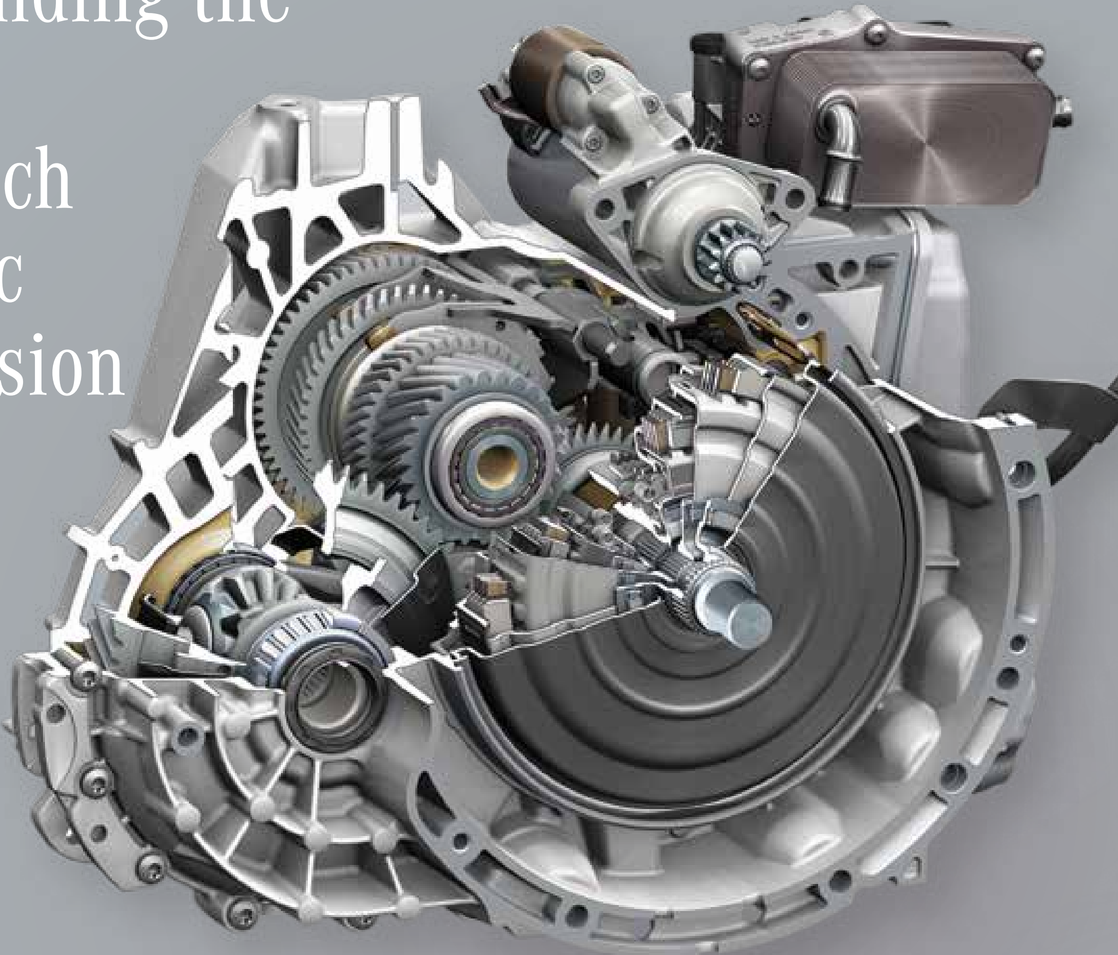
Understanding the 7-Speed Dual-Clutch Automatic Transmission



Like two sticks? Ingenious technology yields the smooth and efficient 7G-DCT

Technology advances constantly. Engines become more efficient and powerful. Braking distances are shorter than ever. Comfort and convenience systems become more sophisticated so drivers can focus their attention more on driving. Engine management systems are more thoroughly integrated than ever before. And safety systems help to reduce accidents, and to help protect drivers and passengers from injury when accidents occur.

Amidst all of this, there is a constant need to improve drivetrains, including automatic transmissions. Engineers are continually searching for ways to increase the number of forward speeds in pursuit of improved performance, drivability, and fuel economy. At the same time, market forces dictate the need for smoothing the shifting of gears such that the transition is all but unnoticeable.

All of these demands and challenges may seem insurmountable. Yet brilliant minds within the Mercedes-Benz family continue to design automatic transmissions that meet and exceed the needs of the marketplace.

