LATEST TECHNOLOGICAL ADVANCEMENT (IC ENGINE & PARTS) BY AUDI: A REPORT

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Abstract: Recently, Audi has developed a new innovative 2 litre TFSI engine with a revised combustion process/cycle for its new A4 Car Model.The following report article gives a brief description of the recent technological advancement boosted by Audi in the field of Automobile Engineering. The Audi Engineers have successfully introduced the TFSI system in market with decreased fuel consumption & increased engine efficiency.

Keywords: TFSI Engine, Miller Cycle, Compression Ratio, Active Noise Cancellation, Audi Valve Lift System, B-Cycle Process.

1. INTRODUCTION

In the modern face of ever-tightening emissions regulations all over the world, the world's car manufacturers are bound to find some innovative ways to cut fuel consumption as much as possible without compromising the engine efficiency. In its quest for greater fuel efficiency in an engine, Audi has developed a 4-cylinder “TFSI engine” that can make a use of a new combustion method, resulting in highest efficiency in a class of 2 litre gasoline engine, as claimed by Audi.The combustion method used in Audi's new internal combustion engine is similar to the “Miller cycle”.

Fig 1. Audi introduces new combustion method in latest high efficiency engine

To achieve the new figures as per the changes made in engine, Audi has shortened the engine's intake time, by reducing the crank angle from 200 degrees to 140 degrees to achieve the goal, despite shortening the intake time, the engine could still achieve optimum cylinder charges.It is more due to higher boost pressure on the inlet side of engine. Under the engine's new combustion cycle, the intake valve also closes earlier (few seconds) than it usually would (based on valve timing process), which allows Audi to run an ever efficiency. Thus,boosting its compression ratio for the change. The new engine has the fuel consumption benefits of a downsizing engine in partial load operation condition, while at higher loads it has the advantages of a large-displacement engine operation, as claimed by Audi's Head of Engine Development. It results in optimal efficiency & performance characteristics enhances across the entire engine speed range.

The new engine, which was launched in at Vienna's Annual Motor Symposium being the coming-generation A4 Model, has also been designed effectively to spend very less time in the engine's warm-up phase. Also, Audi has deeply focused on reducing friction within engine components.On top of these efficiency-driven changes, the newly fabricated engine is also light in weight, weighing just 140 kg (308.6 lb).The new Audi A4 Model is powered by a 2.0 TFSI engine operating according to the highly efficient, Audi-optimized combustion principle. Overall, the engineers used 29 new components and materials, and adjusted the power unit so that it also runs optimally on gas. The pistons and valves have been specially modified and allow for an optimal compression ratio.

The turbo engine produces 125 kW (170 hp). Its maximum torque of 270 N-m (*199.1 lb-ft*) is available at 1,650 rpm. An electronic controller reduces the high pressure of the gas flowing from the tank from as much as 200 bars to a working pressure of 5 to 10 bar in the engine. This operation is performed dynamically and precisely in response to the power requested by the driver. The correct pressure is always present in the gas line and at the injector valves – low pressure for efficient driving in the lower speed range, and higher pressure for more power and torque.

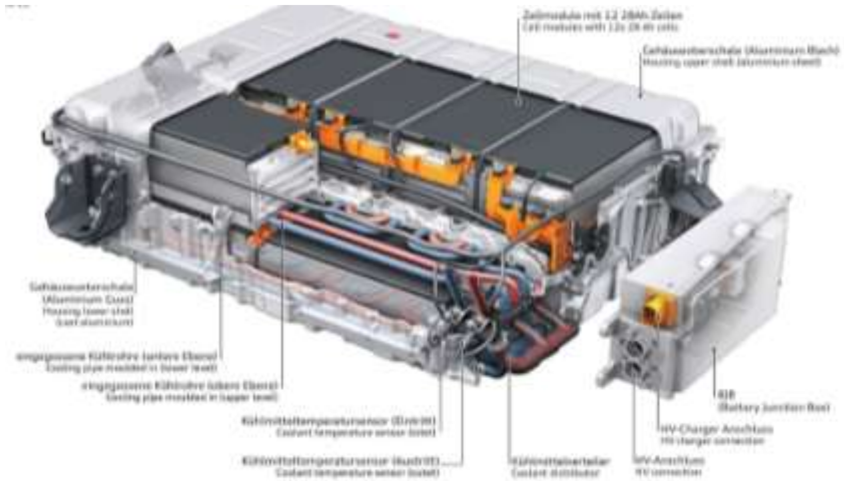
The engine was tested in extreme temperature conditions and had to withstand minus 35 degrees. Additional features were developed to protect the components required for CNG operation from cold temperatures. These prevent the gas valves from freezing up. To ensure smooth running in high summertime temperatures, the developers made modifications especially to components for the gasoline mode. The component may heat up to as much as 400 ˚C as a result of the CNG combustion process.

