

12.1.1 Manual Passenger Car Transmissions (MT)

4-speed manual gearboxes were standard for passenger cars in Europe until the early 1980s. As engine power and vehicle weight increased and c_w ratings improved, larger overall gear ratios became necessary. Large overall gear ratios facilitate moving-off, provide good acceleration, and also reduce engine speed and hence fuel consumption at high speeds. Manual transmissions therefore now usually have either five or six speeds.

1/ Single-Stage 5-Speed Manual Passenger Car Gearbox; VW MQ

A large proportion of vehicles are fitted with front-wheel drive and transverse-mounted gearbox. Single-stage countershaft transmissions with integral final drive are always used in this drive configuration. This format is compact, and reduces the space needed to accommodate the powertrain, importantly by eliminating the propeller shaft. It has the major advantage over the standard drive configuration that the complete powertrain including the engine can be preassembled as a “package” and fitted to the car body. The 5-speed gearbox in Figure 12.1 is a typical example of the front-transverse format (*the basic concept is explained in Section 6.6.1 and Figure 6.18b*).

The gearwheels of first gear to fifth gear are mounted on the input shaft in sequence, starting from the clutch side. A striking feature is the fifth gear located outside the cast gearbox housing, which is encased against the environment by a separate sheet metal pan. The reason for this feature is that this gearbox is developed from a 4-speed gearbox, with the fifth gear added on. The distance between bearings is kept small by the resultant location of a main bearing between fourth and fifth gear. This has a beneficial effect on shaft deflection under load, although the fifth gear is overhung.

The tapered roller bearings of the input shaft have a collar at the bearing outer ring to counteract the axial forces against the housing. These special bearings allow the wall of the housing to be thinner, since no collars are required on the housing, and no grooves for circlips.

The toothing of the reverse gear is located on the first and second gear sliding sleeve. All forward gears have a single-cone synchronizer. The synchronizers are activated by swing forks, whose plain bearings are clearly visible over the input shaft. The swing forks are in turn activated by means of a central selector shaft (mounted vertically in the middle of the gearbox).

The gearbox housing is open to both sides and has an integrally cast half of the axle drive housing. The clutch bell housing, which carries the other half of the axle drive housing, is bolted to the gearbox. The other side of the gearbox housing is closed off with a metal cover, as already mentioned. The bevel gear differential is lubricated by the gearbox oil circulation. The worm gear of the speedometer drive can be seen at the drive cage of the differential. The clutch release bearing with its operating lever is located in the clutch bell housing, sitting on the gearbox input shaft. The lever is designed as a formed sheet metal part.

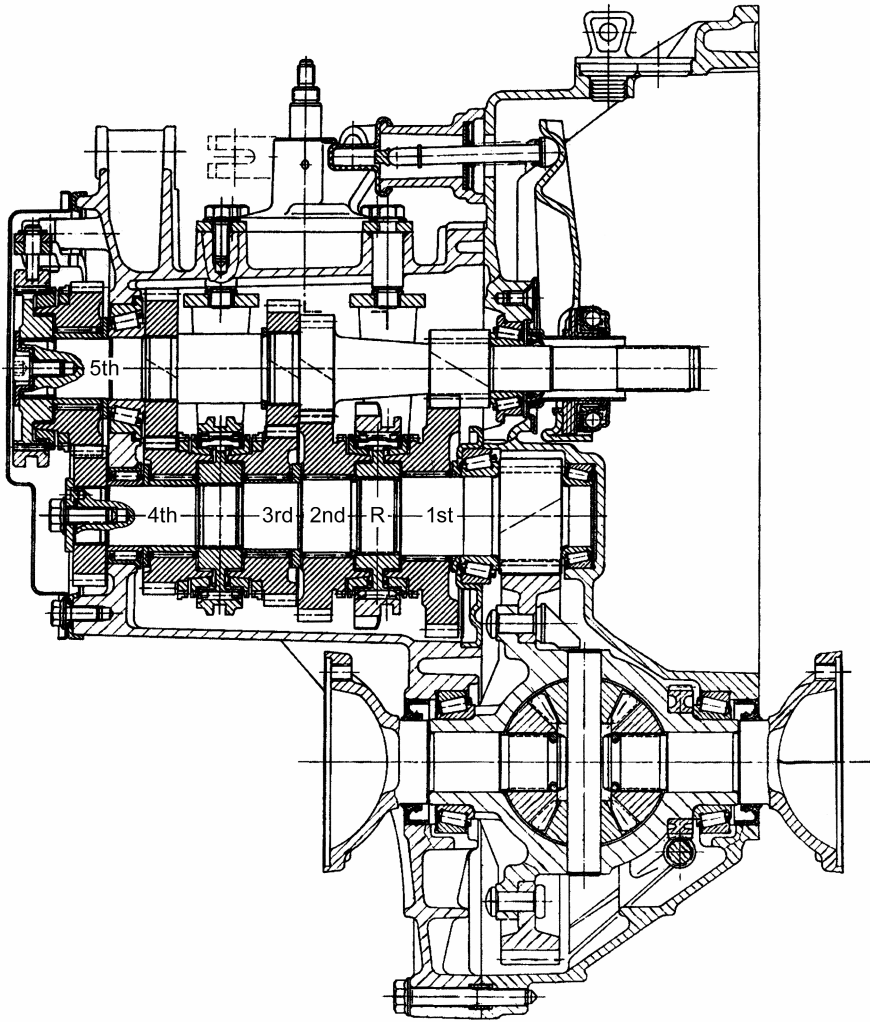


Fig. 12.1. 5-speed manual passenger car gearbox VW MQ, gearbox diagram Figure 6.18b

