THE NEW AUTOMATIC TRANSMISSION 9G-TRONIC from Mercedes-Benz,

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SUMMARY

The first nine-speed automatic transmission with torque converter, the 9G-TRONIC for premium vehicles, is celebrating its world premiere. Equipped with the innovative power transmission, the E 350 BLUETEC is set to become one of the most fuel-efficient six-cylinder diesel models in its class. Thanks to the high level of efficiency of the patented transmission design, NEDC fuel consumption in the E-Class is reduced to 5.3 liters of diesel per 100 km. As is typical of the brand, the transmission features outstanding comfort and barely perceptible gear changes. The E 350 BLUETEC featuring the 9G-TRONIC as new standard and is available to order in continental Europe with immediate effect.

HISTORY OF AUTOMATIC TRANSMISSION AND SYSTEM IDENTIFICATION

Mercedes-Benz develops and produces planetary gear set automatic transmissions for the rear wheel drivetrains for more than 50 years. The first generation automatic transmission started in 1960 as K4A025, a 4 speed planetary gear set – automatic transmission with hydraulic clutch as starting element, see figure 1. In former times the search process for planetary gear systems was done analytically [1, 2]. Due to the high effort first computer programs were designed to support the calculation. In order to search a new high efficient transmission system for the 9G-TRONIC an innovative consistent software tool had to be developed. With the specific boundary conditions of

- Size
- Spread
- Number of gears
- Optimum gear teeth efficiency

several billions of planetary couple systems were analyzed, evaluated and partly designed. The selected system of the 9G-TRONIC got world-wide patented in 2008. The system is designed for a torque capacity up to 1.000 Nm.

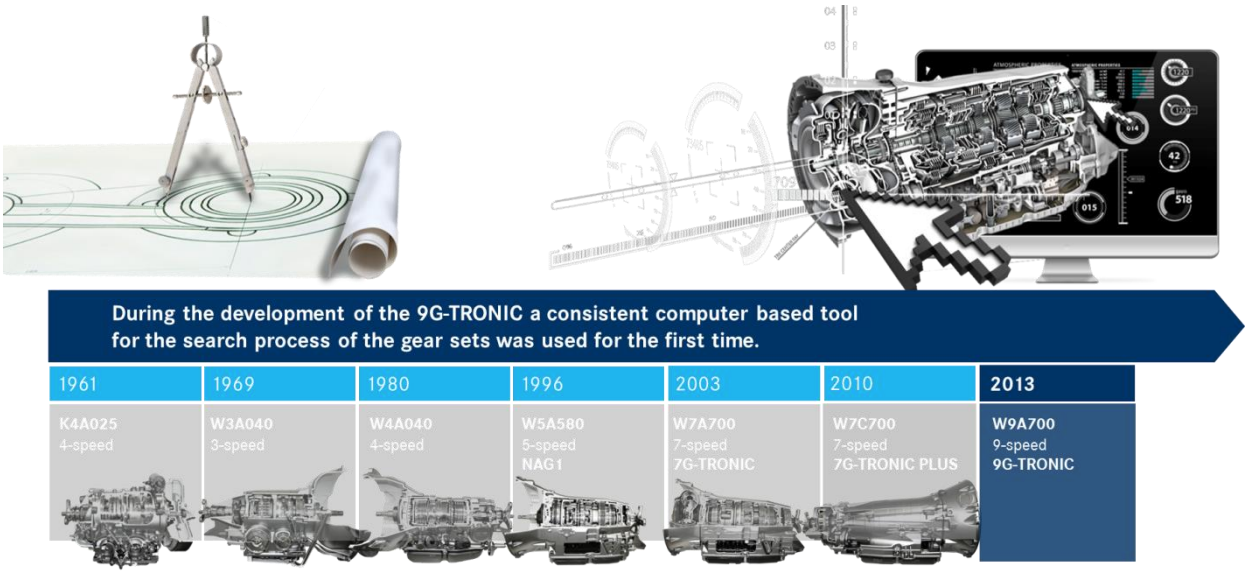
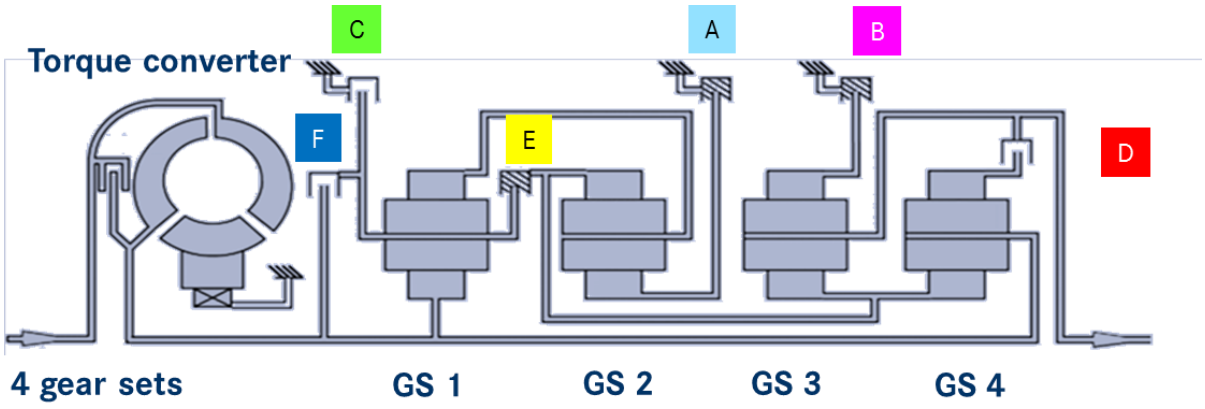


