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February 2016

quattro with ultra technology – the permanently available all-wheel drive system

The equipment and data specified in this document refer to the model range offered in Germany. Subject to change without notice; errors and omissions excepted.

* The fuel consumption and emission values of all models available on the German market and named in this text are listed on the last page of this basic information.

quattro with ultra technology – all-wheel drive for the future

Audi opens a new chapter in the history of quattro: The new quattro with ultra technology combines driving dynamics and safety with high efficiency, making the all-wheel drive system fit for the future. The system is designed for numerous Audi models with longitudinally mounted front engines. An initial variant will debut in the new Audi A4 allroad quattro* in mid-2016.

With quattro permanent all-wheel drive, Audi has extended its lead over a period of more than three decades. Now it's time for the next big step: quattro in combination with ultra technology.

The development goal of quattro with ultra technology is an all-wheel drive system optimized for efficiency with no discernible differences to permanent systems with respect to traction and driving dynamics. The system should set benchmarks in its class for fuel consumption and CO_2 emissions, particularly under everyday conditions. With correspondingly equipped test vehicles, Audi developers used on average 0.3 liters/100 kilometers less fuel than with conventional all-wheel drive. The tests were conducted on a route throughout the Ingolstadt area and in normal traffic.

At first glance, these requirements hardly appear to be reconcilable. But through the interaction of the newly developed all-wheel drive components and a sophisticated operating strategy, the Audi developers were able to achieve this goal. The results: The all-wheel drive system's intelligent control works predictively, always looking ahead by means of a comprehensive array of sensors and the continuous analysis of the driving dynamics, road condition and driver behavior data collected. Consequently, the quattro all-wheel drive system is always ready when needed. During standard operation at low loads without the risk of wheel slip, the new quattro taps into all the advantages of front-wheel drive.

All-wheel drive is always deactivated when it is not needed, but remains permanently available, significantly reducing the potential fuel consumption difference between front-wheel drive and permanent all-wheel drive.

The strategy

The all-wheel drive system is activated before the driver needs it. In fact, all activations and deactivations follow a highly differentiated strategy.

The quattro electronics are networked with a number of other control units. Every ten milliseconds, the system acquires and analyzes a wide variety of data, such as steering angle, lateral and longitudinal acceleration and engine torque to name just a few.

Activation of the all-wheel drive system follows a three-stage strategy: proactive, predictive, i.e. forward-looking, and reactive.

On the proactive level, the focus is on the data delivered by the networked systems in the car. The control unit uses these data to, for example, compute the point when the inside front tire will reach the limit of grip during fast cornering. The calculation is completed roughly 0.5 seconds prior. If the wheel approaches the limit of grip to within a defined threshold, the all-wheel drive system is activated.

With predictive activation, the quattro control unit orients primarily on the driver's style, the status of the ESC and the mode selected in drive select, and on the trailer detection system.

With reactive activation, which rarely occurs in practice, the system reacts to sudden changes in the coefficient of friction. These occur, for example, when the wheels go from dry asphalt to a sheet of ice.

quattro all-wheel drive is more frequently active in winter than in summer because the coefficients of friction are lower then. The need for all-wheel drive is generally higher at low and moderate speeds with acceleration phases than when driving fast at a constant speed. Use of quattro all-wheel drive is therefore lower on the highway, in particular.

However, the car can also be driven safely on a snow-covered road with just front-wheel drive if the road is straight and speed remains constant. On the other hand, if the car is being driven dynamically on a winding road, all-wheel drive remains active at all times, even on dry, grippy asphalt.

The optimal distribution of power between the front and rear axles is computed continuously when the system is active. The control strategy considers ESC data, ambient conditions, the driving situation and the wishes of the driver. The power can be optimally distributed between the two axles at all times as a function of these factors.

There is generally sufficient time available for deactivation of the all-wheel drive system. In contrast, operational requirements determine the speed at which the clutches close to activate the system. In certain driving situations, this has to occur in just fractions of a second.

By networking quattro drive with Audi drive select, the driver can adjust the all-wheel-drive properties to suit his or her individual requirements. The auto mode in drive select provides the best possible traction and balanced driving dynamics. In dynamic mode, power is sent to the rear axle sooner and to a larger degree, improving the driving dynamics particularly at low coefficients of friction. Wheel-selective torque control – a software function of the ESC – smooths out the handling as needed by minimally braking the inside wheels.

Two clutches – the technology

The enhanced efficiency is made possible by two clutches in the drivetrain. When the system changes to front-wheel drive, the front clutch – a multi-plate clutch at the transmission takeoff – disconnects the propshaft. An integrated decoupler in the rear-axle differential also opens, shutting down the primary cause of drag losses in the rear section of the drivetrain. At the same time, the quattro drivetrain is nearly four kilograms *(8.8 lb)* lighter than the previous system despite the new technical components. That, too, saves fuel and benefits handling.

