

Table 6.10. (continued)

6.25b	7	AMT, 2-stage	S	Getrag	247	12.15–12.16	10/
6.26	6	DCT, principle	FT	VW	DSG	12.17–12.20	11/
6.27	7	DCT	S	ZF	7 DCT 50	12.21	12/
6.30–6.31	4	AT, w/o CC	FT	ZF	4 HP 14	—	—
—	5	AT, w/o CC	S	MB	W5A 030	12.22	13/
6.32	5	AT	S	MB	W5A 580	12.23	14/
6.33	7	AT	S	MB	W7A 700	12.24	15/
6.34	6	AT	S	ZF	6 HP 26	12.25	16/
6.35	6	AT	FT	AISIN	TF 80-SC	12.26	17/
6.36	5	Countershaft-type automatic transmission	FT	MB	W5A 180	12.27	18/
6.37–6.38	6	Hybrid, parallel	S	BMW/ ZF	Active Transmission	12.28	19/
6.39	∞	Hybrid, power-split	FT	Toyota/ Lexus	P310	12.29	20/
6.41	∞	CVT, toroid principle	—	—	—	—	—
—	∞	CVT, chain variator	FL	Audi	Multitronic	12.30	21/
—	∞	CVT, chain variator	FT	MB	Autotronic	12.31	22/
6.43	∞	CVT, chain variator	FT	ZF	CFT 30	12.32	23/
6.44	∞	CVT, geared neutral	—	—	—	—	—

6.6.1 Manual Passenger Car Transmissions (MT)

Manual passenger car transmissions include all transmissions in which both the process of changing gear and the process of engaging the master clutch and moving-off are carried out manually by the driver. They are all fitted with spur gears. Transmissions with dog clutch engagement are not available for passenger cars. They are only offered with synchromesh. To shed light on the basic principles involved, the following will include an historical account of the development of manual transmissions. The systematics of manual transmissions will be discussed using examples ranging from the 4-speed transmissions still common in the 1990s up to the most current designs. As always in this book, all gear numbers refer to

forward gears. A separate section will be devoted to deriving all-wheel drive variants from the basic principles.

Manual passenger car transmissions can be subdivided according to number of stages into further categories (see also Section 6.3). “Stage” is defined here as the power flow from one shaft to another. This subdivision relates mainly to the forward gears of the main gearbox itself, not to any integral final drives, differentials and intermediate shafts needed to drive them. This yields the following categories:

- single-stage countershaft transmissions with 4 to 6 gears and integral final drive (e.g. Figure 6.18a) and
- two-stage (coaxial) countershaft transmissions with 4 to 6 gears (e.g. Figure 6.19a).

Single-stage countershaft transmissions are used in passenger cars in which the engine is located next to the drive axle, which is to say in front-wheel drive vehicles with front engines, or in rear-wheel drive vehicles with rear engines. This applies to both normal engine configurations – transverse and longitudinal. In the case of single-stage countershaft transmissions, the final drive is usually integrated into the gearbox housing. If a very short overall transmission length is required for space reasons, the ratio can occur by means of a third, offset shaft. Figure 6.21 shows such a three-shaft gear unit.

In the transmission diagrams used in this chapter, integral final drives, where present, and reverse gears of the various transmissions are represented by “grey” lines for the sake of completeness. It should be noted that in reverse gears the shafts of the idler gears are located in a different plane to the main shafts (compare also with Section 6.5). The location and size of the idler gears are intended only to give an impression of the fundamental design.

Two-stage countershaft transmissions are used in passenger cars with standard drive. They normally contain no integral final drive components since they are generally flanged directly onto the front-mounted engine, and linked to the drive axle by a propeller shaft. An exception is two-stage transmissions mounted on the rear axle to give more even weight distribution with front-mounted engines (see also Figure 6.2h/i). Parts of the final drive are integrated in such transmissions.

The synchronizer packs are each allocated to one shift gate, and serve mostly to shift two neighbouring gears. In each shift gate there is usually first and second gear, third and fourth gear, fifth and reverse gear, or alternatively fifth and sixth gear. There are also designs which use a separate shifting element for the fifth and reverse gear, which can be unsynchronized in reverse gear.

The example of a single-stage 4-speed gearbox is the VW unit, as used for example in the early 1990s in the VW Golf (Figure 6.18a). In this gearbox, the gear pair of the first gear is located directly beside a shaft bearing. The total number of gear pairs remains the same compared to a two-stage 4-speed transmission, since although the gear pair of the *input constant gear CG* (sometimes called *head set*) (Figure 6.19) is not required, one is needed for the fourth gear. Single-stage transmissions have no direct gear. Single-stage 5-speed transmissions (Figure 6.18b) differ from single-stage 4-speed transmissions only in having an additional gear pair which is “attached onto” the housing side opposite the input side.