Figure 1: Development of planetary gear set automatic transmission generations at Mercedes-Benz

TRANSMISSION SYSTEM

The system design of the 9G-TRONIC is shown in figure 2. It consists of 4 standard planetary gear sets and 6 shift elements, which are 3 clutches and 3 brakes. With these gear sets and shift elements the 9G-TRONIC realizes nine forward speeds and one reverse speed.



Gear	A	B	C	D	E	F	nt/nab
1	●	●			●		5,503
2		●			●	●	3,333
3	●	●				●	2,315
4	●	●		●			1,661
5	●			●		●	1,211
6				●	●	●	1,000
7	●			●	●		0,865
8			●	●	●		0,717
9	●		●	●			0,601
R	●	●	●				-4,932
P	●	●					0,000

Figure 2: Planetary gear system and shift pattern of 9G-TRONIC.

The number of coupled elements for the transmission is a minimum for 9 speeds under the set of constraints. For a modern planetary gear system with more than 8 speeds and a high ratio an extremely long input shaft is characteristic. The shaft is coupled in the transmission system to the 4th planetary gear set. The transmission system is designed that the number of speeds correlates to the overall ratio. With 9 speeds an optimized gear ratio hat to between 8 and 10. Thus a harmonic stepping for the 9G-TRONIC is possible which leads in a comfortable driving.

THE MECHANICS OF THE 9G-TRONIC

The design of the automatic transmission 9G-TRONIC is shown in figure 3. Compared with predecessor transmissions the 9G-TRONIC is completely new due to the revolutionary transmission concept.