2/ Two-Stage 5-Speed Manual Passenger Car Gearbox; ZF S 5-31

Figure 12.2 shows a two-stage coaxial 5-speed passenger car countershaft-type manual gearbox with direct drive in fifth gear (*the basic concept is explained in Section 6.6.1 and Figure 6.19b*). In this design, first and second gear are roughly in the middle of the main shaft. This contravenes the principle whereby gears with higher torque conversion should be located as close as possible to a main bearing (Section 8.2 “General Design Guidelines” for Shafts). But the resultant shaft deflection can be controlled by appropriate gearing geometry.

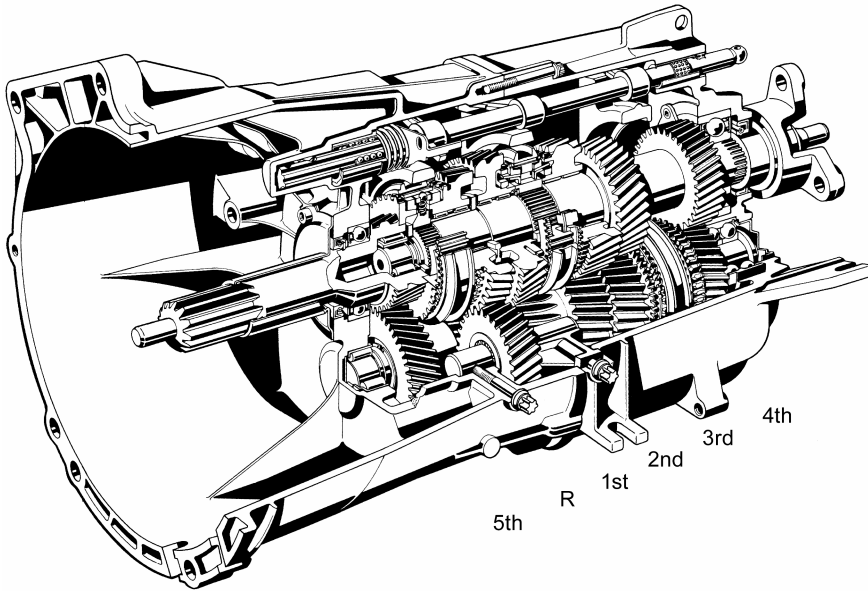


Fig. 12.2. 5-speed manual passenger car gearbox ZF S 5-31, gearbox diagram Figure 6.19b

The advantage of this structural design is that the more frequently used gears of third and fourth gear are near a bearing point, making them run more quietly.

In contrast to *in-line gearboxes*, where all synchronizers are mounted on the gearbox main shaft, in this gearbox the synchronizers for third and fourth gear are moved to the countershaft. This arrangement means the idler respectively shift gears for third and fourth gear are no longer on the countershaft itself, but linked to the output side. Their speeds thus no longer have to be matched to the output speed during synchronization, which reduces the frictional work and shifting force required to change gear. It is not possible to move any more idler gears to the countershaft, since the differential rotational speeds are too great. The synchronizers for first and second gear are of double-cone design, significantly reducing shifting force. All other gears, including reverse gear, have single-cone synchronizers.

Since the idler gears in third and fourth do not rotate when the vehicle is stationary in neutral, they do not produce as much rattle as idler gears mounted on the main shaft (see also Section 7.5).

The kinematics of the shift system is shown in Figure 12.3. Instead of separate selector bars for each individual shift fork, a central selector shaft 1 is used with swing forks 5–7. This has weight advantages, and is more cost-effective. The central selector shaft runs in linear ball bearings 4, which reduces gearshift effort. The swing forks have a pivot 9 supported in the housing, around which they pivot on the lever principle. This enables gearshifting effort to be reduced by selecting a suitable lever ratio. In this type of design, the swing forks (or gates) are changed by the shaft turning.