And so it is with the 7G-DCT dual-clutch 7-speed automatic transmission. First introduced about five years ago, this transmission is a brilliant piece of engineering – relatively simple in concept, yet glassy smooth in shifting and very reliable and durable.

Specific benefits of this design include:

- Short shift times
- Compact design

- Comprehensive integration of all transmission-related functions —hydraulic, electronic, and mechanical
- Unusually efficient and smooth transition between gears
- High customer satisfaction

This dual-clutch transmission can be operated in any of three modes the driver may select – Manual, Sport, or Economy (M, S, or E). Vehicles equipped with this transmission also feature an electronic version of what might be considered the most novel “prindle” ever offered in a motor vehicle – P-R-N-D-1-2-3-4-5-6-7.

A Look Inside

The essence of the 7G-DCT transmission is a blend of what are essentially two manual transmissions, each engaged by its own clutch assembly, and all controlled by an electronic management system.

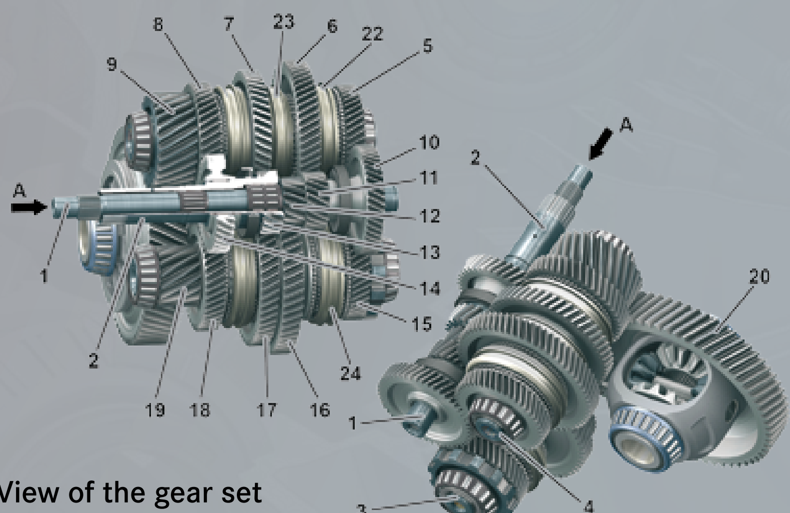
This transmission is not unlike two manual transmissions, operating on two separate mainshafts, both powered by a common equivalent of a cluster gear. Synchronizers are surprisingly similar to those used in manual transmissions, with several key differences. One “mainshaft” contains the gears and synchronizers for the odd-numbered gears – 1, 3, 5, and 7. The other contains the even numbered gears – 2, 4, and 6 plus reverse. These are considered “sub-transmissions.”

Only one gear at a time is engaged in each sub-transmission. However, the electronic management system is so “smart” that it pre-selects and engages the next appropriate gear in the other sub-transmission in anticipation of changing driving conditions. So the shift pattern actually moves from one sub-transmission to the other, and back to the first as the need arises for a subsequent gear.

The beauty of this arrangement is that, with each successive gear pre-selected, gear changes are quick yet silky-smooth, nearly to the point of being unnoticeable.

Individual gears are selected by synchronizer sleeves and synchro rings that bear a striking resemblance to those used in manual transmissions. And, as in manual transmissions, gears are pre-meshed with their mates on the “cluster gear,” and locked to their mainshaft by the synchronizers.

Your own experience with manual transmissions will remind you that shifting in and out of higher gears is smooth and easy. However as you get to the lower gears, shifting becomes a bit harder. This is a function of the torque characteristics of the gear ratios.



View of the gear set

1. Internal shaft
2. Hollow shaft
3. Output shaft 1
4. Output shaft 2
5. 7th gear idler gear
6. 3rdgear idler gear
7. Reverse gear idler gear
8. 6th gear idler gear
9. Output shaft fixed gear 2
10. Internal shaft fixed gear (5th gear/7th gear)
11. Internal shaft fixed gear (3rd gear)
12. Internal shaft fixed gear (1st gear)
13. Hollow shaft fixed gear (2nd gear/reverse gear)
14. Hollow shaft fixed gear (4th gear/6th gear)
15. 5th gear idler gear
16. 1st gear idler gear
17. 2nd gear idler gear
18. 4th gear idler gear
19. Output shaft fixed gear 1
20. Spur gear (pinion differential)
22. Sliding sleeve (3rd gear/7th gear)
23. Sliding sleeve (reverse gear)
24. Sliding sleeve (1st gear/5th gear)

A. Engine Torque

Recognizing the physics of these gear ratios, Mercedes-Benz engineers came up with an ingenious design that allows for smoother shifts among all gears, including lower gears. They have achieved this by building in multiple synchronizers in the lower-speed gears.