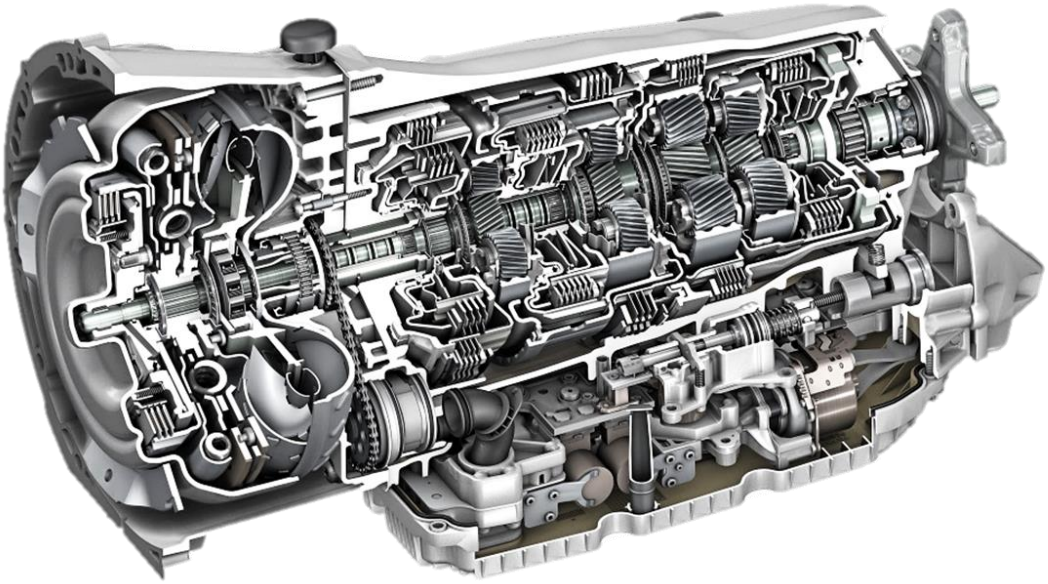


Figure 3: Design of the 9G-TRONIC with essential components

The mechanics of the transmission is laid-out as a compact design unit for standard drivetrain configuration, see figure 3. Similar to the predecessor transmission a two-piece case concept was implemented with the aluminum torque converter case and for light weight a magnesium transmission case [3, 4]. Main advantage of the two-piece case is high modularity with possibility to adapt easily to different engines as well as the simple modular implementation to the standard and all-wheel drive variants in Mercedes-Benz vehicles.
The four planetary gear sets have specific designs. The planetary carriers of the gear set one and two consist of aluminum die cast with high functional integration. The carriers of gear set three and four in the rear range are sheet metal structures, in order to apply high output torque to the transmission.
The six shift elements have optimized design. Material and nut design are varied for each shift element, depending on actuating and fuel economy potential. Substantial characteristics are power, specific design and lubricating of the shift element. For quick shifts the volumes of the pistons are reduced to a necessary minimum.

The oil pan is implemented as a plastic part and has high functional integration with two filters. The automatic transmission fluid is a low viscous full-synthetic fluid, which is produced first time from natural gas. Thus high stability is achieved and sloping shearing stresses over life time can be neglected.