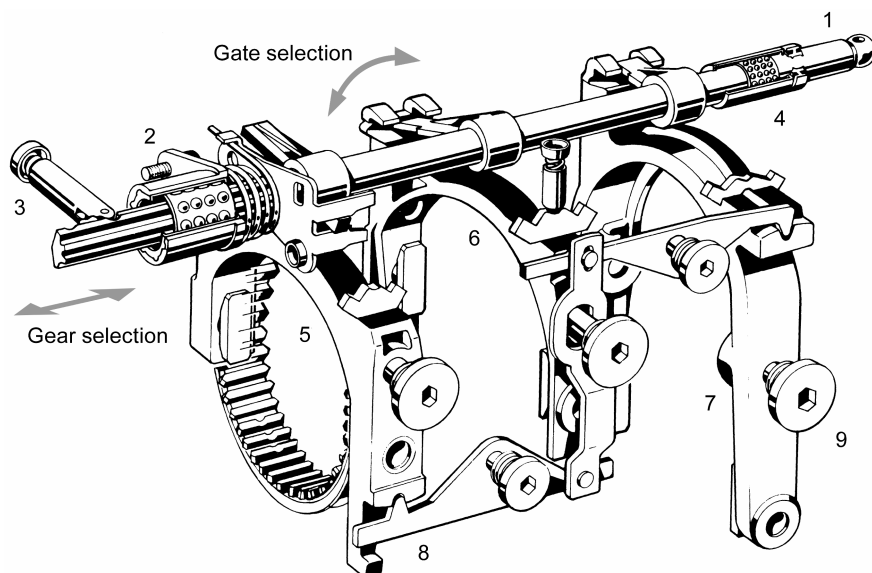


Fig. 12.3. Operation of the shifting elements in the gearbox in Figure 12.1. 1 Central selector shaft; 2 swing fork; 3 detent pin; 4 ball sleeve; 5–7 swing forks; 8 interlock; 9 pivot of the swing fork

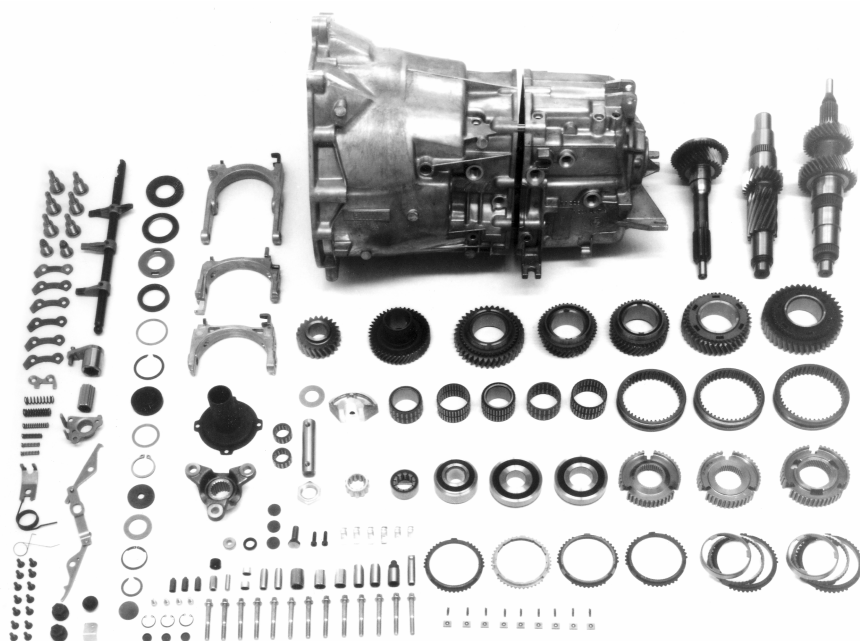


Fig. 12.4. Individual parts of the 5-speed manual passenger car gearbox ZF S 5-31

The countershaft runs in a cylindrical roller bearing on the input side and in a double-row angular contact ball bearing on the output side, instead of the more usual tapered roller bearings or single-row deep groove ball bearings, making shifting more precise and the gearbox quieter.

No tapered roller bearings were used anywhere in the gearbox, since they entail a number of disadvantages. These include changing the internal bearing clearance as a result of temperature-related changes in length in the gearbox, and increased clearance caused by relaxation of the housing. Tapered roller bearings also make it impossible to use “clean bearings” that are sealed against dirt by a sealing collar. Using them makes it possible to extend the oil change intervals. The gearbox housing itself is of end-loaded design with an integrally cast clutch bell housing (Figure 12.4), which ensures the housing is very rigid [12.54].

3/ Two-Stage 6-Speed Manual Passenger Car Gearbox; Getrag 286

Changes in technological general conditions in automotive engineering have led to the development of manual gearboxes with six speeds. These changes were improved c_w ratings enabling higher top speeds, increased vehicle weight due to more comprehensive equipment, and the desire for improved elasticity figures [12.54].

An example of 6-speed manual gearboxes for passenger cars is shown in Figure 12.5 (*the basic concept is explained in Section 6.6.1 and Figure 6.20a*). This is a two-stage countershaft gearbox with constant gear mounted on the input side.

The transmission shafts are longer than the gearbox shown in Figure 12.2. This is firstly because of the additional gear pair, and secondly because of the larger face widths needed for vehicles with powerful engines. In order to minimise the resultant shaft deflection under load, the gear pairs for first and second gear are located near the output side main bearing.

The gear pairs in third and fourth gear are mounted in the centre of the gearbox. The gear pattern resulting from the configuration of the gear pairs, with a gate each for first and second gear, third and fourth gear, and fifth and sixth gear, represents a logical extension of the familiar gear pattern of 5-speed gearboxes.

To reduce rattling noise, the third and fourth gear idler gears were moved onto the countershaft. To reduce the gearshift effort, the first and second gear synchronizers are triple-cone synchronizers, and the third and fourth gear synchronizers are double-cone synchronizers. The fifth and sixth gear and reverse gear synchronizers have a single cone.