All in all, Audi engineers have achieved unparalleled efficiency in CNG engines through these measures. In the NEDC, the Audi A4 Avant g-tron consumes just 3.8 kilograms of CNG per 100 km, corresponding to CO_2 emissions of 102 grams per km. In gasoline mode, the figures are 5.5 litres per 100 km & 126 grams of CO_2 per km. The figures for the A5 Sportback g-tron model are identical in CNG mode. When running on gasoline, it consumes 5.6 litres per 100 km and emits 126 grams of CO_2 per km. Both models accelerate from 0 to 100 km/h in 8.4 seconds. The A4 Avant g-tron reaches a top speed of 221 km/h, the A5 Sportback g-tron 224 km/h.

The overall range of the new midsize models is 950 km – including up to 500 km on CNG alone. This fuel is stored in four tanks that are distributed space-efficiently through the rearward structure. There is also a gasoline tank with a capacity of 25 litres. Fuel costs compared with an equivalent gasoline engine are much lower, at around four euros per 100 km.

2. TURBOCHARGED FUEL STRATIFIED INJECTIONSYSTEM (TFSI)

It denotes a type of forced-aspiration process (Turbo) engine where the fuel is injected by means of a pressure straight into the combustion chamber in a way as to create a stratified charged particle in the fuel.The technology increases the torque and power of internal combustion engines, makes them as much as 15% more economical & reduces exhaust emissions to a greater extent.

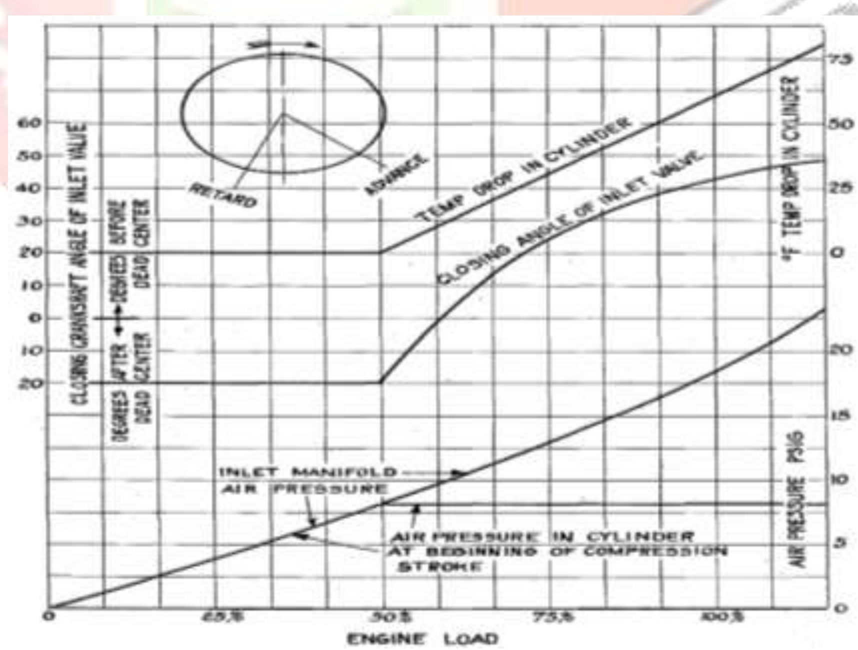


Advantages Of TFSI:

