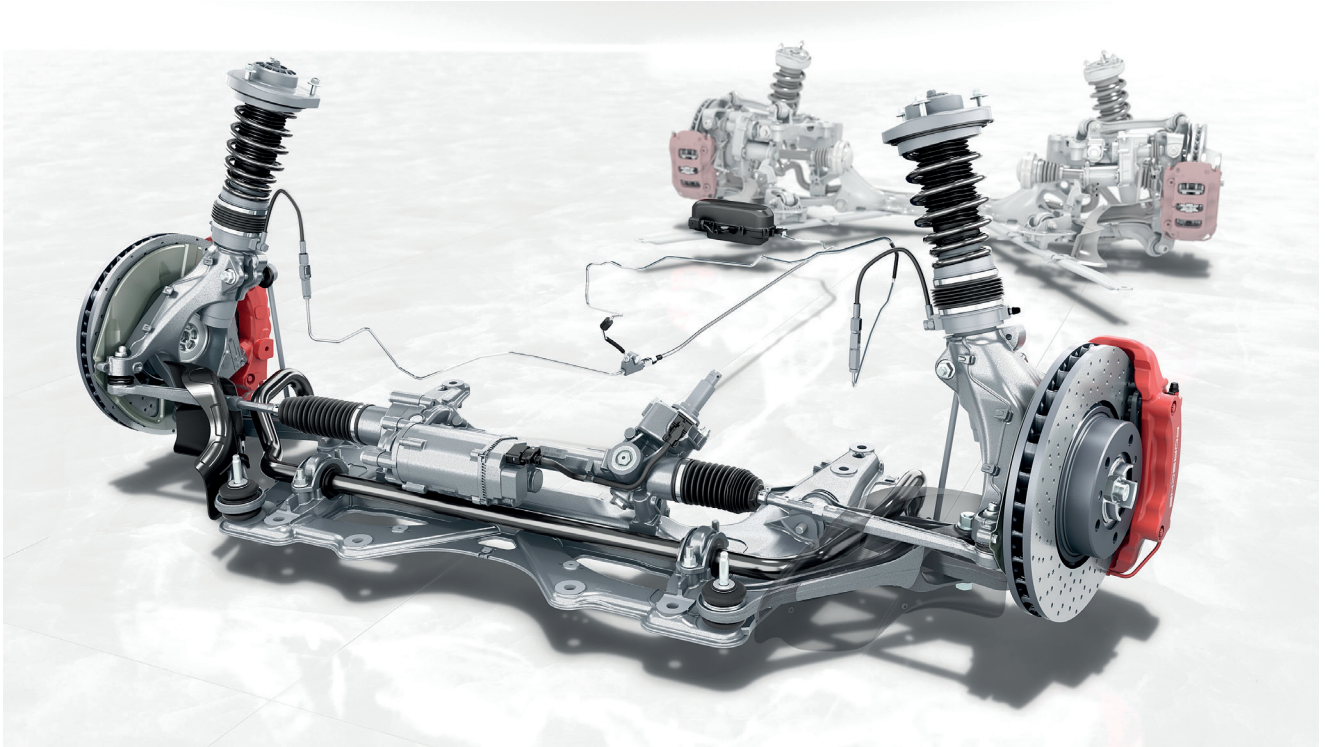




PORSCHE



## **Porsche chassis development**

Dynamic training Nardò 2016

Press kit

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Wide spread between performance and comfort

## **The three cornerstones of Porsche chassis development**

Porsche represents first-class driving dynamics, efficiency and comfort in every market segment. Every model within each model line is designed to strike this balance between performance and comfort from the outset. Outstanding driving dynamics require precisely balanced interaction between the overall concept, the drive and the chassis. During the course of its development, every Porsche is fine-tuned and optimised on the racing track. The lap times recorded during this process have always been and continue to be an indicator of development progress. The excellent handling that results from this process ensures that Porsche drivers are able to experience fun and emotional driving each and every day. This performance-orientated design forms part of the core Porsche brand identity.