Specifically, this transmission uses three synchronizer cones for engaging first, second and third gears. The three friction surfaces combine to allow the gears to be slowed or speeded up more quickly and with less force than with fewer synchronizers. The result is shorter and smoother shift times, which translate into smoother and quicker gear changes.

Similarly, two synchronizers are used in fourth through seventh gear. The progression to higher gears requires less synchronization to achieve similarly smooth and speedy gear changes. And a single synchronizer is used for reverse gear, where there is only one gear ratio involved, and reverse gear is selected far less often than forward speeds.

The synchronizers are all operated by electro-hydraulically-controlled shift forks. The control module receives input data from a variety of sources and sensors and determines which gear is to be pre-selected.

Each of the two "mainshafts" has its own separate multi-disc clutch mechanism. Like the synchronizers, the clutches, immersed in transmission fluid, are operated electro-hydraulically by the transmission control unit. Each clutch "module" incorporates two individual clutches, each with four disc pairs. This arrangement affords smooth yet firm engagement and disengagement for a satisfying yet barely noticeable transition from one gear to another.

Another interesting feature is the use of permanent magnets attached to the shift forks. These magnets provide inputs to the transmission control unit to identify which gear(s) are engaged at any given time.

Here's How It Works

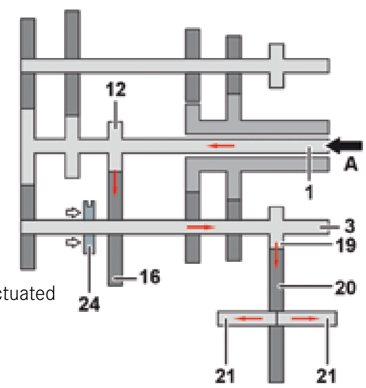
Engine torque is transmitted through the transmission from the crankshaft to a dual-mass flywheel. Power then

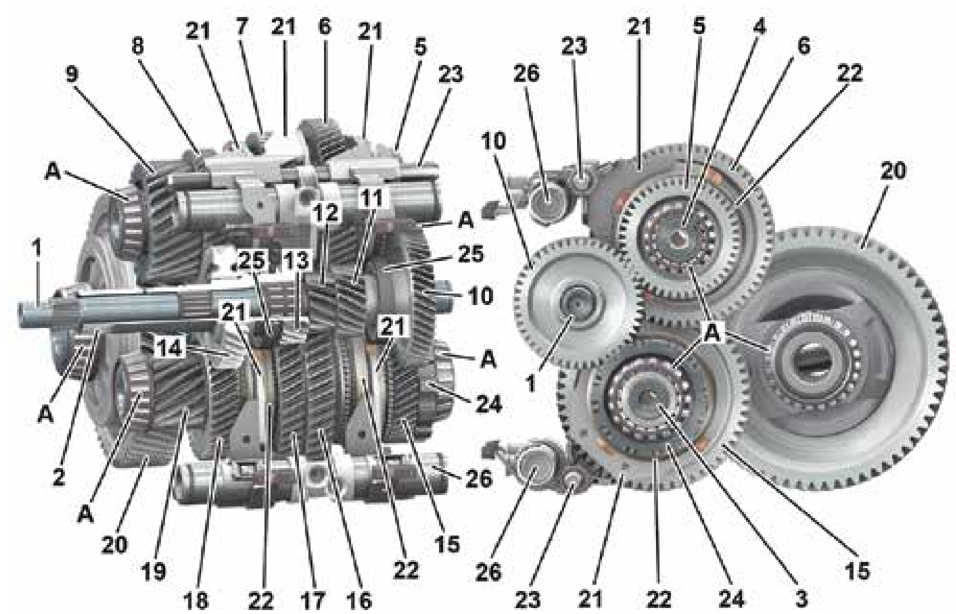
Power flow in 1st gear

1. Internal shaft
3. Output shaft 1
12. Internal shaft fixed gear (1st gear)
16. 1st gear idler gear
19. Output shaft fixed gear 1
20. Spur gear (pinion differential)
21. Left and right drive shaft
24. Sliding sleeve (1st gear/5th gear)
A. Engine torque

The following clutch/shift fork is engaged/actuated in order to provide power flow in 1st gear:

- K1 clutch (outer clutch)
- Shift fork (1st gear/5th gear)