- Exact fuel distribution & appropriate fuel charge inside the combustion chamber of engine.
- During the injection process, the fuel gets evaporated, thus reducing the heat &cooling the cylinder chamber.
- Higher compression ratio, which translates into more power increasing the overall efficiency.
- Fuel combustion efficiency also goes up.
- Higher power is generated during pick-up of vehicle, decreasing additional overload on engine

3. MILLER CYCLE

As Audi is calling the event in different terminology as a "new combustion method," which it reality it isn't. They are essentially adapting Miller-cycle breathing technology for their ambitious engine. While refusing to stick the Miller-cycle tag onto its new engine, Audi's board member for technical development, admitted "at its core, its principle is comparable to the Miller cycle. They added to it that they are now taking crucial steps further with right-sizing,". "Right-sizing involves the optimal interplay of vehicle class, displacement, output, torque, and efficiency characteristics under everyday conditions." The system was the brainchild of American engineer Ralph Miller, who earned a patent for it on Christmas Eve, 1957. It works with both gas and diesel fuels and with two- and four-stroke cycles.



Typically, a Miller-cycle engine leaves the intake valve open on the compression phase longer than a normal engine. The turbocharger helps the Miller-cycle engine to avoid power losses, even as it slashes fuel consumption by increasing the fuel-air mix in the cylinder after the intake valve closes.Audi has heavily changed the traditional intake period, shortening the duration from around 200 crankshaft degrees down to just 140 degrees. It also closes the intake valves later than normal, well after the bottom dead centre. The expansion portion of the cycle is much longer than the compression phase to extract maximum work from every fuel-air mix.The engine will capitalize on existing technologies to push the Miller-cycle philosophy even further, making use of the combination of direct and indirect (in the intake manifold) fuel injection and variable valve timing.

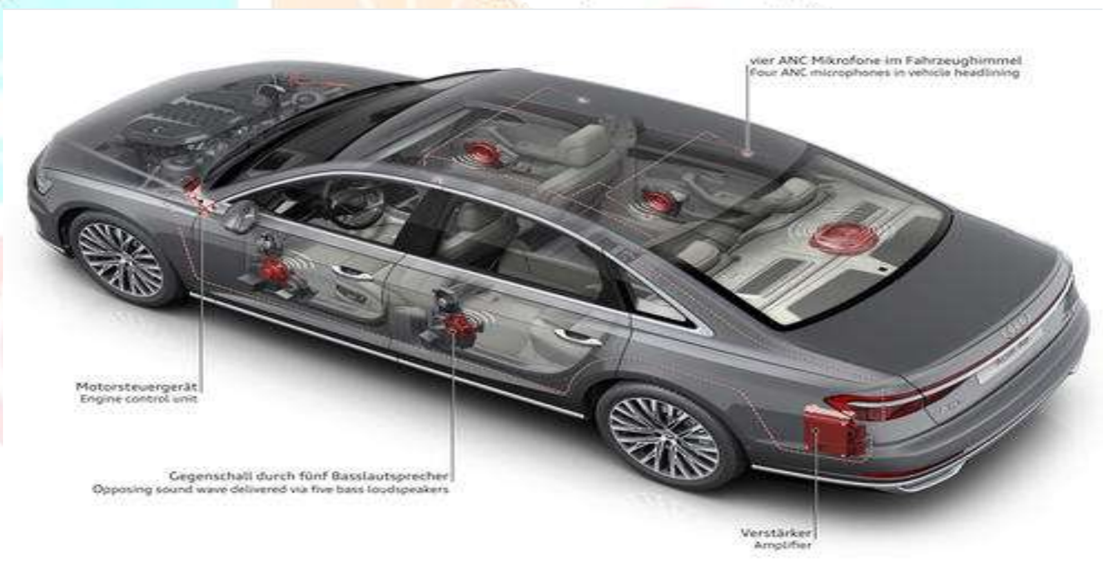
When the engine runs at part-throttle or low loads, Audi says it will deliver an extra fuel-injection burst from its indirect fuel-injection system before the air-fuel mixture even reaches the combustion chamber. It also uses its existing variable valve lift to give the engine a short intake time on part throttle and up to 170 degrees of intake timing on full throttle or in heavy load situations. The technology is first applied to a 2 litre, turbocharged, direct-injected gas unit making 188 horsepower and 236 lb-ft. of torque and is installed in the Audi A4 model.