A chassis is only as good as its mechanical basis. Porsche consistently applies this mantra from the world of motorsport to its vehicles and owes its racing successes notched up over more than half a century to this very attitude. The sportscar manufacturer implements active systems with the sole purpose of improving the balance between performance and comfort and optimising individual properties. After all, even the best mechatronic system may be able to conceal the weaknesses of an average chassis, but it will fall short of turning it into a sportscar chassis.

The Porsche chassis concept is based on three cornerstones. The first consists of fundamental concept features of the overall vehicle, such as the wheelbase, the track width, the weight and the weight distribution. The mechanics of the chassis, including the axle concept, brakes and tyres, forms the second cornerstone. The third cornerstone is formed by the mechatronic chassis systems, such as the stabilisation system (PSM), rear-axle steering, damping control system (PASM) and active anti-roll stabilisation (PDCC).

## **The first cornerstone: The overall vehicle concept**

The overall vehicle concept forms the basis for the performance-orientated design of the driving properties. A long wheelbase provides excellent directional stability, large track widths and a low centre of gravity for low wheel load fluctuations while cornering. For the driver, this means high lateral acceleration, low load change responses and excellent stability. The balanced axle-load distribution in combination with rear torque distribution results in optimum traction and neutral self-steering properties. The requirements for the driving dynamics are consistently taken into account in the overall vehicle concept from a very early stage in a new model's development. For instance, the requirements are established in the vehicle package as early as the concept phase. These requirements guarantee, among other things, excellent braking performance in terms of installation space for the brakes and cool air supply to the brakes – even for the top model in the model line.

## **The second cornerstone: Chassis mechanics**

The second cornerstone is the chassis mechanics. The first step here is to establish the dimensions of the wheels and tyres. Porsche uses mixed tyres in virtually all its model lines – the rear tyres have a wider tread than the front tyres. In the super sportscar segment, the rear axle wheels also have a larger diameter. Porsche also has very high requirements when it comes to tyre properties. This includes both tyre performance, i.e. longitudinal and lateral power transmission, along with efficiency and comfort. For instance, over the past ten years, the company has succeeded in reducing roll resistance as a factor in fuel consumption by around 20 per cent, while still increasing longitudinal and lateral adhesion.

The axle concepts with their continuously enhanced kinematic properties ensure correct positioning of the wheels in relation to the road in all driving conditions, thereby ensuring optimum power transmission from the tyres. On many sportscars, rebound buffer springs on all four wheel suspensions reduce roll and pitch movements when the car is driven in a particularly sporty manner, while at the same time improving rebound handling. Porsche offers lowering on virtually all models. This technique further reduces the vehicle centre of gravity, thereby enhancing lateral dynamics. All Porsche models are equipped with fixed-calliper brakes on the

front axle, which deliver ultimate braking performance, excellent stability and a good braking sensation. For particularly high braking performance requirements, all model lines are available with the option of the Porsche Ceramic Composite Brake (PCCB) with its lightweight and exceptionally stable ceramic brake discs.

### **The third cornerstone: Mechatronic systems**

Mechatronic systems, the third cornerstone of the chassis concept, are becoming increasingly important in terms of driving properties and improving the balance between the supposedly opposing properties of performance and comfort. A core strategy at Porsche is to use innovations to improve this balance as a whole rather than one single property. Sportscars with PASM and PDCC offer not only greater stability when cornering at high speed, but also a higher degree of comfort on long journeys. Porsche Traction Management (PTM) improves both driving dynamics and traction and stability on a wide range of different driving surfaces.