Gear set

1. *Internal shaft*
2. *Hollow shaft*
3. *Output shaft 1*
4. *Output shaft 2*
5. *7th gear idler gear*
6. *3rd gear idler gear*
7. *Reverse gear idler gear*
8. *6th gear idler gear*
9. *Output shaft fixed gear 2*
10. *Internal shaft fixed gear (5th gear/7th gear)*
11. *Internal shaft fixed gear (3rd gear)*
12. *Internal shaft fixed gear (1st gear)*
13. *Hollow shaft fixed gear (2nd gear/ reverse gear)*
14. *Hollow shaft fixed gear (4th gear/6th gear)*
15. *5th gear idler gear*
16. *1st gear idler gear*
17. *2nd gear idler gear*
18. *4th gear idler gear*
19. *Output shaft fixed gear 1*
20. *Spur gear (pinion differential)*
21. *Shift fork*
22. *Sliding sleeve*
23. *Shift rod*
24. *Park pawl gear*
25. *Sensor rotor*
26. *Gear actuator cylinder*

A. Tapered roller bearing

flows through the central shaft, which contains fixed gears. These gears are in constant mesh with those on the two "mainshafts," but remember that the gears on the mainshafts are free-wheeling about their shafts until a synchronizer assembly locks a selected gear to the shaft. The transmission control unit directs one of the two clutch modules to engage, and power is then taken through the mainshaft/output shaft for the selected gear.

A novel and innovative feature of this dual-clutch transmission is the differential ring gear, which is in constant mesh with fixed gears on the two output shafts. When a gear is selected and the appropriate clutch is engaged, power then flows through the fixed drive gear on the output shaft and to the differential gear, which then provides propulsion to the drive wheels of the car.

The other mainshaft/output shaft and its fixed differential drive gear then free-wheel while power is directed through the other output shaft. The mechanical action, including both the clutch action and the gear selection and synchronization, are surprisingly similar to those of a manual transmission. But, being electronically-controlled, they provide much smoother, faster, and more positive gear selection and engagement.

Oil Is A Key Player

The oil in this dual-clutch transmission performs a number of key roles. As noted earlier, the entire power transmission role is controlled electro-hydraulically. So, the transmission oil controls every moving/mechanical component within the transmission. It actuates the multi-plate clutch modules, it provides movement for the synchronizer assemblies, it lubricates all of the gears and moving parts, and all other actuators as well. In addition, it performs an important cooling function, especially critical given the friction generated by the inter-acting components.

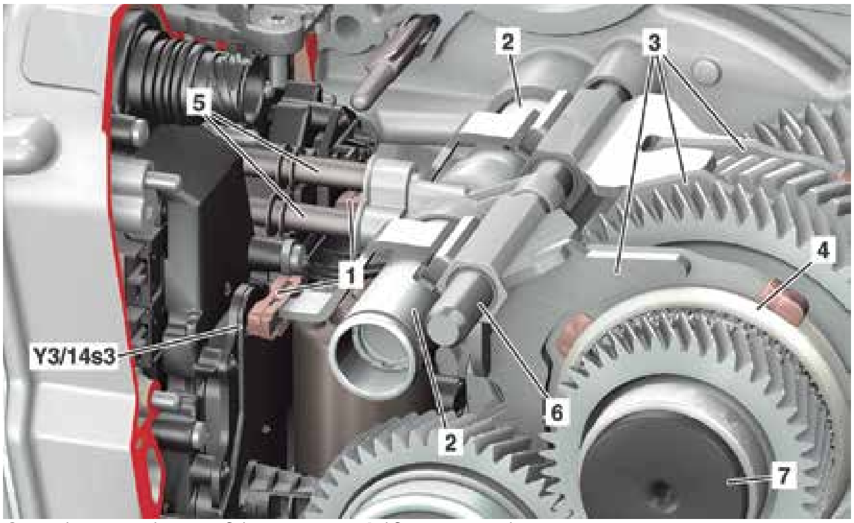
Because the oil supply and flow are so critical, this transmission actually incorporates three different oiling supply systems:

- Splash lubrication
- A primary mechanically-driven vane-type oil pump
- An electric auxiliary oil pump

Splash lubrication assures that the gears and bearings receive adequate lubrication. The primary mechanical pump provides pressurized oil to the electro-hydraulically actuated dual clutches and synchronizers. This pump is gear-driven, with a drive gear permanently attached to the dual clutch, constantly powered whenever the engine is running. The driven gear is attached to the mechanical primary pump, which is located in the transmission housing behind the dual clutch. This mechanical pump provides anywhere from 3.5 bar (50 psi) to 22 bar (320 psi) based on direction from the transmission control unit.