Figure 12.5 shows the central selector shaft running in ball bearings. This view does not show the four additional selector bars for the respective gates. Shifting between these selector bars is controlled by turning of the central selector shaft, acting through lever mechanisms. The gear selection detent is located on the input side end of the central selector shaft. The torsion spring mounted on the right of the selector shaft defines the initial position for the gate selection rotary movement.

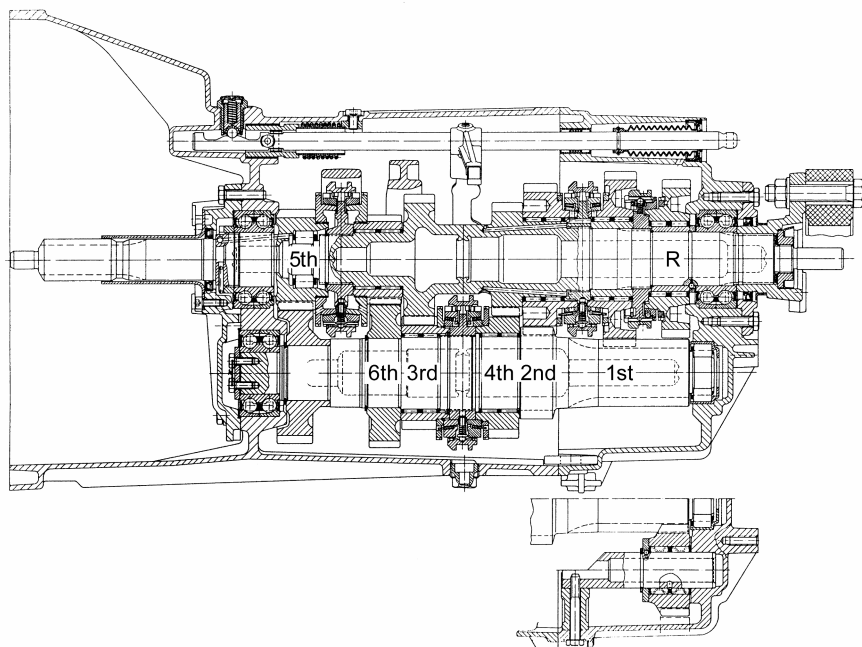


Fig. 12.5. 6-speed manual passenger car gearbox Getrag 286, *gearbox diagram*
Figure 6.20a

The countershaft runs in a cylindrical roller bearing on the output side and in a double-row angular contact ball bearing on the input side, which makes the gearbox run more quietly. Bearings sealed to exclude dirt (clean bearings) increase bearing service life, and can enable smaller and therefore lighter bearings to be used.

The main shafts and countershafts of the gearbox are hollow drilled to contour. This is achieved using two-piece shafts, which are friction welded after the internal contour has been bored. This confers weight advantages. The gearbox housing itself is of end-loaded design with integrally cast clutch bell housing, and is thus very rigid [12.54].

4/ Single-Stage 6-Speed Manual Passenger Car Gearbox; Opel F28-6

More and more powerful models of passenger cars with front-wheel drive are being produced. This has led to the development of 6-speed gearboxes as single-stage passenger car gearboxes as well [12.3] (*the basic concept is explained in Section 6.6.1 and Figure 6.20b*).

The gearbox in Figure 12.6 is an example of this type. The gearwheels of the individual gears are mounted on the input shaft as follows, starting from the clutch side. The gearwheels of first and second gear are located at the bearing, and their idler gears and synchronizers are located on the countershaft.

