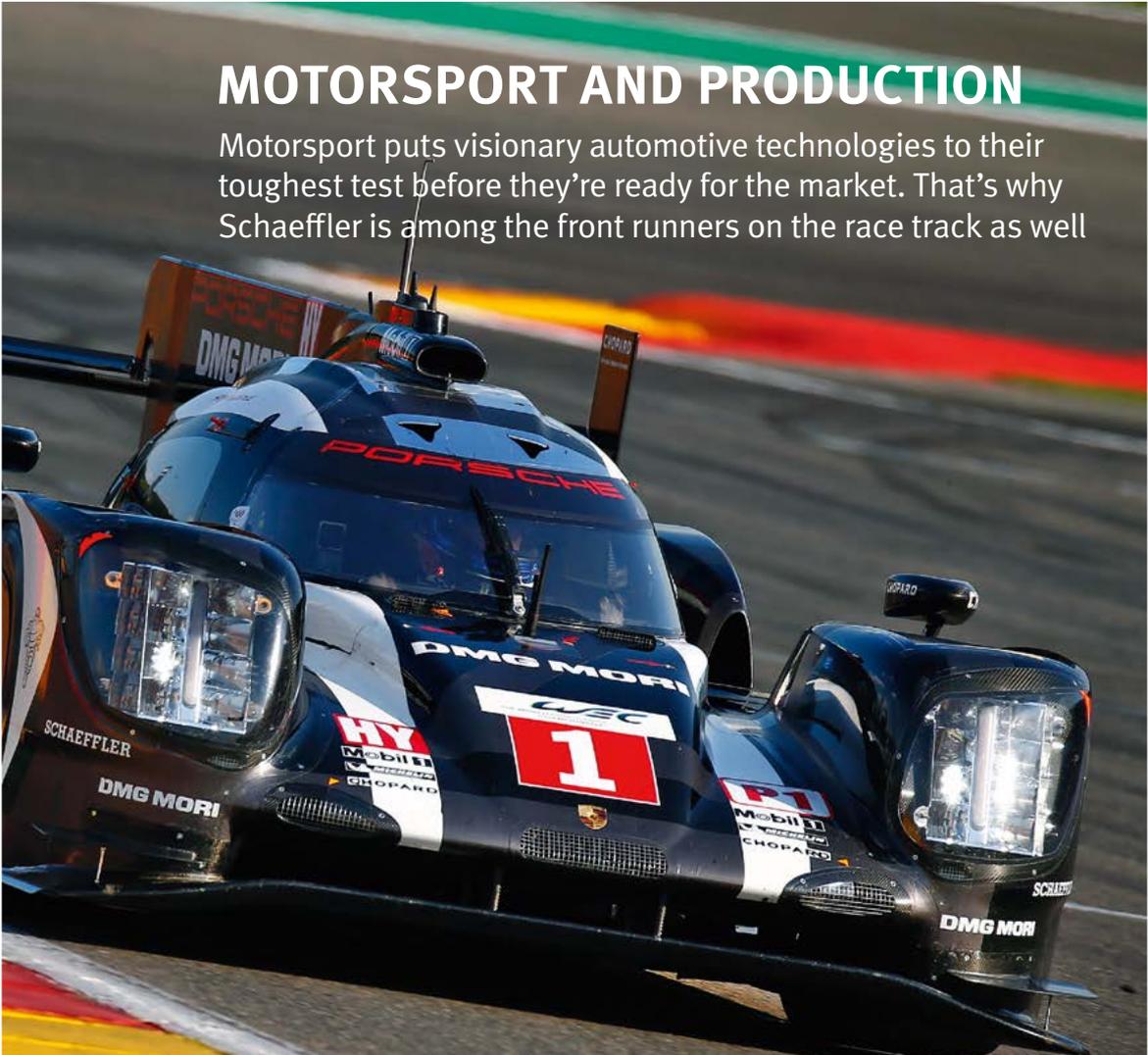


MOTORSPORT AND PRODUCTION

Motorsport puts visionary automotive technologies to their toughest test before they're ready for the market. That's why Schaeffler is among the front runners on the race track as well



INNOVATIVE

Hybrid concepts
by Schaeffler

p. **8**



SCHAEFFLER AND PORSCHE

From the legendary 356 to the
918 high-tech hybrid race car

p. **12**

EDITORIAL



Jörg Walz
Vice President
Communications
and Marketing
Schaeffler Automotive

Technology transfer – is a wonderful word because, at Schaeffler, it implies that we're actively involved in highly diverse motorsport disciplines – and that, at the end of a strenuous day, we've not only learned a lot, but sometimes have a reason to celebrate. Like our partner Porsche who triumphed on the

most challenging race day in 2015, the Le Mans 24 Hours. This is an exciting era in the automotive industry in which motorsport has again assumed a more important part in the development and implementation of "mobility for tomorrow" – talking about hybrid and fully electric mobility. Enjoy the read of our current brochure on technology transfer between motorsport and production.