### **Porsche Stability Management on the racing circuit**

At the heart of the active driving dynamics control systems is Porsche Stability Management (PSM), which delivers a high degree of active driving safety at longitudinal and lateral limits. PSM contains the functions ABS (anti-lock brake system), ASR (anti-slip regulation), MSR (engine drag torque control) and ABD (automatic brake differential), as well as “precharging of the brake system”, and “brake assist”. Precharging the brake system enhances braking readiness, which in turn reduces stopping distances in emergency situations. If the accelerator pedal is released very quickly – as is typically the case prior to an emergency stop – brake fluid is transferred from the PSM hydraulic unit to the wheel brakes before the brake pedal is actuated. This causes the brake pads to press lightly against the brake discs, ensuring that the brake system is optimally prepared for the imminent braking. As a result, the response behaviour of the brake system is significantly improved and stopping distances are reduced.

PSM can be switched off in two stages. In conjunction with the Sport Chrono Package, the system offers an individually switchable mode with the designation PSM Sport, activated via the PSM button located in the centre console. From a functional perspective, “PSM Sport” is very different to the normal mode and allows ambitious drivers to take their Porsche even closer

to its limits – on the race track, for example. Compared with “PSM On”, the function enables significantly larger yaw movements around the vertical axis and a higher degree of slip on the drive wheels, making the dynamic performance of the vehicle even more palpable. This eliminates the need to deactivate the PSM fully, even for seasoned sporty drivers. The “PSM Off” mode is activated by pressing and holding the PSM button. This is in keeping with the Porsche philosophy of allowing drivers to deactivate the control system entirely when desired. However, in “PSM Off” and “PSM Sport” mode, powerful braking in the ABS control range re-activates the full stabilising effect of the PSM system, but only until the brake is released again.

### **More dynamic cornering with PTV and PTV Plus**

When it comes to driving dynamics and driving stability, Porsche Torque Vectoring (PTV) is the perfect accompaniment to the standard Porsche Stability Management (PSM). The system is available in two variants: In combination with a manual transmission as PTV with mechanical differential lock and for PDK vehicles as PTV Plus with electronically controlled, fully variable differential lock. The system essentially uses targeted braking interventions on the inside rear wheel to enhance the vehicle’s steering behaviour and steering precision during highly dynamic driving. It offers considerable advantages, in particular when steering around bends. The inside rear wheel is braked selectively as soon as the driver starts to steer. This means the rear wheel on the outside has a higher drive torque than the inside wheel. This difference in torque produces a yaw moment on the vehicle that provides additional support for the steering. The result? Significantly more agile handling with improved steering behaviour. In addition, PTV Plus delivers a noticeably higher level of traction when accelerating out of bends through targeted use of the differential lock.

### **Four times the power: PTM all-wheel drive**

Porsche traditionally also uses all-wheel drive primarily to increase driving dynamics: With the exception of the 718 sports car, the top models in all model lines use Porsche Traction Management (PTM) for optimum power transmission. Porsche uses an electro-hydraulically controlled multi-plate clutch for exceptionally fast and targeted distribution of power to both axles. This functional principle enables extremely spontaneous and precise clutch control. The result? Even more precise handling and even better traction and driving dynamics. The speedy

PTM also offers benefits when the vehicle is driven at the limits of its lateral dynamics: handling is smoother and more predictable because the control response to accelerator pedal or steering wheel commands is implemented even more precisely. In addition, the dynamic and fully variable distribution of torque between the axles delays wheel slip and therefore activation of the PSM.

### **Basis of the balanced chassis: Active PASM shock-absorber system**

One of the first active chassis systems that Porsche implemented and is still continuously developing is the Porsche Active Suspension Management, or PASM for short. This combines two chassis in one: a sporty yet comfortable chassis for long journeys and an exceptionally sporty chassis for the race track. The normal setting provides a more comfortable basic configuration of the dampers, and switches to a more sporty mode if the vehicle is driven more dynamically. This increases comfort levels, particularly long motorway journeys, as the PASM absorbs minor to moderate bumps in the road surface significantly better than a standard passive chassis. In contrast, the sport setting activates harder damper characteristics that support a highly agile driving style. The reduced car body movements make it easier to achieve fast lap times on the race track.