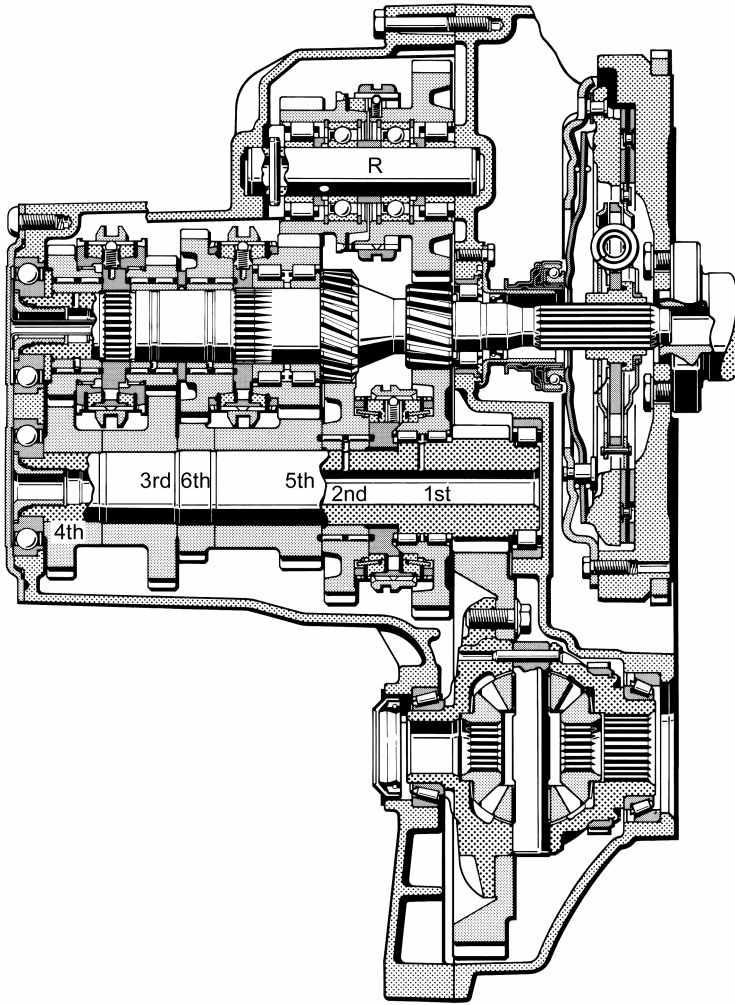


Fig. 12.6. 6-speed manual passenger car gearbox Opel F28-6, *gearbox diagram*
Figure 6.20b

Then come gearwheels of fifth and sixth gear, and finally those of third and fourth gear. Their idler gears are mounted on the input shaft. The design solution adopted for reverse gear is of interest, which dispenses with additional gearing on the input shaft. It is shifted on its own countershaft. This is not located in one plane with the other shafts, as shown in the Figure, but is spatially displaced [12.5].

The power flow in reverse gear is from the fixed gear of first gear to its idler gear, from there to the countershaft of the reverse gear, and from there on to the fixed gear of fifth gear via its idler gear. This design makes it possible for the

overall length of the gearbox to be very short. In this case, it was actually possible to reduce the width compared to its predecessor with five gears.

All gears are synchronized. The first and second gears are fitted with a double-cone synchronizer. The operating elements are not shown in the figure; they have rolling bearings at all bearing points. The structure of the gearbox housing is similar to the gearbox presented in Figure 12.1, so the comments in that case apply here too.

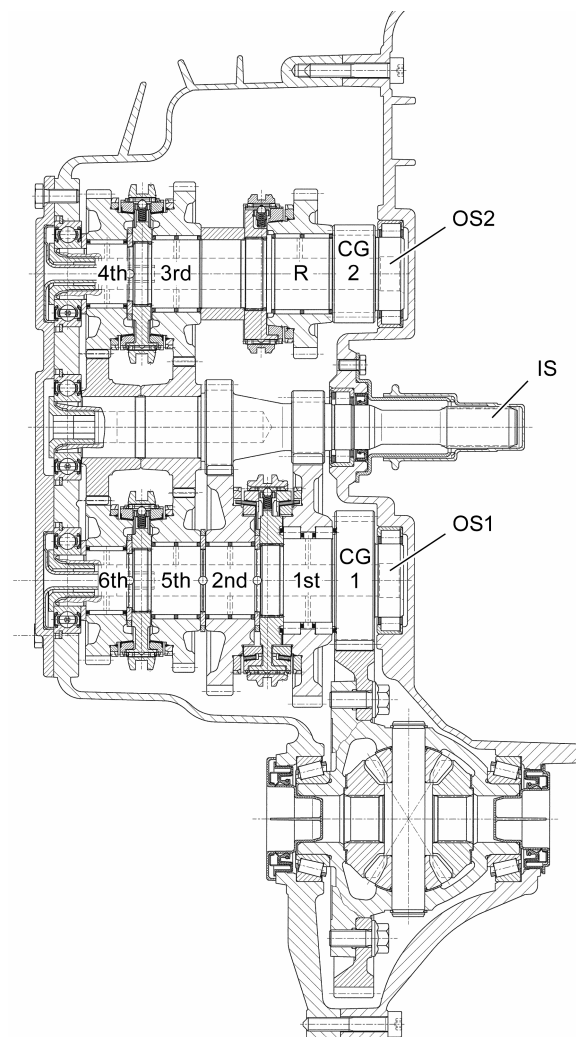


Fig. 12.7. 6-speed manual passenger car gearbox Getrag 285, *gearbox diagram*
Figure 6.21a

5/ Single-Stage 6-Speed Manual Passenger Car Gearbox; Getrag 285

Figure 12.7 shows a three-shaft gearbox developed to have the shortest possible overall length. All gears are synchronized, including the reverse gear. The first and second gears have double-cone synchronizers, and the remaining gears have single-cone synchronizers [12.27] (*the basic concept is explained in Section 6.6.1 and Figure 6.21a*).

The individual gears are arranged on the gearbox input shaft *IS* as follows (starting from the clutch side). Located directly next to the bearing of the input shaft are the first and reverse gears. The shift gear for first gear is on the output shaft *OS1*, the shift gear for reverse gear on the output shaft *OS2*. The reverse gear uses the shift gear of the first gear as a reverse idler gear. Running on two cylindrical roller bearings, the mounting is therefore more elaborate than for the other shift gears, which run on simple needle roller bearings. Following the fixed gear of the second gear are the two fixed gears for the third and fifth gears and for the fourth and sixth gears. Due to the fact that the third and fifth gears and the fourth and sixth gears share their respective fixed gear (double-uses), the input shaft *IS* only has four fixed gears, which allows it to remain short. The power flow is through the output shaft *OS1* in fifth and sixth gear as well as in first and second gear. In third and fourth gear as well as reverse gear, the power flow is through the output shaft *OS2*. All three shafts are mounted via a classic locating/non-locating bearing arrangement, using ball bearings as locating bearings and drawn cup roller bearings as non-locating bearings.

