The innovations of the 911

Class benchmark in terms of performance and efficiency for five decades: The 911.

Time and again, the Porsche engineers from Zuffenhausen and Weissach reinvented the 911, demonstrating beyond doubt the innovative power of the Porsche brand. Although the 911 always led the way in terms of sportiness too, driving performance was never the developers' sole focus. The 911 has always been characterised by intelligent ideas and technologies that combine performance, everyday convenience, safety and lasting quality.

1963: Three-part safety steering safety system

For its launch in 1963, the Porsche 911 was fitted with rack-and-pinion steering, which had already been praised for its precise and very direct mode of operation in previous test reports. This steering system was also part of the vehicle's safety concept. The linkage had a three-part design and the steering gear was positioned in the centre of the vehicle. This meant that the steering wheel did not move directly towards the driver in the event of frontal impact but, due to the steering rod angle, moved away from the driver via the impact tubes and the release elements. Porsche continued to improve the safety steering system. Subsequent generations also featured a mesh tube as the crumple element, the so-called muffler skirt. And from 1991, Porsche was the first car manufacturer to equip all its models with driver and front passenger airbags as standard.

1965: Targa roll-over bar

“The first standard safety cabriolet in the world” – this was the headline when Porsche presented the first 911 Targa at the IAA in September 1965. The innovation in the new sports car model was the fixed Targa bar, derived from the roll-over bar which had proven itself in motor racing events and guaranteed a high level of protection for the occupants. With its removable folding roof and the plastic rear window that could be folded down, the 911 Targa was also extremely flexible and offered its occupants no fewer than four different options for open-top or closed-top driving. And the hood concept, patented in August 1965, also had other advantages. It solved the problem of the fabric hood bulging unattractively at speed on motorways just as reliably as it did the issue of body distortion,
which was common with convertibles at that time. However, the main concept behind the 911 Targa was clearly its high standard of passive safety, which was appreciated by many customers. As early as the beginning of the 1970s, the Targa had an approximately 40 per cent share of the 911 series.

---

1966: Internally ventilated disc brakes

Effective cooling of the brakes is important in a high-performance vehicle — only then can they stably and repeatedly brake the car at high speeds. For this reason, Porsche introduced internally ventilated discs to the 911 S as early as 1966. These discs are double-walled so that air can circulate and frictional heat is reduced. Furthermore, the perforations also have the advantage that water spray is conducted away from the discs very quickly. To improve cooling even more, the disc brake systems on later 911 types also have ram air ducts that guide fresh air through channels onto the brake discs from the front — from openings in the spoiler. No other manufacturer invests so much expertise into the brake systems on their series production cars as Porsche. This is because no other manufacturer has as much experience from motor racing as Porsche. The reason being that Porsche has always developed the brake systems for its racing cars itself. The rewards for all this effort are not only brake systems that are extremely stable and therefore play their part in high-precision driving, the Porsche series production vehicles also always boast the shortest braking distances in their class — a significant safety benefit on public roads.

---

1972: Front and rear spoilers

The Porsche engineers worked unceasingly to make the entire 911 package even better. This included improved aerodynamics — which was taken into account in 1971 with the first front spoiler, based on knowledge taken directly from the field of motor racing. It was used on the 911 S and later on the 911 E. The spoiler guided the air away to the side, thus reducing the lift on the front section. It improved directional stability and made the car easier to handle. The 911 T was also fitted with the front spoiler one year later. The 911 Carrera RS 2.7 introduced the rear spoiler — it featured the distinctive “ducktail” and was one of the reasons why this type became a cult car. The next rear spoiler that could genuinely be called “historic” was that on the 911 Turbo. Its large, flat design adorned the vehicle and, in addition to its reliable function, it was also a statement about the power and the speed of the Turbo.