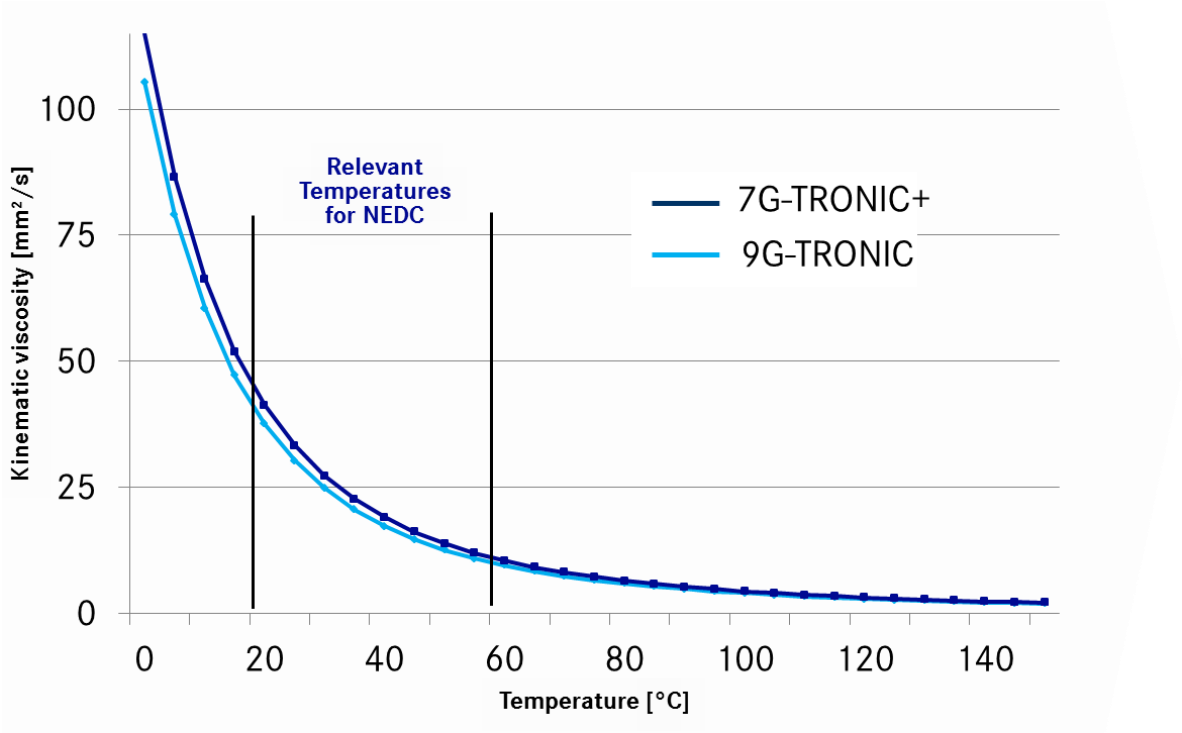


Figure 4: Viscosity of the new full synthetic automatic transmission fluid

THE TORQUE CONVERTER

As starting element the 9G-TRONIC has the fuel economy torque converter, which is further improved from the 7G-TRONIC PLUS [5]. It is adapted to the constraints of the interface to the 9G-TRONIC, see figure 5. All converters contain a torque converter lockup clutch and a double torsional damper with pendulum technology for high comfort at low engine speeds. Due to the damper technology with pendulum secondary tasks as slip or absorber sinks can be reduced in the vehicle. With a ratio of 9.15 the deep engine speeds are possible up to high velocities of 120 km/h.

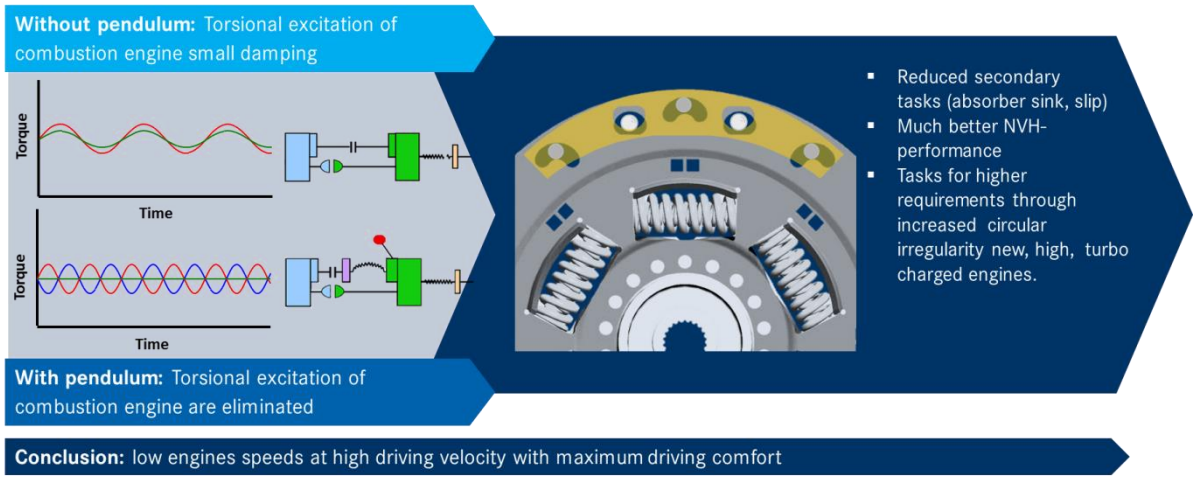


Figure 5: The Torque converter technology with pendulum: Pre - condition for usage of 9 speeds and high spread

The torque converter lockup clutch is equipped with a return spring, whereby an advanced bypass is also reproducibly possible with deep rotational speeds and spinning.

