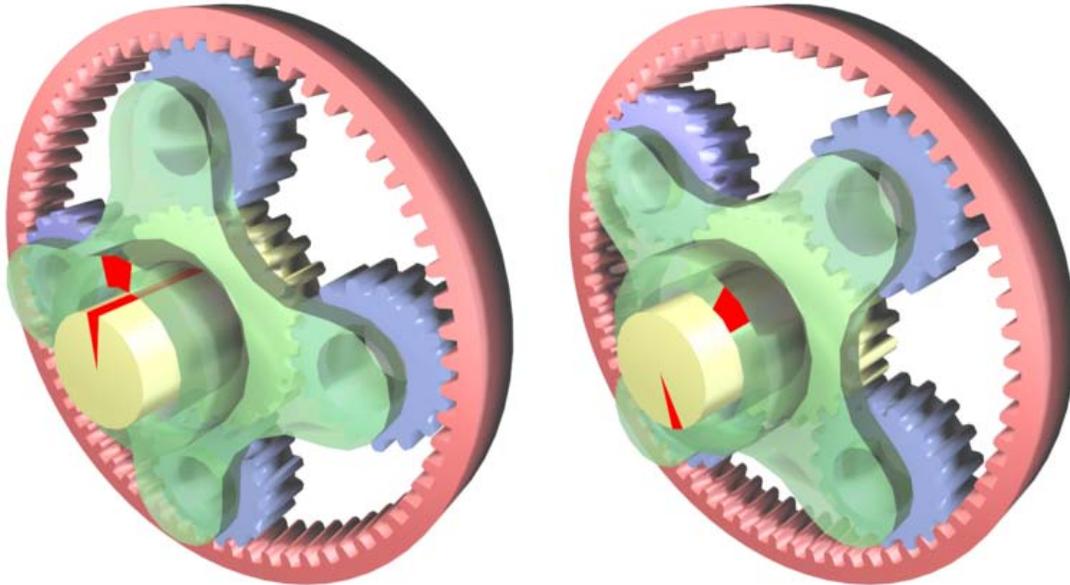
Many manual transmissions include both synchronized and unsynchronized gearing; it is not uncommon for the first/reverse gear to lack synchros. Those gears are meant to be shifted into only when the vehicle is stopped.

Some manual transmissions have an extremely low ratio for first gear, which is referred to as a "creeper gear" or "granny gear". Such gears are usually not synchronized. This feature is common on pickup trucks tailored to trailer-towing, farming, or construction-site work. During normal on-road use, the truck is usually driven without using the creeper gear at all, and second gear is used from a standing start.

Non-synchronous

There are commercial applications engineered with designs taking into account that the gear shifting will be done by an experienced operator. They are a manual transmission, but are known as non-synchronized transmissions. Dependent on country of operation, many local, regional, and national laws govern the operation of these types of vehicles. This class may include commercial, military, agricultural, or engineering vehicles. Some of these may use combinations of types for multi-purpose functions. An example would be a PTO, or *power-take-off* gear. The non-synchronous transmission type requires an understanding of gear range, torque, engine power, and multi-functional clutch and shifter functions.

Automatic



Epicyclic gearing or planetary gearing as used in an automatic transmission.

Most modern North American and Australian and many larger, high specification European and Japanese cars have an automatic transmission that will select an appropriate gear ratio without any operator intervention. They primarily use hydraulics to select gears, depending on pressure exerted by fluid within the transmission assembly. Rather than using a clutch to engage the transmission, a fluid flywheel, or torque converter is placed in between the engine and transmission. It is possible for the driver to control the number of gears in use or select reverse, though precise control of which gear is in use may or may not be possible.

Automatic transmissions are easy to use. However, in the past, automatic transmissions of this type have had a number of problems; they were complex and expensive, sometimes had reliability problems (which sometimes caused more expenses in repair), have often been less fuel-efficient than their manual counterparts (due to "slippage" in the torque converter), and their shift time was slower than a manual making them uncompetitive for racing. With the advancement of modern automatic transmissions this has changed.

Attempts to improve the fuel efficiency of automatic transmissions include the use of torque converters which lock up beyond a certain speed, or in the higher gear ratios, eliminating power loss, and overdrive gears which automatically actuate above certain speeds; in older transmissions both technologies could sometimes become intrusive, when conditions are such that they repeatedly cut in and out as speed and such load factors as grade or wind vary slightly. Current computerized transmissions possess very complex programming to both maximize fuel efficiency and eliminate any intrusiveness.

For certain applications, the slippage inherent in automatic transmissions can be advantageous; for instance, in drag racing, the automatic transmission allows the car to be stopped with the engine at a high rpm (the "stall speed") to allow for a very quick launch when the brakes are released; in fact, a common modification is to increase the stall speed of the transmission. This is even more advantageous for turbocharged engines, where the turbocharger needs to be kept spinning at high rpm by a large flow of exhaust in order to keep the boost pressure up and eliminate the turbo lag that occurs when the engine is idling and the throttle is suddenly opened.

Semi-automatic

The creation of computer control also allowed for a sort of cross-breed transmission where the car handles manipulation of the clutch automatically, but the driver can still select the gear manually if desired. This is sometimes called a "clutchless manual," or "automated manual" transmission. Many of these transmissions allow the driver to give full control to the computer. They are generally designed using manual transmission "internals", and when used in passenger cars, have synchromesh operated helical constant mesh gear sets.

Specific type of this transmission includes: Easytronic, and Geartronic.

A "dual-clutch" transmission uses two sets of internals which are alternately used, each with its own clutch, so that only the clutches are used during the actual "gearchange".

Specific type of this transmission includes: Direct-Shift Gearbox.

There are also sequential transmissions which use the rotation of a drum to switch gears.

Bicycle gearing



Shimano XT rear derailleur on a mountain bike

Bicycles usually have a system for selecting different gear ratios. There are two main types: derailleur gears and hub gears. The derailleur type is the most common, and the most visible, using sprocket gears. Typically there are several gears available on the rear sprocket assembly, attached to the rear wheel. A few more sprockets are usually added to the front assembly as well. Multiplying the number of sprocket gears in front by the number to the rear gives the number of gear ratios, often called "speeds".

Hub gears use epicyclic gearing and are enclosed within the axle of the rear wheel. Because of the small space, they typically offer fewer different speeds, although at least

one has reached 14 gear ratios and Fallbrook Technologies manufactures a transmission with technically infinite ratios.

Causes for failure of bicycle gearing include: worn teeth, damage caused by a faulty chain, damage due to thermal expansion, broken teeth due to excessive pedaling force, interference by foreign objects, and loss of lubrication due to negligence.

Uncommon types

Dual clutch transmission

This arrangement is also sometimes known as a direct shift gearbox or powershift gearbox. It seeks to combine the advantages of a conventional manual shift with the qualities of a modern automatic transmission by providing different clutches for odd and even speed selector gears. When changing gear, the engine torque is transferred from one gear to the other continuously, so providing gentle, smooth gear changes without either losing power or jerking the vehicle. Gear selection may be manual, automatic (depending on throttle/speed sensors), or a 'sports' version combining both options.

Continuously variable

The Continuously Variable Transmission (CVT) is a transmission in which the ratio of the rotational speeds of two shafts, as the input shaft and output shaft of a vehicle or other machine, can be varied continuously within a given range, providing an infinite number of possible ratios.

The continuously variable transmission (CVT) should not be confused with the Infinitely Variable Transmission (IVT).

The other mechanical transmissions described above only allow a few different gear ratios to be selected, but this type of transmission essentially has an infinite number of ratios available within a finite range. The continuously variable transmission allows the relationship between the speed of the engine and the speed of the wheels to be selected within a continuous range. This can provide even better fuel economy if the engine is constantly running at a single speed. The transmission is in theory capable of a better user experience, without the rise and fall in speed of an engine, and the jerk felt when poorly changing gears.

Infinitely variable

The IVT is a specific type of CVT that has an infinite range of input/output ratios in addition to its infinite number of possible ratios; this qualification for the IVT implies that its range of ratios includes a zero output/input ratio that can be continuously approached from a defined 'higher' ratio. A zero output implies an infinite input, which can be continuously approached from a given finite input value with an IVT. [Note: remember that so-called 'low' gears are a reference to low ratios of output/input, which

have high input/output ratios that are taken to the extreme with IVTs, resulting in a 'neutral', or non-driving 'low' gear limit.]

Most (if not all) IVTs result from the combination of a CVT with an epicyclic gear system (which is also known as a planetary gear system) that facilitates the subtraction of one speed from another speed within the set of input and planetary gear rotations. This subtraction only needs to result in a continuous range of values that includes a zero output; the maximum output/input ratio can be arbitrarily chosen from infinite practical possibilities through selection of extraneous input or output gear, pulley or sprocket sizes without affecting the zero output or the continuity of the whole system. Importantly, the IVT is distinguished as being 'infinite' in its ratio of high gear to low gear within its range; high gear is infinite times higher than low gear. The IVT is always engaged, even during its zero output adjustment.

The term 'infinitely variable transmission' does not imply reverse direction, disengagement, automatic operation, or any other quality except ratio selectability within a continuous range of input/output ratios from a defined minimum to an undefined, 'infinite' maximum. This means continuous range from a defined output/input to zero output/input ratio.

Electric variable

The Electric Variable Transmission (EVT) is a transmission that achieves CVT action and in addition can use separate power inputs to produce one output. An EVT is usually designed around an epicyclic differential gear system (also known as a planetary gear system). The epicyclic gear acts as a differential, performing a "power-split" function; a portion of the mechanical power is carried directly through the gear set (the "mechanical path"). The rest of the power is converted to and from electrical energy by electric motor-generators (the "electrical path"). Hence, the EVT is a class of Power Split Transmission (PST).

Many EVTs are linked to batteries or other electrical energy storage devices. This enables them to store or draw electrical power for better operation under various conditions.

The pair of motor/generators forms an Electric Transmission in its own right, but at a lower capacity, than the EVT it is contained within. Generally the Electric Transmission capacity within the EVT is a quarter to a half of the capacity of the EVT. An EVT is often preferable to a pure electrical transmission because the mechanical transmission is cheaper, more compact, and more efficient than the electrical path.

The EVT linked to a battery is the essential method for transmitting power in some hybrid vehicles, enabling an Internal Combustion Engine (ICE) to be used in conjunction with motor/generators for vehicle propulsion. Vehicle speed is controlled primarily by adjusting the amount of power flowing through the electrical as opposed to the mechanical path. The EVT may be used to generate electrical power for storage in a battery, especially through 'regenerative braking' during deceleration. Various

configurations of power generation, usage and balance can be implemented with an EVT, enabling great flexibility in propelling hybrid vehicles.

The Toyota single mode hybrid and General Motor 2 Mode hybrid are production systems that use EVTs. The Toyota system is in the Prius, Highlander, and Lexus RX400h and GS450h models. The GM system is used in the Allison Bus hybrid powertrains and the Tahoe and Yukon models. The Toyota system uses one power-split epicyclic differential gearing system over all driving conditions and is sized with an electrical path rated at approximately half the capacity of the EVT. The GM system uses two different EVT ranges: one designed for lower speeds with greater mechanical advantage, and one designed for higher speeds. The electrical path is rated at approximately a quarter of the capacity of the EVT. Other arrangements are possible and applications of EVTs are growing rapidly in number and variety.

EVTs are capable of continuously modulating output/input speed ratios like mechanical CVTs, but offer the distinct difference and benefit of being able to also apportion power from two different sources to one output.

Hydrostatic

Hydrostatic transmissions transmit all power hydraulically, using the components of hydraulic machinery. Hydrostatic transmissions do not make use of the hydrodynamic forces of the fluid flow. There is no solid coupling of the input and output. The transmission input drive is a central hydraulic pump and final drive unit(s) is/are a hydraulic motor, or hydraulic cylinder (see:*washplate*). Both components can be placed physically far apart on the machine, being connected only by flexible hoses. Hydrostatic drive systems are used on excavators, lawn tractors, forklifts, winch drive systems, heavy lift equipment, agricultural machinery, etc. An arrangement for motor-vehicle transmission was probably used on the Ferguson *F-1* P99 racing car in about 1961.

The Human Friendly Transmission of the Honda DN-01 is hydrostatic.

Hydrodynamic

If the hydraulic pump and/or hydraulic motor make use of the hydrodynamic effects of the fluid flow, i.e. pressure due to a change in the fluid's momentum as it flows through vanes in a turbine. The pump and motor usually consist of rotating vanes without seals and are typically placed in close proximity. The transmission ratio can be made to vary by means of additional rotating vanes, an effect similar to varying the pitch of an airplane propeller.

The torque converter in most automotive automatic transmissions is, in itself, a hydrodynamic transmission.

It was possible to drive the Dynaflo transmission without shifting the mechanical gears.

Hydrodynamic transmissions are used in many passenger rail vehicles. In this application the advantage of smooth power delivery may outweigh the reduced efficiency caused by turbulence energy losses in the fluid.

Electric

Electric transmissions convert the mechanical power of the engine(s) to electricity with electric generators and convert it back to mechanical power with electric motors. Electrical or electronic adjustable-speed drive control systems are used to control the speed and torque of the motors. If the generators are driven by turbines, such arrangements are called turbo-electric. Likewise installations powered by diesel-engines are called diesel-electric. Diesel-electric arrangements are used on many railway locomotives, ships and large mining trucks.

Virtual transmission

Virtual Transmission allows for the same traction motor to be both a low-speed high torque and high-speed electric motor, using the winding/software that runs on the new electric motors. This virtual transmission will require less complex engineering, and less weight. The alternator and starter for the Chevrolet Volt can be combined into a single armature, smaller and lighter than each alternator and starter individually.

Chapter 2

Manual Transmission



A floor-mounted gear shift lever in a modern passenger car with a manual transmission

A **manual transmission**, also known as a **manual gearbox** or **standard transmission** (informally, a "manual", "straight shift", "stick (shift)" (US), or "straight drive") is a type of transmission used in motor vehicle applications. It generally uses a driver-operated clutch, typically operated by a pedal or lever, for regulating torque transfer from the internal combustion engine to the transmission, and a gear stick, either operated by hand (as in a car) or by foot (as on a motorcycle).

A conventional manual transmission is frequently the base equipment in a car; other options include automated transmissions such as an automatic transmission (often a manumatic), a semi-automatic transmission, or a continuously variable transmission (CVT).

Overview

Manual transmissions often feature a driver-operated clutch and a movable gear stick. Most automobile manual transmissions allow the driver to select any forward gear ratio ("gear") at any time, but some, such as those commonly mounted on motorcycles and some types of racing cars, only allow the driver to select the next-higher or next-lower gear. This type of transmission is sometimes called a sequential manual transmission. Sequential transmissions are commonly used in auto racing for their ability to make quick shifts.

Manual transmissions are characterized by gear ratios that are selectable by locking selected gear pairs to the output shaft inside the transmission. Conversely, most automatic transmissions feature epicyclic (planetary) gearing controlled by brake bands and/or clutch packs to select gear ratio. Automatic transmissions that allow the driver to manually select the current gear are called Manumatics. A manual-style transmission operated by computer is often called an *automated* transmission rather than an *automatic*.

Contemporary automobile manual transmissions typically use four to six forward gears and one reverse gear, although automobile manual transmissions have been built with as few as two and as many as eight gears. Transmission for heavy trucks and other heavy equipment usually have at least 9 gears so the transmission can offer both a wide range of gears and close gear ratios to keep the engine running in the power band. Some heavy vehicle transmissions have dozens of gears, but many are duplicates, introduced as an accident of combining gear sets, or introduced to simplify shifting. Some manuals are referred to by the number of forward gears they offer (e.g., 5-speed) as a way of distinguishing between automatic or other available manual transmissions. Similarly, a 5-speed automatic transmission is referred to as a "5-speed automatic."

Unsynchronized transmission

The earliest form of a manual transmission is thought to have been invented by Louis-René Panhard and Emile Levassor in the late 19th century. This type of transmission offered multiple gear ratios and, in most cases, reverse. The gears were typically engaged by sliding them on their shafts (hence the phrase *shifting gears*), which required a lot of

careful timing and throttle manipulation when shifting, so that the gears would be spinning at roughly the same speed when engaged; otherwise, the teeth would refuse to mesh. These transmissions are called *sliding mesh* transmissions and sometimes called a crash box, because of the difficulty in changing gears and the loud grinding sound that often accompanied. Newer manual transmissions on cars, instead have all gears mesh at all times; these are referred to as *constant-mesh* transmissions, with "synchro-mesh" being a further refinement of the constant mesh principle.

In both types, a particular gear combination can only be engaged when the two parts to engage (either gears or clutches) are at the same speed. To shift to a higher gear, the transmission is put in neutral and the engine allowed to slow down until the transmission parts for the next gear are at a proper speed to engage. The vehicle also slows while in neutral and that slows other transmission parts, so the time in neutral depends on the grade, wind, and other such factors. To shift to a lower gear, the transmission is put in neutral and the throttle is used to speed up the engine and thus the relevant transmission parts, to match speeds for engaging the next lower gear. For both upshifts and downshifts, the clutch is released (engaged) while in neutral. Some drivers use the clutch only for starting from a stop, and shifts are done without the clutch. Other drivers will depress (disengage) the clutch, shift to neutral, then engage the clutch momentarily to force transmission parts to match the engine speed, then depress the clutch again to shift to the next gear, a process called double clutching. Double clutching is easier to get smooth, as speeds that are close but not quite matched need to speed up or slow down only transmission parts, whereas with the clutch engaged to the engine, mismatched speeds are fighting the rotational inertia and power of the engine.

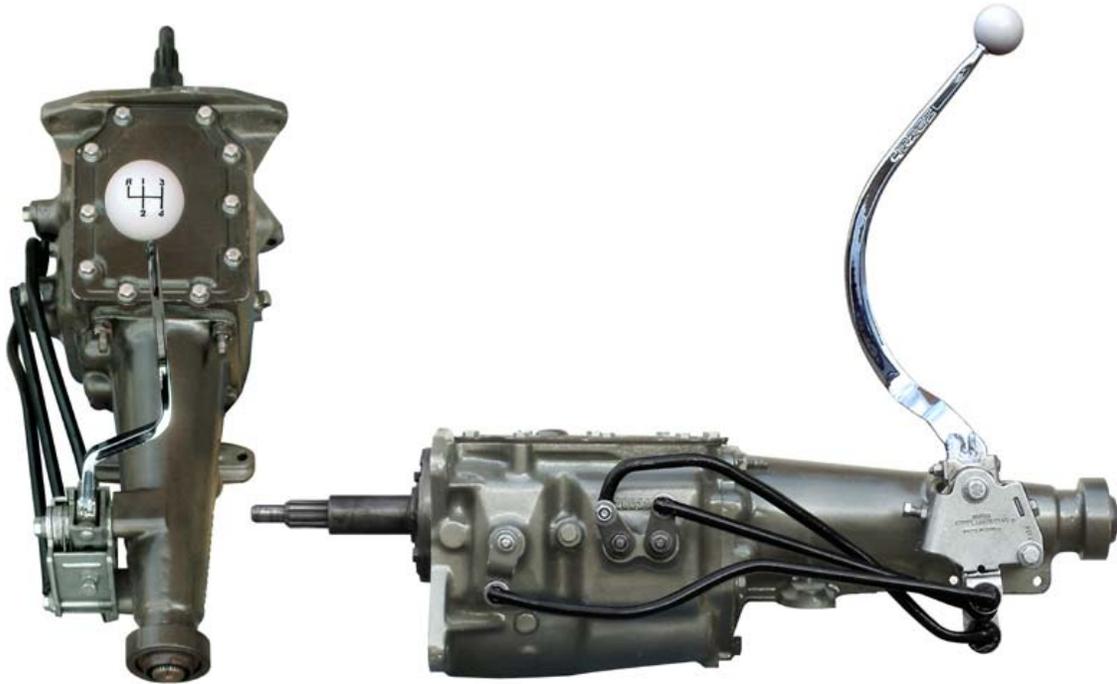
Even though automobile and light truck transmissions are now almost universally synchronised, transmissions for heavy trucks and machinery, motorcycles, and for dedicated racing are usually not. Non-synchronized transmission designs are used for several reasons. The friction material, such as brass, in synchronizers is more prone to wear and breakage than gears, which are forged steel, and the simplicity of the mechanism improves reliability and reduces cost. In addition, the process of shifting a synchromesh transmission is slower than that of shifting a non-synchromesh transmission. For racing of production-based transmissions, sometimes half the teeth (or *dogs*) on the synchros are removed to speed the shifting process, at the expense of greater wear.

Heavy duty trucks often use unsynchronized transmissions. Military trucks usually have synchronized transmissions, allowing untrained personnel to operate them in emergencies. In the United States, traffic safety rules refer to non-synchronous transmissions in classes of larger commercial motor vehicles. In Europe, heavy duty trucks use synchronized gearboxes as standard.

Similarly, most modern motorcycles use unsynchronized transmissions as synchronizers are generally not necessary or desirable. Their low gear inertias and higher strengths mean that forcing the gears to alter speed is not damaging, and the pedal operated selector on modern motorcycles is not conducive to having the long shift time of a synchronized

gearbox. Because of this, it is necessary to synchronize gear speeds by blipping the throttle when shifting into a lower gear on a motorcycle.

Synchronised transmission



Top and side view of a typical manual transmission, in this case a Ford Toploader, used in cars with external floor shifters.

Most modern cars are fitted with a synchronised gear box. Transmission gears are always in mesh and rotating, but gears on one shaft can freely rotate or be locked to the shaft. The locking mechanism for a gear consists of a collar (or *dog collar*) on the shaft which is able to slide sideways so that teeth (or *dogs*) on its inner surface bridge two circular rings with teeth on their outer circumference: one attached to the gear, one to the shaft. When the rings are bridged by the collar, that particular gear is rotationally locked to the shaft and determines the output speed of the transmission. The gearshift lever manipulates the collars using a set of linkages, so arranged so that one collar may be permitted to lock only one gear at any one time; when "shifting gears," the locking collar from one gear is disengaged before that of another engaged. One collar often serves for two gears; sliding in one direction selects one transmission speed, in the other direction selects another.

In a synchromesh gearbox, to correctly match the speed of the gear to that of the shaft as the gear is engaged, the collar initially applies a force to a cone-shaped brass clutch attached to the gear, which brings the speeds to match prior to the collar locking into place. The collar is prevented from bridging the locking rings when the speeds are mismatched by synchro rings (also called blocker rings or baulk rings, with the latter being spelt *balk* in the U.S.). The synchro ring rotates slightly due to the frictional torque

from the cone clutch. In this position, the dog clutch is prevented from engaging. The brass clutch ring gradually causes parts to spin at the same speed. When they do spin the same speed, there is no more torque from the cone clutch, and the dog clutch is allowed to fall in to engagement. In a modern gearbox, the action of all of these components is so smooth and fast it is hardly noticed.

The modern cone system was developed by Porsche and introduced in the 1952 Porsche 356; cone synchronisers were called *Porsche-type* for many years after this. In the early 1950s, only the second-third shift was synchromesh in most cars, requiring only a single synchro and a simple linkage; drivers' manuals in cars suggested that if the driver needed to shift from second to first, it was best to come to a complete stop then shift into first and start up again. With continuing sophistication of mechanical development, however, fully synchromesh transmissions with three speeds, then four speeds, and then five speeds, became universal by the 1980s. Many modern manual transmission cars, especially sports cars, now offer six speeds.

Reverse gear, however, is usually not synchromesh, as there is only one reverse gear in the normal automotive transmission and changing gears into reverse while moving is not required. Among the cars that have synchromesh in reverse are the 1995-2000 Ford Contour and Mercury Mystique, '00-'05 Chevrolet Cavalier, Mercedes 190 2.3-16, the V6 equipped Alfa Romeo GTV/Spider (916), certain Chrysler, Jeep, and GM products which use the New Venture NV3500 and NV3550 units, the European Ford Sierra and Granada/Scorpio equipped with the MT75 gearbox, the Volvo 850, and almost all Lamborghinis and BMWs.

Internals

Shafts

Like other transmissions, a manual transmission has several shafts with various gears and other components attached to them. Typically, a rear-wheel-drive transmission has three shafts: an input shaft, a *countershaft* and an output shaft. The countershaft is sometimes called a *layshaft*.

In a rear-wheel-drive transmission, the input and output shaft lie along the same line, and may in fact be combined into a single shaft within the transmission. This single shaft is called a *mainshaft*. The input and output ends of this combined shaft rotate independently, at different speeds, which is possible because one piece slides into a hollow bore in the other piece, where it is supported by a bearing. Sometimes the term *mainshaft* refers to just the input shaft or just the output shaft, rather than the entire assembly.

In some transmissions, it's possible for the input and output components of the mainshaft to be locked together to create a 1:1 gear ratio, causing the power flow to bypass the countershaft. The mainshaft then behaves like a single, solid shaft, a situation referred to as *direct drive*.