Figure 12.8 shows the side view. Because the synchronizing units on the two output shafts are far apart, a long selector shaft with two selector fingers is required.

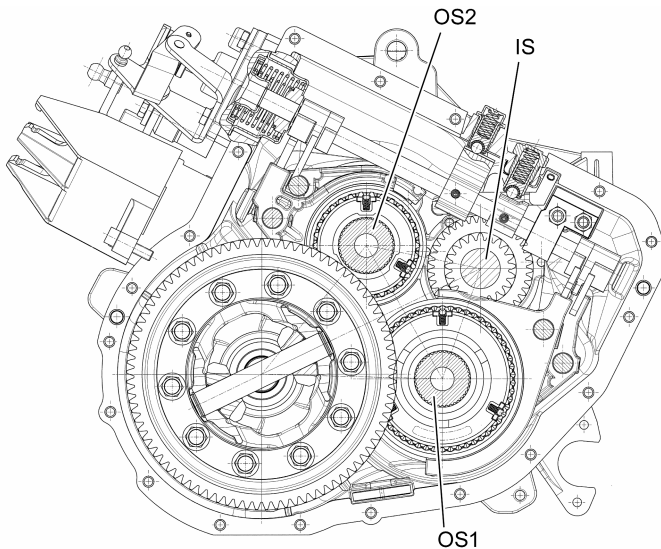


Fig. 12.8. 6-speed manual passenger car gearbox Getrag 285

There are two synchronizing units on each output shaft activated by identical selector fingers. The cam profiles necessary for locking are between the selector fingers. The selection forces holding the gearshift lever in the third/fourth gear gate are created by means of coil springs in the gearshift cover. Selecting in other gates yields corresponding restoring forces.

6/ Single-Stage 6-Speed Manual Passenger Car Gearbox; Mercedes-Benz FSG 300-6

The gearbox shown in Figures 12.9 and 12.10 is similar in layout to that shown in Figure 12.7. However, only one fixed gear with double-use is used in this case. While this increases the freedom of ratio selection, it also increases the gearbox length (*the basic concept is explained in Section 6.6.1 and Figure 6.21b*).

Located directly next to the main bearing is the first gear, followed by the second gear. The sixth and third gears, with separate fixed gears, are located at the centre, followed by the fourth and fifth gears, which share a common fixed gear.

The power flow of first to fourth gear is through the upper output shaft *OS1*, while that of fifth, sixth and reverse gear through the lower output shaft *OS2*. With this arrangement, the output shaft, with its smaller number and geometrically smaller gears, dips into the oil sump, which results in smaller drag torques [12.16].

The reverse gear has a separate reverse idler gear for reversing the rotational direction. This idler gear is also stepped so as to achieve the necessary ratio. In the gearshifting pattern, reverse gear is located to the immediate left of second gear.

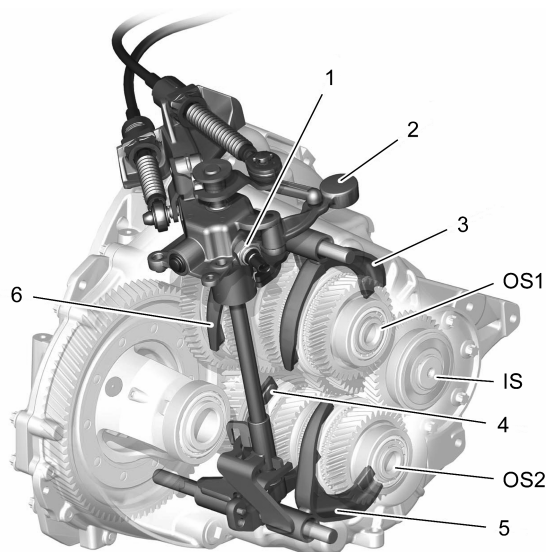


Fig. 12.9. Shifting mechanism of the 6-speed manual passenger car gearbox Mercedes-Benz FSG 300-6.

- 1 Reverse light switch;
- 2 shifting weight;
- 3 shift fork, 3rd/4th gear;
- 4 shift fork, reverse gear;
- 5 shift fork, 5th/6th gear;
- 6 shift fork, 1st/2nd gear