4. SPECIFICATIONS OF AUDI A4 MODEL

4.1. Eight-Speed Tiptronic

The eight-speed tiptronic is a classic torque-converter automatic transmission whose great strength lies in its high level of shifting and drive off comfort. Gear shifts are gentle, spontaneous, fast and highly flexible. Audi uses it in many models with a longitudinally mounted engine. A rpm-adaptive torsion damper balances out undesired engine vibration and enables efficient driving at extra-low engine speeds.

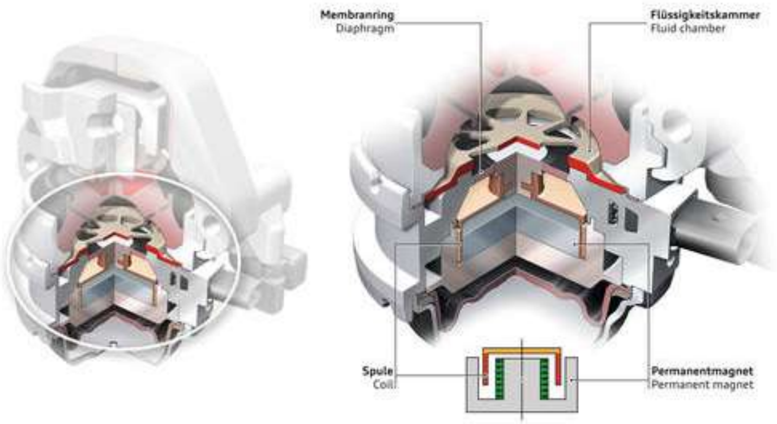
As soon as the driver releases the brake, the clutch closes, and the damping effect of the torque converter ensures a smooth drive-off.The dynamic shift program (DSP), which controls the eight-speed tiptronic, is housed in a small steel box within the gear-shift unit. It utilizes a fast processor. The eight-speed tiptronic is able to work together with the Audi start-stop system. It integrates a small, permanently filled hydraulic reservoir for this purpose. In the fourth generation of the A8 (D5), the eight-speed tiptronic has an electric oil pump. It handles lubrication of the transmission and enables engagement of the gear that is needed for an engine restart.



4.2.Active Noise Cancellation

Active Noise Cancellation (ANC) is used to eradicate undesirable noise with cancellation sound. The system applies the principle of destructive interference, which is also known as the cancellation sound principle. When two sound waves of the same frequency are superimposed, their amplitudes cancel one another if they have the same magnitude and exhibit a phase offset of 180 degrees.

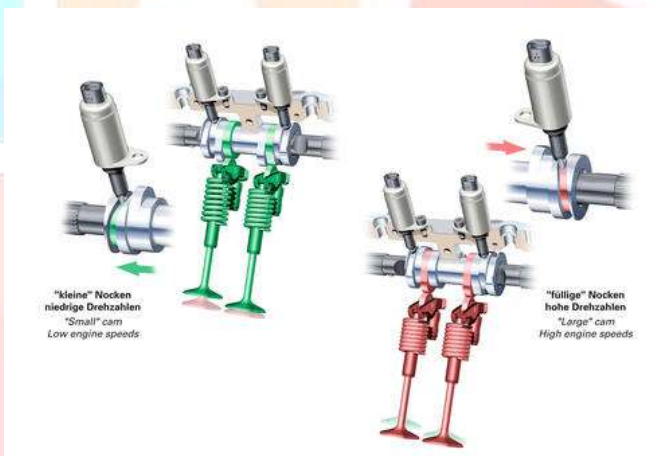
In the car interior, small microphones are used to record the background noise in multiple zones. From their signals, the ANC control unit computes a differentiated spatial sound field. It supplements this with information about engine speed. In all zones in which the system detects noise for which it has been pre-calibrated, it initiates a precisely modulated cancellation sound. The ANC system is always active – whether the sound system is turned on, turned off or set to loud, soft or mute. ANC works with all available factory-installed sound systems.