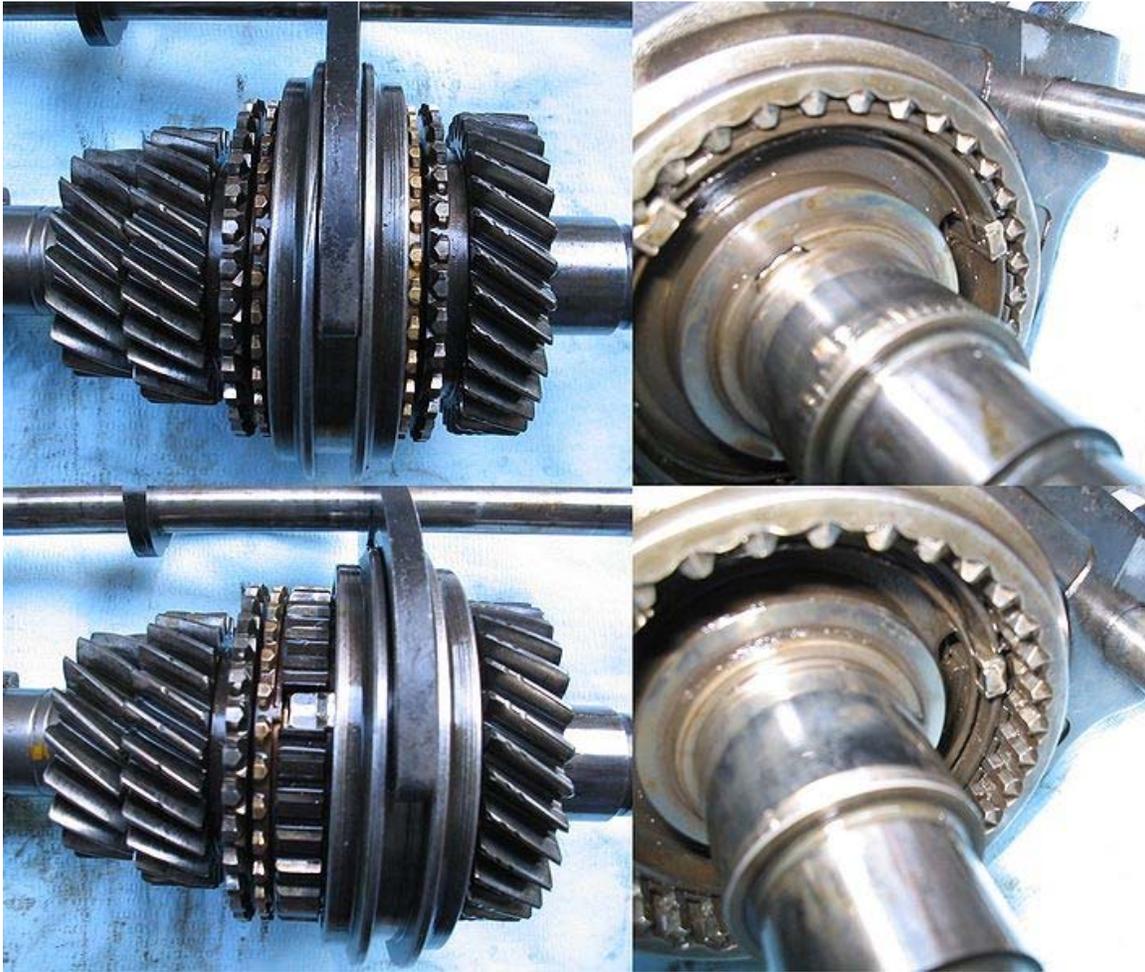
Even in transmissions that do not feature direct drive, it's an advantage for the input and output to lie along the same line, because this reduces the amount of torsion that the transmission case has to bear.

Under one possible design, the transmission's input shaft has just one pinion gear, which drives the countershaft. Along the countershaft are mounted gears of various sizes, which rotate when the input shaft rotates. These gears correspond to the forward speeds and reverse. Each of the forward gears on the countershaft is permanently meshed with a corresponding gear on the output shaft. However, these driven gears are not rigidly attached to the output shaft: although the shaft runs through them, they spin independently of it, which is made possible by bearings in their hubs.

Most front-wheel-drive transmissions for transverse engine mounting are designed differently. For one thing, they have an integral final drive and differential. For another, they usually have only two shafts; input and countershaft, sometimes called input and output. The input shaft runs the whole length of the gearbox, and there is no separate input pinion. At the end of the second (counter/output) shaft is a pinion gear that mates with the ring gear on the differential.

Front-wheel and rear-wheel-drive transmissions operate similarly. When the transmission is in neutral, and the clutch is disengaged, the input shaft, clutch disk and countershaft can continue to rotate under their own inertia. In this state, the engine, the input shaft and clutch, and the output shaft all rotate independently.

Dog clutch



Dog clutches. The gear-like teeth ("dogs", right-side images) engage and disengage with each other.

Among many different types of clutches, a dog clutch provides non-slip coupling of two rotating members. It is not at all suited to intentional slipping, in contrast with the foot-operated friction clutch of a manual-transmission car.

The gear selector does not engage or disengage the actual gear teeth which are permanently meshed. Rather, the action of the gear selector is to lock one of the freely spinning gears to the shaft that runs through its hub. The shaft then spins together with that gear. The output shaft's speed relative to the countershaft is determined by the ratio of the two gears: the one permanently attached to the countershaft, and that gear's mate which is now locked to the output shaft.

Locking the output shaft with a gear is achieved by means of a dog clutch selector. The dog clutch is a sliding selector mechanism which is splined to the output shaft, meaning that its hub has teeth that fit into slots (splines) on the shaft, forcing that shaft to rotate

with it. However, the splines allow the selector to move back and forth on the shaft, which happens when it is pushed by a selector fork that is linked to the gear lever. The fork does not rotate, so it is attached to a collar bearing on the selector. The selector is typically symmetric: it slides between two gears and has a synchromesh and teeth on each side in order to lock either gear to the shaft.

Synchromesh



Synchronizer rings

If the teeth, the so-called dog teeth, make contact with the gear, but the two parts are spinning at different speeds, the teeth will fail to engage and a loud grinding sound will be heard as they clatter together. For this reason, a modern dog clutch in an automobile has a synchronizer mechanism or *synchromesh*, which consists of a cone clutch and blocking ring. Before the teeth can engage, the cone clutch engages first which brings the selector and gear to the same speed using friction. Moreover, until synchronization occurs, the teeth are prevented from making contact, because further motion of the

selector is prevented by a *blocker* (or *baulk*) ring. When synchronization occurs, friction on the blocker ring is relieved and it twists slightly, bringing into alignment certain grooves and notches that allow further passage of the selector which brings the teeth together. Of course, the exact design of the synchronizer varies from manufacturer to manufacturer.

The synchronizer has to change the momentum of the entire input shaft and clutch disk. Additionally, it can be abused by exposure to the momentum and power of the engine itself, which is what happens when attempts are made to select a gear without fully disengaging the clutch. This causes extra wear on the rings and sleeves, reducing their service life. When an experimenting driver tries to "match the revs" on a synchronized transmission and force it into gear without using the clutch, the synchronizer will make up for any discrepancy in RPM. The success in engaging the gear without clutching can deceive the driver into thinking that the RPM of the layshaft and transmission were actually exactly matched. Nevertheless, approximate rev. matching *with clutching* can decrease the general delta between layshaft and transmission and decrease synchro wear.

Reverse

The previous discussion normally applies only to the forward gears. The implementation of the reverse gear is usually different, implemented in the following way to reduce the cost of the transmission. Reverse is also a pair of gears: one gear on the countershaft and one on the output shaft. However, whereas all the forward gears are always meshed together, there is a gap between the reverse gears. Moreover, they are both attached to their shafts: neither one rotates freely about the shaft. What happens when reverse is selected is that a small gear, called an *idler gear* or *reverse idler*, is slid between them. The idler has teeth which mesh with both gears, and thus it couples these gears together and reverses the direction of rotation without changing the gear ratio.

In other words, when reverse gear is selected, it is in fact *actual* gear teeth that are being meshed, with no aid from a synchronization mechanism. For this reason, the output shaft must not be rotating when reverse is selected: the car must be stopped. In order that reverse can be selected without grinding even if the input shaft is spinning inertially, there may be a mechanism to stop the input shaft from spinning. The driver brings the vehicle to a stop, and selects reverse. As that selection is made, some mechanism in the transmission stops the input shaft. Both gears are stopped and the idler can be inserted between them. There is a clear description of such a mechanism in the Honda Civic 1996-1998 Service Manual, which refers to it as a "noise reduction system":

Whenever the clutch pedal is depressed to shift into reverse, the mainshaft continues to rotate because of its inertia. The resulting speed difference between mainshaft and reverse idler gear produces gear noise [grinding]. The reverse gear noise reduction system employs a cam plate which was added to the reverse shift holder. When shifting into reverse, the 5th/reverse shift piece, connected to the shift lever, rotates the cam plate. This causes the 5th synchro set to stop the rotating mainshaft.

A reverse gear implemented this way makes a loud whining sound, which is not normally heard in the forward gears. The teeth on the forward gears of most consumer automobiles are helically cut. When helical gears rotate, there is constant contact between gears, which results in quiet operation. In spite of all forward gears being always meshed, they do not make a sound that can be easily heard above the engine noise. By contrast, most reverse gears are spur gears, meaning that they have straight teeth, in order to allow for the sliding engagement of the idler, which is difficult with helical gears. The teeth of spur gears clatter together when the gears spin, generating a characteristic whine.

It is clear that the spur gear design of reverse gear represents some compromises (less robust, unsynchronized engagement and loud noise) which are acceptable due to the relatively small amount of driving that takes place in reverse. The gearbox of the classic SAAB 900 is a notable example of a gearbox with a helical reverse gear engaged in the same unsynchronized manner as the spur gears described above. Its strange design allows reverse to share cogs with first gear, and is exceptionally quiet, but results in difficult engagement and unreliable operation. However, many modern transmissions now include a reverse gear synchronizer and helical gearing.

Design variations

Gear variety

Manual transmissions in passenger vehicles are often equipped with 4, 5, or more recently 6 forward gears in conventional manual transmissions with a gear stick, and up to 8 forward gears in semi-automatic transmissions. Nearly all have one reverse gear. In three or four speed transmissions, in most cases, the topmost gear is *direct* (i.e., a 1:1 ratio). For five speed or higher transmissions, the highest gear is usually an overdrive gear, with a ratio of less than 1:1. Older cars were generally equipped with 3-speed transmissions, or 4-speed transmissions for high performance models and 5-speeds for the most sophisticated of automobiles; in the 1970s, 5-speed transmissions began to appear in low priced mass market automobiles and even compact pickup trucks, pioneered by Toyota (who advertised the fact by giving each model the suffix *SR5* as it acquired the fifth speed). Today, mass market automotive manual transmissions are essentially all 5-speeds, with 6-speed transmissions beginning to emerge in high performance vehicles in the early 1990s, and recently beginning to be offered on some high-efficiency and conventional passenger cars. Some 7-speed manual-derived transmissions are offered on high-end performance cars, such as the Bugatti Veyron 16.4, or the BMW M5. Both of these cars feature a paddle shifter. Recently, even 8-speed transmissions were being offered, such as in the Lexus IS F, and in 2012 Mercedes-Benz plan to introduce a 9-speed gearbox.

External overdrive

On earlier models with three or four forward speeds, the lack of an overdrive ratio for relaxed and fuel-efficient highway cruising was often filled by incorporating a separate

overdrive unit in the rear housing of the transmission. This unit was separately actuated by a knob or button, often incorporated into the gearshift knob.

Shaft and gear configuration

On a conventional rear-drive transmission, there are three basic shafts; the input, the output, and the countershaft. The input and output together are called the *mainshaft*, since they are joined inside the transmission so they appear to be a single shaft, although they rotate totally independently of each other. The input length of this shaft is much shorter than the output shaft. Parallel to the mainshaft is the countershaft. There are a number of gears fixed along the countershaft, and matching gears along the output shaft, although these are not fixed, and rotate independently of the output shaft. There are sliding *dog collars*, or *dog clutches*, between the gears on the output shaft, and to engage a gear to the shaft, the collar slides into the space between the shaft and the inside space of the gear, thus rotating the shaft as well. One collar is usually mounted between two gears, and slides both ways to engage one or the other gears, so on a four speed there would be two collars. A front-drive transmission is basically the same, but may be simplified. There often are two shafts, the input and the output, but depending on the direction of rotation of the engine, three may be required. Rather than the input shaft driving the countershaft with a pinion gear, the input shaft takes over the countershaft's job, and the output shaft runs parallel to it. The gears are positioned and engaged just as they are on the countershaft and output shaft of a rear-drive. This merely eliminates one major component, the pinion gear. Part of the reason that the input and output are in-line on a rear drive unit is to relieve torsional stress on the transmission and mountings, but this isn't an issue in a front-drive as the gearbox is integrated into the transaxle.

The basic process is not universal. The fixed and free gears can be mounted on either the input or output shaft, or both.

The distribution of the shifters is also a matter of design; it need not be the case that all of the free-rotating gears with selectors are on one shaft, and the permanently splined gears on the other. For instance a five speed transmission might have the first-to-second selectors on the countershaft, but the third-to-fourth selector and the fifth selector on the mainshaft, which is the configuration in the 1998 Honda Civic. This means that when the car is stopped and idling in neutral with the clutch engaged and the input shaft spinning, the third, fourth and fifth gear pairs do not rotate.

In some transmission designs (Volvo 850 and V/S70 series, for example) there are actually two countershafts, both driving an output pinion meshing with the front-wheel-drive transaxle's ring gear. This allows the transmission designer to make the transmission narrower, since each countershaft need only be half as long as a traditional countershaft with four gears and two shifters.

Clutch

In all vehicles using a transmission (virtually all modern vehicles), a coupling device is used to separate the engine and transmission when necessary. The clutch accomplishes this in manual transmissions. Without it, the engine and tires would at all times be inextricably linked, and any time the vehicle stopped the engine would stall. Without the clutch, changing gears would be very difficult, even with the vehicle moving already: deselecting a gear while the transmission is under load requires considerable force, and selecting a gear requires the revolution speed of the engine to be held at a very precise value which depends on the vehicle speed and desired gear. In a car the clutch is usually operated by a pedal; on a motorcycle, a lever on the left handlebar serves the purpose.

- When the clutch pedal is fully depressed, the clutch is fully disengaged, and no torque is transferred from the engine to the transmission (and by extension to the drive wheels). In this uncoupled state it is possible to select gears or to stop the car without stopping the engine.
- When the clutch pedal is fully released, the clutch is fully engaged, and practically all of the engine's torque is transferred. In this coupled state, the clutch does not slip, but rather acts as rigid coupling, and power is transmitted to the wheels with minimal practical waste heat.
- Between these extremes of engagement and disengagement the clutch slips to varying degrees. When the clutch slips it still transmits torque despite the difference in speeds between the engine crankshaft and the transmission input. Because this torque is transmitted by means of friction rather than direct mechanical contact, considerable power is wasted as heat (which is dissipated by the clutch). Properly applied, slip allows the vehicle to be started from a standstill, and when it is already moving, allows the engine rotation to gradually adjust to a newly selected gear ratio.
- Learning to use the clutch efficiently requires the development of muscle memory and a level of coordination analogous to that required to learn a musical instrument or to play a sport.
- A rider of a highly-tuned motocross or off-road motorcycle may "hit" or "fan" the clutch when exiting corners to assist the engine in revving to the point where it delivers the most power.

Gear shift types

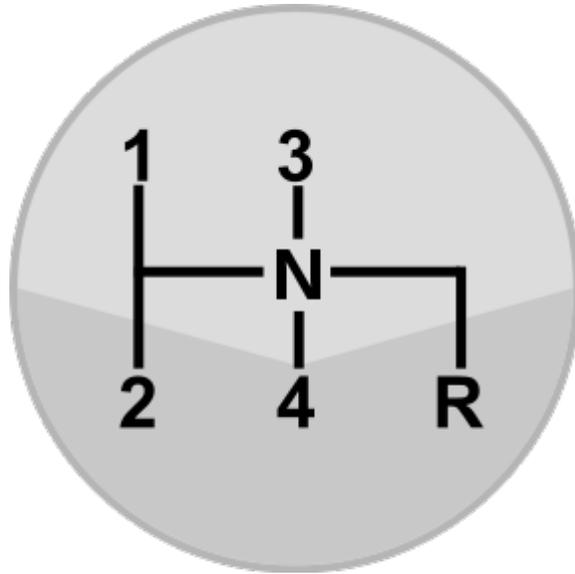
Floor-mounted shifter



A 5 speed gear lever

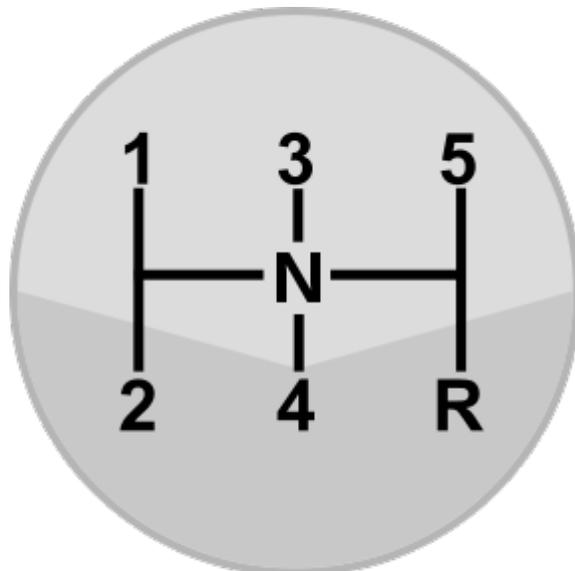
In many modern passenger cars, gears are selected by manipulating a lever connected to the transmission via linkage or cables and mounted on the floor of the automobile. This is called a **gear stick**, **shift stick**, **gearshift**, **gear lever**, **gear selector**, or **shifter**. Moving the lever forward, backward, left, and right into specific positions selects particular gears.

A sample layout of a *four-speed* transmission is shown below. **N** marks *neutral*, the position wherein no gears are engaged and the engine is decoupled from the vehicle's drive wheels. In reality, the entire horizontal line is a neutral position, although the shifter is usually equipped with springs so that it will return to the **N** position if not moved to another gear. The **R** marks reverse, the gear position used for moving the vehicle rearward.



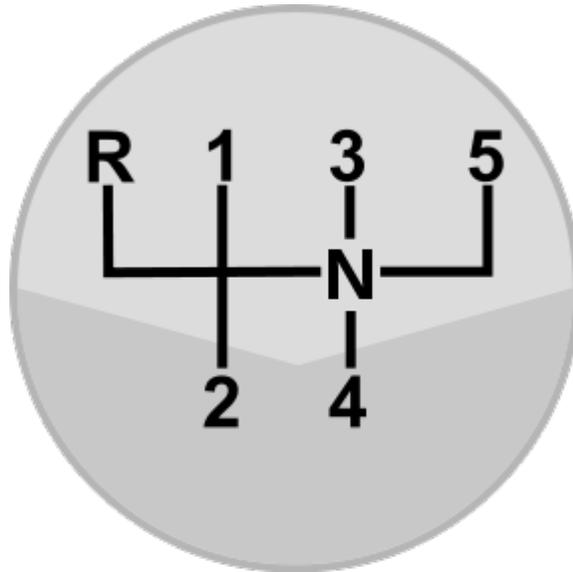
This layout is called the **shift pattern**. Because of the shift quadrants, the basic arrangement is often called an *H-pattern*. The shift pattern is usually molded or printed on or near the gear knob. While the layout for gears one through four is nearly universal, the location of reverse is not. Depending on the particular transmission design, reverse may be located at the upper left extent of the shift pattern, at the lower left, at the lower right, or at the upper right. There is usually a mechanism that only allows selection of reverse from the neutral position, or a reverse blockout that must be released by depressing the spring-loaded gear knob or lifting a spring-loaded collar on the shift stick, to reduce the likelihood that reverse will be inadvertently selected by the driver.

This is the most common five-speed shift pattern:

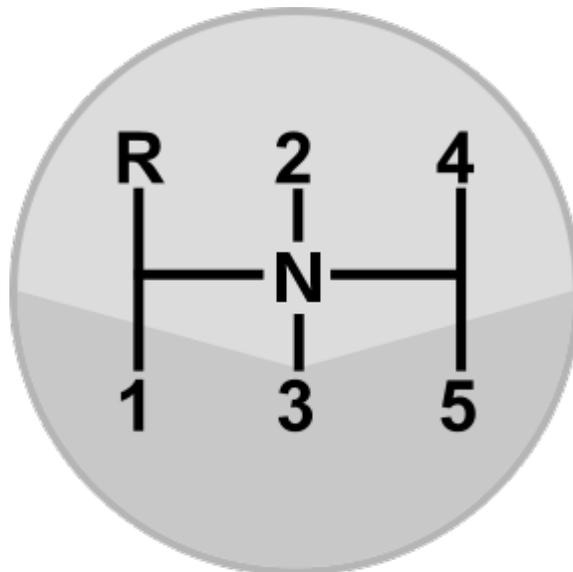


This layout is reasonably intuitive because it starts at the upper left and works left to right, top to bottom, with reverse at the end of the sequence and toward the rear of the car.

This is another five-speed shift pattern, which can be found in Saabs, BMWs, some Audis, Eagle, Volvos, Volkswagens, Škodas, Opels, Hyundais, most Renaults, some diesel Fords, and more:



Dog-leg first shift patterns are used on many race cars and on older road vehicles with three-speed transmissions:

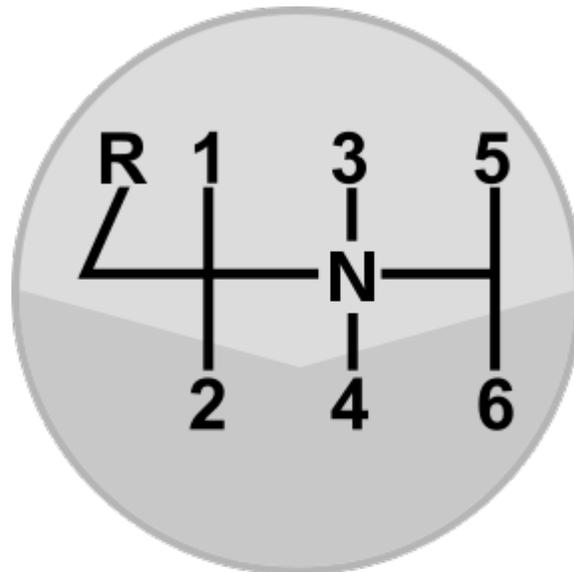


The name derives from the up-and-over path between first and second gears. Its use is common in race cars and sports cars, but is diminishing as six speed and sequential

gearboxes are becoming more common. Having first gear across the dog leg is beneficial as first gear is traditionally only used for getting the car moving and hence it allows second and third gears to be aligned fore and aft of each other, which facilitates shifting between the two. As most racing gearboxes are non-synchromesh there is no appreciable delay when upshifting from first through the dog leg into second.

This gear pattern can also be found on some heavy vehicles in which first gear is an extra-low ratio for use in extreme standing-start conditions, and would see little use in normal driving.

This is a typical shift pattern for a six-speed transmission:



Six speeds is the maximum usually seen in single range transmissions, however many semi trucks and other large commercial vehicles have manual transmissions with 8, 16 or even 20 speeds, which is made possible due to multi-range gearboxes. In such a case, Reverse is placed outside of the "H," with a canted shift path, to prevent the shift lever from intruding too far into the driver's space (in left-hand drive cars) when reverse is selected. This is the most common layout for a six-speed manual transmission.

Most front-engined, rear-wheel drive cars have a transmission that sits between the driver and the front passenger seat. Floor-mounted shifters are often connected directly to the transmission. Front-wheel drive and rear-engined cars often require a mechanical linkage to connect the shifter to the transmission.

"Four-on-the-Floor"

Historically, four-speed floor shifters were sometimes referred to as "four on the floor," during the period when steering column mounted shifters were more common. The latter, often being the standard non-performance transmission, usually had only three forward speeds and were referred to as "three on the tree."