The PASM responds in a flash to dynamic changes during driving. For example, the system increases damper force to both axles in the event of sudden steering movements, e.g. during unexpected manoeuvres to avoid an obstacle. This reduces lateral inclination or instability of the body and makes it significantly easier to control the vehicle, particularly in extreme situations. In normal mode, the damper force is increased if the vertical movement of the body exceeds a certain value, for example when driving over bumps in the road surface. This reliably prevents instability of the vehicle body. In contrast, sport mode slightly reduces the damper force as car body movements increase to improve contact between the wheels and the road. This prevents any jumping or displacement of the car, while at the same time noticeably improving comfort. In normal mode, depending on the vehicle speed and lateral acceleration, the damper force is set differently for the inner side and outer side of the vehicle when cornering. This prevents vehicle

instability and significantly increases driving precision. The damper characteristics are adjusted individually for the front and rear axle during heavy acceleration, during gear changes and when the accelerator pedal is released.

### **Precise feedback: Electromechanical steering**

For the driver, steering is the most important tool for receiving communication on the driving status, particularly in sportscars. For the current 911 generation, Porsche has introduced a completely new electromechanical power steering system, which outperforms all systems available on the market to date in terms of power and precision. This has a noticeable impact on performance: When braking on road surfaces with different coefficients of friction, a steering impulse is triggered in the direction of travel. This enables the driver to stabilise the vehicle more easily and keep the vehicle in the desired lane. Within the steering system, a driving status monitor accurately identifies the currently available rack-and-pinion force, on the basis of which the appropriate steering torque is controlled in a variable manner. This ensures an optimum steering sensation in every driving situation, along with a good level of contact with the road surface. The driver is provided with useful information about the road and driving status via the steering wheel, while occurrences that could disturb the driver, such as bumps, are filtered out.

### **Greater agility around bends, greater stability when changing lanes:**

#### **Rear-axle steering**

All 911 and Panamera models can be equipped with active rear-axle steering, or, depending on the model, are already equipped with this feature as standard. This rear-axle steering makes the two and four-door sportscars considerably more agile when steering around tight bends, more stable when changing lanes at high speeds and easier to handle in urban traffic. If the driver steers into a bend at less than around 50 km/h, the front and rear wheels steer in the opposite direction. This effectively shortens the wheelbase, allowing the sportscar to be driven effortlessly around the bend with smaller steering movements. A 911 with rear-axle steering also feels like a compact car when it comes to manoeuvring: the turning circle is reduced by 0.5 metres to 10.7 metres. But when it comes to changing lanes suddenly at high speeds, it's a different story. In such circumstances, the front and rear wheels steer in the same direc-



tion and the wheelbase is effectively extended. This provides greater stability and the faster build-up of lateral force at the rear axle allows the vehicle to change direction more spontaneously and harmoniously. But that's not all: The use of rear-axle steering delivers a considerably more direct steering ratio at the front axle, with a steering sensation that is unrivalled among the competition.

### **Three specific variants: Active anti-roll stabilisation (PDCC)**

Anti-roll bars are the third fundamental chassis component to influence driving properties after suspension and damping. Typically designed as elastic torsion bars, they connect the wheel carriers of an axle and restrict lateral inclination of the vehicle when cornering. The hardness of the anti-roll bars on the front and rear axle can be adjusted to influence the wheel-load distribution during cornering and therefore the steering behaviour. Anti-roll bars primarily influence suspension behaviour when driving over bumps in the road surface affecting only one side of the vehicle, as they transfer the forces to the other side. This adjustment is therefore always a compromise between the lowest possible degree of lateral inclination and a high level of suspension comfort with alternating springs. Unlike passive spring bars, active anti-roll stabilisation (Porsche Dynamic Chassis Control, PDCC) can remove this conflict of objectives and even almost completely compensate for lateral inclination. The anti-roll bars also actively influence self-steering properties. Porsche uses three different designs of anti-roll bars depending on the model line. In all three designs, actuators are used to actively generate forces on the anti-roll bars.