The multi-plate clutch

The all-wheel drive clutch is located at the rear end of the transmission. An electric motor integrated into the quattro control unit powers a spindle drive that actuates the multi-plate clutch. Depending on the model, the clutch comprises a package of five or seven pairs of plates that rotate in an oil bath. The friction rings are arranged behind one another in pairs. The first is permanently meshed with the clutch basket, which rotates with the input shaft. The next ring is meshed with the output shaft to the rear axle differential. When the plates are pressed together, the all-wheel drive system is activated. The contact pressure of the plates is used to distribute the drive torque variably and dynamically between the axles.

The integrated decoupler

The decoupler integrated into the rear-axle differential works according to a different principle. The shaft to the right rear wheel is divided into two parts beyond the point where it exits the differential. The left sub-shaft with the axle bevel gear in the differential and the right sub-shaft are each connected to a claw element. Both can be positively coupled.

The claw clutch is opened electromechanically and closed via pretensioned springs. If both the all-wheel drive clutch and the decoupler are open, the large components in the rear-axle differential relevant for friction and drag losses as well as the propshaft stop. Only the axle bevel gear and the compensating gears in the differential, which compensate for differences in the speed of rotation of the vehicle’s drive wheels during cornering, continue to rotate under zero load. However, they cause only very slight drag losses.

To activate the all-wheel drive system, the stationary components are accelerated in fractions of a second via the controlled multi-plate clutch. The claw clutch closes as soon as the propshaft and thus the differential housing are rotating at the necessary speed. An electromagnetically actuated metal pin then disengages the locking lever. The springs relax and the claw clutch closes.

The use of pretensioned springs when closing the claw clutch allows for very short shift times.

quattro with ultra technology – the transmission
The key to achieving a significant efficiency gain in single-axle operation is a directly driven axle with optimal efficiency. The new generation of manual and S tronic transmissions ideally fulfill all the prerequisites, as efficiency was also a primary focus during their development.

The first model with the next-generation quattro will be the new A4 allroad quattro* with S tronic in the second quarter of 2016. The technology will then gradually roll out to additional models with longitudinally mounted front engines and manual or S tronic transmissions.

Audi quattro – the success story

Roughly seven million all-wheel drive cars built in 36 years – quattro is an unparalleled success story. quattro technology debuted in 1980 in the legendary, original Ur-quattro. In the premium segment, Audi offers the widest range of cars by far with all-wheel drive: The quattro all-wheel drive system is available in every model series, from the compact S1 upwards. It is one of the pillars of the brand.

quattro is a technology icon. The term stands for driving safety and sportiness, technical competence and a dynamic approach to life. The success of the quattro models on the road and in motorsport have contributed, as did a legendary series of TV commercials, such as the clip with the ski jump in Kaipola, Finland, which the Audi 100 CS quattro climbed in 1986 on its own power.

“quattro” means “Audi,” and “Audi” often means “quattro.” In 2015, more than 40 percent of all Audi customers chose a quattro model. This percentage is a testament to the success of the technology. The Audi Q5 topped the list with more than 260,000 units. The quattro models sold particularly well in the United States, Canada, Russia and in the markets of the Middle East. In Germany, new car registrations included over 120,000 new Audi models with all-wheel drive, placing Audi at the top of the field.

Audi quattro – the technology portfolio

Aside from its model range, Audi offers a very wide variety of car concepts – and quattro technology is correspondingly wide-ranging.

Modular longitudinal platform: the self-locking center differential
In Audi models with a longitudinally mounted front engine, the heart of the quattro drivetrain is a self-locking center differential. It is configured as a purely mechanical planetary gear with zero lag. During normal driving operation, the self-locking center differential distributes the power asymmetrically, with 60 percent flowing to the rear axle and 40 percent to the front axle.

Oblique splines produce axial forces immediately when torque is transferred by the differential. These forces act on friction discs to produce a locking torque that diverts the torque to the wheels with the better traction.

In its latest form, the center differential can divert 70 percent of the torque to the front, or up to 85 percent to the rear. The high locking values enable a clearly defined distribution of torque and highly precise interaction with the control systems, such as the ESC and wheel-selective torque control.

Even more dynamic: the sport differential
For even greater dynamics and driving safety, top-of-the-line Audi models based on the modular longitudinal platform can also be equipped with the sport differential. The sport differential really allows the handling to shine. It actively distributes the drive torque between the rear wheels, literally pushing the car into the curve and eliminating any tendency toward understeer. The vehicle is stabilized in the case of oversteer. The result is agile and predictable road behavior at all times.