Column-mounted shifter

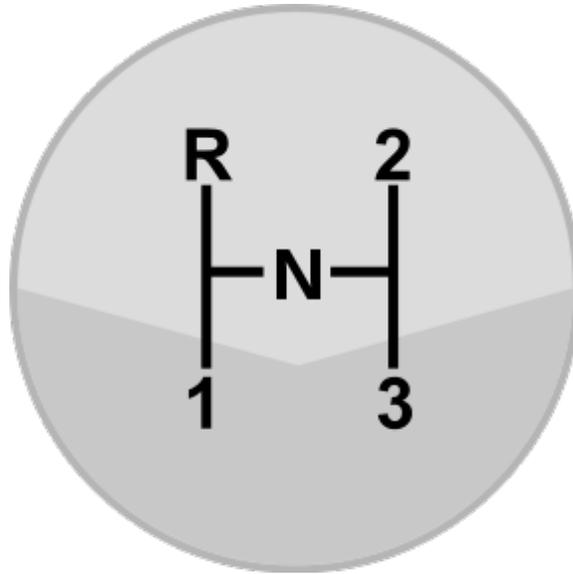


Column mounted gear shift lever in a Saab 96

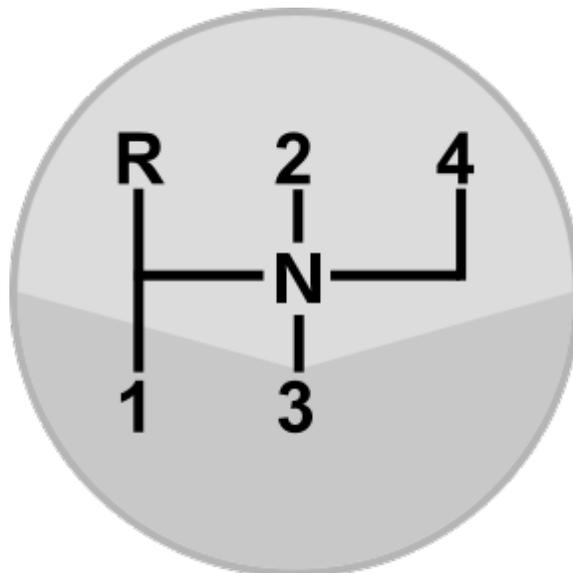
Some cars have a gear lever mounted on the steering column of the car. It was common in some countries in the past but is no longer common today. However, many automatic transmissions still use this placement.

Column shifters are mechanically similar to floor shifters, although shifting occurs in a vertical plane instead of a horizontal one. Column shifters also generally involve additional linkages to connect the shifter with the transmission. Also, the pattern is not "intuitive," as the shifter has to be moved backward and upward into R to make the car go backward. The major advantage of a column shifter is that the driver can switch between the two most commonly used gears without letting go of the steering wheel, by reaching the lever using the index and middle fingers.

A 3-speed column shifter, nicknamed "Three on the Tree" began appearing in America in the late 1930s and became common during the 1940s and '50s. Its layout is as shown below:



First gear in a 3-speed is often called "low," while third is usually called "high." There is, of course, no overdrive. Later, European and Japanese models began to have 4-speed column shifters and some of these made their way to the USA. Its layout is shown here:



However, the column manual shifter disappeared in North America by the mid 1980s, last appearing in the 1987 Chevrolet c10. But in the rest of the world, the column mounted shifter remained in production, and was in fact common in some places. For example, all Toyota Crown and Nissan Cedric taxis in Hong Kong had the 4-speed column shift until 1999 when automatic began to be offered. Since the late 1980s or early 1990s, a 5-speed column shifter has been made in some vans sold in Asia and Europe, such as Toyota Hiace and Mitsubishi L400.

Console-mounted shifter

Newer small cars and MPV's, like the Suzuki MR Wagon, the Fiat Multipla, the Toyota Matrix, the Pontiac Vibe, the Chrysler RT platform cars and the Honda Civic Si EP3 may feature a manual or automatic transmission gear shifter located on the vehicle's instrument panel. Console-mounted shifters are similar to floor-mounted gear shifters in that most of the ones used in modern cars operate on a horizontal plane and can be mounted to the vehicle's transmission in much the same way a floor-mounted shifter can. However, because of the location of the gear shifter in comparison to the locations of the column shifter and the floor shifter, as well as the positioning of the shifter to the rest of the controls on the panel often require that the gearshift be mounted in a space that does not feature a lot of controls integral to the vehicle's operation or frequently used controls, such as those for the car stereo or car air conditioning, to help prevent accidental activation or driver confusion, especially in right-hand drive cars.

More and more small cars and vans from manufacturers such as Suzuki, Honda, and Volkswagen are featuring console shifters in that they free up space on the floor for other car features such as storage compartments without requiring that the gear shift be mounted on the steering column. Also, the basic location of the gear shift in comparison to the column shifter makes console shifters easier to operate than column shifters.

Sequential manual

Some transmissions do not allow the driver to arbitrarily select any gear. Instead, the driver may only ever select the next-lowest or next-highest gear ratio. Sequential transmissions often incorporate a synchro-less dog-clutch engagement mechanism (instead of the synchromesh dog clutch common on H-pattern automotive transmissions), in which case the clutch is only necessary when selecting first or reverse gear from neutral, and most gear changes can be performed without the clutch. However, sequential shifting and synchro-less engagement are not inherently linked, though they often occur together due to the environment(s) in which these transmissions are used, such as racing cars and motorcycles.

Sequential transmissions are generally controlled by a forward-backward lever, foot pedal, or set of paddles mounted behind the steering wheel. In some cases, these are connected mechanically to the transmission. In many modern examples, these controls are attached to sensors which instruct a transmission computer to perform a shift—many of these systems can be switched into an automatic mode, where the computer controls the timing of shifts, much like an automatic transmission.

Motorcycles typically employ sequential transmissions, although the shift pattern is modified slightly for safety reasons. In a motorcycle the gears are usually shifted with the left foot pedal, the layout being this:



The gear shift lever on a 2003 Suzuki SV650S motorcycle.

6 5↓ 4↓ 3↓ 2↓ N 1

The pedal goes one step—both up and down—from the center, before it reaches its limit and has to be allowed to move back to the center position. Thus, changing multiple gears in one direction is accomplished by repeatedly pumping the pedal, either up or down. Although neutral is listed as being between first and second gear for this type of transmission, it "feels" more like first and second gear are just "further away" from each other than any other two sequential gears. Because this can lead to difficulty in finding neutral for inexperienced riders most motorcycles have a neutral indicator light on the instrument panel to help find neutral. The reason neutral does not actually have its own spot in the sequence is to make it quicker to shift from first to second when moving. Depending on the age of your motorcycle, gearbox, or skill, you can accidentally shift into neutral, although most high end, newer model motorcycles have found ways around this. The reason for having neutral between the first and second gears instead of at the bottom is that when stopped, the rider can just click down repeatedly and know that they will end up in first and not neutral. This allows a rider to quickly move his bike from a standstill in an emergency situation. This may also help on a steep hill on which high torque is required. It could be disadvantageous or even dangerous to attempt to be in first without realizing it, then try for a lower gear, only to get neutral.

On motorcycles used on race tracks, the shifting pattern is often reversed, that is, the rider clicks down to upshift. This usage pattern increases the ground clearance by placing the riders foot above the shift lever when the rider is most likely to need it, namely when leaning over and exiting a tight turn.

The shift pattern for most underbone motorcycles with an automatic centrifugal clutch is also modified for two key reasons - to enable the less-experienced riders to shift the gears without problems of "finding" neutral, and also due to the greater force needed to "lift" the gearshift lever (because the gearshift pedal of an underbone motorcycle also operates the clutch). The gearshift lever of an underbone motorcycle has two ends. The rider clicks down the front end with the left toe all the way to the top gear and clicks down the rear end with the heel all the way down to neutral. Some underbone models such as the Honda Wave and Kawasaki Fury series have a "rotary" shift pattern, which means that the rider can shift directly to neutral from the top gear, but for safety reasons this is only possible when the motorcycle is stationary. Some models also have gear position indicators for all gear positions at the instrument panel.

Semi-manual

Some new transmissions (Alfa Romeo's Selespeed gearbox and BMW's *Sequential Manual Gearbox* (SMG) for example) are conventional manual transmissions with a computerized control mechanism. These transmissions feature independently selectable gears but do not have a clutch pedal. Instead, the transmission computer controls a servo which disengages the clutch when necessary.

These transmissions vary from sequential transmissions in that they still allow nonsequential shifts: BMWs SMG system, for example, can shift from 6th gear directly to 4th gear.

In the case of the early second generation Saab 900, a 'Seletronic' option was available where gears were shifted with a conventional shifter, but the clutch is controlled by a computer.

Benefits and drawbacks

Benefits

Manual transmissions generally offer better fuel economy than automatic torque converter transmissions; however the disparity has been somewhat offset with the introduction of locking torque converters on automatic transmissions. Increased fuel economy with a properly operated manual transmission vehicle versus an equivalent automatic transmission vehicle can range from 5% to about 15% depending on driving conditions and style of driving. Manual transmissions do not require active cooling and generally weigh less than comparable automatics. The manual transmission couples the engine to the transmission with a rigid clutch instead of a torque converter which slips by nature. Manual transmissions also lack the parasitic power consumption of the automatic

transmission's hydraulic pump. Additionally, they require less maintenance and are easier to repair because they have fewer moving parts and are, mechanically, much simpler than automatic transmissions. When properly operated by an experienced driver, manual transmissions also tend to last longer than automatic transmissions.

Manual transmissions also generally offer a higher selection of gear ratios. Many vehicles offer a 5-speed or 6-speed manual, whereas the automatic option would typically be a 4-speed. The higher selection of gears allowed for more uses of the engine's power band, allowing for higher fuel economy and power output. This is generally due to the space available inside of a manual transmission versus an automatic since the latter requires extra components for self-shifting, such as torque converters and pumps. Automatic transmissions are now adding more speeds as the technology matures. ZF currently makes an 8-Speed automatic transmission, which is used on the Rolls Royce Ghost and the Bentley Mulsanne. The automatic transmission in the Nissan 370Z also has 7 speeds.

Manual transmissions are more efficient than conventional automatics and belt-driven continuously-variable transmissions. The driver has more direct control over the car with a manual than with an automatic, which can be employed by an experienced, knowledgeable driver who knows the correct procedure for executing a driving maneuver, and wants the vehicle to realize his or her intentions exactly and instantly. When starting forward, for example, the driver can control how much torque goes to the tires, which is useful on slippery surfaces such as ice, snow or mud. This can be done with clutch finesse, or by starting in second gear instead of first. An engine coupled with a manual transmission can often be started by the method of push starting. This is particularly useful if the starter is inoperable or defunct or the battery has drained below operable voltage. Likewise, a vehicle with a manual transmission and no clutch/starter interlock switch can be moved, if necessary, by cranking the starter while in gear. This is useful when the vehicle will not start, but must be immediately moved e.g. off the road in the event of a breakdown, if the vehicle has stalled on a railway crossing, or in extreme off-roading cases such as an engine that has stalled in deep water.

Currently only fully manual transmissions allow the driver to fully exploit the engine power at low to medium engine speeds. This is because even automatic transmissions which provide some manual mode (e.g. tiptronic), use a throttle kickdown switch, which forces a downshift on full throttle and causes the gearbox to ignore a user command to upshift on full throttle. This is especially notable on uphill roads, where cars with automatic transmission need to slow down to avoid downshifts, whereas cars with manual transmission and identical or lower engine power are still able to maintain their speed.

In contrast to most manual gearboxes, most automatic transmissions have a free-wheel-clutch. This means that the engine does not slow down the car when the driver steps off the throttle, also known as engine braking. This leads to more usage of the brakes in cars with automatic transmissions. However, the automatic gearboxes in commodity Nissans and Hondas disable the free wheel operation completely if the driver has selected a gear

position other than "D" - either "1", "2", or "D with overdrive off". This works by blocking the free-wheel sprag using a multi-disk clutch called the "overrun clutch".

Drawbacks

The smoothness and correct timing of gear shifts are wholly dependent on the driver's experience and skill. If an inexperienced driver selects the wrong gear by mistake, she/he can do damage to the engine and/or transmission.

Attempting to select reverse while the vehicle is moving forward causes severe gear wear (except in transmissions with synchromesh on the reverse gear). Most manual transmissions have a gate that locks out reverse directly from 5th gear however, to help prevent this. In order to engage reverse from 5th, the shift lever has to be moved to the center position between 2nd and 3rd, then back over and into reverse. Many newer six-speed manual transmissions have a collar under the shift knob which must be lifted to engage reverse to also help prevent this.

Choosing too low a gear with the car moving at speed can over-rev and damage the engine. There is a learning curve with a manual transmission; the driver must develop a feel for properly engaging the clutch, especially when starting forward on a steep road or when parking on an incline.

Some automatic transmissions can shift ratios faster than a manual gear change can be accomplished, due to the time required for the average driver to push the clutch pedal to the floor and move the gearstick from one position to another. This is especially true in regards to dual clutch transmissions, which are specialized computer-controlled manual transmissions. Even though some automatic transmissions and semi-automatic transmissions can shift faster, many purists still prefer a regular manual transmission.

Manual transmissions place a slightly greater workload on the driver in heavy traffic situations, when the driver must often operate the clutch pedal. In comparison, automatic transmissions merely require moving the foot from the accelerator pedal to the brake pedal, and vice versa. Manual transmissions require the driver to remove one hand periodically from the steering wheel while the vehicle is in motion.

Applications and popularity

Many types of automobiles are equipped with manual transmissions. Small economy cars predominantly feature manual transmissions because they are cheap and efficient, although many are optionally equipped with automatics. Economy cars are also often powered by very small engines, and manual transmissions make more efficient use of the power produced.

Sports cars are also often equipped with manual transmissions because they offer more direct driver involvement and better performance. Off-road vehicles and trucks often

feature manual transmissions because they allow direct gear selection and are often more rugged than their automatic counterparts.

Conversely, manual transmissions are no longer popular in many classes of cars sold in North America, Australia and Asia, although they remain dominant in Europe and developing countries. Nearly all cars are available with an automatic transmission option, and family cars and large trucks sold in the US are predominantly fitted with automatics, however in some cases if a buyer wishes he/she can have the car fitted with a manual transmission at the factory. In Europe most cars are sold with manual transmissions. Most luxury cars are only available with an automatic transmission. In most cases where both transmissions are available for a given car, automatics are an at cost option, but in some cases the reverse is true. Some cars, such as rental cars and taxis, are nearly universally equipped with automatic transmissions in countries such as the US, but the opposite is true in Europe. As of 2008, 75.2% of vehicles made in Western Europe were equipped with manual transmission, versus 16.1% with automatic and 8.7% with other.

In some places (for example Australia, New Zealand (for the second-phase Restricted licence, but not the final Full licence), Belgium, China, Estonia, Dominican Republic, Finland, France, Germany, Ireland, Israel, Netherlands, Norway, Poland, Singapore, Slovenia, South Africa, South Korea, Spain, Sri Lanka, Sweden, Turkey, U.A.E and the UK), when a driver takes the licensing road test using an automatic transmission, the resulting license is restricted to the use of automatic transmissions. This treatment of the manual transmission skill seems to maintain the widespread use of the manual transmission. As many new drivers worry that their restricted license will become an obstacle for them where most cars have manual transmissions, they make the effort to learn with manual transmissions and obtain full licenses. Some other countries (such as India, Pakistan, Malaysia, Serbia, Brazil, and Denmark) go even further, whereby the license is granted only when a test is passed on a manual transmission. In Denmark and Brazil you are allowed to take the test on an automatic if you are handicapped, with such license you will not be able to drive a manual transmission.

Truck transmissions

Some trucks have transmissions that look and behave like ordinary car transmissions - these transmissions are used on lighter trucks, typically have up to 6 gears, and usually have synchromesh.

For trucks needing more gears, the standard "H" pattern can get very complicated, so additional controls are used to select additional gears. The "H" pattern is retained, then an additional control selects among alternatives. In older trucks, the control is often a separate lever mounted on the floor or more recently a pneumatic switch mounted on the "H" lever; in newer trucks the control is often an electrical switch mounted on the "H" lever. Multi-control transmissions are built in much higher power ratings, but rarely use synchromesh.

There are several common alternatives for the shifting pattern. Usual types are:

- **Range transmissions** use an "H" pattern through a narrow range of gears, then a "range" control shifts the "H" pattern between high and low ranges. For example, an 8-speed range transmission has an H shift pattern with four gears. The first through fourth gears are accessed when low range is selected. To access the fifth through eighth gears, the range selector is moved to high range, and the gear lever again shifted through the first through fourth gear positions. In high range, the first gear position becomes fifth, the second gear position becomes sixth, and so on.
- **Splitter transmissions** use an "H" pattern with a wide range of gears, and the other selector splits each sequential gear position in two: First gear is in first position/low split, second gear is in first position/high split, third gear is in second position/low split, fourth gear is in second position/high split, and so on.
- **Range-Splitter transmissions** combine range-splitting and gear-splitting. This allows even more gear ratios. Both a range selector and a splitter selector are provided.

Although there are many gear positions, shifting through gears usually follows a regular pattern. For example, a series of upshifts might use "move to splitter direct; move to splitter overdrive; move shift lever to #2 and move splitter to underdrive; move splitter to direct; move splitter to overdrive; move shift lever to #3 and move splitter to underdrive"; and so on. In older trucks using floor-mounted levers, a bigger problem is common gear shifts require the drivers to move their hands between shift levers in a single shift, and without synchromesh, shifts must be carefully timed or the transmission will not engage. For this reason, some splitter transmissions have an additional "under under" range, so when the splitter is already in "under" it can be quickly downshifted again, without the delay of a double shift.

Today's truck transmissions are most commonly "range-splitter". The most common 13 speed has a standard H pattern, and the pattern from left upper corner is as follows: R, down to L, over and up to 1, down to 2, up and over to 3, down to 4. The "butterfly" range lever in the center front of the knob is flipped up to high range while in 4th, then shifted back to 1. The 1 through 4 positions of the knob are repeated. Also, each can be split using the thumb-actuated under-overdrive lever on the left side of the knob while in high range. The "thumb" lever is not available in low range, except in 18 speeds; 1 through 4 in low range can be split using the thumb lever and L can be split with the "Butterfly" lever. L cannot be split using the thumb lever in either the 13 or 18 speed. The 9 speed transmission is basically a 13 speed without the under-overdrive thumb lever.

Truck transmissions use many physical layouts. For example, the output of an N-speed transmission may drive an M-speed secondary transmission, giving a total of N*M gear combinations; for example a 4-speed main box and 3-speed splitter gives 12 ratios. Transmissions may be in separate cases with a shaft in between; in separate cases bolted together; or all in one case, using the same lubricating oil. The second transmission is often called a "Brownie" or "Brownie box" after a popular brand. With a third transmission, gears are multiplied yet again, giving greater range or closer spacing. Some

trucks thus have dozens of gear positions, although most are duplicates. Sometimes a secondary transmission is integrated with the differential in the rear axle, called a "two-speed rear end." Two-speed differentials are always splitters. In newer transmissions, there may be two countershafts, so each main shaft gear can be driven from one or the other countershaft; this allows construction with short and robust countershafts, while still allowing many gear combinations inside a single gear case.

Heavy-duty transmissions are almost always non-synchromesh. One argument is synchromesh adds weight that could be payload, is one more thing to fail, and drivers spend thousands of hours driving so can take the time to learn to drive efficiently with a non-synchromesh transmission. Heavy-duty trucks driven frequently in city traffic, such as cement mixers, need to be shifted very often and in stop-and-go traffic. Since few heavy-duty transmissions have synchromesh, automatic transmissions are commonly used instead, despite their increased weight, cost, and loss of efficiency.

Heavy trucks are usually powered with diesel engines. Diesel truck engines from the 1970s and earlier tend to have a narrow power band, so need many close-spaced gears. Starting with the 1968 Maxidyne, diesel truck engines have increasingly used turbochargers and electronic controls that widen the power band, allowing fewer and fewer gear ratios. A transmission with fewer ratios is lighter and may be more efficient due to fewer transmissions in series. Fewer shifts also makes the truck more drivable. As of 2005, fleet operators often use 9,10,13 or 18-speed transmissions, but automated manual and semi-automatic transmissions are becoming more common on heavy vehicles, as they can improve efficiency and drivability, reduce the barrier to entry for new drivers, and may improve safety by allowing the driver to concentrate on road conditions.

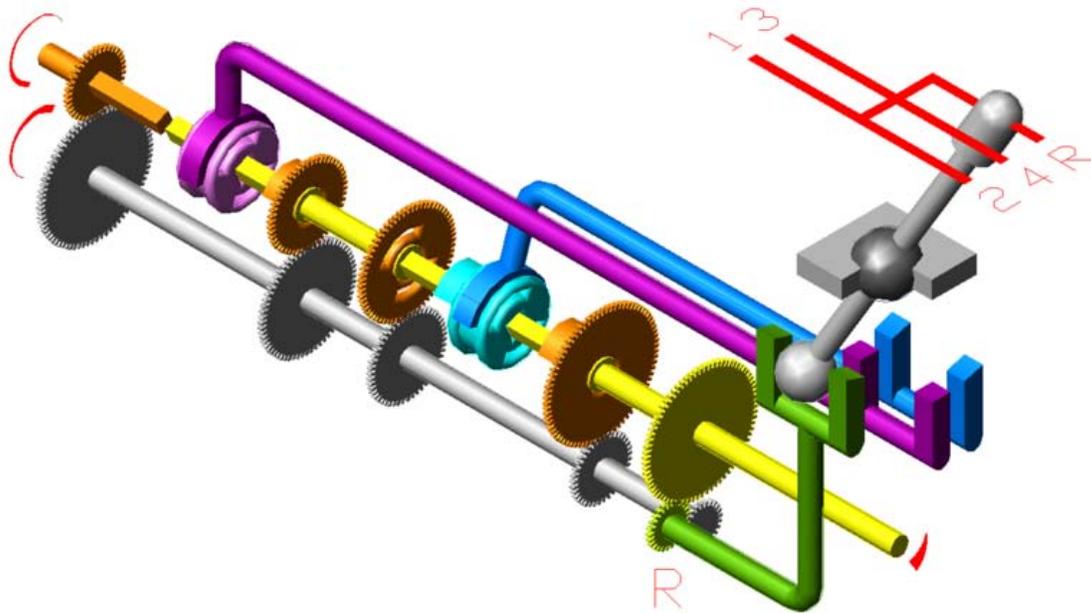
Maintenance

Because clutches use changes in friction to modulate the transfer of torque between engine and transmission, they are subject to wear in everyday use. A very good clutch, when used by an expert driver, can last hundreds of thousands of kilometres (or miles). Weak clutches, abrupt downshifting, inexperienced drivers, and aggressive driving can lead to more frequent repair or replacement.

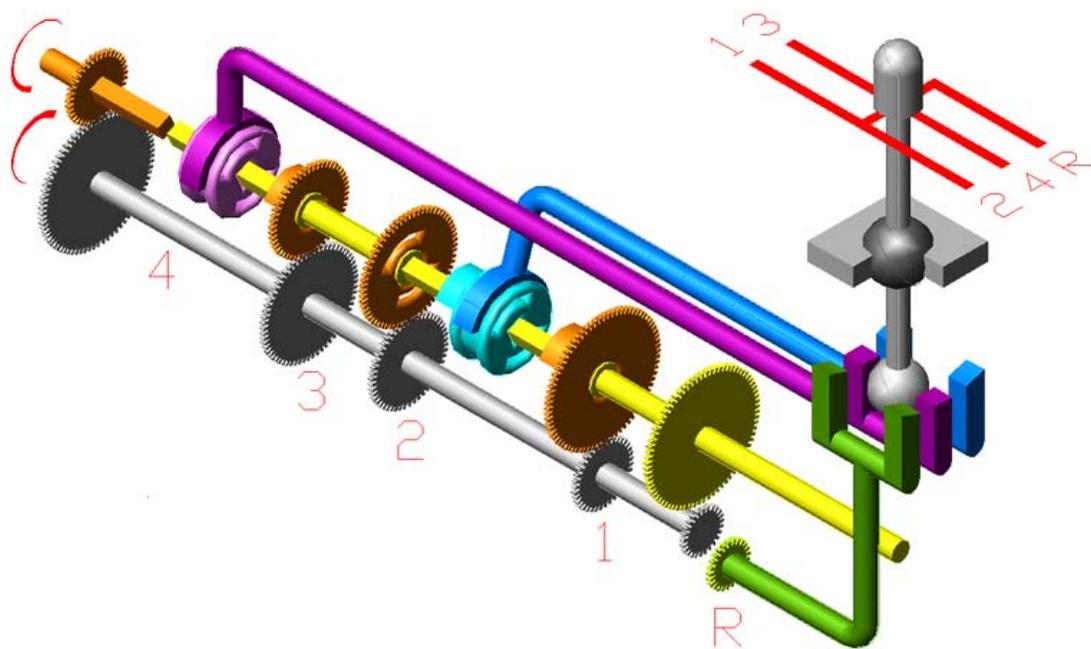
Manual transmissions are lubricated with gear oil or engine oil in some cars, which must be changed periodically in some cars, although not as frequently as the automatic transmission fluid in a vehicle so equipped. (Some manufacturers specify that changing the gear oil is never necessary except after transmission work or to rectify a leak.)