To briefly explain the technical principle: spoilers at the front and rear enhance the vehicle’s aerodynamics and improve directional stability, braking and steering characteristics, cornering behaviour and the car’s response to cross winds, especially at high speeds. They guide the air around the outside of the vehicle (front spoiler) and prevent too much air underneath the car which would result in unnecessary lift and significant turbulence on the underside of the vehicle, especially if it is not lined and therefore has clefts. The role of the rear spoiler is to discharge the air flowing around the vehicle at the right place — the spoiler lip — with as little turbulence as possible. The rear spoiler being designed as a wing in the form of an upside-down aeroplane wing makes it possible to increase the contact pressure on the rear wheels and therefore generate downforce. The vehicle’s even air flow and the controlled negative lift increase the top speed and reduce fuel consumption.
1973: Turbocharging

The search on the part of automotive engineers for the "ideal charge" – optimum combustion of the air-fuel mixture – is almost as old as the combustion engine itself. The technicians' aim is to get as much air as possible into the cylinders so that when it is compressed and mixed with fuel, it can create a high operating pressure and therefore high output by means of combustion. The 911 Turbo, presented in 1973, was a forward-looking study as its 3-litre turbo engine boasted charge pressure control on the exhaust side which had previously been thoroughly tested in the motor racing sector. With the 911 Turbo, which was ready for series production in 1974, Porsche was the first car manufacturer to successfully adapt the turbocharger to the various driving states. Instead of the conventional intake-side control, the company developed exhaust-side charge pressure control. This prevented unwanted excess pressure during partial load or overrun by guiding excess exhaust gases via a bypass instead of through the exhaust gas turbine. When charge pressure was needed again during an acceleration phase, the bypass valve closed and the turbine could work to its full capacity in the exhaust stream.

1975: Hot-dip galvanised body

In 1975, Porsche responded to the issue of corrosion with emphatic success. The 911 was the first series production car to be given a body that was hot-dip galvanised on both sides – allowing Porsche to offer a six-year corrosion guarantee, which was extended to seven years for the 1981 model year and then later to as much as ten years. The treated body-in-white not only improved the service life but also vehicle safety, as the process preserved the overall rigidity and the crash safety characteristics of the body, despite vehicle ageing. It played a part in the reputation of the 911 as being an extremely durable vehicle – two thirds of all the 911 cars ever built are still licensed for road use today. Extensive tests were carried out before the body was launched for series production. This included trials with stainless steel as the body material – three shiny silver prototypes were made from this material, one of which can be seen today at the Deutsches Museum in Munich. However, the engineers decided not to use stainless steel but rather to galvanise the body-in-white, as this was easier to produce. Driving the prototypes through a bath of salty water to test resistance to corrosion is a legendary part of the test course in Weissach.

1977: Charge-air cooling

One of the secrets to the success of the 911 series is its constant and systematic enhancement. Each year, many small details on the 911 have been improved, making it closer and closer to Ferry Porsche's ideal image of the perfect sports car. This philosophy was also applied to the 911 Turbo. The main features of the 911 Turbo, reworked in 1977, were an increased displacement of 3.3 litres and a charge-air cooler positioned underneath the rear spoiler. Derived from the field of motor racing, it was a world first in a series production car. The charge-air cooler reduces the intake air temperature by up to 100 degrees Celsius, thus enabling the engine to achieve higher output and torque in all engine speed ranges – cooler gases are denser and therefore charge the engine more effectively. The result was a stable 300 hp at 5,500 rpm and a maximum torque of 412 Newton metres. Furthermore, charge-air cooling also reduces the thermal load on the engine. The exhaust gas temperatures fall, as do the emissions, and fuel consumption is reduced. Another advantage is the improvement in antiknock properties – excess temperatures causing the mixture to self-ignite is virtually ruled out.
1983: Digital engine electronics

Digital engine electronics (DEE) celebrated its debut in 1983 with the new naturally aspirated engine with 3.2-litre displacement. Its most important advantages were better fuel consumption, cleaner combustion and therefore maximum power output. The system worked with a shared control unit into which all the engine’s operating states were programmed. The correct injection quantity and the exact ignition point were assigned to each engine speed, each accelerator pedal position and temperature. The overrun fuel cut-off, i.e. no fuel was consumed when the engine was overrunning, and electronic idle speed control when auxiliary components were activated were useful additions provided by the digital engine electronics. The knock control system ensured “healthy” engine operating conditions. DEE is combined with various injection systems, depending on the engine.