THE ELECTROHYDRAULIC SYSTEM

The electrohydraulic control unit is completely new with an implemented direct control technology. Considerable advantage of the direct control is reduced leakage and reduced number of parts in the hydraulic system. Therefore a high functional integration in a small space was possible. In particular to it, all components, which are involved in the hydraulics, lubrication and control procedures are integrated into the electrohydraulic control unit see figure 6.

Specific characters of the electrohydraulic control unit are:

- Highly functional Integration
- 9 uniform magnets, coupled direct to the control plate
- Integrated electric auxiliary oil pump, applied by demand
- All scolding and solenoid valves are placed on the electrohydraulic control unit
- The complete sensors (three speed sensors, pressure sensor, position sensor) are a part of the control unit
- The controller of the transmission is combined to the electrohydraulic control unit

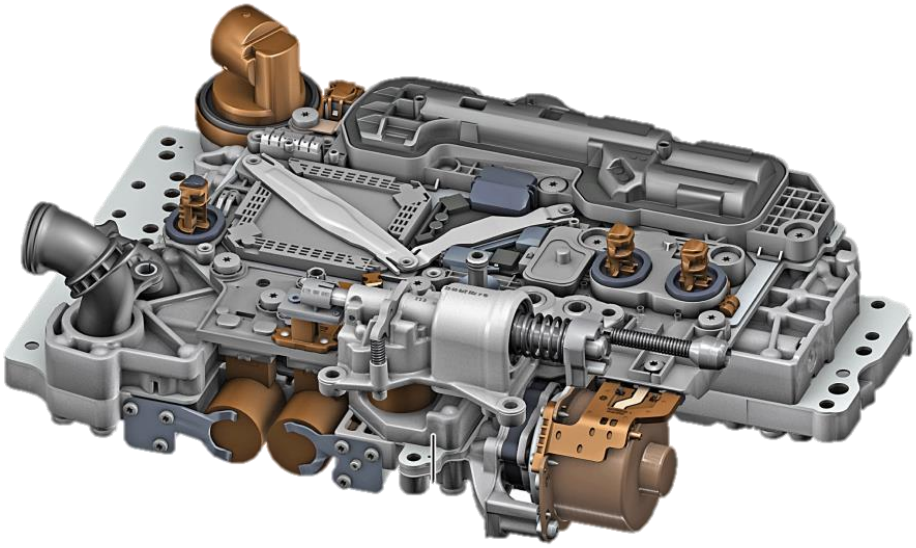


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Figure 6: Electrohydraulic control unit concept with hydraulic valve body assembly, auxiliary electric pump and shift by wire system

A pressure sensor for reduction and adjustment of the main pressure, three rotational speed sensors for control of direct and indirect gear changes over several speeds and a position sensor for the park by wire system.

The controller plate of the 9G-TRONIC is completely integrated in the electrohydraulic control unit in the transmission and contains a 32-Bit micro controller of the newest generation with 200 MHz and 3MB flash memory in a molded case, see figure 7. The controller is placed on a plate which is hold in an aluminum case. Further all sensors for

speeds, temperature, pressure and position are mounted on the controller plate. The actuators, nine single magnets, are contacted directly to the transmission controller. The vehicle connection is realized with a 4 pin connector. The challenges with the functions were also to integrate the newest specifications as the ISO 26262. In addition the activation and interference suppression of the electric auxiliary oil pump were integrated into the controller, see figure 7.