Gear oil has a characteristic aroma due to the addition of sulfur-bearing anti-wear compounds. These compounds are used to reduce the high sliding friction by the helical gear cut of the teeth (this cut eliminates the characteristic whine of straight cut spur gears). On motorcycles with "wet" clutches (clutch is bathed in engine oil), there is usually nothing separating the lower part of the engine from the transmission, so the same

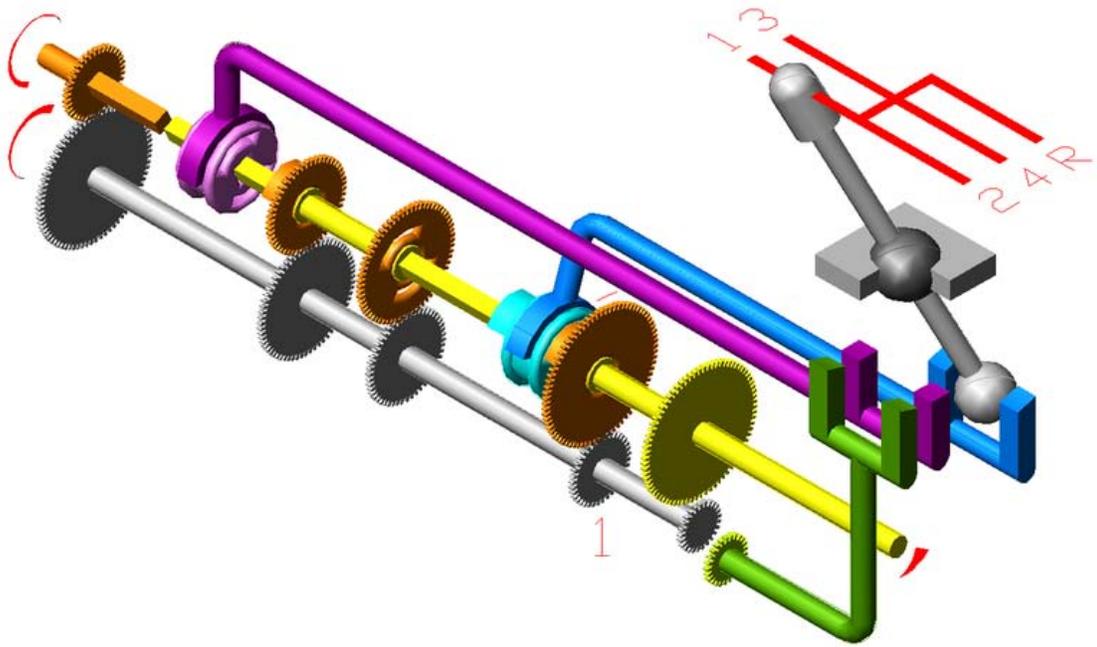
oil lubricates both the engine and transmission. The original Mini placed the gearbox in the oil sump below the engine, thus using the same oil for both.



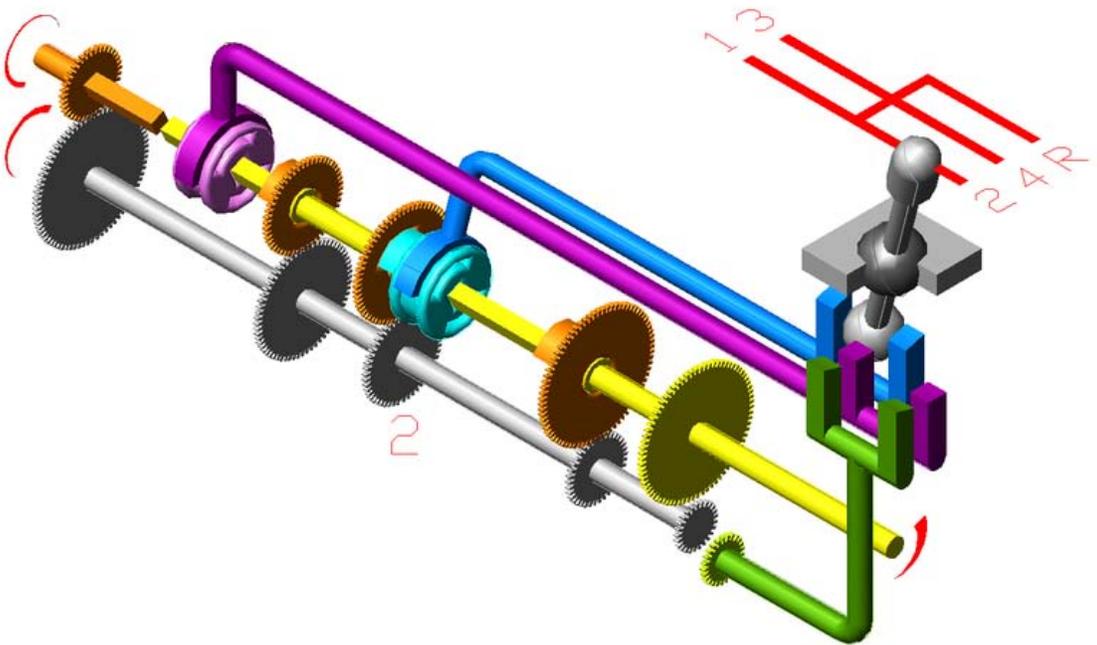
Reverse



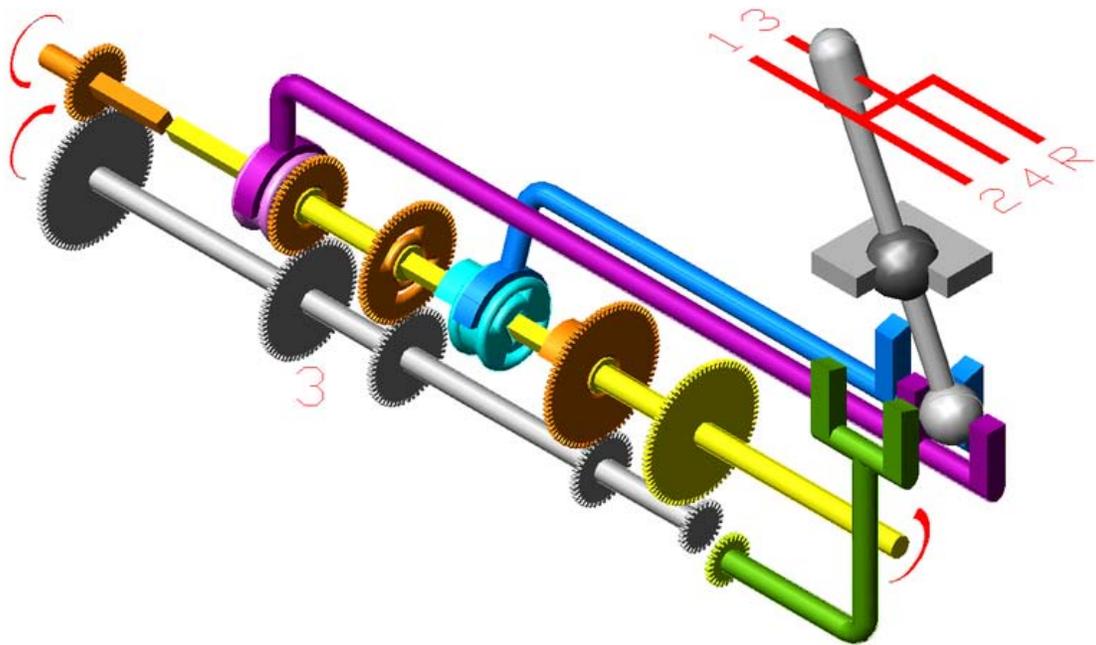
Neutral



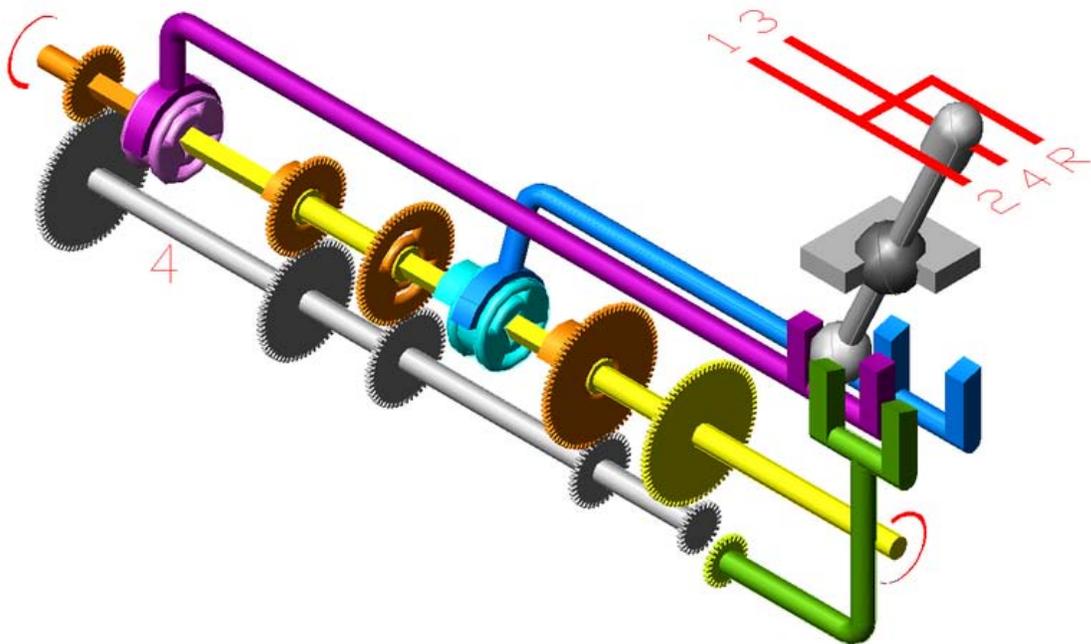
First gear



Second gear



Third gear



Fourth gear

Chapter 3

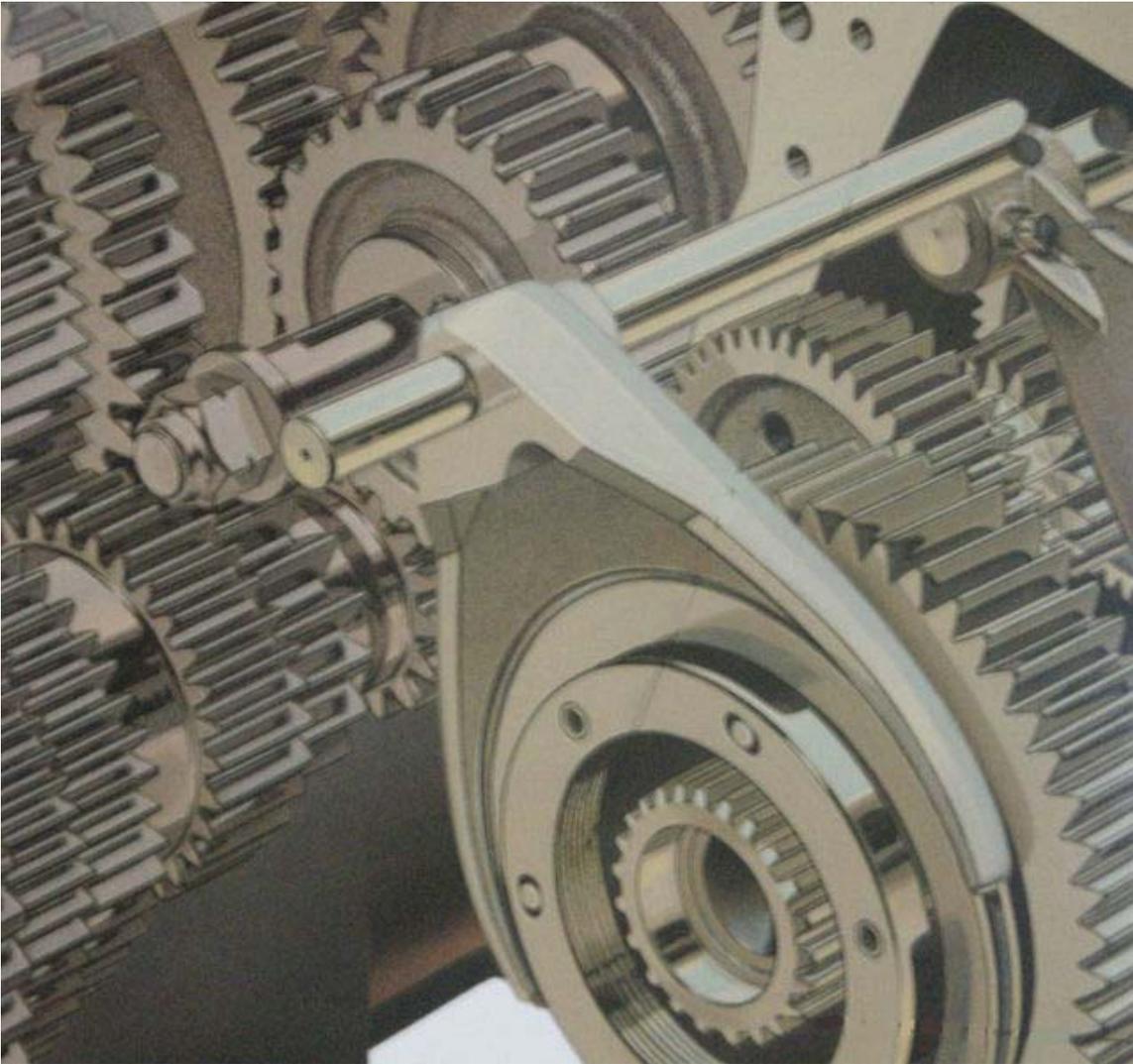
Non-Synchronous Transmission

A **non-synchronous transmission** is a form of transmission based on gears that do not use synchronizing mechanisms. They are found primarily in various types of agricultural, and commercial vehicles. Because the gear boxes are engineered without "cone and collar" synchronizing technology, the non-synchronous transmission type requires an understanding of gear range, torque, engine power, range selector, multi-functional clutch, and shifter functions. Engineered to pull tremendous loads, often equal to or exceeding 40 tons, some vehicles may also use a combination of transmissions for different mechanisms. An example would be a PTO.

History

In 1842, the reversing lever was invented and patented as the Walschaerts valve gear in Belgium, and reversing lever descriptions exist in British, and American mechanic's diagrams. In 1890, Panhard used a chain-drive with a Daimler engine in a horseless carriage. Industrial marketing has since then coined spectacular names for various vehicle parts. Changing from the Locomobile, a 1906 race-car to what is now called the automobile, advertisers used design wording from the engineering departments to give new ideas a desirable appeal for sales promotions. From 1932, synchronizer mechanisms began to appear in automotive transmissions. The split off of automotive transmission types that has prevailed in engineering designs uses three major categories: *automatic*, *manual*, and *non-synchronous*. Some of the differences are improvements, including the continuously variable transmission installed in hybrid vehicles that are powered partly by an internal combustion engine, and partly by an electric motor. The concepts of transmission continue to employ methods for transferring the most conceivably efficient use of power.

How non-synchronization works



Non-synchronous transmissions are engineered with the understanding that a trained operator will be shifting gears in a known coordination of timing. Commercial vehicle operators use a double-clutching technique that is taught in driver's trade schools. The most skillful drivers can shift these transmissions without using the clutch by bringing the engine to exactly the right rpm in neutral before attempting to complete a shift, a technique called "float-shifting." With payloads of cargo ranging in commercial freight of 80,000 lbs (40 tons (short) or 36.3 tonnes) or more, some heavy haulers have over 24 gears that an operator will shift through before reaching a top cruising speed of 70 mph. Many low-low (creeper) gears are used in farm equipment to plow, till, or harvest. An inexperienced operator would suddenly find a piece of heavy equipment stuck in gear under full power, or even worse unable to shift into gear a runaway vehicle in neutral headed down a steep slope, unless he understood the synchronizing skill, and torque issues in non-synchronous transmissions. Many mountain roads require heavy equipment operators to remain in gear and not shift while passing down a steep grade. For more details about steep grade operation see either jake brake, or engine brake. Many other

circumstances face operators of non-synchronous transmissions. Safety and operator skills need to be learned before operating any of these types of vehicles.

Double clutching (commercial motor vehicle)



Operators of 18-wheelers, farm equipment, tractors and other heavy equipment learn to float the transmission in and out of gear, beginning with dis-engaging the clutch by pressing the clutch pedal *only part way, enough* to pull the transmission out of gear, re-engaging the clutch in neutral (between gears by letting the clutch pedal all the way back out) to let the engine revolutions decelerate enough for the idle sprockets to shift, and free gear shafts to slow their revolutions per minute (RPM), then dis-engage the clutch again (by pressing the clutch pedal *only part way to the floor*) a 2nd time, and float the higher gear into engaging the drive coupling and fly wheel and engaging the clutch plates.

Professional operators of heavy equipment take extensive safety training before ever learning how to double-clutch. Once an operator is familiar with range, range selector, rpm, velocity, and torque of heavy equipment like an 18-wheeler, they can begin to anticipate when to shift gears. Operators become familiar with ranges of gears. They also learn not to leave their foot on the clutch while driving, because these types of transmissions use the clutch for several very different purposes. The depth the clutch is depressed to the floor will determine what the clutch will be doing as a synchronizing function.

Clutch brake

Unlike any other type of transmission, non-synchronous transmissions often have a mechanism for slowing down, or stopping an idle gear. In commercial motor vehicles, this mechanism is called the *clutch brake*, and is used by depressing the clutch all the way to the floor. This is useful in 18-wheelers that have just started their diesel engines, and are releasing parking locks, and engaging the transmission from a stop. The clutch brake not only slows or stops the idle gear axis, but can also prevent shifting into gear until the clutch is lifted a few inches off the floor. In order to shift into gear, the clutch must be half way off the floor, otherwise the clutch brake will prevent the transmission from being shifted into or out of gear. Mechanics must often repair or replace the *clutch brake* in a non-synchronous transmission when an inexperienced operator wears it out, it becomes inoperable, or has lost its function.

Comparison of transmissions

Non-synchronous transmissions are designed to depend upon an operator experienced in changing gears. These types of transmissions are known to heavy equipment operators as non-synchronous transmissions. The operators must understand how to shift these transmissions into and out of gear. Many learn how to do this in certifying schools.

All *automatic transmissions* have synchronizing mechanisms. Most manual transmissions also have synchronizers. But, there are still other types of transmissions used mostly in commercial applications that are non-synchronous.

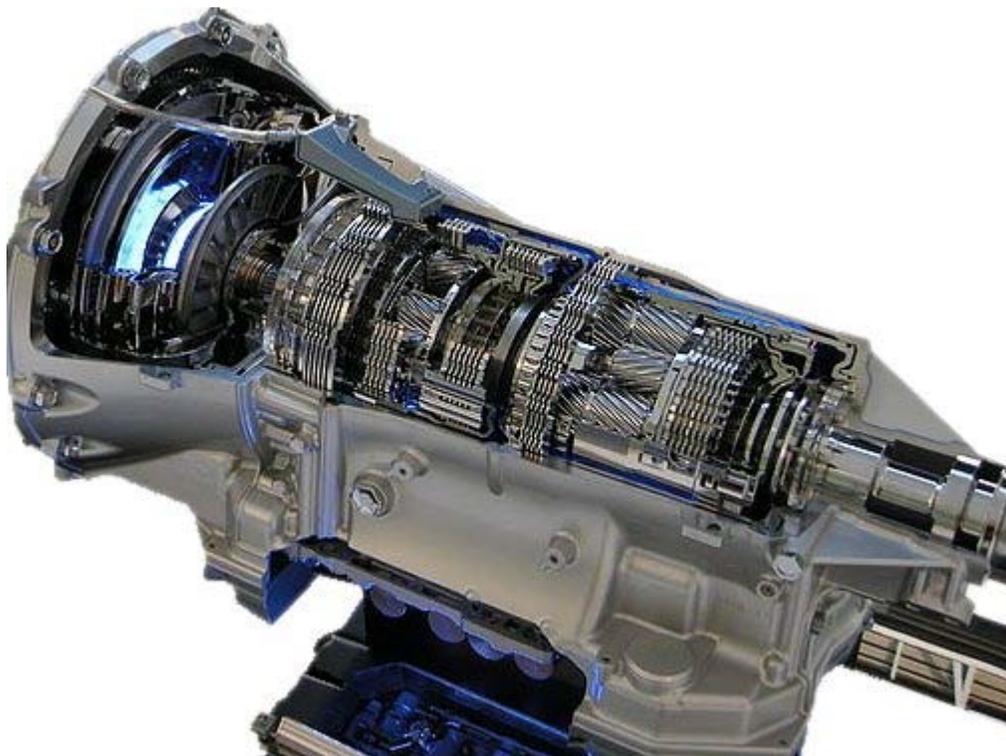
Fully synchronous,hydrau-pneumatic systems are designed to change gears based on engine performance, and other velocity indicators, delivering torque to drive wheels. These transmissions have synchronizing mechanisms (called cone & collar synchronizers) that are designed to keep gear dog-teeth from being broken off.

Heavy equipment for industrial, military, or farm use have different torque and load issues. They have unique stress from massive horsepower that would make converter faces shear. For the reasons of engineering a dependable, longer-life piece of equipment, these machines often use non-synchronous transmissions.

Any transmission that requires the operator to manually synchronize engine crank-shaft revolutions (RPM) with drive-shaft revolutions is non-synchronous.

Chapter 4

Automatic Transmission



An 8-gear automatic transmission

An **automatic gearbox** is one type of motor vehicle transmission that can automatically change gear ratios as the vehicle moves, freeing the driver from having to shift gears manually. Most automatic transmissions have a defined set of gear ranges, often with a parking pawl feature that locks the output shaft of the transmission.

Similar but larger devices are also used for heavy-duty commercial and industrial vehicles and equipment. Some machines with limited speed ranges or fixed engine speeds, such as some forklifts and lawn mowers, only use a torque converter to provide a variable gearing of the engine to the wheels.

Besides automatics, there are also other types of automated transmissions such as continuous variable transmissions (CVTs) and semi-automatic transmissions, that free the driver from having to shift gears manually, by using the transmission's computer to change gear, if for example the driver were redlining the engine. Despite superficial similarity to other automated transmissions, automatic transmissions differ significantly in internal operation and driver's "feel" from semi-automatics and CVTs. An automatic uses a torque converter instead of clutch to manage the connection between the transmission gearing and the engine. In contrast, a CVT uses a belt or other torque transmission schema to allow an "infinite" number of gear ratios instead of a fixed number of gear ratios. A semi-automatic retains a clutch like a manual transmission, but controls the clutch through electrohydraulic means.

A conventional manual transmission is frequently the base equipment in a car, with the option being an automated transmission such as a conventional automatic, semi-automatic, or CVT. The ability to shift gears manually, often via paddle shifters, can also be found on certain automated transmissions (manumatics such as Tiptronic), semi-automatics (BMW SMG), and continuous variable transmissions (CVTs) (such as Lineartronic).

Comparison with manual transmission

Most cars sold in North America since the 1950s have been available with an automatic transmission. Conversely, automatic transmission is less popular in Europe, with 80% of drivers opting for manual transmission.. In most Asian markets and in Australia, automatic transmissions have become very popular since the 1990s.

Vehicles equipped with automatic transmissions are less complex to drive. Consequently, in some jurisdictions, drivers who have passed their driving test in a vehicle with an automatic transmission will not be licensed to drive a manual transmission vehicle. Examples of driving license restrictions are Croatia, Dominican Republic, Israel, United Kingdom, some states in Australia, France, Portugal, Latvia, Lebanon, Lithuania, Ireland, Belgium, Germany, Pakistan, the Netherlands, Sweden, Austria, Norway, Poland, Hungary, South Africa, Trinidad and Tobago, China, Hong Kong, Macau, Mauritius, South Korea, Romania, Singapore, Philippines, United Arab Emirates, India, Estonia, Finland, Switzerland, Slovenia, Republic of Ireland and New Zealand (Restricted licence only).

Automatic transmission modes

Conventionally, in order to select the transmission operating 'mode', the driver moves a selection lever located either on the steering column or on the floor (as with a manual). In

order to select modes, or to manually select specific gear ratios, the driver must push a button in (called the shift lock button) or pull the handle (only on column mounted shifters) out. Some vehicles position selector buttons for each mode on the cockpit instead, freeing up space on the central console. Vehicles conforming to US Government standards must have the modes ordered P-R-N-D-L (left to right, top to bottom, or clockwise). Prior to this, quadrant-selected automatic transmissions often used a P-N-D-L-R layout, or similar. Such a pattern led to a number of deaths and injuries owing to unintentional gear selection, as well as the danger of having a selector (when worn) jump into Reverse from Low gear during engine braking maneuvers.

Automatic transmissions have various modes depending on the model and make of the transmission. Some of the common modes include

Park (P)

This selection mechanically locks the output shaft of transmission, restricting the vehicle from moving in any direction. A parking pawl prevents the transmission from rotating, and therefore the vehicle from moving, although the vehicle's non-driven roadwheels may still rotate freely. For this reason, it is recommended to use the hand brake (or parking brake) because this actually locks (in most cases) the rear wheels and prevents them from moving. This also increases the life of the transmission and the park pin mechanism, because parking on an incline with the transmission in park without the parking brake engaged will cause undue stress on the parking pin. An efficiently-adjusted hand brake should also prevent the car from moving if a worn selector accidentally drops into reverse gear during early morning fast-idle engine warm-ups. It should be noted that locking the transmission output shaft does not positively lock the driving wheels. If one driving wheel slips while the transmission is in "park," the other will roll freely as the slipping wheel rotates in the opposite direction. Only a (properly adjusted) parking brake can be relied upon to positively lock both of the parking-braked wheels. (This is not the case with certain 1950's Chrysler products that carried their parking brake on the transmission tailshaft, a defect compounded by the provision of a bumper jack). It is typical of front-wheel-drive vehicles for the parking brake to be on the rear (non-driving) wheels, so use of both the parking brake and the transmission park lock provides the greatest security against unintended movement on slopes. Unfortunately, the rear of most front-wheel-drive vehicles has only about half the weight on the rear wheel as is on the front wheels, greatly reducing the security provided by the parking brake as compared to either rear-wheel-drive vehicles with parking brake on the rear wheels (which generally have near half of the total vehicle weight on the rear wheels, except for empty pickup and open-bed trucks) or to front-wheel-drive vehicles with the parking brake on the front wheels, which generally have about two-thirds of the vehicle's weight (unloaded) on the front wheels.