1988: All-wheel drive

Porsche gained extensive experience of using all-wheel drive in a sports car with the Type 959, a technology demonstrator in every respect. Produced in low numbers as a special series, its influence could be seen in its successor, Porsche’s first series production all-wheel drive sports car, the 911 Carrera 4, which was introduced in 1988. For excellent driving dynamics, the 959 had an electronic, infinitely variable centre-differential lock, and torque was distributed to the two axles depending on the wheel-load distribution and the friction coefficients of the wheels on the road. For the same purpose, the engineers then set up the Carrera 4 with a basic torque distribution of 31 to 69 per cent (front axle to rear axle) via a planetary transfer gear. The car also featured a hydraulically operated centre and axle differential lock for virtually infinite adjustment of the distribution ratio. Their function was controlled by an electronics system integrated into the ABS control unit. The next Carrera 4, introduced in 1994, represented the next evolutionary stage of the Porsche all-wheel drive. For example, it was fitted with an optimally adapted, very light viscous multi-plate clutch as the axle clutch.

1989: Tiptronic

From 1989, Porsche offered an innovative gearbox in the 964 series 911 – the Tiptronic, the perfect synthesis of comfort and sportiness. The driving data was only marginally lower than that of the same vehicles with manual 5 or 6-speed gearboxes. The Tiptronic was an automatic gearbox with intelligent shift programmes and the option for individual manual intervention. In addition to the conventional selector lever positions, it also featured a second parallel gate in which simply tapping on the selector lever changed the gear immediately. “Tapping” the lever forwards shifted up a gear and “tapping” it backwards shifted down, as long as the engine speed limits were not exceeded. If you forgot to shift up, the gearbox automatically shifted to the next gear up when the permitted maximum engine speed was reached. The electronics system had five shift programmes. The programme with the most favourable shifting points was activated, depending on the temperament of the driver and the traffic situation. The engine speed was reduced temporarily by retarding the ignition point to facilitate smoother gear changes.
1993: LSA aluminium chassis

The new chassis designed in accordance with the “LSA” concept (Light, Stable, Agile) in the 993 series finally put an end to the capriciousness of the rear engine-powered 911. It mainly affected the rear axle, which was based on a multi-link suspension tested in motor races and which facilitated excellent driving dynamics. The axle kinematics are designed to ensure that the vehicle’s suspension compresses significantly less when accelerating and driving round bends. This stabilises the overall handling. Furthermore, lightweight spring struts with aluminium dampers improve agility. The principle of systematic lightweight design was also applied in order to keep the gross weight and the unsprung weight down. The result of all these measures was that the chassis made it possible to change lanes quickly and safely, even at high speeds. Rolling noises and vibrations were also reduced.

1995: Bi-turbocharging

The 993 series 911 Turbo, presented in 1995, was given a 3.6-litre engine fitted with two small turbochargers. The engine’s performance curve was not dissimilar to a high-displacement naturally aspirated engine. From as low as 2,000 rpm, the engine generated plenty of thrust which changed into impressive, rousing velocity as of 3,500 rpm, pressing the occupants into their seats. In addition to the output that increased to 300 kW (408 hp) and the rise in the maximum torque to 540 Newton metres, the Weissach engineers also aimed to reduce the engine’s acceleration turbo lag to a previously unknown minimum. They achieved this by using two small turbochargers instead of one large one, whereby the low moment of inertia of the smaller blades had the most significant effect. The two regulated turbines with integrated bypass flap generated a boost pressure of 0.8 bar. The impressive increase in output and engine speed was also due to optimisation of the charge cycle, the high level of efficiency of the two charge-air coolers and the knock control system that facilitated running the engine at optimum efficiency.

1995: OBD II emissions control system

Another technical highlight of the six-cylinder car was the new OBD (on-board diagnostics) II emissions monitoring system, which was used for the first time by a series production manufacturer. It facilitated early detection of faults or defects in the exhaust and fuel system. The extensive measures for reducing emissions were very effective on the 911 Turbo. To the great surprise of the experts, the turbo engine turned out to be the lowest emission series production engine in the world. The supercharged 993 was also the first biturbo with air mass control in automotive history. The OBD continually monitored the operation of the entire exhaust system with catalytic converters and oxygen sensors, the functioning of the tank ventilation system with activated charcoal filters, the air injection system and the fuel system. Misfiring was also recorded. At the time it was launched, OBD II was already mandatory in the USA, and other markets soon followed. OBD required a great deal of development work and an extremely complex engine management system.

2001: Ceramic brake disc

In 2000, Porsche presented the 911 Turbo model line 996. On request, it could be equipped with ceramic composite brake discs; these were standard on the 911 GT2. The new brake, known as the Porsche Ceramic Composite Brake (PCCB), was a significant technological advancement that set new standards, in particular in terms of decisive criteria, such as responsiveness, fading stability, weight and service life. Porsche was the first car manufacturer in the world to develop a ceramic composite brake disc with an involute cooling channel for efficient interior cooling.