4.3. Active Engine Mounts

Audi uses active engine mounts in some of its model series. They reduce undesirable vibration excitation from the engine by generating compensating counter-oscillations. The hydraulically damped engine mounts utilize an electromagnetic oscillating coil actuator for this purpose. To ensure that it always supplies the proper control signal – even during quick changes in vehicle state – an algorithm constantly evaluates the data of accelerometers mounted in the engine compartment and adapts the control signal to accordingly.

Active engine mounts help to enhance ride comfort in models with cylinder deactivation and in diesel models. They are also used in plug-in hybrid vehicles to ensure a uniform driving experience while switching between operating modes.



4.4. Audi Valve Lift System (AVS)

The Audi Valve lift system (AVS) is a technology for variable valve control. Audi uses it for different purposes in different engines, but the working principle is the same for all engines: Sleeves are mounted onto the camshafts which have cam profiles with varying contours. Electromagnetically actuated pins push the sleeves axially several millimetres by engaging into spiral-shaped slots on their outer contours. Either the low cam or the high cam opens the valve, depending on the position of the sleeve.

In the new 3.0 TFSI, the 2.9 TFSI and the 2.0 TFSI with 140 kW (190 hp), the AVS acts on the intake valves. It adjusts their lift and timing (opening duration) over two levels according to engine load and speed, and thereby controls the amount of air that is inducted. In part-load operation, the lift and opening duration are relatively small. The throttle valve can remain wide open, and this largely eliminates throttle losses. At higher loads, the AVS switches to a higher lift and later valve closing. The combustion chamber charge increases in size, and the engine can aspirate air freely for more power and torque.In some four-cylinder gasoline engines and in the 2.5 TFSI with its five cylinders, the AVS varies the lift of the exhaust valves. This reduces flushing losses in the combustion chamber and ensures optimal flow of exhaust gas to the turbocharger, particularly in the low rpm range. The results are dynamic engine response and increased torque.

In the 1.4 TFSI, the 4.0 TFSI and the new W 12, the system serves to deactivate half of the cylinders at a moderate driving pace, which reduces fuel consumption. The deactivated cylinders largely run without losses, like compressed gas springs, while the active cylinders operate at the better efficiency levels found in higher load regions.The 4.0 TDI presents another variant of this technology. Here, the Audi valvelift system manages the two turbochargers, which are switched according to a strategy based on stages. The exhaust gases, which each cylinder discharges from its two exhaust valves, flow through separate channels within a dual-flow manifold system. Each channel supplies one of the two turbochargers. At low loads and engine speeds, the AVS keeps one of the two exhaust valves closed so that the full exhaust flow reaches what is referred to as the 'active' turbocharger. With increasing engine speed, the second exhaust valve opens, and this activates the second turbocharger as well. Other AVS units are mounted on the intake camshafts; they serve to regulate the amount of intake air charge in the combustion chambers as needed.

4.5. Audi Wireless Charging

The batteries of some Audi e-tron models can be charged inductively by Audi Wireless Charging (AWC). This new, convenient charging technology involves the use of a floor pad that induces an alternating current in the secondary coil mounted in the car under the front axle. Once the driver has positioned the car over the floor pad – with visual assistance on the MMI provided by the parking system – the charging station's charging coil automatically extends upward and starts the charging process at 3.6 kW.

The alternating magnetic field induces an alternating voltage in the secondary coil mounted in vehicle underbody across an air gap. The integrated electronics convert the alternating current to direct current and feed it into the high-voltage electrical system. The efficiency of the energy transfer from the electrical grid to the battery is more than 90 percent. As soon as the battery is fully charged, the charging process stops automatically, and the charging station's coil is automatically retracted. The driver can also interrupt the process at any time.