A car should be allowed to come to a complete stop before setting the transmission into park to prevent damage. Usually, Park (P) is one of only two selections in which the car's engine can be started, the other being Neutral (N). In many modern cars and trucks, the driver must have the foot brake applied before

the transmission can be taken out of park. The Park position is omitted on buses/coaches with automatic transmission (on which a parking pawl is not practical), which must be placed in neutral with the parking brakes set. Advice is given in some owner's manuals [example: 1997 Oldsmobile Cutlass Supreme owner's manual] that if the vehicle is parked on a steep slope using the park lock only, it may not be possible to release the park lock (move the selector lever out of "P"). Another vehicle may be required to push the stuck vehicle uphill slightly to remove the loading on the park lock pawl.

Most automobiles require **P** or **N** to be set on the selector lever before the internal combustion engine can be started. This is typically achieved via a normally open 'inhibitor' switch, which is wired in series with the starter motor engagement circuit, and is only closed when P or N is selected, thus completing the circuit (when the key is turned to the start position)

Reverse (R)

This engages reverse gear within the transmission, giving the ability for the vehicle to drive backwards. In order for the driver to select reverse in modern transmissions, they must come to a complete stop, push the shift lock button in (or pull the shift lever forward in the case of a column shifter) and select reverse. Not coming to a complete stop can cause severe damage to the transmission. Many modern automatic transmissions have a safety mechanism in place, which does to some extent prevent (but does not completely avoid) inadvertently putting the car in reverse when the vehicle is moving forwards. This mechanism usually consists of a solenoid-controlled physical barrier on either side of the Reverse position, which is electronically engaged by a switch on the brake pedal. Therefore, the brake pedal needs to be depressed in order to allow the selection of reverse. Some electronic transmissions prevent or delay engagement of reverse gear altogether while the car is moving.

Some shifters with a shift button allow the driver to freely move the shifter from R to N or D, or simply moving the shifter to N or D without actually depressing the button. However, the driver cannot put back the shifter to R without depressing the shift button to prevent accidental shifting, especially at high speeds, which could damage the transmission.

Neutral/No gear (N)

This disengages all gear trains within the transmission, effectively disconnecting the transmission from the driven roadwheels, so the vehicle is able to move freely under its own weight and gain momentum without the motive force from the engine (engine braking). This is the only other selection in which the vehicle's engine can be started.

Drive (D)

This position allows the transmission to engage the full range of available forward gear trains, and therefore allows the vehicle to move forward and accelerate through its range of gears. The number of gear 'ratios' a transmission has depends on the model, but they initially ranged from three (predominant before the 1990s), to four and five speeds (losing popularity to six-speed autos, though still favored by Chrysler and Honda/Acura). Six-speed automatic transmissions are now probably the most common offering Toyota Camry V6 models, the Chevrolet

Malibu LTZ, Corvette, GM trucks, Pontiac G8, Ford Falcon BF 2005-2007 and Falcon FG 2008 - current in Australia with 6 speed ZF, and most newer model Ford/Lincoln/Mercury vehicles). However, seven-speed autos are becoming available (found in Mercedes 7G gearbox), as are eight-speed autos in the newer models of Lexus and BMW cars.

OverDrive (D, OD, or a boxed [D])

This mode is used in some transmissions to allow early computer-controlled transmissions to engage the Automatic Overdrive. In these transmissions, Drive (D) locks the Automatic Overdrive off, but is identical otherwise. OD (Overdrive) in these cars is engaged under steady speeds or low acceleration at approximately 35–45 mph (56–72 km/h). Under hard acceleration or below 35–45 mph (56–72 km/h), the transmission will automatically downshift. Vehicles with this option should be driven in this mode unless circumstances require a lower gear.

Third (3)

This mode limits the transmission to the first three gear ratios, or sometimes locks the transmission in third gear. This can be used to climb or going down hill. Some vehicles will automatically shift up out of third gear in this mode if a certain RPM range is reached in order to prevent engine damage. This gear is also recommended while towing a caravan.

Second (2 or S)

This mode limits the transmission to the first two gear ratios, or locks the transmission in second gear on Ford, Kia, and Honda models. This can be used to drive in adverse conditions such as snow and ice, as well as climbing or going down hills in the winter time. Some vehicles will automatically shift up out of second gear in this mode if a certain RPM range is reached in order to prevent engine damage.

Although traditionally considered second gear, there are other names used. Chrysler models with a three-speed automatic since the late 1980s have called this gear **3** while using the traditional names for *Drive* and *Low*.

First (1 or L [Low])

This mode locks the transmission in first gear only. It will not change to any other gear range. This, like second, can be used during the winter season, or for towing.

As well as the above modes there are also other modes, dependent on the manufacturer and model. Some examples include

D5

In Hondas and Acuras equipped with five-speed automatic transmissions, this mode is used commonly for highway use (as stated in the manual), and uses all five forward gears.

D4

This mode is also found in Honda and Acura four- or five-speed automatics, and only uses the first four gear ratios. According to the manual, it is used for "stop and go traffic", such as city driving.

D3 or 3

This mode is found in Honda, Acura, Volkswagen and Pontiac four-speed automatics and only uses the first three gear ratios. According to the manual, it is used for "stop & go traffic", such as city driving.

S or Sport

This is commonly described as 'Sport mode'. It operates in an identical manner as 'D' mode, except that the upshifts change much higher up the engine's rev range. This has the effect on maximising all the available engine output, and therefore enhances the performance of the vehicle, particularly during acceleration. This mode will also downchange much higher up the rev range compared to 'D' mode, maximising the effects of engine braking. This mode will have a detrimental effect on fuel economy. Hyundai has a Norm/Power switch next to the gearshift for this purpose on the Tiburon.

Some early GM's equipped with Tourqueflite transmissions used (S) to indicate Second gear, being the same as the 2 position on a Chrysler, shifting between only first and second gears. This would have been recommended for use on steep grades, or slippery roads like dirt, or ice, and limited to speeds under 40 mph. (L) was used in some early GM's to indicate (L)ow gear, being the same as the 2 position on a Chrysler, locking the transmission into first gear. This would have been recommended for use on steep grades, or slippery roads like dirt, or ice, and limited to speeds under 15 mph.

+ -, and M

This is for the 'manual mode' selection of gears in certain automatics, such as Porsche's Tiptronic. The M feature can also be found in Chrysler and General Motors products such as the Dodge Magnum and Pontiac G6, as well as Toyota's Camry, Corolla, Fortuner, Previa and Innova. Mitsubishi and some Audi models (TT), meanwhile do not have the M, and instead have the + and -, which is separated from the rest of the shift modes; the same is true for some Peugeot products like Peugeot 206. Meanwhile, the driver can shift up and down at will by toggling the (console mounted) shift lever like a semi-automatic transmission. This mode may be engaged either through a selector/position or by actually changing the gears (e.g., tipping the gear-down paddles mounted near the driver's fingers on the steering wheel).

Winter (W)

In some Mercedes-Benz, BMW and General Motors Europe models, a 'Winter mode' can be engaged so that second gear is selected instead of first when pulling away from stationary, to reduce the likelihood of loss of traction due to wheelspin on snow or ice. On GM cars, this was D2 in the 1950s, and is Second Gear Start after 1990. On Ford, Kia, and Honda automatics, this feature can be accessed by moving the gear selector to 2 to start, then taking your foot off the accelerator while selecting D once the car is moving.

Brake (B)

A mode selectable on some Toyota models. In non-hybrid cars, this mode lets the engine do compression braking, also known as engine braking, typically when encountering a steep downhill. Instead of engaging the brakes, the engine in a non-hybrid car switches to a lower gear and slows down the spinning tires. The

engine holds the car back, instead of the brakes slowing it down. For hybrid cars, this mode converts the electric motor into a generator for the battery. It is not the same as downshifting in a non-hybrid car, but it has the same effect in slowing the car without using the brakes. GM called this HR (hill retarder) and GR (grade retarder) in the 1950s.

Hydraulic automatic transmissions

The predominant form of automatic transmission is hydraulically operated; using a fluid coupling or torque converter, and a set of planetary gearsets to provide a range of gear ratios.

Parts and operation



A cut-away model of a torque converter

A hydraulic automatic transmission consists of the following parts:

- *Torque converter*: A type of fluid coupling, hydraulically connecting the engine to the transmission. It takes the place of a mechanical clutch, allowing the transmission to stay 'in gear' and the engine to remain running while the vehicle is stationary, without stalling. A torque converter differs from a fluid coupling, in that it provides a variable amount of torque multiplication at low engine speeds, increasing "breakaway" acceleration. This is accomplished with a third member in the "coupling assembly" known as the stator, and by altering the shapes of the

vanes inside the coupling in such a way as to curve the fluid's path into the stator. The stator captures the kinetic energy of the transmission fluid, in effect using the leftover force of it to enhance torque multiplication.

- *Pump*, not to be confused with the impeller inside the torque converter, is typically a gear pump mounted between the torque converter and the planetary gearset. It draws transmission fluid from a sump and pressurizes it, which is needed for transmission components to operate. The input for the pump is connected to the torque converter housing, which in turn is bolted to the engine's flywheel, so the pump provides pressure whenever the engine is running and there is enough transmission fluid.
- *Planetary gearset*: A compound epicyclic planetary gearset, whose bands and clutches are actuated by hydraulic servos controlled by the valve body, providing two or more gear ratios.
- *Clutches and bands*: to effect gear changes, one of two types of clutches or bands are used to hold a particular member of the planetary gearset motionless, while allowing another member to rotate, thereby transmitting torque and producing gear reductions or overdrive ratios. These clutches are actuated by the valve body (see below), their sequence controlled by the transmission's internal programming. Principally, a type of device known as a sprag or roller clutch is used for routine upshifts/downshifts. Operating much as a ratchet, it transmits torque only in one direction, free-wheeling or "overrunning" in the other. The advantage of this type of clutch is that it eliminates the sensitivity of timing a simultaneous clutch release/apply on two planetaries, simply "taking up" the drivetrain load when actuated, and releasing automatically when the next gear's sprag clutch assumes the torque transfer. The bands come into play for manually selected gears, such as low range or reverse, and operate on the planetary drum's circumference. Bands are not applied when drive/overdrive range is selected, the torque being transmitted by the sprag clutches instead. Bands are used for braking; the GM Turbo-Hydramatics incorporated this..
- *Valve body*: hydraulic control center that receives pressurized fluid from the *main pump* operated by the fluid coupling/torque converter. The pressure coming from this pump is regulated and used to run a network of spring-loaded valves, check balls and servo pistons. The valves use the pump pressure and the pressure from a centrifugal governor on the output side (as well as hydraulic signals from the range selector valves and the *throttle valve* or *modulator*) to control which ratio is selected on the gearset; as the vehicle and engine change speed, the difference between the pressures changes, causing different sets of valves to open and close. The hydraulic pressure controlled by these valves drives the various clutch and brake band actuators, thereby controlling the operation of the planetary gearset to select the optimum gear ratio for the current operating conditions. However, in many modern automatic transmissions, the valves are controlled by electro-mechanical servos which are controlled by the electronic engine control unit (ECU) or a separate transmission control unit (TCU).
- *Hydraulic & lubricating oil*: called automatic transmission fluid (ATF), this component of the transmission provides lubrication, corrosion prevention, and a hydraulic medium to convey mechanical power (for the operation of the

transmission). Primarily made from refined petroleum, and processed to provide properties that promote smooth power transmission and increase service life, the ATF is one of the few parts of the automatic transmission that needs routine service as the vehicle ages.

The multitude of parts, along with the complex design of the valve body, originally made hydraulic automatic transmissions much more complicated (and expensive) to build and repair than manual transmissions. In most cars (except US family, luxury, sport-utility vehicle, and minivan models) they have usually been extra-cost options for this reason. Mass manufacturing and decades of improvement have reduced this cost gap.

Energy efficiency

Hydraulic automatic transmissions are almost always less energy efficient than manual transmissions due mainly to viscous and pumping losses; both in the torque converter and the hydraulic actuators. A relatively small amount of energy is required to pressurize the hydraulic control system, which uses fluid pressure to determine the correct shifting patterns and operate the various automatic clutch mechanisms.

Manual transmissions use a mechanical clutch to transmit torque, rather than a torque converter, thus avoiding the primary source of loss in an automatic transmission. Manual transmissions also avoid the power requirement of the hydraulic control system, by relying on the human muscle power of the vehicle operator to disengage the clutch and actuate the gear levers, and the mental power of the operator to make appropriate gear ratio selections. Thus the manual transmission requires very little engine power to function, with the main power consumption due to drag from the gear train being immersed in the lubricating oil of the gearbox.

The energy efficiency of automatic transmission has increased with the introduction of the torque converter lock-up clutch, which practically eliminates fluid losses when engaged. Modern automatic transmission also minimize energy usage and complexity, by minimizing the amount of shifting logic that is done hydraulically. Typically, control of the transmission has been transferred to computerized control systems which do not use fluid pressure for shift logic or actuation of clutching mechanisms.

The on road acceleration of an automatic transmission can occasionally exceed that of an otherwise identical vehicle equipped with a manual transmission in turbocharged diesel applications. Turbo-boost is normally lost between gear changes in a manual whereas in an automatic the accelerator pedal can remain fully depressed. This however is still largely dependent upon the number and optimal spacing of gear ratios for each unit, and whether or not the elimination of spooldown/accelerator lift off represent a significant enough gain to counter the slightly higher power consumption of the automatic transmission itself.

History and improvements

Modern automatic transmissions can trace their origins to an early "horseless carriage" gearbox that was developed in 1904 by the Sturtevant brothers of Boston, Massachusetts. This unit had two forward speeds, the ratio change being brought about by flyweights that were driven by the engine. At higher engine speeds, high gear was engaged. As the vehicle slowed down and engine RPM decreased, the gearbox would shift back to low. Unfortunately, the metallurgy of the time wasn't up to the task, and owing to the abruptness of the gear change, the transmission would often fail without warning.

The next significant phase in the automatic transmission's development occurred in 1908 with the introduction of Henry Ford's remarkable Model T. The Model T, in addition to being cheap and reliable by the standards of the day, featured a simple, two speed plus reverse planetary transmission whose operation was manually controlled by the driver using pedals. The pedals actuated the transmission's friction elements (bands and clutches) to select the desired gear. In some respects, this type of transmission was less demanding of the driver's skills than the contemporary, unsynchronized manual transmission, but still required that the driver know when to make a shift, as well as how to get the car off to a smooth start.

In 1934, both REO and General Motors developed semi-automatic transmissions that were less difficult to operate than a fully manual unit. These designs, however, continued to use a clutch to engage the engine with the transmission. The General Motors unit, dubbed the "Automatic Safety Transmission," was notable in that it employed a power-shifting planetary gearbox that was hydraulically controlled and was sensitive to road speed, anticipating future development.

Parallel to the development in the 1930s of an automatically-shifting gearbox was Chrysler's work on adapting the fluid coupling to automotive use. Invented early in the 20th century, the fluid coupling was the answer to the question of how to avoid stalling the engine when the vehicle was stopped with the transmission in gear. Chrysler itself never used the fluid coupling with any of its automatic transmissions, but did use it in conjunction with a hybrid manual transmission called "Fluid Drive" (the similar Hy-Drive used a torque converter). These developments in automatic gearbox and fluid coupling technology eventually culminated in the introduction in 1939 of the General Motors Hydra-Matic, the world's first mass-produced automatic transmission.

Available as an option on 1940 Oldsmobiles and later Cadillacs, the Hydra-Matic combined a fluid coupling with three hydraulically-controlled planetary gearsets to produce four forward speeds plus reverse. The transmission was sensitive to engine throttle position and road speed, producing fully automatic up- and down-shifting that varied according to operating conditions.

The Hydra-Matic was subsequently adopted by Cadillac and Pontiac, and was sold to various other automakers, including Bentley, Hudson, Kaiser, Nash, and Rolls-Royce. It also found use during World War II in some military vehicles. From 1950-1954, Lincoln

cars were also available with the Hydra-Matic. Mercedes-Benz subsequently devised a four-speed fluid coupling transmission that was similar in principle to the Hydra-Matic, but of a different design.

Interestingly, the original Hydra-Matic incorporated two features which are widely emulated in today's transmissions. The Hydra-Matic's ratio spread through the four gears produced excellent "step off" and acceleration in first, good spacing of intermediate gears, and the effect of an overdrive in fourth, by virtue of the low numerical rear axle ratio used in the vehicles of the time. In addition, in third and fourth gear, the fluid coupling only handled a portion of the engine's torque, resulting in a high degree of efficiency. In this respect, the transmission's behavior was similar to modern units incorporating a lock-up torque converter.

In 1956, GM introduced the "Jetaway" Hydra-Matic, which was different in design than the older model. Addressing the issue of shift quality, which was an ongoing problem with the original Hydra-Matic, the new transmission utilized two fluid couplings, the primary one that linked the transmission to the engine, and a secondary one that replaced the clutch assembly that controlled the forward gearset in the original. The result was much smoother shifting, especially from first to second gear, but with a loss in efficiency and an increase in complexity. Another "innovation" for this new style Hydra-Matic was the appearance of a "Park" position on the selector. The original Hydra-Matic, which continued in production until the mid-1960s, still used the "Reverse" position for parking pawl engagement.

The first torque converter automatic, Buick's Dynaflo, was introduced for the 1948 model year. It was followed by Packard's Ultramatic in mid-1949 and Chevrolet's Powerglide for the 1950 model year. Each of these transmissions had only two forward speeds, relying on the converter for additional torque multiplication. In the early 1950s, BorgWarner developed a series of three-speed torque converter automatics for American Motors, Ford Motor Company, Studebaker, and several other manufacturers in the US and other countries. Chrysler was late in developing its own true automatic, introducing the two-speed torque converter PowerFlite in 1953, and the three-speed TorqueFlite in 1956. The latter was the first to utilize the Simpson compound planetary gearset.

General Motors produced multiple-turbine torque converters from 1954 to 1961. These included the Twin-Turbine Dynaflo and the triple-turbine Turboglide transmissions. The shifting took place in the torque converter, rather than through pressure valves and changes in planetary gear connections. Each turbine was connected to the drive shaft through a different gear train. These phased from one ratio to another according to demand, rather than shifting. The Turboglide actually had two speed ratios in reverse, with one of the turbines rotating backwards.

By the late 1960s, most of the fluid-coupling four-speed and two-speed transmissions had disappeared in favor of three-speed units with torque converters. Also around this time, whale oil was removed from automatic transmission fluid. By the early 1980s, these were being supplemented and eventually replaced by overdrive-equipped transmissions

providing four or more forward speeds. Many transmissions also adopted the lock-up torque converter (a mechanical clutch locking the torque converter pump and turbine together to eliminate slip at cruising speed) to improve fuel economy.

As computerised engine control units (ECUs) became more capable, much of the logic built into the transmission's valve body was offloaded to the ECU. (Some manufacturers use a separate computer dedicated to the transmission, but sharing information with the engine management computer.) In this case, solenoids turned on and off by the computer control shift patterns and gear ratios, rather than the spring-loaded valves in the valve body. This allows for more precise control of shift points, shift quality, lower shift times, and (on some newer cars) semi-automatic control, where the driver tells the computer when to shift. The result is an impressive combination of efficiency and smoothness. Some computers even identify the driver's style and adapt to best suit it.

ZF Friedrichshafen and BMW were responsible for introducing the first six-speed (the ZF 6HP26 in the 2002 BMW E65 7-Series). Mercedes-Benz's 7G-Tronic was the first seven-speed in 2003, with Toyota introducing an eight-speed in 2007 on the Lexus LS 460. Derived from the 7G-Tronic, Mercedes-Benz unveiled a semi-automatic transmission with the torque converter replaced with a wet multi clutch called the AMG SPEEDSHIFT MCT.

Automatic transmission models

Some of the best known automatic transmission families include:

- General Motors — Powerglide, "Turbo-Hydramatic" TH350, TH400 and 700R4, 4L60-E, 4L80-E, Holden Trimatic
- Ford: Cruise-O-Matic, C4, C6, AOD/AODE, E4OD, ATX, AXOD/AX4S/AX4N
- Chrysler: TorqueFlite 727 and 904, A500, A518, 45RFE, 545RFE
- BorgWarner (later Aisin AW)
- ZF Friedrichshafen automatic transmissions
- Allison Transmission
- Voith Turbo
- Aisin AW; Aisin AW is a Japanese automotive parts supplier, known for its automatic transmissions and navigation systems
- Honda
- Nissan/Jatco
- Volkswagen Group - 01M
- Drivetrain Systems International (DSI) - M93, M97 and M74 4-speeds, M78 and M79 6-speeds

Automatic transmission families are usually based on Ravigneaux, Lepelletier , or Simpson planetary gearsets. Each uses some arrangement of one or two central sun gears, and a ring gear, with differing arrangements of planet gears that surround the sun and mesh with the ring. An exception to this is the Hondamatic line from Honda, which uses sliding gears on parallel axes like a manual transmission without any planetary gearsets.

Although the Honda is quite different from all other automatics, it is also quite different from an automated manual transmission (AMT).

Many of the above AMTs exist in modified states, which were created by racing enthusiasts and their mechanics by systematically re-engineering the transmission to achieve higher levels of performance. These are known as "performance transmissions". An example of a manufacturer of high performance transmissions of General Motors and Ford transmissions is PerformaBuilt.

Continuously variable transmissions

A fundamentally different type of automatic transmission is the *continuously variable transmission* or *CVT*, which can smoothly and steplessly alter its gear ratio by varying the diameter of a pair of belt or chain-linked pulleys, wheels or cones. Some continuously variable transmissions use a hydrostatic drive — consisting of a variable displacement pump and a hydraulic motor — to transmit power without gears. CVT designs are usually as fuel efficient as manual transmissions in city driving, but early designs lose efficiency as engine speed increases.

A slightly different approach to CVT is the concept of *toroidal CVT* or *infinitely variable transmission* (IVT). These concepts provide zero and reverse gear ratios.

Some current hybrid vehicles, notably those of Toyota, Lexus and Ford Motor Company, have an "electronically-controlled CVT" (E-CVT). In this system, the transmission has fixed gears, but the ratio of wheel-speed to engine-speed can be continuously varied by controlling the speed of the third input to a differential using an electric motor-generator.

Manually controlled automatic transmissions

Most automatic transmissions offer the driver a certain amount of manual control over the transmission's shifts (beyond the obvious selection of forward, reverse, or neutral). Those controls take several forms:

Throttle kickdown

Most automatic transmissions include some means of forcing a downshift into the lowest possible gear ratio if the throttle pedal is fully depressed. In many older designs, kickdown is accomplished by mechanically actuating a valve inside the transmission. Most modern designs use a solenoid-operated valve that is triggered by a switch on the throttle linkage or by the engine control unit (ECM) in response to an abrupt increase in engine power.

Mode selection

Allows the driver to choose between preset shifting programs. For example, 'Economy mode' saves fuel by upshifting at lower engine speeds, while 'Sport mode' (aka Power or Performance) delays shifting for maximum acceleration. The modes also change how the computer responds to throttle input.

Low gear ranges

Conventionally, automatic transmissions have selector positions that allow the driver to limit the maximum ratio that the transmission may engage. On older transmissions, this was accomplished by a mechanical lockout in the transmission valve body preventing an upshift until the lockout was disengaged; on computer-controlled transmissions, the same effect is accomplished by firmware. The transmission can still upshift and downshift automatically between the remaining ratios: for example, in the 3 range, a transmission could shift from first to second to third, but not into fourth or higher ratios. Some transmissions will still upshift automatically into the higher ratio if the engine reaches its maximum permissible speed in the selected range.

Manual controls

Some transmissions have a mode in which the driver has full control of ratio changes (either by moving the selector, or through the use of buttons or paddles), completely overriding the automated function of the hydraulic controller. Such control is particularly useful in cornering, to avoid unwanted upshifts or downshifts that could compromise the vehicle's balance or traction. "Manumatic" shifters, first popularized by Porsche in the 1990s under the trade name Tiptronic, have become a popular option on sports cars and other performance vehicles. With the near-universal prevalence of electronically controlled transmissions, they are comparatively simple and inexpensive, requiring only software changes, and the provision of the actual manual controls for the driver. The amount of true manual control provided is highly variable: some systems will override the driver's selections under certain conditions, generally in the interest of preventing engine damage. Since these gearboxes also have a throttle kickdown switch, it is impossible to fully exploit the engine power at low to medium engine speeds.