The ceramic composite brake discs were perforated like metal brake discs but weighed around 50 per cent less. Firstly, this reduced the weight of the vehicle by 20 kilograms, which saves fuel; secondly, they also reduced the unsprung weight, which is another contributing factor in improving the responsiveness of the shock absorbers. Ceramic brake discs offer other benefits: their friction coefficient is always constant, and emergency braking with PCCB requires neither considerable pedal pressure nor any technical aids to assist in increasing the maximum brake force in fractions of a second. PCCB produces maximum deceleration immediately and without pressure being applied to the brake pedal. Wet responsiveness is excellent because the brake pads – which have also been redeveloped – take on less water than conventional brake pads. The ceramic brake disc handles even extreme loads without complaint – which can occur frequently, particularly when adopting a sporty driving style.
In 2006, the 911 Turbo surprised the motoring world by featuring variable turbine geometry, a world first for a turbocharged petrol engine. Variable turbine geometry uses guide blades to simulate the cross-section of a turbocharger always optimised in size. At low engine speeds, the blades angle to form small air-flow openings. The exhaust gas flowing through a smaller cross-section is accelerated accordingly, hitting the turbine wheel with a high level of energy and therefore acting as a small turbocharger. This blade angle is maintained until the system has built up the required boost pressure.

With the flow of exhaust gas continuing to increase as a function of higher engine speed, the VTG guide blades open up and regulate the boost pressure accordingly. The electronic management and the electrically driven control mechanism – the control of which are integrated into the engine's Motronic management system – are set up to give the blades an adjustment period from “open” to “closed” of approximately 100 milliseconds. Furthermore, the variable turbine geometry of the turbocharger is able to handle even the maximum conceivable flow of exhaust gas. This eliminates the need for a bypass valve.

The principle of variable turbine geometry (VTG) has been applied to diesel engines on a large scale for nearly ten years. However, the systems used on diesel engines could not be transferred readily to petrol engines, mostly for thermal reasons. For example, exhaust gas temperatures at the point leading into the turbine on a diesel engine are between 700 and 800°C. The exhaust gas on Porsche’s turbocharged power units, on the other hand, has a temperature of 1000°C. This creates a significantly higher load and extra strain on the adjustable guide blades, demanding the utmost of the materials and construction method applied. Only the development of materials that are extremely resistant to high temperatures allowed the production of VTG turbochargers with the long-term performance and life expectancy required. Porsche’s engineers also developed a two-stage oil cooling system including a follow-up pump, as well as a water cooling system for the bearing housing, to help reduce the high temperatures.

The optionally available Porsche double-clutch transmission (PDK) was featured in a series production sports car for the very first time when it was fitted into the 997 series of the 911 in 2008. It had seven forward gears and one reverse gear and was initially available in the Carrera and Carrera S. Its main advantages were faster gear changes in comparison with manual gearboxes and automatic converter gearboxes. The gears were already engaged when the driver changed gear and drive was not lost during the process. The PDK also provided weight benefits — despite two additional gears in comparison with the manual gearboxes prevalent at that time, it weighs approximately ten kilogrammes less than the Tiptronic S gearbox.

In the 1980s, Porsche was the first manufacturer in the world to use this gearbox technology successfully in motor racing in the 956/962, and therefore it had the most experience with dual-clutch gearboxes for high-performance sports cars. The Porsche Doppelkupplung combined the driving dynamics and the good mechanical efficiency of a manual gearbox with the shifting and ride comfort of an automatic gearbox. The PDK was therefore designed in line with the requirements of a 911 driver, in terms of both
sportiness and comfort. The first six of the seven forward gears had a sporty set-up, whereas the seventh gear had a long ratio for maximum fuel economy.

2011: Intelligent aluminium-steel construction

In the 991 series of the 911, which was introduced in 2011, Porsche further perfected the lightweight design for sports cars. This achieved a number of goals: improving vehicle dynamics while reducing fuel consumption, as well as enhancing safety and raising levels of comfort in comparison with earlier vehicles. The engineers chose a concept that puts the right material in the right place, using the right construction method. For the first time, this has meant that the current vehicle generation is lighter than its direct predecessor – by approximately 40 kilogrammes. And this is despite the additional weight originally expected due to the longer wheelbase, the more stringent safety requirements and the enhancements to the overall package.