AWC technology is ideal for a home garage or office parking place. Its operation is not impaired by rain or a thin layer of snow. The technology is suitable for outdoor use, and it is protected against theft by screw bolts in the ground. There is no risk to people or animals, because the magnetic field is only generated when a car is positioned over the pad and the charging process is actively running. The safety concept is rounded out by detection of metal objects and mechanical pinch protection.

4.6. B-Cycle Process

The B-cycle combustion process is an efficiency technology for gasoline engines by Audi. It has been specifically designed for the part-load range, which is the predominant operating mode during normal driving. Essentially, the new method is comparable with what is known as the Miller cycle. However, Audi engineers have advanced it decisively – by adding increased compression, turbocharging and the Audi valvelift system (AVS). The results: During a moderate style of driving, drivers experience the fuel-efficiency advantages of a small displacement engine; while driving in a sporty style, on the other hand, they benefit from the dynamic performance of a large engine.

The B-cycle combustion process is currently being used in three TFSI engines: in a variant of the 2.0 TFSI, in the new 3.0 TFSI mono-turbo and in the new 2.9 TFSI with its bi-turbo charging. Here, Audi is demonstrating its great benefits in the high-performance area. The V6 produces 331 kW, but in the NEDC driving cycle it consumes less than nine litres of fuel per 100 km.

The core characteristic of the new combustion process is an unusually short opening time during induction in part-load. The intake valves of the V6 TFSI already close at a crank angle of 130 degrees – well before the pistons reach bottom dead centre (BDC). This and increased pressure in the induction manifold reduce throttle losses. The amount of inducted fresh air remains relatively small; accordingly, the compression phase begins later when the piston travels upward after the BDC point. This permits a high geometric compression ratio of 11.2:1 – the combustion takes place with a relatively small combustion chamber volume. Compared to the short compression phase, the expansion phase is lengthened significantly. The result is greater engine work output at the same fuel consumption, which significantly boosts efficiency.

In the classic Miller cycle, the reduced cylinder charge is disadvantageous to torque and power output. Audi has neutralized these effects by implementing turbocharging and the two-stage Audi valvelift system (AVS). At higher load and engine speed, the AVS of the V6 TFSI closes the intake valves later – the opening time is increased to 180 degrees crank angle in the 3.0 TFSI and to 200 degrees in the 2.9 TFSI that is used in the RS4/RS5. Simultaneously, valve lift increases from 6.0 to 10 millimetres. The cylinder charge also increases considerably – the engine revs up powerfully and delivers an impressive output.

4.7. Cylinder On Demand

The efficiency system cylinder on demand (COD), which builds upon the Audi valvelift system (AVS), involves cylinder deactivation. Audi implements it in some of its engines – the 1.4 TFSI, 4.0 TFSI, 5.2 FSI and the new 6.3 TFSI. At low to medium load and engine speed, the system deactivates half of the cylinders in the upper gears. In COD operation, the eight-cylinder engine runs as a V4. In the V10 and W12, one of the cylinder banks is deactivated.

The COD system shuts off fuel injection and ignition, and in the TFSI engines it also closes the valves. Electromagnetically extending pins slide the cam units – these are sleeves which have two different cam profiles – several millimeters onto the camshafts by engaging into the spiral contours on the outsides of the cam units. When the profiles known as ‘zero-lift’ profiles are rotating over the valves, they do not actuate the valves, and the valve springs keep them closed.The switching process takes just milliseconds, and the driver virtually does not even notice it. In the active cylinders one and four, the operating points shift to higher load, which boosts efficiency, while the deactivated cylinders follow – essentially with no losses – like compressed gas springs at low pressure. When the driver presses the accelerator pedal, the deactivated cylinders are reactivated. The COD system can reduce fuel consumption by several tenths of a liter per 100 kilometers in real-life use by the customer.

4.8. Electric powered compressor

The electric powered compressor (EPC) made its debut in the Audi SQ7, a large sport SUV, where it works together with the 4.0 TDI. It assists the V8 diesel’s two turbochargers with 7 kW of power when driving off and at very low revs – that is, whenever the exhaust gas stream supplies insufficient energy for spontaneous torque build-up.