The electrically-driven auxiliary oil pump is mounted on the transmission control unit. Its role is to supplement the primary mechanical pump under certain conditions, including low rpm operation, during ECO start/stop operation, and to provide supplemental cooling at elevated transmission oil temperatures.

This pump is helpful at low engine speeds as may be encountered off-idle or during coast. This electric pump also provides operating pressure in ECO start/stop mode. With the engine off, all actuators return to their basic no-load state, so no gears can be engaged and no clutches engages without an adequate supply of oil pressure. This electric pump minimizes any delay between a start-off request and actual start-up of the engine.



Sectional view of internal shift operation

1. Permanent magnet
2. Gear actuator cylinder
3. Shift fork
4. Sliding sleeve of synchronization device
5. Oil pipe
6. Shift rod
7. Output shaft 2

Y3/14s3 Shift fork 3 position sensor

Furthermore, under heavy load conditions, such as driving in mountainous country or when towing, the transmission control unit will monitor the operating temperatures of the clutch plates and oil and will activate the electric auxiliary pump as needed to provide supplemental cooling to these critical components. The electric auxiliary transmission oil pump provides up to 8 bar (116 psi) depending on demands from the transmission control unit.

The transmission oiling system includes a transmission oil heat exchanger that acts as an interface between the transmission oil and the engine coolant. A separate pump provides a flow of metered engine coolant through the transmission oil heat exchanger. The flow is regulated based on transmission oil temperature. This heat exchanger is of a stacked plate design, and is located on top of the transmission housing.

Innovative Parking Pawl

As with other ingenious systems and components in the dual-clutch 7-speed transmission, the parking pawl mechanism is likewise innovative and effective. Like the clutches and synchronizers, the parking pawl mechanism is electro-hydraulic in operation. In essence, it is a “Park by wire” system. It includes a select lever, a pawl lift solenoid, a pawl position sensor, a switch-over valve, and the parking lock mechanism, all operated by the electronic transmission control unit.

The parking pawl can be activated manually by the vehicle’s DIRECT SELECT lever. It can also engage under a variety of other conditions, such as when the driver’s door is opened while the engine is running. This is a safety feature to assure that the vehicle cannot be left unattended unless it is in Park.

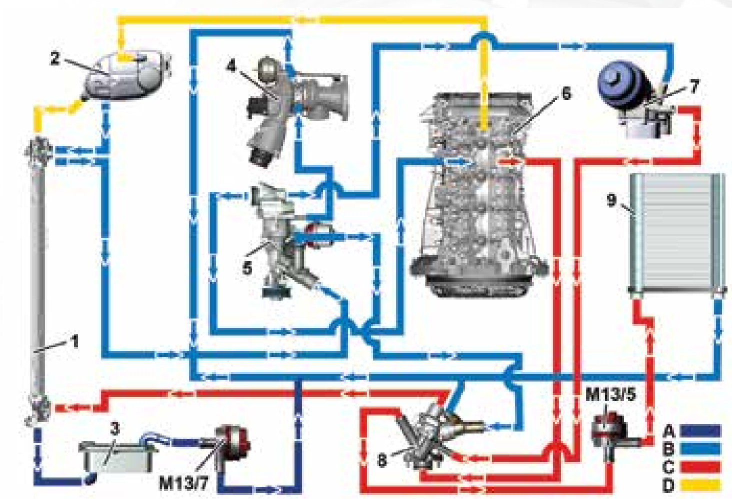
The parking pawl mechanism is integrated with the dual clutch transmission system, and is activated by one of two systems, depending on whether Park has been selected by use of the DIRECT SELECT lever, or if it has been engaged by some alternate method.

When the parking pawl is engaged by way of the DIRECT SELECT lever, the park detent engages the teeth of the park pawl gear, and is held in place by means of the spring-loaded pressure cone. A locking pin locks the piston in place, which puts pressure on the pressure cone itself by means of the pressure cone spring. This mechanical apparatus secures the transmission in Park even when there is no hydraulic pressure present.

When Park is selected by any means other than via the DIRECT SELECT lever, the pressure cone and the park detent are in the same position such that the park pawl gear can rotate freely. The piston is pushed against the force of the piston spring and is locked in place by the locking pin, which is activated by the park pawl lift solenoid.