Second gear takeoff

Some automatics, particularly those fitted to larger capacity or high torque engines, either when '2' is manually selected, or by engaging a "winter mode", will start off in second gear instead of first, and then not shift into a higher gear until returned to D. Also note that as with most American automatic transmissions, selecting "2" using the selection lever will not tell the transmission to be in only 2nd gear, rather, it will simply limit the transmission to 2nd gear after prolonging the duration of 1st gear through higher speeds than normal operation. The 2000-2002 Lincoln LS V8 (the five-speed automatic *without* manumatic capabilities (as opposed to the optional sport package w/ manu-matic 5sp) started in 2nd gear during most starts both in winter and summer by selecting the "D5" transmission selection notch in the shiftgate (For fuel savings), whereas "D4" would always start in 1st gear. This is done to reduce torque multiplication when proceeding forward from a standstill in conditions where traction was limited — on snow- or ice-covered roads, for example.

Some automatic transmissions modified or designed specifically for drag racing may also incorporate a transmission brake, or "trans-brake," as part of a manual valve body. Activated by electrical solenoid control, a trans-brake simultaneously engages the first and reverse gears, locking the transmission and preventing the input shaft from turning.

This allows the driver of the car to raise the engine RPM against the resistance of the torque converter, then launch the car by simply releasing the trans-brake switch.

Chapter 5

Semi-Automatic Transmission

A semi-automatic transmission is one that cannot change gears automatically but only half-automatically. ("Semi" meaning half in Latin.) This requires the driver to intervene in order to execute a gear change by moving a gear lever or pressing a clutch pedal or actuating a switch lever or other action. An **automated transmission** (also known as **self-changing transmission**, **clutchless manual transmission**, automated manual transmission, flappy-paddle gearbox, or paddle shift gearbox) is a system which uses electronic sensors, pneumatics, processors and actuators to execute gear shifts on the command of the driver or by a computer. This removes the need for a clutch pedal which the driver otherwise needs to depress before making a gear change, since the clutch itself is actuated by electronic equipment which can synchronise the timing and torque required to make gear shifts quick and smooth. The system was designed by automobile manufacturers to provide a better driving experience, especially in cities where congestion frequently causes stop-and-go traffic patterns.

Many modern automated transmissions can also operate in the same manner as a conventional type of automatic transmission by allowing the transmission's computer to automatically change gear if, for example, the driver were redlining the engine. The ability to shift gears manually, often via paddle shifters, can also be found on certain automatic transmissions (manumatics such as Tiptronic) and continuous variable transmissions (CVTs) (such as Lineartronic). Despite superficial similarity to other automated transmissions, automated transmissions differ significantly in internal operation and driver's "feel" from manumatics and CVTs. A manumatic, like a standard automatic transmission, uses a torque converter instead of clutch to manage the link between the transmission and the engine, while a CVT uses a belt instead of a fixed number of gears.

The automated transmission may be derived from a conventional automatic; for instance Mercedes-Benz's AMG SPEEDSHIFT MCT automated transmission is based on the 7G-Tronic manumatic, however the latter's torque converter has been replaced with a wet,

multi-plate launch clutch.. Other automateds have their roots in a conventional manual; the SMG II drivelogic (found in the BMW M3 (E46) is a Getrag 6-speed manual transmission, but with an electrohydraulically actuated clutch pedal, similar to an Formula One style transmission.

Operation



Steering wheel of Ferrari F430 with paddle-shifters

In standard mass-production automobiles, the gear lever appears similar to manual shifts, except that the gear stick only moves forward and backward to shift into higher and lower gears, instead of the traditional H-pattern. The Bugatti Veyron uses this approach for its seven-speed transmission. In Formula One, the system is adapted to fit onto the steering wheel in the form of two paddles; depressing the right paddle shifts into a higher gear, while depressing the left paddle shifts into a lower one. Numerous road cars have inherited the same mechanism.

Hall effect sensors sense the direction of requested shift, and this input, together with a sensor in the gear box which senses the current speed and gear selected, feeds into a central processing unit. This unit then determines the optimal timing and torque required for a smooth clutch engagement, based on input from these two sensors as well as other factors, such as engine rotation, the Electronic Stability Control, air conditioner and dashboard instruments.

The central processing unit powers a hydro-mechanical unit to either engage or disengage the clutch, which is kept in close synchronization with the gear-shifting action the driver has started. In some cases, the hydro-mechanical unit contains a servomotor coupled to a gear arrangement for a linear actuator, which uses brake fluid from the braking system to impel a hydraulic cylinder to move the main clutch actuator. In other cases, the clutch actuator may be completely electric.

The power of the system lies in the fact that electronic equipment can react much faster and more precisely than a human, and takes advantage of the precision of electronic signals to allow a complete clutch operation without the intervention of the driver.

For the needs of parking, reversing and neutralizing the transmission, the driver must engage both paddles at once, after this has been accomplished the car will prompt for one of the three options.

The clutch is really only needed to start the car. For a quicker upshift, the engine power can be cut, and the collar disengaged until the engine drops to the correct speed for the next gear. For the teeth of the collar to slide into the teeth of the rings, both the speed and position must match. This needs sensors to measure not only the speed, but the positions of the teeth, and the throttle may need to be opened softer or harder. The even-faster shifting techniques like powershifting require a heavier gearbox or clutch or even a dual clutch transmission.

History

Racing

According to the Car Crazy episode "Le Mans Museum of the Automobile", the paddle shifter interface could be found as early as 1912. The system used an inner steering wheel to select a gear level and can be seen on the "Bollée Type F Torpédo" of 1912, on show at the "Musée Automobile de la Sarthe" at the Le Mans race circuit.

In Formula One, the first attempt at clutch-less gear changing was in the early 1970s, with the system being tested by the Lotus team. However, it would be much later that attention was turned back to the concept. In 1989, John Barnard and Harvey Postlethwaite, then-Ferrari engineers and designers, created a automated gearbox for use in the Ferrari 640 single-seater. Despite serious problems in testing, the car won its first race at the hands of Nigel Mansell. By 1994, the automated transmission was dominant in terms of gearbox technology, and the last F1 car fitted with a manual gearbox raced in 1995.

After concerns that the technology allowed software engineers to pre-program the cars to automatically change to the optimum gear according to the position on the track, without any driver intervention, a standardized software system was mandated, ensuring the gears would only change up or down when instructed to by the driver. Buttons on the steering wheel, which go directly to a certain gear—rather than sequentially—are still permitted.

Chrysler

Historically, the first automated transmission which was marketed by a major manufacturer was the 1941 M4/Vacamatic Transmission by Chrysler. It was an attempt to compete against rivals' automatic transmissions, though it still had a clutch, it was primarily used to change range. The main difference was the addition of a fluid coupling between engine and clutch, and the shifting mechanism.

In normal driving, the clutch was not used. The transmission itself was a fully synchronised manual type, with four forward gears, one reverse, where the shifting was done 'automatically' by either vacuum cylinders (early, M4, Vacamatic), or hydraulic cylinders (late, M6, Presto-Matic).

Packard

Nearly simultaneously, Packard introduced the Electro-Matic clutch, which was a vacuum operated clutch pedal, signaled by the position of the accelerator. Significantly, it came with an 'off' switch, probably due to the fact that the system was somewhat unstable during engine warm-up. Packard's system was used in conjunction with their regular transmission so the H-pattern shifting remained.

Earlier, and by many manufacturers, an arrangement to disengage the clutch during coasting was tried to ease shifting. Called "freewheeling", it was bedeviled by the absence of adequate brakes.

Volkswagen

In later production years, the Volkswagen Beetle offered an optional "Autostick", which was essentially a clutchless manual with three forward gears, using the Saxomat auto-clutch.

Renault

For the Renault 8, a automated transmission was offered in 1965. It was produced by Jaeger, and consisted of a three speed electrically operated gearbox and a powder ferromagnetic coupler.

Mercedes-Benz

Mercedes used a system similar to the VW Autostick, called Hydrak. Hydrak had one major flaw- the oil supply for the torque converter was sealed within the converter itself and did not circulate via a pump, and also had no oil cooler. Idling in gear for even short periods would overheat the oil and burn up the seals in the converter, which would then need to be replaced.

Citroën

Citroën produced a number of variants on automated transmission. The Citroën DS, introduced in 1955, used a hydraulic system to select gears and operate the conventional clutch using hydraulic servos. There was also a speed controller and idle speed step-up device, all hydraulically operated. This allowed clutchless shifting with a single selector mounted behind the steering wheel. This system was nicknamed 'Citro-Matic' in the U.S.

The Citroën 2CV gained an optional centrifugal clutch, marketed in English-speaking countries as "Trafficlutch". It did not help with gear changing, but it disengaged automatically when the engine slowed to an idle. A device was fitted to the carburettor to prevent the throttle closing abruptly, and the resultant clutch disengagement and lack of engine braking.

Later, the manufacturer introduced optional automated transmissions on their medium and large saloon and estate models in the 1970s; the Citroën GS and CX models had the option of three-speed, automated transmission marketed as 'C matic'. This was simpler than the DS implementation: instead of hydraulics it used a floor mounted quadrant lever operating conventional gear selector rods and an electrically controlled wet plate clutch in conjunction with a torque converter. The torque converter gave more of the feel of a conventional automatic transmission, which was completely lacking in the DS. Citroën automated transmission of this era made no use of electronics: the entire gear selecting operation was carried out by simply moving the gear lever from one ratio to the next.

NSU

The German automobile manufacturer NSU produced a automated system for the rotary-engined Ro80 saloon car in the 1960s, similar in concept to Citroën's system except that it used an electric switch on the gear shifter which disengaged the clutch.

Honda

Honda marketed both cars and motorcycles with the Hondamatic transmission in the 1970s and early 1980s. This transmission is frequently referred to as the 'Bang-O-Matic' by mechanics. The design is noteworthy because it preserves engine braking by eliminating a sprag between first and second gears.

Daihatsu

The 993 cc Daihatsu Charade in 1985 at least had the option of a two-speed automated transmission, which was similar to a conventional auto with torque converter and planetary gearset but lacked a full valve body for making decisions regarding shifting. This was left entirely to the driver and as a result could be accelerated from rest in top gear if desired, depending entirely on the torque converter action. The standing ¼mile time with two 60 kg (130 lb) occupants and using low gear appropriately was 21.0 sec while using top gear only was 21.5 sec.

Ferrari

Ferrari's first automated gearbox in a road car (They had used them previously in their Formula One cars since 1989) went on sale in 1997 in the Ferrari F355. The most recent iteration of its robotised manual came forward in the Ferrari 599 GTO which was capable of changing gear in 60 ms. In the new Ferrari California & Ferrari 458 Italia, Ferrari has opted to use a double-clutch transmission.

Vauxhall

Vauxhall Motors in Great Britain (Opel in continental Europe) produced a automated transmission gearbox, the Easytronic gearbox. As with all standard automateds, the Easytronic car has only two pedals (accelerator pedal and brake pedal) but it does have a clutch, though this is inbuilt into the car and is electrohydraulic. The Easytronic can be driven in "manual mode" simply by using the paddle shifter selector to change gears if the driver wishes to do so, or alternatively it can be driven in exactly the same way as a fully conventional automatic—however, many Easytronic owners have complained that gear shifts in "automatic mode" are jerky; a common complaint with semi-autos based on a conventional manual gearbox. As with conventional, full automatic transmission cars, the Easytronic will "creep" forwards when the driver's foot is released from the brake pedal when the car is stationary.

Other applications

Trucks, buses, and trains

Automated transmissions have also made its way into the truck and bus market in the early 2000s. Volvo offers its I-shift on its heavier trucks and buses, while ZF markets its ASTronic system for trucks, buses and coaches. In North America, Eaton offers the "AutoShift" system which is an add-on to traditional non-synchromesh manual transmissions for heavy trucks. These gearboxes have a place in public transport as they have been shown to reduce fuel consumption in some specific cases.

Bristol/Leyland Buses

The British employed Pneumatic valve bodies to regulate gear shifting by charging pistons with compressed air within the gearbox. These pneumatic pistons or gear-levers are activated by a series of valve bodies and controlled by electronic actuators linked to the gear shifter. As each gear cycle is energized, air valves open and close to engage the corresponding gear-lever. Compressed air is drawn from the braking system and in the event of loss of pressure, the transmission will remain in the last gear selected or if in neutral, will not shift into gear.

In the UK though, automated transmission has been very popular on buses for some time, from the 1950s right through to the 1980s, an example being the well known London Routemaster, although the latter could also be driven as a fully automatic in the three

highest gears. Most heavy-duty bus manufacturers offered this option, using a gearbox from Self-Changing Gears Ltd of Coventry, and on urban single- and double-deck buses it was the norm by the 1970s. This coincided with the development of city buses with engines and transmissions at the rear rather than the front, which was beyond the capability of a manual gearchange/clutch linkage from the driver's position. Leyland manufactured many buses with automated transmission, including its Leopard and Tiger coaches. Fully automatic transmission became popular with increasing numbers of continental buses being bought in the UK, and more and more British manufacturers began offering automatic options, mostly using imported gearboxes, and automated transmission lost favour. These days, very few buses with automated transmission remain in service, although many are still on the roads with private owners. Modern types of automated transmission though is becoming more common, mostly replacing manual gearboxes in coaches and small buses.

The Self-Changing Gears automated gearbox was also fitted to the several thousand diesel railcars built for the British railway system in the late 1950s-early 1960s, which lasted in service until the 1990s-2000s. Their whole engine-transmission system was based on that from the main bus manufacturers of the period such as Leyland and AEC. Gear selection was by the train driver with a hand-held lever as the train accelerated. Such trains were formed of a number of such railcars coupled together and each power car had two engine/automated gearbox units mounted under the floor. Synchronising controls by control cables connected through the train ensured all the gearboxes under all coaches of the train changed gear together.

Motorcycles

In addition to the Hondamatic system noted above, Yamaha Motor Company introduced a automated transmission on its 2007 model year FJR1300 sport-touring motorcycle in 2006. Notably, this system can be shifted either with the lever in the traditional position near the left foot, or with a switch accessible to the left hand where the clutch lever would go on traditional motorcycles.

Honda has begun production of the VFR1200F, which includes an optional dual clutch transmission, the first to be fitted to a motorcycle.

ATVs

Honda released automated electric shift ATVs starting in model year 1998 with the TRX450FE aka Foreman 450ES ESP (Electric Shift Program). Shifting is accomplished by pressing either one of the gear selector arrows on the left handlebar control. The current selected gear is indicated by a digital display. The primary components of the shifting mechanisms were the same on both the manual and electric shift models, but the major difference was the deletion of the shift pedal and the addition of an internal electric shift servo which actuated the components (clutch assy, shift drum, etc.) in one motion instead of the traditional foot lever. In the event of a malfunction, a supplied override lever can be placed on a shaft protruding from the crankcase in the traditional spot where

the pedal would have been. This electric shift technology was later applied to their complete line of ATVs.

Marketing names

- 2-tronic, EGC (Electric Gearbox Control) or Piloted Manual – Peugeot
- Twin Clutch SST – Mitsubishi
- Dual clutch transmission (DCT), a generic term – Volkswagen Group, Bugatti, Koenigsegg
- Direct-Shift Gearbox (DSG) – Volkswagen Group: SEAT, Skoda Auto, Volkswagen
 - S tronic – Audi
- Dualogic – Fiat
- Duo Select – Maserati
- Durashift EST – Ford
- E-Gear – Lamborghini
- Easytronic – Opel / Vauxhall
- Multimode manual transmission – Toyota
- PDK (Porsche Doppelkupplungen)/Sportomatic (Clutchless manual pre-1969) – Porsche
- Pleasure Shift – Saleen
- Quickshift – Renault
- Retrotek, MasterShift, Twist Machine, etc. – Detroit's Big 3
- Sensonic or ACS – Saab
- Selespeed – Alfa Romeo, Fiat
- SensoDrive or EGS (Electronic Gearbox System) or BMP – Citroen
- Steptronic, SMG/SSG (Electrohydraulic manual transmission) – BMW
- Speedgear – Fiat
- Sportshift – Aston Martin
- MasterShift – Aftermarket

Types

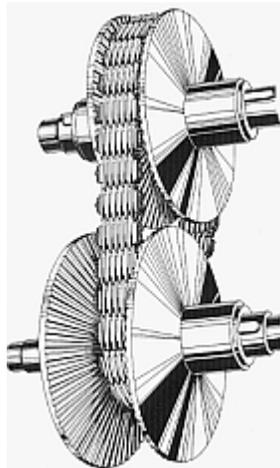
- Dual clutch transmission
- Electrohydraulic manual transmission (e.g., BMW sequential manual gearbox, SMG)
- Saxomat
- Multimode manual transmission

Chapter 6

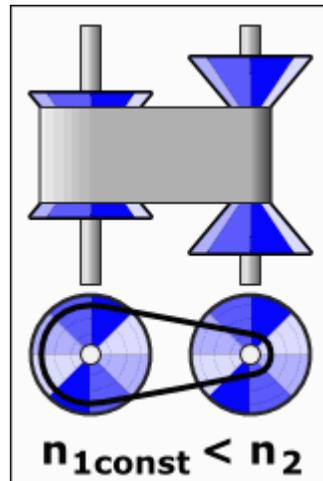
Continuously Variable Transmission

A **continuously variable transmission (CVT)** is a transmission that can change steplessly through an infinite number of effective gear ratios between maximum and minimum values. This contrasts with other mechanical transmissions that offer a fixed number of gear ratios. The flexibility of a CVT allows the driving shaft to maintain a constant angular velocity over a range of output velocities. This can provide better fuel economy than other transmissions by enabling the engine to run at its most efficient revolutions per minute (RPM) for a range of vehicle speeds. Alternatively it can be used to maximize the performance of a vehicle by allowing the engine to turn at the RPM at which it produces peak power. This is typically higher than the RPM that achieves peak efficiency.

Uses



A Chain-driven CVT



Principle of Variator

Many small tractors for home and garden use have simple rubber belt CVTs. For example, the John Deere Gator line of small utility vehicles use a belt with a conical pulley system. They can deliver an abundance of power and can reach speeds of 10–15 mph (16–24 km/h), all without need for a clutch or shifting gears. Nearly all snowmobiles, old and new, and motorscooters use CVTs, typically the rubber belt/variable pulley variety.

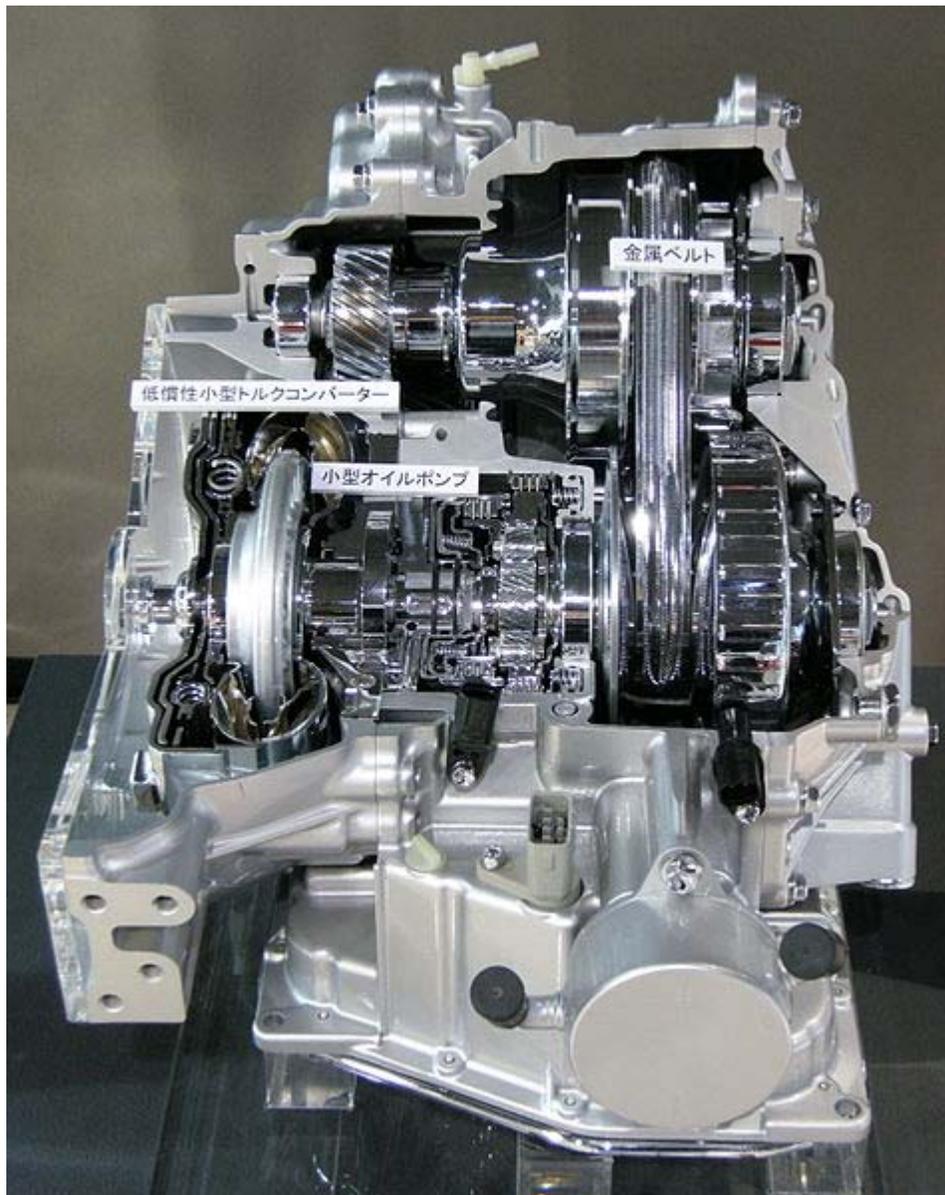
Some combine harvesters have CVTs. The CVT allows the forward speed of the combine to be adjusted independently of the engine speed. This allows the operator to slow or accelerate as needed to accommodate variations in thickness of the crop.

CVTs have been used in aircraft electrical power generating systems since the 1950s and in Sports Car Club of America (SCCA) Formula 500 race cars since the early 1970s. CVTs were banned from Formula 1 in 1994 because they were making the cars too fast. More recently, CVT systems have been developed for go-karts and have proven to increase performance and engine life expectancy. The Tomcar range of off-road vehicles also utilizes the CVT system.

Some drill presses and milling machines contain a pulley-based CVT where the output shaft has a pair of manually-adjustable conical pulley halves through which a wide drive belt from the motor loops. The pulley on the motor, however, is usually fixed in diameter, or may have a series of given-diameter steps to allow a selection of speed ranges. A handwheel on the drill press, marked with a scale corresponding to the desired machine speed, is mounted to a reduction gearing system for the operator to precisely control the width of the gap between the pulley halves. This gap width thus adjusts the gearing ratio between the motor's fixed pulley and the output shaft's variable pulley, changing speed of the chuck. A tensioner pulley is implemented in the belt transmission to take up or release the slack in the belt as the speed is altered. In most cases the speed must be changed with the motor running.

CVTs should be distinguished from Power Sharing Transmissions (PSTs), as used in newer hybrid cars, such as the Toyota Prius, Highlander and Camry, the Nissan Altima, and newer-model Ford Escape Hybrid SUVs. CVT technology uses only one input from a prime mover, and delivers variable output speeds and torque; whereas PST technology uses two prime mover inputs, and varies the ratio of their contributions to output speed and power. These transmissions are fundamentally different. However the Mitsubishi Lancer, Honda Insight and Honda CR-Z hybrids, the Nissan Tiida/Versa (only the SL model), Nissan Cube, Juke, Rogue, Altima, Murano, Maxima, Jeep Patriot and Compass use CVT.

Types



Toyota Super CVT - i

Variable-diameter pulley (VDP) or Reeves drive

In this most common CVT system, there are two V-belt pulleys that are split perpendicular to their axes of rotation, with a V-belt running between them. The gear ratio is changed by moving the two sections of one pulley closer together and the two sections of the other pulley farther apart. Due to the V-shaped cross section of the belt, this causes the belt to ride higher on one pulley and lower on the other. Doing this changes the effective diameters of the pulleys, which in turn changes the overall gear ratio. The distance between the pulleys does not change, and neither does the length of the belt, so changing the gear ratio means both pulleys must be adjusted (one bigger, the other smaller) simultaneously in order to maintain the proper amount of tension on the belt.

The V-belt needs to be very stiff in the pulley's axial direction in order to make only short radial movements while sliding in and out of the pulleys. This can be achieved by a chain and not by homogeneous rubber. To dive out of the pulleys one side of the belt must push. This again can be done only with a chain. Each element of the chain has conical sides, which perfectly fit to the pulley if the belt is running on the outermost radius. As the belt moves into the pulleys the contact area gets smaller. The contact area is proportional to the number of elements, thus the chain has lots of very small elements. The shape of the elements is governed by the static of a column. The pulley-radial thickness of the belt is a compromise between maximum gear ratio and torque. For the same reason the axis between the pulleys is as thin as possible. A film of lubricant is applied to the pulleys. It needs to be thick enough so that the pulley and the belt never touch and it must be thin in order not to waste power when each element dives into the lubrication film. Additionally, the chain elements stabilize about 12 steel bands. Each band is thin enough so that it bends easily. If bending, it has a perfect conical surface on its side. In the stack of bands each band corresponds to a slightly different gear ratio, and thus they slide over each other and need oil between them. Also the outer bands slide through the stabilizing chain, while the center band can be used as the chain linkage.