The electric powered compressor is suppled from a 48-volt electrical subsystem that is coupled to the 12-volt electrical system. It is located in a bypass behind the intercooler and is activated via a flap. Instead of the turbine rotor, it integrates a compact electric motor that accelerates the compressor wheel to 70,000 revolutions per minute in less than 250 milliseconds.

The EPC enables spontaneous response of the SQ7 TDI and dynamic drive-off performance from a standstill. Here, the large SUV immediately gains a lead of several meters over its competitors. Sporty drivers will appreciate the overtaking power and immediate power delivery when exiting a curve. In a relaxed style of driving, EPC technology avoids unnecessary downshifts and thereby keeps rev levels and fuel consumption low.

4.9.Quattro Drive System With Ultra-Technology

It combines driving dynamics and safety with high efficiency. This is all attributable to combining the newly developed all-wheel drive components with a sophisticated operating strategy and a torque split that is perfectly matched to the car. This optimized all-wheel drive system engages only when required.

The ultra-technology reduces fuel consumption significantly. The quattro with ultra-technology reduces the added consumption associated with all-wheel drive by around 60%.The control system for the quattro powertrain is comprehensively networked. It acquires and evaluates data – in ten millisecond cycles – such as the steering angle, transverse and longitudinal acceleration and engine torque.The concept with two clutches in the powertrain gives quattro with ultra-technology. Despite the additional components, the quattro with ultra-technology is nearly four kilograms lighter than the previous system. The quattro with ultra-technology has been designed for numerous Audi models with a longitudinally mounted front engine.

5. RIGHTSIZING

Rightsizing is a continuation of the conventional downsizing. It enables additional gains in fuel economy in the near full-load region by modified combustion processes and selection of displacement. Innovative technologies are used to achieve this such as the Audi valvelift system (AVS), integration of the exhaust manifold into the cylinder head and a turbocharger with an electric wastegate actuator. They make it possible to design the engines to attain an optimal combination of displacement, power, torque and fuel economy for the required use conditions. The cylinder on demand (COD) system is another example of this. It shuts down four or two cylinders in the part-load region. This solution is a variant of the rightsizing strategy.

6. ENGINE

Following engines are available from launch, 3petrol's and 4 diesels. All are available in both the A4 Saloon and A4 Avant. The figures below are for the saloon only.

engine type	max. power	max. torque	0–100 km/h (62 mph)	top speed	CO_2 emissions	fuel consumption (combined)
petrol engines						
1.4 TFSI	150 PS (110 kW; 148 bhp)	250 N·m (184 lb·ft) @ 1500-3500 rpm	8.7 sec	210 km/h (130 mph)	131 g/km	5.5 L/100 km (51 mpg-imp; 43 mpg-US)
2.0 TFSI ultra	190 PS (140 kW; 187 bhp)	320 N·m (236 lb·ft) @ 1450-4200 rpm	7.2 sec	210 km/h (130 mph)	124 g/km	5.5 L/100 km (51 mpg-imp; 43 mpg-US)
2.0 TFSI	252 PS (185 kW; 249 bhp)	370 N·m (273 lb·ft) @ 1600-4500 rpm	5.8 sec	250 km/h (155 mph)	137 g/km	5.9 L/100 km (48 mpg-imp; 40 mpg-US)
3.0 V6 TFSI (S4)	354 PS (260 kW; 349 bhp)	500 N·m (369 lb·ft) @ 1370-4500 rpm	4.4 sec	250 km/h (155 mph)	170 g/km	7.5 L/100 km (38 mpg-imp; 31 mpg-US)