The sport differential is a conventional differential with two superposition units mounted on the left and right, each containing a multi-plate clutch and an internal gear. The drive torque can be variably distributed between the wheels of the rear axle with the help of the superposition units. The hydraulic controller actuates the multi-plate clutches. An electric motor drives the high-performance oil pump, which generates the required hydraulic pressure. All functions are controlled and monitored by a separate control unit. The active distribution of torque provides for better driving dynamics, traction and stability.

Modular transverse platform: Electrohydraulic multi-plate clutch
For the compact models with transverse-mounted engine, Audi uses a quattro drivetrain featuring an electronically controlled multi-plate clutch with hydraulic actuator. It is mounted on the rear axle for better weight distribution.

Inside the clutch is a package of metal friction rings mounted in pairs one behind the other. One ring of each pair is permanently meshed with the clutch basket, which rotates with the propshaft. The other ring of each pair is connected to the shaft leading to the rear differential. The electronically controlled multi-plate clutch guarantees the best possible traction, driving dynamics and driving safety while providing for dynamic handling with actively controlled torque distribution.

In the Audi TT, Audi S1, RS Q3* and Audi RS 3 Sportback*, there is a strong dynamic bias to the management of the multi-plate clutch. On a road surface with a low coefficient of friction, controlled drifts are possible when in sport mode or with the ESC deactivated. In contrast, when driven sedately, the clutch of the TT can be automatically opened temporarily to save fuel. The quattro drive is immediately reactivated when the driving situation changes. In all three model series, the quattro all-wheel drive system works closely together with wheel-selective torque control, a software function of the ESC stabilization control that uses light, defined braking to precisely distribute the drive torque to further improve handling at the limit.

Audi R8: actively controlled front differential

In the Audi R8, the seven-speed S tronic with integrated rear-axle differential and locking center differential is mounted in the back behind the engine and sends the power to the front axle via a propshaft. The electrohydraulic multi-plate clutch integrated in the front differential transmits the calculated torque to the front wheels within just a few milliseconds. The combination of the high-performance transmission mechanism and the all-wheel drive software tailored to a mid-engine sports car allows for driving dynamics featuring an unprecedented balance between agility and driving safety.

The future: e-tron quattro

Audi presented a future form of the quattro drive – the electrified quattro, aka the e-tron quattro – in the Audi e-tron quattro concept, a concept study that was the star of the IAA 2015. The sport SUV uses three powerful electric motors, one on the front axle and two on the rear axle. At low load, one motor is solely responsible for propulsion. When the driver floors the accelerator and all three electric motors are working together, however, 370 kW of output and more than 800 Nm *(590.0 lb-ft)* of torque are available.

The drivetrain management system orients on the position of the accelerator, the mode chosen in Audi drive select, the driving program – S or D – and the battery charge level. The focus is on not just powerful performance, but also maximum efficiency. At the start of a trip, the Audi e-tron quattro concept can compute a strategy for using the smallest possible amount of electricity. Underway it can recover energy by means of braking recuperation.

Power is distributed to the front and rear axle as a function of a multitude of parameters. During sporty driving, the concept with the two electric motors on the rear axle enables electric torque vectoring similar to the function of the sport differential. The Torque Control Manager actively distributes the power between the rear wheels as necessary. This torque control provides for maximum dynamics and stability. Thanks to the nearly instantaneous response of the electric motors, all control actions are lightning-quick.

Audi quattro – the history

The origins of quattro technology can be traced back to the winter of 1976-77, when a group of Audi engineers conducted test drives in the deep snow in Sweden. An Iltis traveled along for comparison purposes – despite its output of a mere 55 kW (75 hp), the leggy military all-terrain vehicle easily outdid the much more powerful Audi prototypes with their front-wheel drive systems.

Audi's solution, which made quattro technology possible in the first place, was the hollow shaft – a drilled-out, 263 millimeter *(10.4 in)* secondary shaft in the transmission through which power flowed in two directions. It drove the housing of the center differential from its rearmost end. The differential sent 50 percent of the power along the propshaft to the rear axle, which was equipped with a locking differential. The other half of the drive torque was transferred to the front axle's differential along an output shaft rotating inside the hollow secondary shaft.

The hollow shaft permitted all-wheel drive that was virtually tension-free, light, compact and efficient, and that operated without the need for a heavy transfer case or second propshaft. The quattro concept was no longer suitable just for slow all-terrain vehicles, but in particular for sporty automobiles and high-volume production.