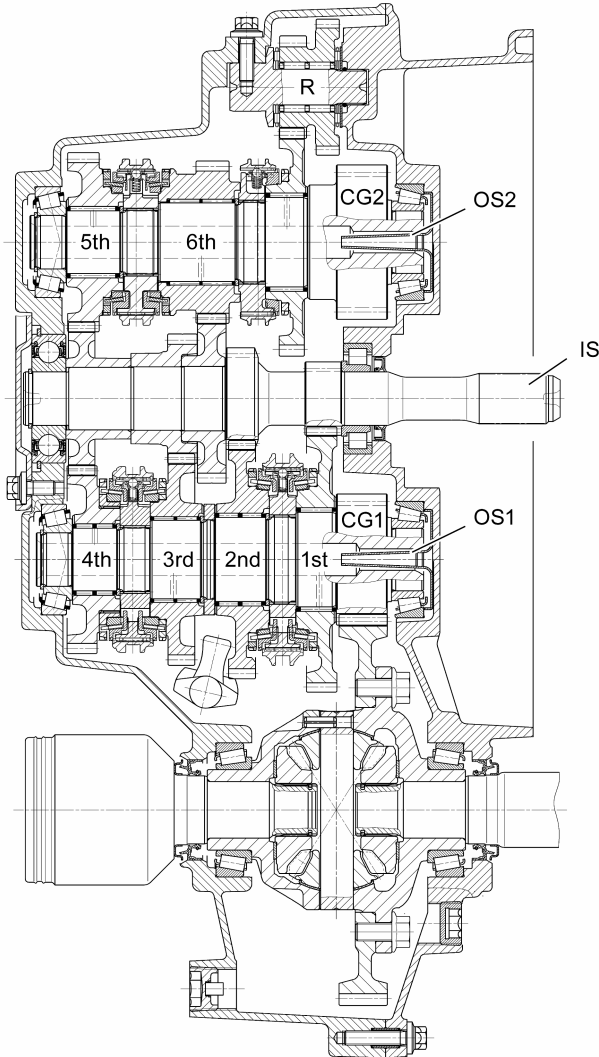


Fig. 12.10. 6-speed manual passenger car gearbox Mercedes-Benz FSG 300-6, gearbox diagram Figure 6.21b

The selector shaft with two selector fingers is also similar to that of the Getrag 285 gearbox, but instead of the selector shaft lying diagonally over the input shaft, it lies in this case between the gear set and the differential, which yields a highly compact design (see Figure 12.9).

7/ Two-Stage 6-Speed Manual Passenger Car Gearbox; Getrag 217

Another example of 6-speed manual transmission is provided by the Getrag 217 shown in Figure 12.11 (*the basic concept is explained in Section 6.6.1 and Figure 6.22a*). The gear configuration in the variant for petrol engines shown here corresponds to that of the transmission shown in Figure 12.5. Since this gearbox is designed for smaller engines, the design is more compact and cost-effective than the one in Figure 12.5. Thus, simple ball bearings are used as main bearings instead of double angular contact ball bearings. The shafts are not friction welded, but rather deep drilled. Although the gearbox is, relatively speaking, somewhat heavier, this is compensated for by its cost-effectiveness. Because the masses needing to be synchronized are smaller, smaller synchronizers can be used; in first and second gear, double-cone synchronizers are used instead of triple-cone synchronizers.

This gearbox is designed for petrol and diesel engines. Since a greater overall gear ratio is required for diesel engines because of the smaller rotational speeds, the fourth gear is used as direct gear instead of fifth gear, as in the petrol variant.

The configuration of the third and fourth gears is thus exchanged for that of the fifth and sixth gears and the direct gear is an even gear, not an odd one. This must be compensated for by modifications to the internal gearshift system in such a way that the usual gearshifting pattern is realised on the gearshift lever. By changing few components, shifting can be achieved for both variants, while simultaneously fulfilling increasing standards of shifting comfort. Since for one of the variants direct gear is an even gear and an odd gear for the other one, the shifting direction must be reversed for one of the variants.

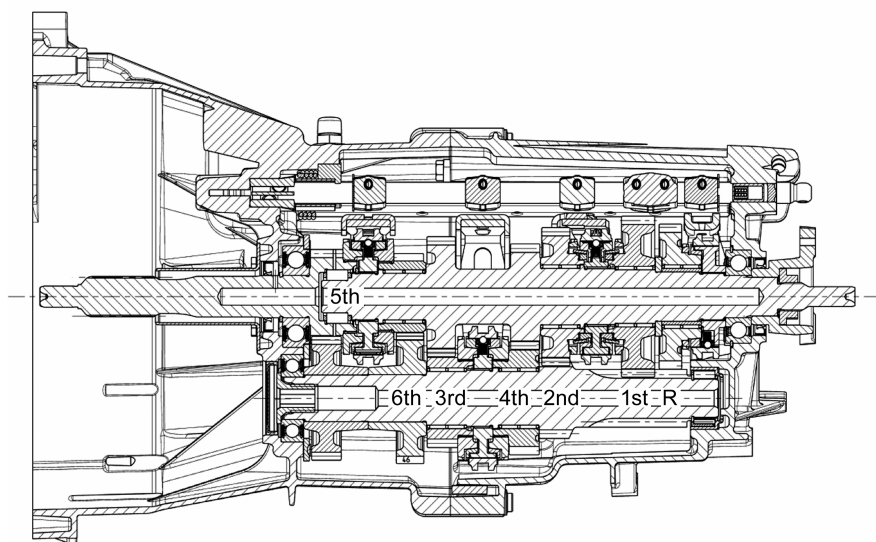


Fig. 12.11. 6-speed manual passenger car gearbox Getrag 217, spark ignition engine design; gearbox diagram Figure 6.22a

This is achieved by using swing forks or shift forks. In the case of swing forks, the motion at the gear sliding sleeve is opposed to that of the selector shaft. The interchanging of gear pairs 3, 4 and 5, 6 is compensated for through different positions of the selector fingers on the central selector shaft and through modified engaging elements on the forks. The interlock mechanism preventing the simultaneous selection of multiple gears is the same for both variants.