In the Panamera, the new Porsche Dynamic Chassis Control Sport (PDCC Sport) system optimises driving dynamics through the integration of electromechanical anti-roll bars. One electromechanical actuator – consisting of a direct current motor and a three-stage planetary gear set – on each axle connects the two halves of the centrally divided anti-roll bars. Depending on the lateral acceleration, the actuator turns the two anti-roll bar halves in opposing directions, with the result that lateral inclination of the body is almost completely compensated for. The electromechanical system responds considerably faster than systems with hydraulic actuators, but requires a 48-volt power supply due to the high actuator dynamics and forces.

In contrast, the PDCC in the Cayenne is based on hydraulic actuators. Depending on the steering and level of lateral acceleration, the hydraulic pivot motors on the active front and rear axle anti-roll bars build up forces that counter the lateral inclination of the vehicle. The PDCC off-road mode can be activated by pressing the rocker switch in the centre console. On uneven surfaces, the anti-roll bar halves are disengaged, allowing them to turn more easily to provide improved traction and greater axle articulation. The wheels remain on the ground for a longer period of time, which means that they can transfer a greater degree of force.

The third variant of the PDCC is used in the 911. Instead of using a pivot motor and divided anti-roll bars, in this variant, a system specifically developed for the sportscar concept with actively adjustable hydraulic cylinders is positioned directly on the wheel suspensions. This system saves weight and is designed with the space constraints in mind. The hydraulic cylinders replace the rigid coupling rods normally used to connect the anti-roll bars. The lower section of the hydraulic cylinders is connected to the outer fastening point on the anti-roll bars, while the upper section is connected to the respective wheel carrier. The electronically controlled filling of the hydraulic cylinders with oil changes the stroke of the cylinders and causes the respective anti-roll bar to be preloaded to a greater or lesser degree. In addition, depending on the driving situation, the PDCC's intelligent control system is capable of triggering the hydraulic actuators individually, thereby influencing the self-steering properties and in turn improving vehicle stability.

### **Enhanced performance together with increased comfort: Adaptive air suspension**

Porsche equips each of its Cayennes, Panameras and Macans with air suspension, either as standard or as an option, with the primary aim of increasing suspension comfort. For the new Panamera, Porsche has developed a new three-chamber air suspension system. This adaptive air suspension with its new technology is setting standards, particularly when it comes to the level of driving comfort. In contrast to the system used in the predecessor Panamera model, instead of two air chambers per spring strut the new system has three, and it also has an air volume that is approximately 60 per cent higher. This enables a considerably larger spread of the spring rates. The chassis can be set to a lower basic spring rate for increased comfort, as the spring rate can be changed electronically in a fraction of a second where necessary –

for example, during acceleration and braking or to reduce rolling motion. In addition, the air suspension offers the benefits of self-levelling with the ability to choose different degrees of ground clearance.

### **Porsche 4D Chassis Control: Networked chassis systems on the new Panamera**

Porsche has developed an innovative, centrally networked control system for the chassis of the new Panamera known as 4D Chassis Control. Previously, the chassis systems worked largely independently of each other, used their own sensors and responded to the other systems. Porsche 4D Chassis Control analyses the current driving situation centrally in all three dimensions (longitudinal, lateral and vertical acceleration), uses these findings to calculate optimum information about the driving status, and makes this information available to all chassis systems uniformly and in real time – a fourth dimension in chassis control. As a result, the systems are able to respond to the imminent driving situation in an integrated manner.