The largest proportion of the weight saved (around 80 kilogrammes) was due to the new body-in-white with mixed aluminium-steel construction. With the exception of local reinforcement parts, the front body section and large parts of the floor and rear section are made of aluminium. This is also true of the lids, wings and the door structure. The coupé is 44 per cent aluminium and the cabriolet 43 per cent. A significantly larger proportion of the steel parts are made of super high-strength and ultra high-strength materials. The hot forged, press hardened steels provide an extremely high degree of occupant protection.

2011: Seven-speed manual gearbox

The world’s first seven-speed manual gearbox is used in series production of the 911 – again in the 991 series. It gives the 911 a new, crisp shift characteristic. The new gearbox was designed on the basis of the seven-speed double-clutch transmission and provides excellent shifting comfort and sporty shifting forces. The new 911 cars reach their top speed in sixth gear. The seventh gear has a long ratio and helps to save fuel – a high cruising speed is attained at a lower engine speed. The high level of efficiency and the optimised weight of the gearbox help to make the vehicle more fuel efficient. It is also combined with an automatic start/stop function as standard.

As the seven-speed double-clutch transmission is designed as a modular system, many of the same parts were able to be used for the construction of the seven-speed manual gearbox. However, one particular challenge had to be overcome – due to the concept of the Doppelkupplung, the gears are arranged differently than with a normal “H” shift pattern. For this reason, converted shift actuators were developed especially for the manual gearbox version. They enable the traditional “H” shift pattern to be achieved with the Doppelkupplung gear sets too. A patented system prevents the wrong gear from being engaged. For example, the seventh gear can only be engaged directly after the fifth or sixth gear.

2013: Adaptive aerodynamics

In 2013, Porsche introduced the world’s first sports car with adaptive aerodynamics, the new 911 Turbo. The system consists of an extendible front spoiler and adjustable rear wing. It offers drivers a unique combination of everyday convenience, efficiency and performance. While the system automatically adjusts to maximum ground clearance or minimum drag depending on the speed, the 911 is track-ready at the push of a button. For the first time ever, the 911 Turbo achieved a downforce in this performance mode that was close to that of thoroughbred racing 911s. Porsche underlined yet again that its roots lie in racing and continued to transfer experiences gained on the track to series-production sports cars.

2014: Automatic Targa roof

With the 911 Targa of the 991 generation, Porsche returned to its original concept, with the characteristic fixed Targa bar. The innovative roof system consists of two moving parts: a soft top and a glass rear window. At the press of a button, the glass rear window opens to the rear and tilts. It is joined to the convertible top compartment lid. At the same time, two flaps in the Targa bar open and release the soft top kinematics. The soft top is unlatched, folds to the rear into a Z-shape during the opening movement and stows behind the rear seats. A panel running across the car behind the rear seats integrates the soft top. Finally, the flaps in the bar and the rear window close. While the car is stationary, the roof can be opened or closed in about 19 seconds using controls in the centre.
In the new generation of the 911, Porsche is making a consistent advancement by introducing biturbo engines in all 911 Carrera and 911 Targa models. This is a clear enhancement: Over the decades, Porsche has cultivated the turbo engine so that it offers a unique combination of power and efficiency that conventional naturally aspirated engines cannot. The higher specific power of the turbo engines enables the displacement to be reduced. In both engine variants, Porsche is therefore reducing the displacement to three litres. The higher power of the 911 Carrera S comes from the turbochargers with modified compressors, a specific exhaust system and a specially calibrated engine control unit. The rear of the 911 Carrera now delivers 370 hp (272 kW; Fuel consumption combined 8.3 – 7.4 l/100 km; CO2-emissions 190 – 169 g/km), ready to be converted into dynamic power, while the charged six-cylinder engine of the 911 Carrera S provides 420 hp (309 kW; Fuel consumption combined 8.7 – 7.7 l/100 km; CO2-emissions 199 – 174 g/km). In both cases, this represents an increase of 20 hp (15 kW). The improvement in the torque is even more obvious: The 911 Carrera offers 450 Nm and the 911 Carrera S 500 Nm, meaning both drives offer 60 Nm more. It is not just these maximum values that benefit drivers; they can also convert the full torque into acceleration over more than half of the speed range. At the same time, the new generation of engines is much more economical, with fuel consumption reduced by up to one litre per 100 kilometres depending on the version.