Nissan Motors *Extroid CVT*

Toroidal or roller-based CVT (Extroid CVT)

Toroidal CVTs are made up of discs and rollers that transmit power between the discs. The discs can be pictured as two almost conical parts, point to point, with the sides dished such that the two parts could fill the central hole of a torus. One disc is the input, and the other is the output (they do not quite touch). Power is transferred from one side to the other by rollers. When the roller's axis is perpendicular to the axis of the near-conical parts, it contacts the near-conical parts at same-diameter locations and thus gives a 1:1 gear ratio. The roller can be moved along the axis of the near-conical parts, changing angle as needed to maintain contact. This will cause the roller to contact the near-conical parts at varying and distinct diameters, giving a gear ratio of something other than 1:1. Systems may be partial or full toroidal. Full toroidal systems are the most efficient design while partial toroidals may still require a torque converter, and hence lose efficiency.

Magnetic CVT

A magnetic continuous variable transmission system has been developed at the University of Sheffield in 2006 and is now (2011) commercially available. Two rotating transmission disks, each with magnets attached, synchronously revolve. A change in the radius of the magnets on each of the disks, causes a change in the transmission ratio.

Infinitely Variable Transmission (IVT)

A specific type of CVT is the infinitely variable transmission (IVT), in which the range of ratios of output shaft speed to input shaft speed includes a zero ratio that can be continuously approached from a defined "higher" ratio. A zero output speed (low gear) with a finite input speed implies an infinite input-to-output speed ratio, which can be continuously approached from a given finite input value with an IVT. *Low* gears are a reference to low ratios of output speed to input speed. This low ratio is taken to the extreme with IVTs, resulting in a "neutral", or non-driving "low" gear limit, in which the output speed is zero. Unlike neutral in a normal automotive transmission, IVT output rotation may be prevented because the backdriving (reverse IVT operation) ratio may be infinite, resulting in impossibly high backdriving torque; ratcheting IVT output may freely rotate forward, though.

The IVT dates back to before the 1930s; the original design converts rotary motion to oscillating motion and back to rotary motion using roller clutches. The stroke of the intermediate oscillations is adjustable, varying the output speed of the shaft. This original design is still manufactured today, and an example and animation of this IVT can be found [here](#). Paul B. Pires created a more compact (radially symmetric) variation that employs a ratchet mechanism instead of roller clutches, so it doesn't have to rely on friction to drive the output. An article and sketch of this variation can be found [here](#)

Most IVTs result from the combination of a CVT with a planetary gear system (which is also known as an epicyclic gear system) which enforces an IVT output shaft rotation speed which is equal to the difference between two other speeds within the IVT. This IVT configuration uses its CVT as a continuously variable regulator (CVR) of the rotation speed of any one of the three rotators of the planetary gear system (PGS). If two of the PGS rotator speeds are the input and output of the CVR, there is a setting of the CVR that results in the IVT output speed of zero. The maximum output/input ratio can be chosen from infinite practical possibilities through selection of additional input or output gear, pulley or sprocket sizes without affecting the zero output or the continuity of the whole system. The IVT is always engaged, even during its zero output adjustment.

IVTs can in some implementations offer better efficiency when compared to other CVTs as in the preferred range of operation because most of the power flows through the planetary gear system and not the controlling CVR. Torque transmission capability can also be increased. There's also possibility to stage power splits for further increase in efficiency, torque transmission capability and better maintenance of efficiency over a wide gear ratio range.

An example of a true IVT is the SIMKINETICS SIVAT that uses a ratcheting CVR. Its CVR ratcheting mechanism contributes minimal IVT output ripple across its range of ratios.

Another example of a true IVT is the Hydristor because the front unit connected to the engine can displace from zero to 27 cubic inches per revolution forward and zero to -10

cubic inches per revolution reverse. The rear unit is capable of zero to 75 cubic inches per revolution.

Ratcheting CVT

The ratcheting CVT is a transmission that relies on static friction and is based on a set of elements that successively become engaged and then disengaged between the driving system and the driven system, often using oscillating or indexing motion in conjunction with one-way clutches or ratchets that rectify and sum only "forward" motion. The transmission ratio is adjusted by changing linkage geometry within the oscillating elements, so that the summed maximum linkage speed is adjusted, even when the average linkage speed remains constant. Power is transferred from input to output only when the clutch or ratchet is engaged, and therefore when it is locked into a static friction mode where the driving & driven rotating surfaces momentarily rotate together without slippage.

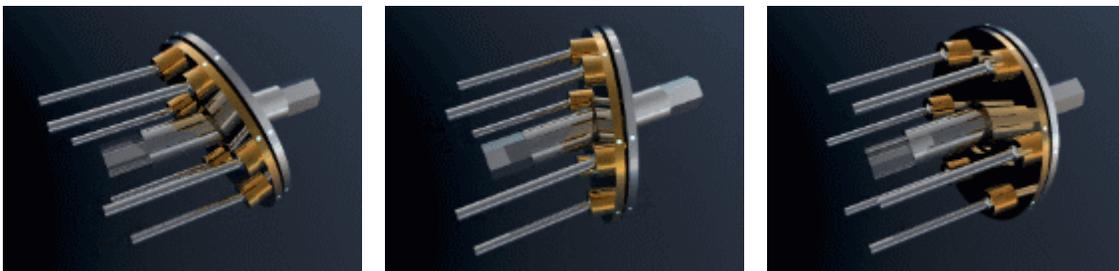
These CVTs can transfer substantial torque, because their static friction actually increases relative to torque throughput, so slippage is impossible in properly designed systems. Efficiency is generally high, because most of the dynamic friction is caused by very slight transitional clutch speed changes. The drawback to ratcheting CVTs is vibration caused by the successive transition in speed required to accelerate the element, which must supplant the previously operating and decelerating, power transmitting element.

Ratcheting CVTs are distinguished from VDPs and roller-based CVTs by being static friction-based devices, as opposed to being dynamic friction-based devices that waste significant energy through slippage of twisting surfaces. An example of a ratcheting CVT is one prototyped as a bicycle transmission protected under U.S. Patent 5,516,132 in which strong pedalling torque causes this mechanism to react against the spring, moving the ring gear/chainwheel assembly toward a concentric, lower gear position. When the pedaling torque relaxes to lower levels, the transmission self-adjusts toward higher gears, accompanied by an increase in transmission vibration.

A running prototype and animation of a functioning two stage ratcheting CVT can be found below:

- Naudic rotorCVT, presented by Varibox CVT Technologies

Hydrostatic CVTs



Honda DN-01 motorcycle.



Japanese Type10 tank uses Hydraulic Mechanical Transmission (HMT).

Hydrostatic transmissions use a variable displacement pump and a hydraulic motor. All power is transmitted by hydraulic fluid. These types can generally transmit more torque, but can be sensitive to contamination. Some designs are also very expensive. However, they have the advantage that the hydraulic motor can be mounted directly to the wheel hub, allowing a more flexible suspension system and eliminating efficiency losses from friction in the drive shaft and differential components. This type of transmission is relatively easy to use because all forward and reverse speeds can be accessed using a single lever.

An integrated hydrostatic transaxle (IHT) uses a single housing for both hydraulic elements and gear-reducing elements. This type of transmission, most commonly manufactured by Hydro-Gear, has been effectively applied to a variety of inexpensive and expensive versions of ridden lawn mowers and garden tractors. Many versions of riding lawn mowers and garden tractors propelled by a hydrostatic transmission are capable of pulling a reverse tine tiller and even a single bladed plow.

One class of riding lawn mower that has recently gained in popularity with consumers is zero turning radius mowers. These mowers have traditionally been powered with wheel hub mounted hydraulic motors driven by continuously variable pumps, but this design is relatively expensive. Hydro-Gear, created the first cost-effective integrated hydrostatic transaxle suitable for propelling consumer zero turning radius mowers.

Some heavy equipment may also be propelled by a hydrostatic transmission; e.g. agricultural machinery including foragers, combines, and some tractors. A variety of heavy earth-moving equipment manufactured by Caterpillar Inc., e.g. compact and small wheel loaders, track type loaders and tractors, skid-steered loaders and asphalt compactors use hydrostatic transmission. Hydrostatic CVTs are usually not used for extended duration high torque applications due to the heat that is generated by the flowing oil.

The Honda DN-01 motorcycle is the first road-going consumer vehicle with hydrostatic drive that employs a variable displacement axial piston pump with a variable-angle swashplate.

Variable toothed wheel transmission

A variable toothed wheel transmission is not a true CVT that can alter its ratio in infinite increments, but rather approaches CVT capability by having a large number of ratios, typically 49. This transmission relies on a toothed wheel positively engaged with a chain where the toothed wheel has the ability to add or subtract a tooth at a time in order to alter its ratio relative to the chain it is driving. The "toothed wheel" can take on many configurations including ladder chains, drive bars and sprocket teeth. The huge advantage of this type of CVT is that it is a positive mechanical drive and thus does not have the frictional losses and limitations of the roller-based or VDP CVT's. The challenge in this type of CVT is to add or subtract a tooth from the toothed wheel in a very precise and controlled way in order to maintain synchronized engagement with the chain. This type of transmission has the potential to change ratios under load because of the large number of ratios, resulting in the order of 3% ratio change differences between ratios, thus a clutch or torque converter is necessary only for pull-away. No CVTs of this type are in commercial use, probably because of above mentioned development challenge.

Although an iCVT works, it has the following weakness:

High Frictional Losses Weakness

The variator pulley of an iCVT is choked using two small choking pulleys. Here one choking pulley is positioned on the tense side of the chain of the iCVT. Hence there is a considerable load on that choking pulley, which magnitude is proportionally to the tension in its chain. Each choking pulley is pulled up by two chain segments, one chain segment to the left and one to the right of the choking pulley; here if the two chain segments are parallel to each other then the load on the choking pulley is twice the tension in the chain. But since the two chain segments are most likely not parallel to each other during operations of an iCVT, it is estimated that the load on a choking pulley is between 1 to 1.8 times of the tension of its chain.

Also, a choking pulley is very small so that its moment arm is very small. A larger moment arm reduces the force needed to rotate a pulley. For example, using a long wrench, which has a large moment arm, to open a nut requires less force than using a

short wrench, which has a small moment arm. Assuming that the diameter of a choking pulley is twice the diameter of its shaft, which is a generous estimate, then the frictional resistance force at the outer diameter of a choking pulley is half the frictional resistance force at the shaft of a choking pulley.

Shock and Durability Weakness

The transmission ratio of an iCVT has to be changed one increment within less than one full rotation of its variator pulley. Has to be changed one increment means that the transmission diameter of the variator pulley has to be changed from a diameter that has a circumferential length that is equal to an integer number of teeth to another diameter that has a circumferential length that is equal to an integer number of teeth; such as changing the transmission diameter of the variator pulley from a diameter that has a circumferential length of 7 teeth to a diameter that has a circumferential length of 8 teeth for example. This is because if the transmission diameter of the variator pulley does not have a circumferential length that is equal to an integer number of teeth, such as a circumferential length of $7\frac{1}{2}$ teeth for example, improper engagement between the teeth of the variator pulley and its chain will occur. For example, imagine having a bicycle pulley with $7\frac{1}{2}$ teeth; here improper engagement between the bicycle pulley and its chain will occur when the tooth behind the $\frac{1}{2}$ tooth space is about to engage with its chain, since it is positioned a distance of $\frac{1}{2}$ tooth to late relative to its chain.

Regarding the previous paragraph, the chain of an iCVT forms an open loop on its variator pulley that partially covers its variator pulley such that an open section, which is not covered by the chain, exist. This is similar to a sprocket of a bicycle where there is a section of the sprocket that is covered by its chain, and a section of the sprocket that is not covered by its chain. During one complete rotation, the toothed section of the variator pulley of an iCVT passes by the open section and re-engages with the chain. Here if the transmission diameter of the variator pulley does not represent an integer number of teeth, improper re-engagement between the teeth of the variator pulley and its chain will occur. Also, the transmission diameter of the variator pulley cannot be changed while the toothed section of the variator pulley is covering the entire open section of its chain loop. Since this is similar to where a plate is glued across the open section of a chain loop, which does not allow expansion or contraction of the chain loop as required for transmission diameter change of the variator pulley. Therefore the transmission diameter of the variator pulley has to be changed one increment during an interval where the variator pulley rotates from an initial position where a portion of the toothed section of the variator pulley is positioned at the open section of the chain loop but not covering the entire open section, to the final position where the toothed section of the variator pulley passes by the open section of the chain loop and is about to re-engage with the chain. Since it takes less than one full rotation to rotate the variator pulley from its initial position to its final position mentioned in the previous sentence, the transmission diameter of the variator pulley has to be changed one increment within less than one full rotation.

In addition, as the transmission diameter is increased, the chain has to be pushed up the inclined surfaces of the pulley halves of the variator pulley, while the tension in the chain tends to pull the chain towards the opposite direction. Hence a large force, which is larger than the tension in the chain, is required to change the transmission diameter. Since the transmission ratio has to be changed within less than one full rotation of the variator pulley, a large force has to be applied on the pulley halves within a very short duration. If for example the variator pulley rotates at 3600 rpm, which is equivalent to 60 revolutions per second, then the force required to change the transmission ratio has to be applied within 1/60 seconds. This would be similar to hitting something with a hammer. Therefore, here significant shock loads are applied to the variator pulley during transmission ratio change that increases the transmission diameter. These shock loads may cause comfort problem for the driver of the vehicle using an iCVT. Also an iCVT has to be designed as to be able to resist these shock loads which would most likely increase the cost and weight of an iCVT.

Torque Transfer Ability & Reliability Weakness

The teeth of the variator pulley of an iCVT are formed by pins that extend from one pulley half to the other pulley half and slide in the grooves of the pulley halves of the variator pulley. Here torque from the chain is transferred to the pins and then from the pins to the pulley halves. Since the pins are round and the grooves are curved, line contact between the pins and the grooves are used to transfer force from the pins to the grooves. The amount of force that can be transmitted between two parts depends on the contact area of the two parts. Since the contact areas between the pins and their grooves are very small, the amount of force that can be transmitted between them, and hence also the torque capacity of an iCVT, is limited.

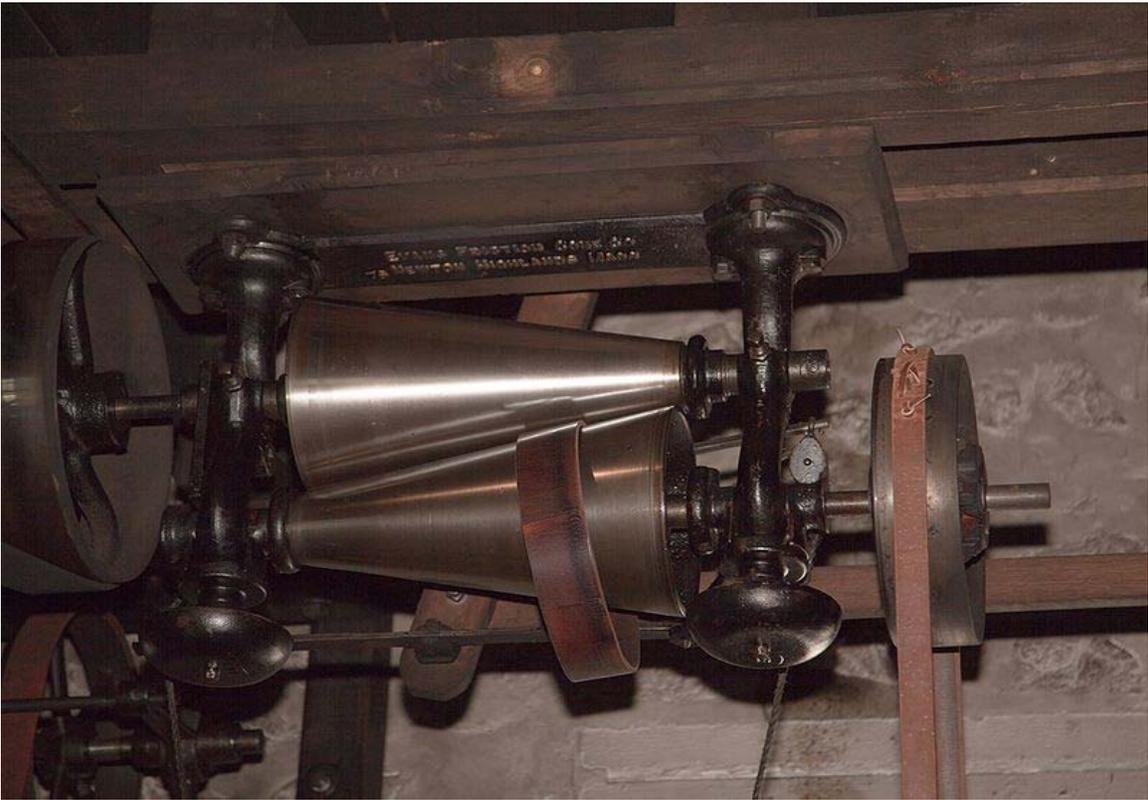
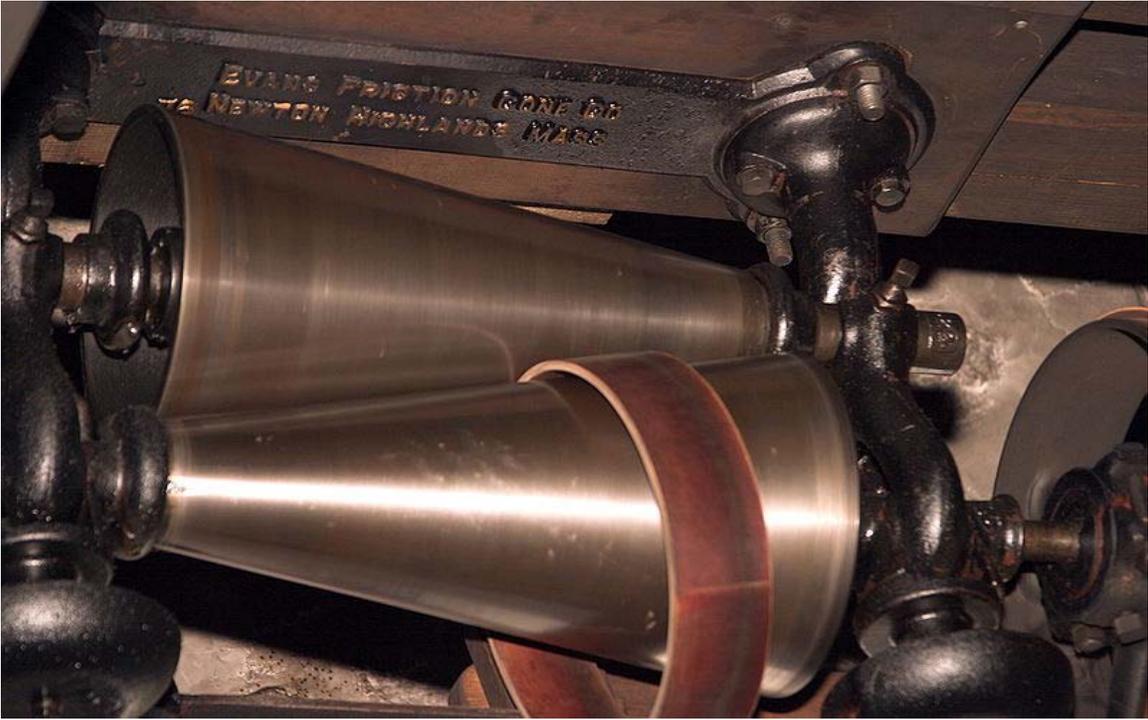
Another possible problem with an iCVT is that the pins of the variator pulley can fall-out when they are not engaged with their chain. And wear of the pins and the grooves of the pulley halves can cause some serious performance and reliability problems.

Single Tooth Cone CVT

A single tooth cone CVT is one of the most promising non-friction CVT designs. Like an iCVT a single tooth cone also does not depend on friction to transmit torque; however, it does not have the weaknesses an iCVT has. A Single Tooth Cone is described in the link below:

- [Single Tooth Cone CVT](#)

Cone CVTs



The Evans friction cone, a type of cone CV

A cone CVT varies the effective gear ratio using one or more conical rollers. The simplest type of cone CVT, the single-cone version, uses a wheel that moves along the slope of the cone, creating the variation between the narrow and wide diameters of the cone.

In a CVT with oscillating cones, the torque is transmitted via friction from a variable number of cones (according to the torque to be transmitted) to a central, barrel-shaped hub. The side surface of the hub is convex with a specific radius of curvature which is smaller than the concavity radius of the cones. In this way, there will be only one (theoretical) contact point between each cone and the hub at any time.

A new CVT using this technology, the Warko, was presented in Berlin during the 6th International CTI Symposium of Innovative Automotive Transmissions, on December 3-7, 2007.

A particular characteristic of the Warko is the absence of a clutch: the engine is always connected to the wheels, and the rear drive is obtained by means of an epicyclic system in output. This system, named "power split", allows the engine to have a "neutral gear": when the engine turns (connected to the sun gear of the epicyclic system), the variator (i.e., the planetary gears) will compensate for the engine rotation, so the outer ring gear (which provides output) doesn't turn at all.

Radial roller CVT

The working principle of this CVT is similar to that of conventional oil compression engines, but, instead of compressing oil, common steel rollers are compressed.

The motion transmission between rollers and rotors is assisted by an adapted traction fluid, which ensures the proper friction between the surfaces and slows down wearing thereof. Unlike other systems, the radial rollers do not show a tangential speed variation (Δ) along the contact lines on the rotors. From this, a greater mechanical efficiency and working life are obtained. The main advantages of this CVT are the manufacturing inexpensiveness and the high power efficiency.

- Girotto Brevetti CVT

History

Leonardo da Vinci, in 1490, conceptualized a stepless continuously variable transmission. The first patent for a friction-based belt CVT was filed in Europe by Daimler and Benz in 1886, and a US Patent for a toroidal CVT was granted in 1935.

In 1910 Zenith Motorcycles built a V2-Motorcycle with the Gradua-Gear which was a CVT. This Zenith-Gradua was so successful in hillclimb events, that it was eventually barred, so that other manufacturers had a chance to win.

1912 the British motorcycle manufacturer Rudge-Whitworth built the Rudge Multigear. The Multi was a much improved version of Zenith's Gradua-Gear. The Rudge Multi was so successful that CVT-gears were eventually barred at the famous Tourist Trophy race (which was the world's most important motorcycle race before World War I) from 1913 on.

In 1922 Browne offered a motorcycle with variable-stroke ratchet drive using a face ratchet.

An early application of CVT was in the British Clyno car, introduced in 1923.

A CVT, called Variomatic, was designed and built by Hub van Doorne, co-founder of Van Doorne's Automobielen Fabriek (DAF), in the late 1950s, specifically to produce an automatic transmission for a small, affordable car. The first DAF car using van Doorne's CVT, the DAF 600, was produced in 1958. Van Doorne's patents were later transferred to a company called VDT (Van Doorne Transmissie B.V.) when the passenger car division was sold to Volvo; its CVT was used in the Volvo 340.

Many snowmobiles use a rubber belt CVT. In 1974, Rokon offered a motorcycle with a rubber belt CVT.

CVTs are used in some ATVs. The first ATV equipped with CVT was Suzuki's LT80 mini in 1987.

In early 1987, Subaru launched the Justy in Tokyo with an electronically controlled continuously variable transmission (ECVT) developed by Fuji Heavy Industries, which owns Subaru. In 1989 the Justy became the first production car in the U.S. to offer CVT technology. While the Justy saw only limited success, Subaru continues to use CVT in its kei cars to this day, while also supplying it to other manufacturers.

In the summer of 1987 the Ford Fiesta and Fiat Uno became the first mainstream European cars to be equipped with steel-belted CVT (as opposed to the less robust rubber-belted DAF design). This CVT, the Ford CTX was developed by Ford, Van Doorne, and Fiat, with work on the transmission starting in 1976.