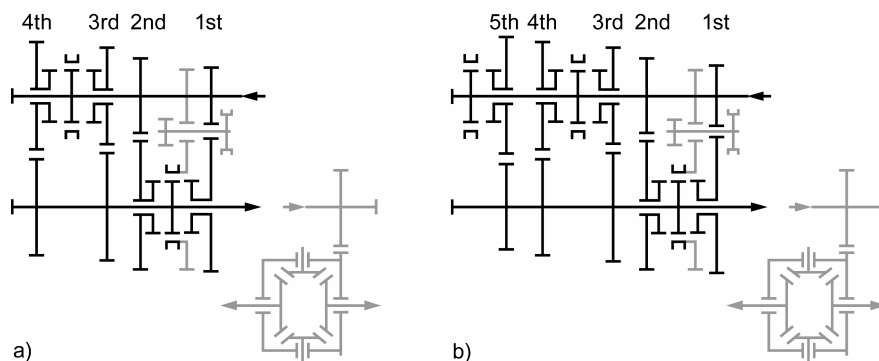


Fig. 6.18. *a* Single-stage 4-speed gearbox (VW); *b* single-stage 5-speed gearbox (VW), production design Figure 12.1

This does not require any design changes in the original gear unit. Often, 5-speed gearboxes have been developed from existing 4-speed gearboxes.

One example of the two-stage 4-speed gearbox is the Getrag gearbox in Figure 6.19a. In accordance with the design principle of placing gear pairs with high torque changes near bearings in order to minimise shaft deflection, the gear pair of the first gear is located on the gearbox output side. The fourth gear is the direct gear. In the 5-speed gearbox shown on the right in Figure 6.19b, the fifth gear is the direct gear. Frequently, the fifth gear is speed increasing (overdrive) and the fourth gear is the direct gear.

In two-stage countershaft transmissions with six gears, as in Figure 6.20a, the gears of the first and second gear are near a shaft bearing. It should also be borne in mind that such transmissions are used principally in high-performance passenger cars, and therefore have a high torque design. Figure 6.20b shows a single-stage countershaft transmission with final drive.

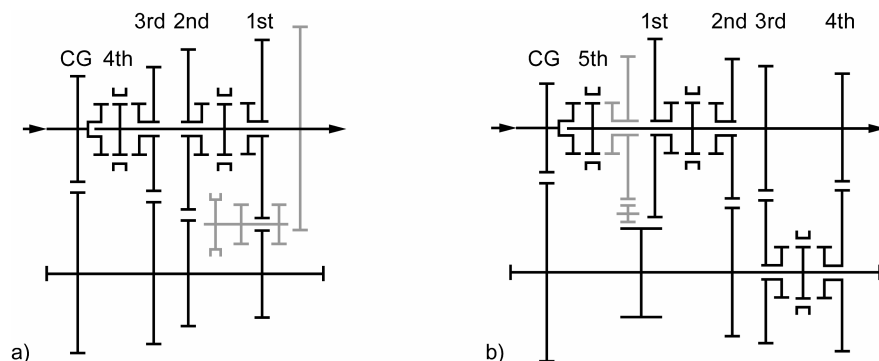


Fig. 6.19. *a* Two-stage 4-speed gearbox (Getrag); *b* two-stage 5-speed gearbox with direct 5th gear, “sports gearbox” (ZF), production design Figure 12.2

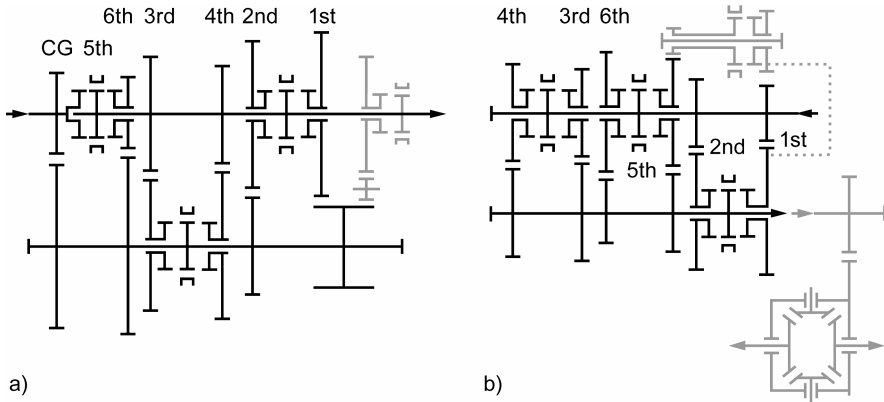


Fig. 6.20. *a* Two-stage 6-speed gearbox (Getrag), production design Figure 12.5;
b single-stage 6-speed gearbox (Opel); production design Figure 12.6