diesel engines						
2.0 TDI	122 PS (90 kW; 120 bhp)	270 N·m (199 lb·ft) @ 1500-3000 rpm	10.5 sec	205 km/h (127 mph)	110 g/km	4.2 L/100 km (67 mpg-imp; 56 mpg-US)
2.0 TDI	136 PS (100 kW; 134 bhp)	320 N·m (236 lb·ft) @ 1500-3000 rpm	9.2 sec	210 km/h (130 mph)	111 g/km 98 g/km	4.2 L/100 km (67 mpg-imp; 56 mpg-US) 3.8 L/100 km (74 mpg-imp; 62 mpg-US)
2.0 TDI 2.0 TDI ultra	150 PS (110 kW; 148 bhp)	320 N·m (236 lb·ft) @ 1500-3250 rpm	8.9 sec	221 km/h (137 mph) 210 km/h (130 mph)	111 g/km 99 g/km	4.2 L/100 km (67 mpg-imp; 56 mpg-US) 3.8 L/100 km (74 mpg-imp; 62 mpg-US)
2.0 TDI 2.0 TDI ultra	190 PS (140 kW; 187 bhp)	400 N·m (295 lb·ft) @ 1750-3000 rpm	7.7 sec	240 km/h (149 mph) 210 km/h (130 mph)	118 g/km 102 g/km	4.5 L/100 km (63 mpg-imp; 52 mpg-US) 3.9 L/100 km (72 mpg-imp; 60 mpg-US)
3.0 TDI V6	218 PS (160 kW; 215 bhp)	400 N·m (295 lb·ft) @ 1250-3750 rpm	6.6 sec	250 km/h (155 mph)	117 g/km	4.5 L/100 km (63 mpg-imp; 52 mpg-US)
3.0 TDI V6 quattro	272 PS (200 kW; 268 bhp)	600 N·m (443 lb·ft) @ 1500-3000 rpm	5.3 sec	250 km/h (155 mph)	137 g/km	5.2 L/100 km (54 mpg-imp; 45 mpg-US)

7. THE CONCLUSION: LATEST ADVANCES IN INTERNAL COMBUSTION ENGINES

- Automakers continue to look to the internal combustion engine and its decades of reliable and resilient service when it comes to offering improved fuel economy and longer engine life.
- The most recent evolution is of aluminium-bodied, the 700-pound lightweighting that comes with switching to aluminium, to meet the fuel-efficiency needs.
- At General Motors, engineers are integrating vehicle and powertrain strategies together to optimize and minimize unnecessary parts in IC engine.
- Improved vehicle efficiency includes added transmission gears (e.g., 6-speed versus 4-speed) lowering engine operation speed, enabling lower numerical axle ratios, & in many cases, increasing performance and capability," also variable cam phasing, direct fuel injection, reducing engine accessory loading, electric power steering, improved vehicle aerodynamics, increased cooling airflow sealing, and reduced tire rolling resistance to the list.
- Using start/stop technology to stop the engine at idle and seamlessly restart it when the brake is released, and advanced battery charging that helps to charge the battery from regenerated vehicle kinetic energy
- Optimization of existing combustion, thermodynamic, and gasoline exchange technologies, as well as improving mechanical processes, will increase the overall efficiency of the ICE.
- From a combustion perspective, technologies are added that allows to operate as close as to the stoichiometric air/fuel ratio as possible without the need for fuel enrichment to manage exhaust temperatures.
- The variable displacement oil pumps also enable the oil output of the pump to be tailored to the demand of the engine rather than pressurizing and then recirculating excess fluid.

8. DESIGNING WITH GREEN IN MIND

While brake power regeneration is something most drivers relate to certain types of hybrid vehicles, the use of brake energy regeneration has been added to both gasoline- and diesel-powered cars. The vehicle's battery is charged when the vehicle is coasting or decelerating. The state of charge of the battery is constantly monitored and the alternator is disconnected at any time when the battery has sufficient charge and the vehicle is accelerating,

No single technology is the best solution for all users. As much as an urban user will benefit from regenerative braking and electric only driving, an advanced gasoline or diesel ICE is the best option for suburban and extra urban use, application of vehicle, fuel costs or, energy costs need to be analysed carefully. The g-tron models are especially eco-friendly when running on Audi e-gas. Compared to a gasoline-powered car in the same performance class, their CO_2 emissions are 80% lower.

Other European automakers are also utilizing a "green-ash" option when updating their take on the ICE. There is no single solution for the drivetrain of the future, but that it will include a mix of different technologies, including alternative fuels such as ethanol blends.

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