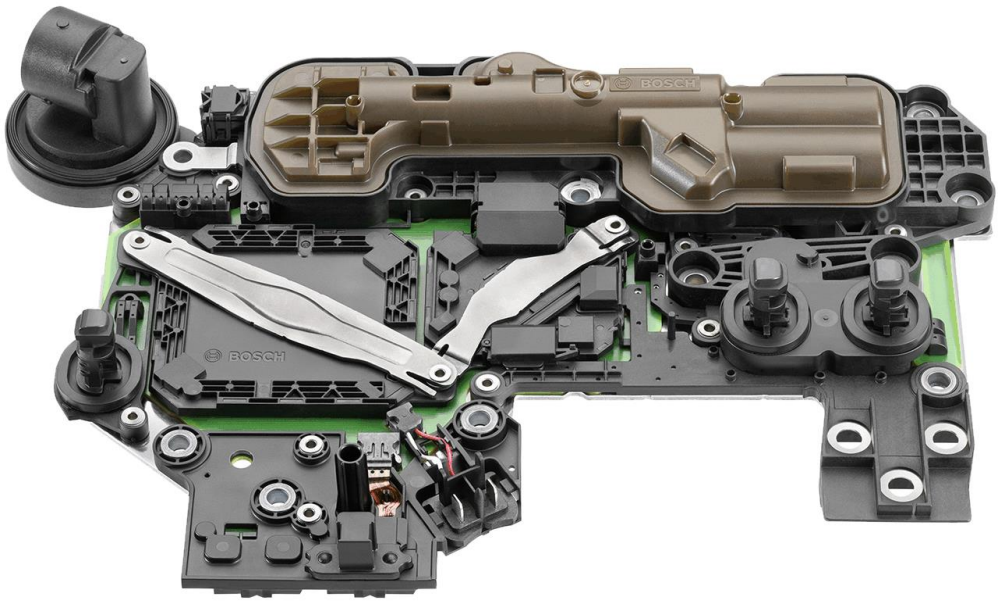

Figure 7: Fully integrated control unit with ITCU, actuation for auxiliary pump and sensors

THE PUMP SYSTEM

For the pressure supply the 9G-TRONIC transmission has two pumps, the primary small off-axis main pump and an integrated electric auxiliary oil pump for support at specific points of demand, see figure 8.

The oil pump (primary pump) maintains the minimum oil feed of the electrohydraulic automatic transmission with the rotational speed of the combustion engine. The propulsion system of the oil pump is connected by a chain drive to the input shaft. The oil pump is mounted in the torque converter case behind the torque converter. It is a two stage vane type pump. The electric pump is activated during start stop mode and takes over the pressure supply of the control elements and actuators. The auxiliary electric pump supports additionally the main pump at low engine speeds of the combustion engine. The systems of the auxiliary pump is a G-rotor pump. The flow rate for lubrication on demand by the electric transmission oil pump is requested within the low speed range of the engine during shifts. The electric pump has the following tasks:

- Support of the main pressure supply
- Support for cooling and lubrication
- Stop start capability
- Fail-safe function of the park lock

Additionally to the oil pump (primary pump) the auxiliary electric pump promotes large quantity of oil for the support of the main pressure. With the auxiliary electric pump adding to pressure and lubrication on demand the main pump could be designed much smaller thereby and a third of the fuel economy potential of the transmission is realized.