Since the mid-1990s, almost all manufacturers have tended towards 6-speed manual transmissions. The existing 5-speed gearboxes are being replaced by new designs with 6 gears, primarily among vehicles with more highly powered engines. Since the length of the gearbox is of great importance when it is transversely mounted, corresponding solutions must be found for short gearboxes.

The gears of transmissions with a three-shaft design are distributed among two output shafts *OS1* and *OS2* which lie parallel to the input shaft *IS*. This allows a very short gearbox, which is necessary for transverse mounting. With this design, 6-speed transmissions have the same overall length as a 4-speed transmission. Three-shaft transmissions are single-stage countershaft transmissions with integral final drive.

Figure 6.21a shows a design optimised for minimal overall length. A fixed gear is allotted to the third and fifth gears and to the fourth and sixth gears respectively – a so-called “double-use” of the fixed gears for two gears each. The different ratios must thus be entirely effected via the respective ratios of the constants, and this with the same axial distance of the output shafts to the gearbox input shaft. A third double-use is realised in the reverse gear. The reverse gear uses the shift gear of the first gear as a reverse idler gear. This is possible because the reverse gear shares the short constant gear *CG2* with the third and fourth gears. This design is thus nearly optimal with respect to overall axial length and the number of necessary gear set parts, with a small limitation of ratio selection. As a result of the two double-uses, only five gears can be selected freely; the sixth gear is the outcome of the others [6.19].

Figure 6.21b shows a three-shaft transmission which allows all gear ratios to be freely selected and is comparable to other manual transmissions. In the figure, the first to fourth gears are on output shaft *OS1*, the fifth, sixth and reverse gears on output shaft *OS2*. Both higher starting torque ratios and higher overall gear ratios can be achieved. The transmission length is, however, somewhat greater, since only one double-use is implemented for the fourth and fifth gears. The reverse idler gear of the reverse gear has its own countershaft.

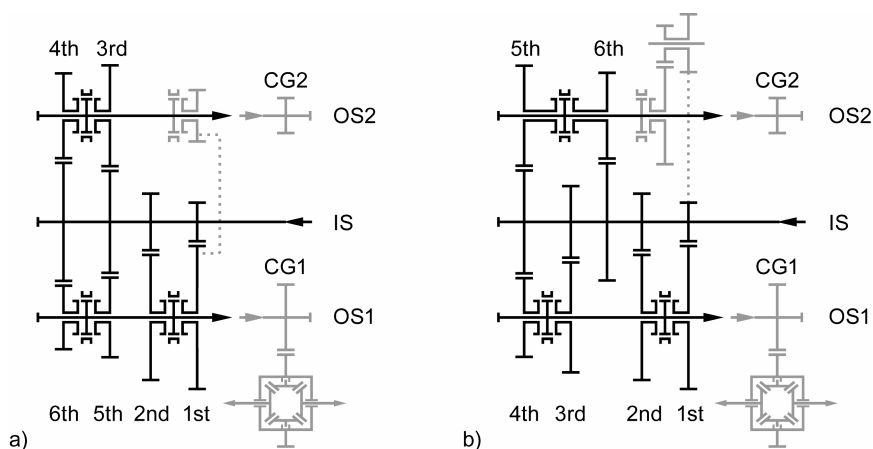


Fig. 6.21. *a* Single-stage 6-speed gearbox with three-shaft design (Getrag), production design Figure 12.7; *b* single-stage 6-speed gearbox with three-shaft design (Mercedes-Benz), production design Figure 12.10

New designs for standard drives have also almost exclusively six gears. These transmissions are always designed as two-stage transmissions. Examples of such transmissions, also referred to as in-line transmissions, are shown in Figure 6.22. Figure 6.22a shows the variant designed for spark ignition engines. The basic design corresponds to that of Figure 6.20a. Figure 6.22b shows the design for diesel engines. Since a greater overall gear ratio is required for diesel engines, the fourth gear was designed as a direct gear instead of the fifth gear, as for petrol engines. The fifth and sixth gears thus have a ratio smaller than 1. These transmissions are also referred to as double-overdrive transmissions. In order to receive the same gear pattern in both cases despite their varying gear configurations, small modifications of the internal gearshift system are required.