1980: debut of the Ur-quattro
The revolutionary technology made a dazzling debut at the 1980 International Geneva Motor Show in the new Audi quattro, a coupe with a boxy shape and 147 kW (200 hp). Originally planned for only low-volume production, high demand led to the Ur-quattro being produced as a production model; repeatedly upgraded, it remained in the model lineup until 1991. In 1984, Audi added the exclusive Sport quattro with 225 kW (306 hp).

In 1986, Audi replaced the manual-locking center differential of the first generation with the Torsen differential (Torsen = torque sensing). The worm gear transmission was capable of variable distribution of drive torque. The next big step came in 2005 with the planetary drive that offered asymmetrical, dynamic distribution of the power.

In parallel, Audi further expanded its line of quattro models. The decision was made back in the early 1980s to offer the quattro drive system in every model line; the new models were important milestones on Audi's path to the premium segment in the market. The first TDI with permanent all-wheel drive appeared in 1995; four years later the technology moved into the compact segment.

Audi quattro – motorsport

Audi first began hatching plans to enter rally racing back in 1977. In early 1981, the brand got off to a rousing start in the World Rally Championship. Hannu Mikkola of Finland won the first six special trials in the snow at the Monte Carlo Rally. With a lead of nearly six minutes, victory ended up slipping though his fingers due to a minor accident. He recorded his first victory at the next race in Sweden.

The quattro then dominated the tracks in 1982. Audi set a new benchmark with seven victories and easily won the manufacturers' championship. The following year Mikkola took home the drivers' title. The 1984 season also started off with a bang – the newly recruited two-time world champion Walter Röhrl won the Monte Carlo Rally ahead of his team colleagues Stig Blomqvist (Sweden) and Hannu Mikkola. At the end of the season, Audi claimed both the manufacturers' title and the drivers' title with Blomqvist.

Over 500 hp: the Audi Sport quattro S1

The competition in the world championship got tougher; rivals took advantage of the liberal rules of what at that time was Group B to build entirely new cars, including some with mid-engine designs. Audi deployed the short-wheelbase Sport quattro during the 1984 season, which promised more agile handling. This was followed in 1985 by the Sport quattro S1 with more than 370 kW (500 hp).

In the middle ratio, the 1,090 kilogram *(2,403.0 lb)* Audi S1 shot from 0 to 100 km/h *(62.1 mph)* in 3.1 seconds. In the last race of the season, the British RAC Rally, Röhrl used a dual-clutch transmission that was actuated pneumatically – a precursor of today's S tronic.

1988: shift to circuit racing
In the following years, Audi shifted to racing touring cars. The brand competed in the American TransAm series with the Audi 200 in 1988, winning the manufacturers' and drivers' titles that first year. The year after, Audi shined in the IMSA GTO series, for which the rules were even looser.

Audi switched to the German Touring Car Championship (DTM) in 1990. Hans Stuck won the drivers' title with the big and powerful V8 quattro that first year, followed by Frank Biela in 1991. Before Audi withdrew from the series in 1992 following a technology conflict, the V8 quattro had won 18 of 36 races.

In 1996, the A4 quattro Supertouring, with its two-liter, four-cylinder engine, entered seven national championships on three continents – and won them all.

Two years later, the European rules largely banished all-wheel drive from touring car competition. The quattro balance sheet up to that point read as follows: four titles for Audi in the rally world championships, three victories at Pikes Peak, a championship win in the TransAm, two DTM titles, eleven national touring car championships and a touring car world cup.

2012: all-wheel drive in the Audi R18 e-tron quattro
It wasn't until 2012 that an Audi all-wheel drive race car – the Audi R18 e-tron quattro with hybrid drive – once again took to the track for a circuit race. A V6 TDI drove the rear wheels; a flywheel accumulator supplied recuperated energy to two electric motors on the front axle. The energy recovered during braking was used to drive the front wheels when exiting corners. The LMP1 prototype thus had quattro all-wheel drive in certain traction-relevant driving situations. Audi impressively documented the concept's potential with three overall wins in a row at the 24 Hours of Le Mans.

Fuel consumption of the models named above:

Audi RS Q3:
Combined fuel consumption in l/100 km: 8.4 *(28.0 US mpg)*;
Combined CO_2 emissions in g/km: 198 *(318.7 g/mi)*

Audi RS 3 Sportback:
Combined fuel consumption in l/100 km: 8.3 – 8.1** *(28.3 – 29.0 US mpg)*;
Combined CO_2 emissions in g/km: 194 – 189** *(312.2 – 304.2 g/mi)*

**Fuel consumption, CO_2 emission figures and efficiency classes given in ranges depend on the tires/wheels used.