The 1992 Nissan March contained Nissan's N-CVT based on the Fuji Heavy Industries ECVT. In the late 1990s, Nissan designed its own CVT that allowed for higher torque and included a torque converter. This gearbox was used in a number of Japanese-market models. Nissan is also the only car maker to bring a roller-based CVT to the market in recent years. Their toroidal CVT, named the Extroid, was available in the Japanese market Y34 Nissan Gloria and V35 Skyline GT-8. However, the gearbox was not carried over when the Cedric/Gloria was replaced by the Nissan Fuga in 2004. The Nissan Murano, introduced in 2003, and the Nissan Rogue, introduced in 2007, also use CVT in their automatic transmission models. In a Nissan Press Release, July 12, 2006, Nissan announced a huge shift to CVT transmissions when they selected their XTronic CVT technology for all automatic versions of the Nissan Versa, Cube, Sentra, Altima and

Maxima vehicles in North America, making the CVT a mainstream transmission system. One major motivator for Nissan to make a switch to CVTs was as a part of their 'Green Program 2010' aimed at reducing CO2 emissions by 2010. To date Nissan has had the most success with producing their CVTs in high volume and on a wide range of vehicles. The CVT found in Nissan's Maxima, Murano and the V6 version of Altima is considered to be the worlds first "3.5L class" belt CVT and can hold much higher torque loads than other belt CVTs.

After studying pulley-based CVT for years, Honda also introduced their own version on the 1995 Honda Civic VTi. Dubbed Honda Multi Matic, this CVT gearbox accepted higher torque than traditional pulley CVTs, and also includes a torque converter for "creep" action. The CVT is also currently employed in the Honda City ZX that is manufactured in India and Honda City Vario manufactured in Pakistan.

Toyota used a Power Split Transmission (PST) in the 1997 Prius, and all subsequent Toyota and Lexus hybrids sold internationally continue to use the system (marketed under the Hybrid Synergy Drive name). The HSD is also referred to as an Electronically-controlled Continuously-variable Transmission. The PST allows either the electric motor or the internal combustion engine (ICE) or both to propel the vehicle. In ICE-only mode, part of the engine's power is mechanically coupled to the drivetrain, with the other part going through a generator and a motor. The amount of power being channeled through the electrical path determine the effective gear ratio. Toyota also offers a non-hybrid CVT called Multidrive for models such as Avensis.

Audi has, since 2000, offered a chain-type CVT (Multitronic) as an option on some of its larger-engine models, for example the A4 3.0 L V6.

Fiat in 2000 offered a Cone-type CVT as an option on its hit model Fiat Punto (16v 80 PS ELX,Sporting).

BMW used a belt-drive CVT as an option for the low- and middle-range MINI in 2001, forsaking it only on the supercharged version of the car where the increased torque levels demanded a conventional automatic gearbox. The CVT could also be manually "shifted" if desired with software-simulated shift points.

GM introduced its version of CVT known as VTi in 2002. It was used in the Saturn Vue and Saturn Ion models. This transmission was quickly withdrawn in 2005 models due to high failure rates.

Ford introduced a chain-driven CVT known as the CFT30 in their 2005 Ford Freestyle, Ford Five Hundred and Mercury Montego. The transmission was designed in cooperation with German automotive supplier ZF Friedrichshafen and was produced in Batavia, Ohio at Batavia Transmissions LLC (a subsidiary of Ford Motor Company) until March 22, 2007. The Batavia plant also produced the belt-driven CFT23 CVT which went in the Ford Focus C-MAX. Ford also sold Escort and Orion models in Europe with CVTs in the 1980s and 1990s.

Contract agreements were established in 2006 between MTD Products and Torotrak for the first full toroidal system to be manufactured for outdoor power equipment such as jet skis, ski-mobiles and ride-on mowers.

The 2007 Dodge Caliber and the related Jeep Compass and Jeep Patriot employ a CVT using a variable pulley system as their optional automatic transmission.

The 2008 Mitsubishi Lancer model is available with CVT transmission as the automatic transmission. DE and ES models receive a standard CVT with Drive and Low gears; the GTS model is equipped with a standard Drive and also a Sportronic mode that allows the driver to use 6 different preset gear ratios (either with the shifter or steering wheel-mounted paddle shifters).

The 2009 SEAT Exeo is available with a CVT automatic transmission (multitronic) as an option for the 2.0 TSI 200 hp (149 kW) petrol engine, with selectable 'six-speeds'.

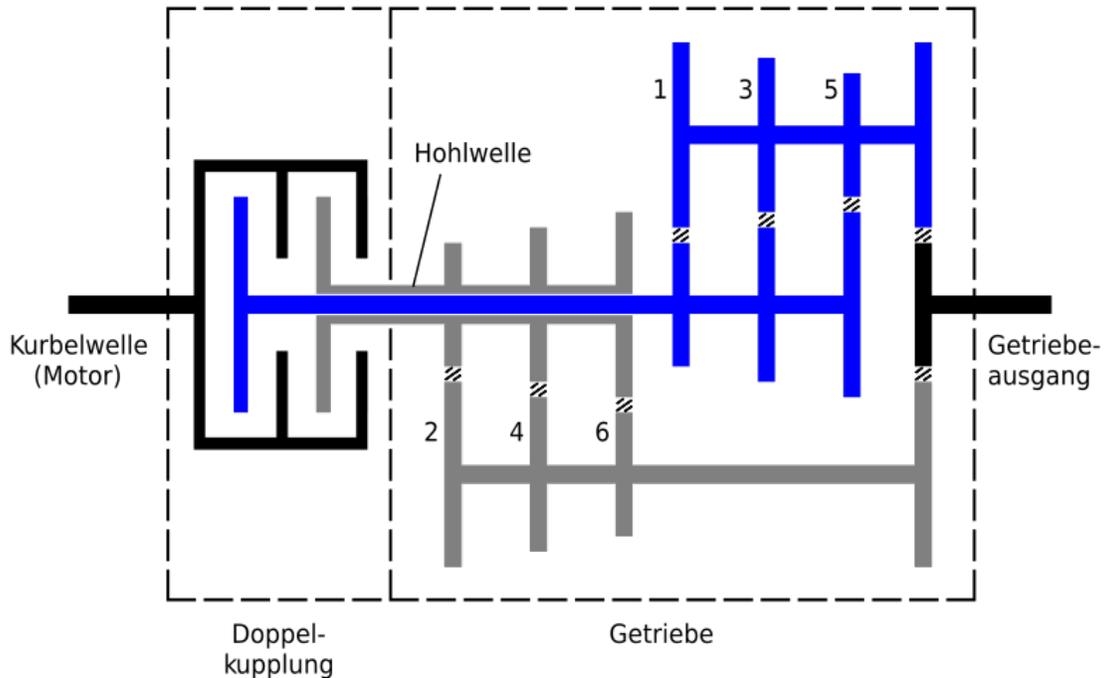
Subaru offers CVT on the 2010 Legacy and 2010 Outback (Lineartronic).

Chapter 7

Dual Clutch Transmission



Part-cutaway view of the Volkswagen Group 6-speed dual clutch transmission, the Direct-Shift Gearbox (DSG). The concentric multi-plate clutches have been sectioned, along with the mechatronics module. This also shows the additional power take-off unit for distributing torque to the rear axle for four-wheel drive applications.



Schematic diagram of a dual clutch transmission. This shows the layout of two side-by-side single-plate clutches.

A **dual clutch transmission**, commonly abbreviated to **DCT** (sometimes informally referred to as a **twin-clutch gearbox**, **double clutch transmission**, or similar variations thereof), is a differing type of semi-automatic or automated manual automotive transmission. It utilises two separate clutches for odd and even gear sets. It can fundamentally be described as two separate manual transmissions (with their respective clutches) contained within one housing, and working as one unit. They are usually operated in a fully automatic mode, and many also have the ability to allow the driver to manually shift gears, albeit still carried out by the transmission's electro-hydraulics.

This type of transmission was invented by Frenchman Adolphe Kégresse just prior to World War II, but he never developed a working model. The first actual DCTs arrived from Porsche in-house development, for Porsche racing cars in the 1980s, when computers to control the transmission became compact enough: the Porsche Doppelkupplungsgetriebe (English: *dual clutch gearbox*) (PDK) used in the Porsche 956 and 962 Le Mans race cars from 1983, and the Audi Sport Quattro S1 rally car.

A dual clutch transmission eliminates the torque converter as used in conventional epicyclic-gear automatic transmissions. Instead, dual clutch transmissions that are currently on the market primarily use two oil-bathed wet multi-plate clutches, similar to the clutches used in most motorcycles, though dry clutch versions are also available.

The first series production road car to be fitted with a DCT was the 2003 Volkswagen Golf Mk4 R32.

As of 2009, the largest number of sales of DCTs in Western Europe are by various marques of the German Volkswagen Group, though this is anticipated to lessen as other transmission makers and vehicle manufacturers make DCTs available in series production automobiles. In 2010, on BMW Canada's website for the 3 Series Coupe, it is described both as a 7-speed double clutch transmission and as a 7-speed automatic transmission. It is actually a dual clutch semi-automatic.

Overview

In DCTs where the two clutches are arranged concentrically, the larger outer clutch drives the odd numbered gears, whilst the smaller inner clutch drives the even numbered gears. Shifts can be accomplished without interrupting torque distribution to the driven roadwheels, by applying the engine's torque to one clutch at the same time as it is being disconnected from the other clutch. Since alternate gear ratios can pre-select an odd gear on one gear shaft whilst the vehicle is being driven in an even gear, (and vice versa), DCTs are able to shift more quickly than other cars equipped with single-clutch automated-manual transmissions (AMTs), a.k.a. single-clutch semi-automatics. Also, with a DCT, shifts can be made more smoothly than with an AMT, making a DCT more suitable for conventional road cars.

Clutch types

There are two fundamental types of clutches utilised in dual clutch transmissions: either two wet multi-plate clutches which are bathed in oil (for cooling), or two dry single-plate clutches. The wet clutch design is generally used for higher torque engines which can generate 350 newton metres (258 ft·lbf) and more (the wet multi-plate clutch DCT in the Bugatti Veyron is designed to cope with 1,250 N·m (922 ft·lbf)), whereas the dry clutch design is generally suitable for smaller vehicles with lower torque outputs up to 250 N·m (184 ft·lbf). However, whilst the dry clutch variants may be limited in torque compared to their wet clutch counterparts, the dry clutch variants offer an increase in fuel efficiency, due to the lack of pumping losses of the transmission fluid in the clutch housing.

Clutch installation

There are now three variations of clutch installation. The original design used a concentric arrangement, where both clutches shared the same plane when viewed perpendicularly from the transmission input shaft, along the same centre line as the engine crankshaft; when viewed head-on along the length of the input shaft, this makes one clutch noticeably larger than the other.

The second implementation utilised two single-plate dry clutches which are side-by-side from the perpendicular view, but again sharing the centre line of the crankshaft.

A latest variation uses two separate but identical sized clutches; these are arranged side-by-side when viewed head-on (along the length of the input shaft and crankshaft centre line), and also share the same plane when viewed perpendicularly. This latter clutch

arrangement (unlike the other two variations) is driven via a gear from the engine crankshaft.

Suppliers

BorgWarner

BorgWarner Inc. is the current leading worldwide supplier of wet dual clutches and electro-hydraulic control modules (mechatronics) for these dual clutch transmissions, along with complete dual clutch transmission and transaxle assemblies. BorgWarner, who call their technology "DualTronic", entered series production (excludes Bugatti Veyron) for Volkswagen Group, who re-named Direct-Shift Gearbox (DSG) in 2003 in the Volkswagen Golf Mk4 R32. The company signed further agreements with three other (unnamed) European automotive manufacturers to incorporate their components in DCTs.

On 14 January 2009, BorgWarner announced the establishment a joint venture with the China Automobile Development United Investment Co., Ltd. (CDUI) which is owned by twelve leading Chinese automakers. This joint venture will be known as the BorgWarner United Transmission Systems Co., Ltd., and will be located in Dalian, China. The company will produce various dual clutch transmission modules beginning in 2011.

The Nissan GT-R uses BorgWarner components which include the dual-clutch module, clutch-control and shift-actuation systems and synchronizer assemblies.

Fiat Powertrain Technologies

Fiat Powertrain Technologies has developed a dual clutch transmission with Magneti Marelli and BorgWarner. Magneti Marelli delivers the control system which integrates BorgWarner's hydraulic actuation module into its own power and transmission control units. It can handle torque inputs of up to 350 N·m (260 lb·ft), making it the highest-torque dry clutch application. Its weight of just 81 kg (179 lb), complete with oil and transmission control unit, its compact three-shaft architecture, especially axially, allowing it to be installed in a wide range of B- and C-segment vehicles. Fiat Powertrain is an independent company looking to maximize its sales to third party organizations, so the DCCT system is likely to go not just to Chrysler-Jeep, which Fiat now controls, but to outside customers, as well.

Getrag

Getrag has developed a complete range of DCT transaxles, including 7DCL750, a seven-speed transaxle for mid-engine longitudinal applications, capable of taking more than 750 N·m (553 ft·lbf). Getrag will be providing its DCT in its first commercial applications, for the Dodge Journey and Volvo S40 and V50, from mid-2008. Getrag has the 6DCT250 dry DCT under development, for use in front wheel drive transverse applications, and uses electro-mechanical actuation, rather than electro-hydraulic.

In the 2nd quarter of 2008, Getrag had signed an agreement with Chrysler to supply its PowerShift DTCs for use in American markets. However, due to the global economic downturn, this was subsequently cancelled.

Getrag is also working with Bosch to develop a DCT for use in hybrid vehicles.

Getrag dual clutch transmissions are used in the BMW M3, BMW Z4 Sdrive35i, Ferrari California, Ferrari 458 Italia, Mercedes-Benz SLS AMG , Mitsubishi Lancer Evolution X ,Ford and Renault vehicles.

Graziano

Italian specialist Graziano Transmissions is in the process of developing a wet clutch DCT for original equipment manufacturer (OEM) fitment into supercars. It aims to be in production by 2010, and will be targeting automakers such as Ferrari, Maserati and Aston Martin. Their DCT is aiming to have a torque handling capacity of 750 N·m (553 ft·lbf), and they are also aiming to improve shift quality over their current automated manual transmissions (AMTs).

LuK

LuK Clutch Systems, LLC. designed and manufacture the dual dry single plate clutch system for the Volkswagen Group seven-speed DQ200 Direct-Shift Gearbox (DSG) introduced in 2008. This DSG variant is used in smaller cars, with smaller displacement engines with relatively low torque outputs. LuK are naming their technology "XSG" for their overview of automated shift gearbox systems, and "Parallel Shift Gearbox" (PSG) for its own proprietary DCT.

Ricardo

English specialist consulting engineering company Ricardo plc designed and built the Bugatti Veyron's seven-speed dual wet multi-plate dual clutch transmission, specifically to cope with the 1,250 N·m (922 ft·lbf) of torque generated by the cars' W16 engine.

ZF

ZF Friedrichshafen AG designed and build with Porsche the two different variants of the Porsche Doppel-Kupplunggetriebe (PDK) seven-speed '7DT' dual wet multi-plate clutch transmission.

Applications

BMW

In January 2008, BMW introduced a dual clutch transmission for their M3 model, manufactured by Getrag and dubbed M Dual Clutch Transmission (M DCT). The same

transmission is used in the second generation Z4 (the Sdrive35i version), and is an available option on the 335is and later 135i builds.



BMW M3 M-Double Clutch Gearshift.

Chrysler

Chrysler is scheduled to receive Fiat Powertrain Technologies C635 dual dry-clutch transmission for use on Chrysler's inline-4 and V6 Pentastar in a C-plus and D-segment car in 2013.

Fiat Group

Ferrari incorporated a Getrag designed and manufactured seven-speed dual wet clutch transmission in their California and 458 Italia sportscars.

Fiat Powertrain Technologies (FPT) started production of "TCT" Dual Dry Clutch Transmission (DDCT) in early 2010 at the Verrone plant. The C635 DDCT gearbox is used for B (supermini), C (compact car), and D segment (large family car) cars, and can handle torque up to 350 N·m (258 ft·lbf). Fiat's C635 DDCT gearbox was introduced in Alfa Romeo MiTo in 2010.

Ford Motor Company

Ford Motor Company has released a wet clutch "PowerShift" transmission on the 2008 Ford Focus (international) and Ford C-MAX. This wet clutch DCT was designed with gearbox specialist Getrag under the GETRAG FORD Transmissions joint venture, founded in 2001, and is expected to feature in other Ford and Volvo models. Ford has announced the US-market version of the Mark VI Ford Fiesta coming in 2011 will feature a dry clutch PowerShift transmission. Ford also announced the introduction of PowerShift transmission to North American market by 2010.

The Volvo version will be built in Koping, Sweden at Volvo's transmission plant. The PowerShift gearbox will be introduced on the second generation Volvo S60, and then on to the V50 and C30 models. The XC60 is expected to get this Ford PowerShift gearbox along with other new models to make more sporty cars.

General Motors

In the company's restructuring plan, it revealed that dry dual clutch transmission would be available in 2012 calendar year. The GM's dual-clutch gearbox will be introduced on the GMC Granite. The new front-wheel drive transmission will incorporate the latest innovations for improving fuel economy and performance. The transmission alone will provide upward of 10 percent improvement in fuel economy over today's conventional six-speed automatic transmissions. The co-developed transmission between GM and SAIC will feature dry, dual-clutch technology. It will provide shift comfort equal to a conventional fully automatic transmission, with superior quality, while reducing CO₂ emissions.

Honda

In October 2009, Honda launched the VFR1200F, a motorcycle with a 1,200 cc V4 engine and optional DCT dubbed the *Next Generation Transmission*. In May 2009, Honda CEO Takeo Fukui mentioned that Honda was working on a new dual clutch transmission system that could be matched with future hybrids.

Hyundai

At the 2009 Geneva Motor Show, Hyundai unveiled ix-onic concept car, which was said to feature a six-speed dual clutch transmission.

On 22 December 2010, Hyundai teased the reveal of its entry-level sports car, the Veloster, a vehicle with a dual-clutch transmission and an estimated fuel consumption of 40 mpg_{US} (5.9 L/100 km; 48 mpg_{imp}). The teaser notes the date of reveal to be 10 January 2011, when it will be shown at the North American International Auto show.

McLaren Automotive

McLaren Automotive introduced dual clutch on MP4-12C. It has been designed by McLaren.

Mercedes-Benz

The Mercedes SLS AMG use a Getrag AMG 'SpeedShift' seven-speed dual clutch gearbox, mounted at the rear in a transaxle configuration, and connected to the engine via a carbon fibre driveshaft enclosed in an aluminium torque tube. According to Mercedes-Benz, it is capable of gear changes in as little as 100 ms. The SLS and the Ferrari California share the same DCT unit.

Mitsubishi

The Mitsubishi Motors Lancer Evolution X and Lancer Ralliart are supplied with Mitsubishi's Twin Clutch SST (abbreviated TC-SST, for "Twin Clutch Sport Shift Transmission" or "Twin Clutch Sportronic Shift Transmission") dual clutch transmission, controllable by steering wheel mounted magnesium paddle shifters. It is the Getrag-built, PowerShift 6DCT470 transmission in the Mitsubishi Lancer Evolution.

Mitsubishi Fuso Truck and Bus Corporation

The Mitsubishi Fuso Truck and Bus Corporation presented a world first with a double-clutch transmission for commercial vehicles. The new six-speed M038S6 "Duonic transmission" features wet clutches and incorporates the ability to creep in traffic for smoother operation. Although Duonic-equipped trucks will probably be driven mostly in fully-automatic mode, the transmission can also be manually shifted.

Nissan

The Nissan GT-R's rear transaxle six-speed dual clutch transmission also contains the differential for the car's four-wheel drive (4WD) system. The dual clutch system was built by BorgWarner, partnered with Nissan's gearbox supplier Aichi Machine Industry, and weighs a total installed mass of 117 kg (258 lb). Nissan reports shift times of 200 milliseconds.

PSA Peugeot Citroën

PSA has dual clutch transmission in Peugeot 4007 and Citroen C-Crosser CUVs, produced by Mitsubishi motors.

Porsche

Porsche AG offers a series production of two new longitudinally-installed, ZF Friedrichshafen AG designed and built with Porsche '7DT' wet-clutch versions of its previously race-only Porsche Doppelkupplungsgetriebe (PDK) transmission.

The first variant, the 7DT-45, is used on its 2009 997 Carrera and Carrera S models. This version is also offered on the 2009 Cayman, Boxster It uses a ZF Sachs ND2015 clutch pack, and has a torque handling capacity of 500 N·m (369 ft·lbf). A higher torque version of the same transmission, the 7DT-70, is also available for the 2010 911 Turbo. This is rated at 780 N·m (575 ft·lbf), and uses a different ZF Sachs clutch - the ND2216.

The second PDK variant, the 7DT-75, is available on the 2009 Panamera. This is constructed fundamentally different to the 7DT-45/7DT-70 versions; in that the internal shafts are mounted above the input shaft, so as to achieve a lower centre of gravity for the Panamera. It also uses just one oil circuit, whereas the 7DT-45/7DT-70 use two separate circuits; with very different specifications of fluids needed.

Both fundamental variants use seven forward speeds, and Porsche claim the Doppelkupplung PDK transmission will replace the outgoing conventional Tiptronic automatic transmissions. However, other reliable industry sources state that Porsche still intends to use conventional automatics; with the eight-speed ZF 8HP being cited. Like all DCTs, the Porsche PDK transmission is fundamentally two separate manual transmissions in one. With the 1st, 3rd, 5th, and 7th gears and reverse available on one shaft, and 2nd, 4th, and 6th gears available on the other shaft.

Porsche claim noteworthy improvements in CO2 emissions of around 15% when comparing DCT installations against its former automatic transmission, of which a half can be directly attributed to the DCT. And when compared directly with a manual transmission; 16% improvement can be directly attributed to the DCT.

Renault

Renault will be introducing a new six-speed dual dry clutch DCT in the early part of 2010. This will initially be made available on the New Mégane with the dCi 110 DPF engine. The DCT system was built by Getrag. This will enable these DCT-equipped Meganes to be the marque's first automatic cars to qualify for the Renault eco² signature.

Volkswagen Group

Volkswagen Group produces DCTs under the Direct-Shift Gearbox (DSG) name, from the German: *Direkt-Schalt-Getriebe*. It is used in all of their mainstream marques, including Volkswagen Passenger Cars, Audi, SEAT, Škoda, and Volkswagen Commercial Vehicles, and also its top-tier marque Bugatti. Audi originally used the Direct-Shift Gearbox (DSG) name, it now uses the name "S tronic" for its DCTs.

The first ever worldwide series production DCT was the Volkswagen Group DQ250 six-speed dual clutch transmission, with dual concentric wet multi-plate clutches. It was produced at the Group's Kassel plant under exclusive license from Borg-Warner for use in transverse powertrain installations, of either front-wheel drive or four-wheel drive (4WD) layouts. The 4WD versions are fundamentally identical to the 2WD versions, but the 4WD versions use an additional bolt-on power take-off unit to direct engine torque to the Haldex Traction rear axle. This DQ250 variant is used in a wide range of models: Volkswagen Passenger Cars (Polo, Golf/Rabbit/Golf Plus, Jetta, Eos, Passat and Touran); Audi cars (A3, and TT); SEAT cars (Ibiza, León, Altea and Toledo); Škoda cars (Octavia and Superb); and Volkswagen Commercial Vehicles (Caddy and T5 Transporter).

A second variant of the Direct-Shift Gearbox went into series production in 2008 – the DQ200. This consists of seven forward ratios, but the notable difference over the original DQ250 is the change from wet- to dry-clutches. This variant uses two single-plate dry clutches, arranged in a tandem design (instead of concentrically) and are therefore similar in size. The DQ200 is again for use in transverse applications, but is intended for use in smaller cars, with smaller displacement engines that generate relatively low torque outputs. When used in the latest Golf with the 90 kilowatts (122 PS; 121 hp) engine, this new 7-speed DSG uses roughly 6% (5.9l/100 km for the 7-speed DSG compared to 6.3l/100 km with the manual) less fuel than the same engine with a manual transmission and up to 20% less than a conventional automatic transmission. The original DQ250 also remains available.

Volkswagen Group subsidiary Audi AG have also developed an all-new DCT - the DL501, for use in longitudinal powertrains. Like the original transverse DQ250, this DL501 utilises dual wet multi-plate clutches, but unlike the DQ250, this variant uses seven forward ratios. This DL501 variant made its debut in the Q5, and also is used in the latest versions of the A4 (B8) and S4 (B8). It is also be considered for use in an all new A6.

Lamborghini, although owned by Volkswagen Group subsidiary Audi AG, does not use a dual clutch transmission; it has a *robotised* single clutch electrohydraulic manual transmission called "E gear", which is identical to the Audi R8 "R tronic" transmission.

English specialist consulting engineering company Ricardo plc produces the seven-speed DCT for the 736 kilowatts (1,001 PS; 987 bhp) 2005 Bugatti Veyron EB 16.4.

Lotus

Lotus Cars has submitted a patent application for a lighter, simpler and more compact dual-clutch transmission system. The gearbox shown in the application is an eight-speed unit, with seven forward gears and reverse.

Railcar use

A different type of dual-clutch transmission has been used in some railcars. The two clutches are placed one on the gearbox input shaft and the other on the gearbox output shaft. When a gearchange is to be made, both clutches are disengaged simultaneously and a brake is applied inside the gearbox. The gearchange is made with all gears stationary, so no synchronizing mechanism is needed. After the gearchange, both clutches are re-engaged. There would be a significant break in transmission so this system would be unsuitable for shunting locomotives.