For example, when steering dynamically into a bend, the electronic damper control system PASM, the adaptive air suspension, rear-axle steering, PTV Plus and PDCC Sport systems – depending on the vehicle equipment – work together to ensure optimum steering behaviour, maximum agility and stability. The Porsche 4D Chassis Control issues a pulse to the chassis systems as soon as the driver steers the vehicle. This means that the systems are able to respond promptly and ensure maximum performance around bends. The new and enhanced individual systems falling under the umbrella of Porsche 4D Chassis Control result in significantly improved performance and comfort alike on the second-generation Panamera.

### **Chassis of the future: The digital evolution**

Progress in digitalisation, sensor technology and actuating technology will be instrumental in shaping chassis development in the future. Their increasing use will help to eliminate compromises and conflicts of objectives by an ever-increasing degree. The balance between sportiness and comfort will improve yet further, complemented by new functions. However, the foundation of a Porsche chassis will always be a functionally flawless and continuously enhanced combination of axle system, tyres and brakes. This is the nucleus of the Porsche DNA, which is made up of first-class driving dynamics and braking performance, race track compatibility, comfort,

and exemplary efficiency. Our focus on these elements ensures that handling remains at the very heart of the Porsche brand – from petrol and diesel engines right through to hybrid and electric drives.

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## The Porsche chassis systems – Glossary

**ABD**

Automatic brake differential

*ABD counteracts wheel spin by individually braking the driving wheel with the higher degree of slip. Integrated in PSM.*

**ABS**

Anti-lock brake system

*Prevents locking of wheels during braking, thereby improving the vehicle's steering behaviour.*

**ASR**

Anti-slip regulation

*Reduces slip on the drive wheels during acceleration through a reduction in engine power. Integrated in PSM.*

**MSR**

Engine drag torque control

*Adjusts engine speed when the acceleration pedal is released to prevent slip on the drive wheels (this slip can be produced by the engine's brake force). Integrated in PSM.*

**PASM**

Porsche Active  
Suspension Management

*Active damper system with four continuously adjustable shock absorbers and two basic modes: Normal setting with a more comfortable basic configuration of the dampers; these switch to a more sporty mode if the vehicle is driven more dynamically. Sport setting with harder damper characteristics that supports an extremely agile driving style and is comparable with the properties of a sports chassis.*

**PCCB**

Porsche Ceramic Composite Brake

*Brake system with brake discs made from a ceramic composite material and specially adapted brake pads. In contrast to a brake system featuring cast-iron discs, PCCB offers faster response times on dry road surfaces, extremely high fading stability as a result of constant coefficients of friction and high safety reserves under high levels of strain. PCCB also weighs around 50 per cent less than a conventional grey cast iron brake disc.*

**PDCC**

Porsche Dynamic Chassis Control

*Almost completely eliminates lateral body movement when cornering. The core elements of this system include active anti-roll bars with variable coupling rods and electromechanical or hydraulic pivot motors integrated on the front and rear axle in place of the conventional mechanical anti-roll bars. This counteracts the lateral movements that typically occur when cornering.*

**PSM**

Porsche Stability Management

*Stabilises the vehicle when this is driven close to the limits of its driving dynamics through targeted braking of individual wheels. Includes further functions such as ABS (anti-lock brake system), ASR (anti-slip regulation), MSR (engine drag torque control) and ABD (automatic brake differential), as well as brake assist, precharging of the brake system and hold assist. PSM can be switched off in two stages.*

**PTM**

Porsche Traction Management

*Active all-wheel drive with electronically controlled, map-controlled multi-plate clutch.*

**PTV**

Porsche Torque Vectoring

*Mechanical rear differential lock with variable torque distribution on the rear axle. Brakes the inside rear wheel in a targeted manner to improve the vehicle's steering behaviour and steering precision.*

**PTV Plus**

Porsche Torque Vectoring Plus

*Works in a similar manner to PTV with variable torque distribution on the rear wheels, but also features an electronically controlled rear differential lock.*

**TPM**

Tyre pressure monitoring

*Continuously monitors pressure in all four wheels. The driver can view air pressure values via a display in the instrument cluster and the system issues a warning in the event of critical deviations from the normal value.*