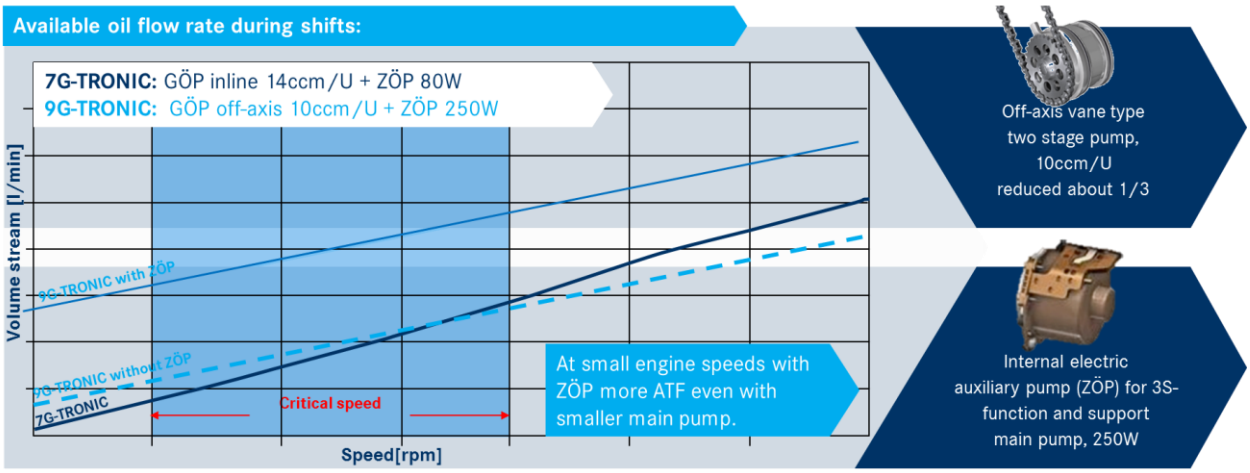

Figure 8: Pump concept with flow rate of the 9G-TRONIC

SOFTWARE AND DRIVABILITY

Essential objective of the functionality of the new transmission are quick and comfortable shifts. Basics for quick and comfortable shifts are specifically designed transmission hardware. In the 9G-TRONIC therefore small volumes for the pistons of the shift elements are implemented. The oil flow in the transmission to the elements was optimized by a fast reacting electrohydraulic control. For the first time a direct control unit is applied.

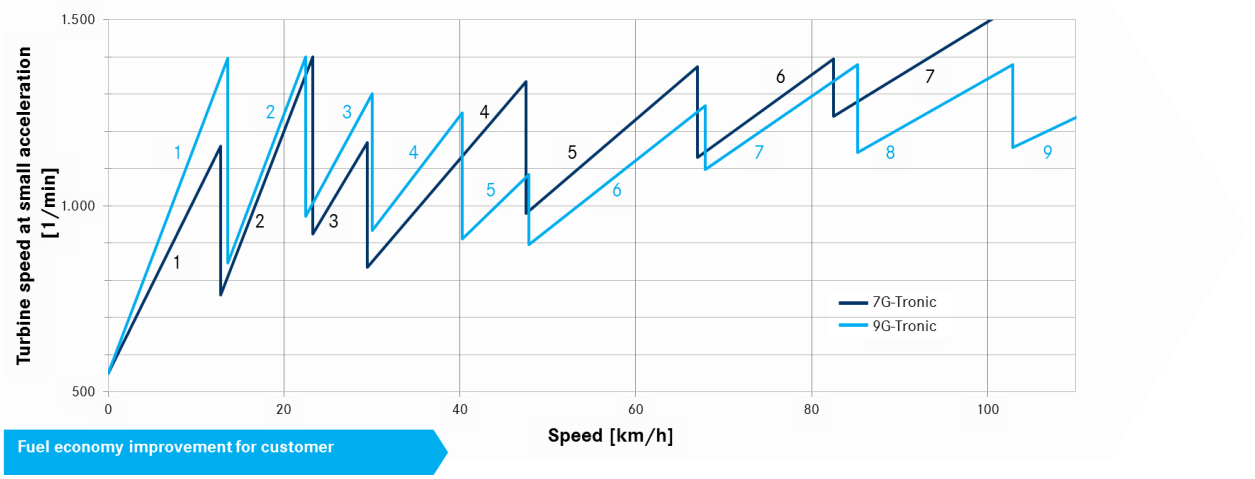

Figure 9: Moderate acceleration with E350 BLUETEC with 9G-TRONIC and 7G-TRONIC.

In figure 9 a moderate acceleration of the E350 BLUETEC with 9G-TRONIC in comparison to the 7G-TRONIC is shown. The main advantage can be seen in the velocity range from 40 km/h to 100 km/h, where the low engine speed is still possible, due to high number of gears and the high ratio spread. Especially under customer driving conditions significant fuel economy improvements are possible.

FUEL ECONOMY

The fuel economy advantage of the 9G-TRONIC is in average 6.5 % in the NEDC. In the E350 BLUETEC the improvement in the NEDC counts to 6g CO2/km for the sedan and 8g CO2/km for the station wagon. The 6.5% fuel economy improvement can be separated into the following measures:

- 2 % due to the number of gears, ratio spread and shift point
- 1% with optimized shift elements
- 0.8% with lubrication on demand
- 2.7 % with the actuating system with small main pump, electric auxiliary pump on demand and direct control concept.

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