In order to change the park pawl position, the transmission control unit actuates the lift solenoid which, in turn, moves the locking pin out of the catch of the piston. Then the piston is pressurized on one side in the direction dictated by whether Park was selected by the DIRECT SELECT lever or by some other means. The transmission control unit energizes the park pawl switchover valve, directing oil pressure to the appropriate piston chamber for piston actuation.

Regardless of the means by which Park is engaged, a permanent magnet attached to the piston provides a signal to the park pawl position sensor, which relays this



Coolant circuit, schematically illustrated on engine 270

1. Radiator
2. Coolant expansion reservoir
3. Transmission oil heat exchanger
4. Turbocharger
5. Coolant pump
6. Engine 270
7. Engine oil/coolant heat exchanger
8. Thermostat
9. Heater heat exchanger

- M13/5 Coolant circulation pump (with code (581) Comfort automatic air conditioning)
- M13/7 Transmission cooling coolant circulation pump

A Low-temperature cooling circuit coolant return
B Coolant return to engine
C Coolant feed
D Coolant circuit ventilation

information to the transmission control unit, so that it "knows" when the transmission is actually in Park.

Technicians should be aware that there is a procedure for releasing the parking pawl in the event of a failure in the power supply or hydraulic pressure control system. You can use an external power supply to energize and release the park pawl piston against the piston spring pressure. But note that it is not possible to release the park pawl without hydraulic pressure.

Finally, the park pawl mechanism in this transmission, obviously, is designed to prevent the vehicle from moving when in Park. If for any reason the parking pawl does not engage, the driver will be advised of a failure in the parking pawl mechanism by a warning light on the instrument panel. In this case the driver has the option of firmly engaging the parking brake. If, by unusual coincidence, the parking brake is also inoperative, the driver will be alerted accordingly, both by warning lamps in the instrument cluster and also by means of a message on the multi-function display. In such circumstances the vehicle will not be secured, and will have to be prevented from rolling by some alternative direct mechanical means.

Home Sweet Home

The 7G-DCT is a particularly well-thought-out transmission. As such, engineers were careful to build in a limp-home provision. In the event of a major problem in the transmission, the driver will be alerted by a message in the multi-function display, and also with an audible signal. Depending on the nature of the problem, the driver may experience a significant change in the operation of the transmission, such as only certain gears being functional or unusual shift quality.

If one of the two sub-transmissions experiences a problem, it is likely that none of the gears associated with that cluster will be available. So if there's a problem in sub-transmission number 1, the driver will likely lose access to speeds 1, 3, 5, and 7. If there is a problem within sub-transmission number 2, then the driver may well lose the availability of speeds 2, 4, 6, and Reverse. In such cases, the gears in the still-functioning sub-transmission will likely still be operational, albeit absent those gears on the other sub-unit.

Similar symptoms may appear if a gear control valve fails. The vehicle would still be able to be driven using the gears available in the other sub-transmission.

If both clutch units fail, such as might happen during a major loss of operating hydraulic pressure, or possibly due to a problem related to the electronics, the vehicle will no longer be able to move under its own power. If this is an intermittent issue, the driver may be able to "limp home" to a repair shop after cycling through an ignition sequence. And if the problem should persist after cycling, then the vehicle will likely be inoperable and will have to be towed.

Another condition that can affect transmission operation is excessively-overheated transmission oil. This is possible under certain high-stress conditions, such as repeated starts uphill, while towing, or in high ambient temperatures.

Under such conditions, the transmission oil may overheat, despite the very efficient heat exchanger fitted. If transmission oil reaches a pre-determined temperature threshold, the transmission control module will alert the engine control module, which will, in turn, reduce engine power until transmission oil temperature drops below the threshold. Under such conditions, the transmission will be prevented from operating in any manual mode until the oil has cooled. This arrangement will allow the operator to continue to drive modestly until the oil has cooled or until he/she can reach a service shop for appropriate diagnosis and repair.

Service Considerations

As you would expect, any disassembly and servicing of the dual-clutch transmission requires a host of special tools and training. As such, pretty much any internal failure within this transmission is best dealt with by replacement with a vehicle-appropriate rebuilt unit from your local Mercedes-Benz parts professional.

Since these transmissions are electronically controlled, all servos, solenoids, etc. are contained within the housing and are essentially non-serviceable for the independent repair shop.

As for routine maintenance, the only scheduled service is regular replacement of the transmission oil. The oil change interval for these transmissions is every five years or 100,000 miles. The only approved oil for this transmission is Shell DCT M 1, available from your local Mercedes-Benz dealership parts department.