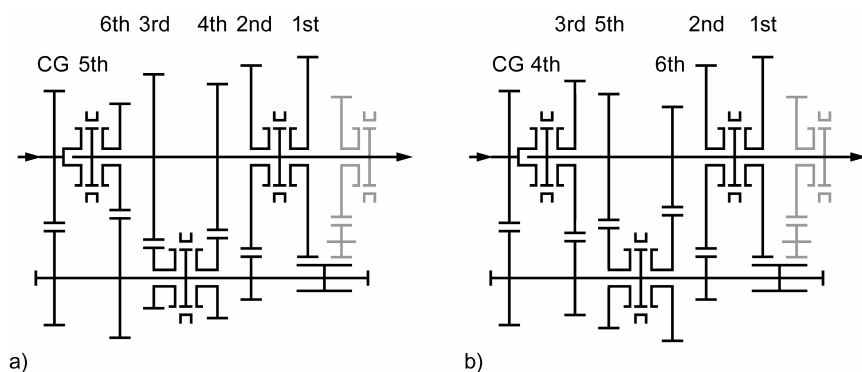


Fig. 6.22. Two stage 6-speed gearbox (Getrag), production design Figure 12.11. *a* Design for spark ignition engines; *b* design for diesel engines

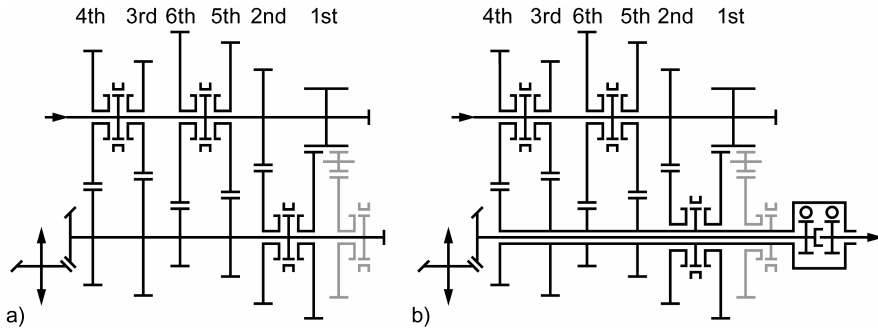


Fig. 6.23. Single-stage 6-speed gearbox for front-longitudinal mounting (Audi). *a* For front-wheel drive, *production design* Figure 12.12; *b* for all-wheel drive with TORSEN centre differential, *production design* Figure 12.64 (bevel gear drive rotated 90°)

New designs for longitudinal transmissions with final drive are exclusively 6-speed transmissions. These are used in front-wheel and all-wheel drive vehicles (e.g. Audi A6) as well as in rear-motor drive vehicles (e.g. Porsche 911) and have a single-stage design. The integral final drive consists of a spiral gearing.

Figure 6.23a shows a transmission for front-wheel drive, Figure 6.23b for all-wheel drive. The gear set is assembled in the same way in both designs. The power flow for the front-wheel variant goes from the input shaft over the output shaft to the front axle differential. In the case of the all-wheel drive design, the flow is from the input shaft over a hollow shaft to an integral TORSEN centre differential. There, the power is distributed among the front and rear axles. Power is transmitted to the front axle via a pinion shaft mounted in the hollow shaft to the front axle differential integrated into the transmission. Power is transmitted to the rear axle via the flange-mounted cardan shaft to the rear axle differential.

6.6.2 Automated Manual Passenger Car Transmissions (AMT)

When manual transmissions for passenger cars began to be automated, the term “Semi-automatic transmission” was used. The term referred to the two operations “Engaging the clutch/Moving-off” and “Changing gear”. One of these operations was automated in semi-automatic transmissions (see Table 6.14 “Automation levels of manual transmissions”).

A typical example of an early semi-automatic manual transmission for passenger cars is the VW torque converter clutch transmission (TCCT) (1967). In this design, there is a mechanical gearshifting clutch mounted behind a hydrodynamic torque converter (Figure 6.24). The process of engaging the gearshifting clutch and moving-off is automated, while changing gears is manual.

The torque converter has three main functions to fulfil in this process: to enable moving-off in any gear, to refine the coarse stepping (three forward gears) of the manual gearbox and to damp the torsional vibration when engaging the gearshifting clutch.

Automotive Transmissions

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