8/ Single-Stage 6-Speed Manual Passenger Car Gearbox; Getrag 466 (Audi ML350/450)

The Audi ML350-6F single-stage 6-speed gearbox shown in Figure 12.12 is designed for front-longitudinal applications (*the basic concept is explained in Section 6.6.1 and Figure 6.23a*). This gearbox thus contains a final drive with differential 1, as with front-transverse drives. In order to achieve a compact design with small centre distance, while being able to transmit high torques, the gearbox has a triple bearing system, i.e. the main shafts run at the centre on additional roller bearings.

Since the bearings are thus statically overdeterminate, the components involved must be correspondingly closely tolerated. Also, the roller bearing internal clearance is increased to prevent distortions. The output shaft runs on the pinion side in a double-row angular contact ball bearing which can absorb the high radial and axial forces of the powertrain. The input shaft is very long as a result of the differential between the clutch and the gear set.

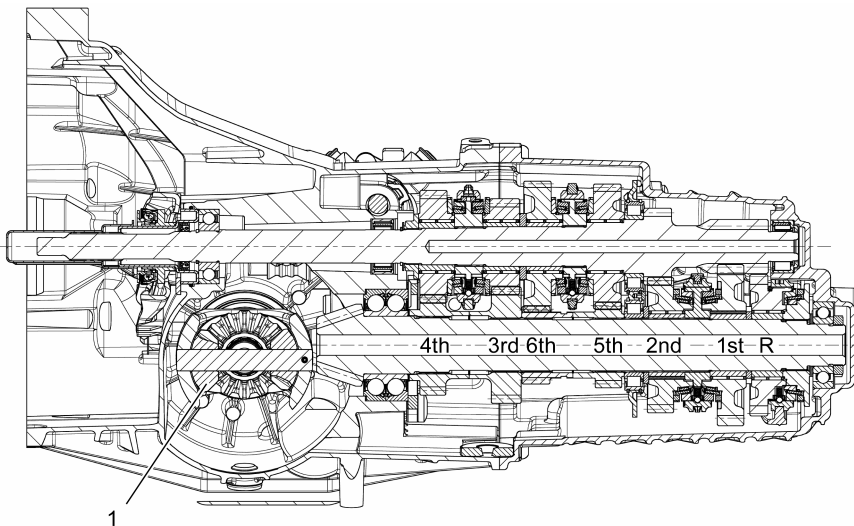


Fig. 12.12. 6-speed manual passenger car gearbox for front-longitudinal drive Audi ML350-6F; gearbox diagram Figure 6.23a. 1 Front axle differential

The locating bearing arrangement is thus divided into two bearings: a roller bearing for taking up the radial forces near the gear set and a four-point contact bearing which principally absorbs the axial force, but also minimises deflection in the clutch area [12.14].

The front-wheel gearbox can be converted with relatively little effort into a gearbox for all-wheel drive (see Figure 12.64). The output shaft with pinion head is thereby replaced by a hollow shaft and a pinion shaft mounted inside it. A centre differential – in this case a TORSEN differential – is integrated at the end of the gearbox. The centre differential distributes the torque at a ratio of 50 : 50 to the front and rear axles.

12.1.2 Automated Manual Passenger Car Transmissions (AMT)

9/ Single-Stage 6-Speed Passenger Car AMT; Getrag 431

The first gearbox in mass production developed purely as an AMT is the Getrag 431, implemented in Smart cars (Figure 12.13). Since this gearbox was developed as an AMT, no account had to be taken of the gearshift pattern in designing the gear set and gearshift system (*the basic concept is explained in Section 6.6.2 and Figure 6.25a*).

This is a single-stage 6-speed gearbox with integrated actuator technology. The six gears are created via a 3-speed main gearbox with reverse gear and the output constant gears CG_H and CG_L of the rear-mounted range-change unit. The gears on the input shaft are arranged as follows. The third/sixth gear is on the clutch side. Contrary to the usual “design rule” dictating that gears with high forces be arranged near bearing planes, the gear pairs for the first and reverse gears are in the shaft centre. Due to the relatively small torques, other criteria were more highly weighted, such as package and costs. The gearing for the second/fifth gear is at the end of the shaft.

This concept allows for cost- and space-effective 6-speed transmissions designs. There are limitations with respect to ratio selection and gear steps resulting from the multi-range design. As opposed to conventional 6-speed gearboxes, however, this gearbox cuts down on one synchronizing unit plus gearshift mechanism. As with all AMTs, gear set components such as gears, shafts, and synchronizers are identical to those of manual transmissions. All main bearings are deep groove ball bearings. Because of the small torque to be transmitted, the differential can also run on ball bearings instead of the usual tapered roller bearings.

The advantages of this design are an improved level of efficiency and a more simple assembly. The differential cage consists of two aluminium die cast shells bolted together with the two output gear rings.

With this gearbox, the internal gearshift system is not designed as with manual transmissions. The gear sliding sleeves are operated by an electrically activated gearshifting drum 2 (Figure 12.14). The shift forks 3 which engage in the grooves are moved axially by the rotation of the gearshifting drum; they are simultaneously locked against each other.

Automotive Transmissions

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