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CONTENTS

- 2 Editorial
- 2 FIA World Endurance Championship (WEC)
- 4 Le Mans 24 hours: experience at the limit
- 7 Interview with Prof. Peter Gutzmer
- 8 Hybrid drive concepts
- 10 A new era
- 12 Automobile manufacturers and suppliers
- 16 Fact Sheet: 2016 Le Mans 24 Hours

#1



CAR NUMBER ONE

Porsche competes in the WEC as the title defender in the manufacturers' and drivers' world championships. And in the pinnacle event of the season at Le Mans, as the 2015 overall winner of the iconic 24-hour race

9 races

in 9 countries on
3 continents

WEC FACTS

60

cars in the season's
pinnacle event, the
Le Mans 24 Hours

CUTTING-EDGE TECHNOLOGY

The FIA World Endurance Championship (WEC) demonstrates the ultimate of all world championships. The high-tech LMP1 race cars are fully focused on efficiency



Reliability is an absolute must. And beyond that, the most powerful contenders always won at Le Mans for decades – they were the fastest and first to cross the finish line after 24 hours.

2014 saw a revolution. From that year on, the power output of the race cars was no longer regulated, but their energy consumption expressed in megajoules – in other words not the energy that's put on the wheels, but the one that flows into the fuel tanks and batteries. This rule has been rewarding the most efficient instead of the most powerful contenders ever since: at Le Mans and at the other rounds of the WEC.

PARADIGM SHIFT IN MOTORSPORT

This has created a perfect parallel, as the design engineers in volume production have to invent increasingly efficient automobiles as well. In the WEC, fuel consumption has been defined on a maximum level. Porsche, for instance, may use 4.31 liters of gasoline per lap,

or else be subject to time penalties. At the same time, the regulations provide incentives for wasting less energy. Energy recuperation systems assist in this. With the 919 Hybrid, Porsche has opted for a combination of kinetic energy recuperation at the front axle and conversion of exhaust energy at the rear – and all this in the most challenging recuperation class.

In this top-end category, eight megajoules of electric energy may be used on the 13.629 kilometers per lap at Le Mans. There are three other classes with recovery of only two, four and six megajoules. ■

WHAT IS A MEGAJOULE?

Joule is the basic unit for energy. 1 megajoule is equal to 1,000,000 joules. It's important to note that energy is power output multiplied by time. 3.6 megajoules equate to one kilowatt hour (kWh), in other words an output of 1 kW (or 1.36 hp) which a motor – ergo an energy source – produces in one hour.

TOUGH, TOUGHER WORLD END RACING CHA

Full throttle twice around the clock – the Le Mans 24 Hours is the toughest test there is in motorsport, with more than 250,000 spectators in the grandstands and billions of TV viewers watching. 2016 sees Porsche return as the title defender and last year's winner. And Schaeffler is part of the action once more

The hunters have become the hunted. As early as in the brand's second attempt following its Le Mans comeback two years ago, Porsche, in 2015, triumphed with the 919 Hybrid, scoring its 17th overall victory in total – its previous all-out success dating to 1998. In 2016, Porsche – just like its two main rivals, Audi and Toyota – is competing with only two instead of three vehicles in the “large” LMP1 class. The regulations that have been in effect for the top category since 2014, which limit the usable amount of energy but permit considerable freedom in the fields of hybrid and powertrain technology (see related story on page 2), has provided new impetus for innovation and, beyond that, been making for extremely thrilling races. There are various engine concepts – depending on the manufacturer – and temporary four-wheel drive has become standard by now.

AN IDEAL PLATFORM FOR SCHAEFFLER

In the light of the visionary regulations, efficiency, high technology and reliability have become more important than ever at Le Mans and in the WEC. They're exactly the same topics which automotive engineering

– and therefore Schaeffler – is currently, and will continue to be, absolutely focused on for the next decades. The analogy between motorsport and production is coming very close again to its original meaning. Anything that withstands and wins the world's toughest race proves suitability for production “at its best.” That's why the rule makers at the Fédération Internationale de l'Automobile (FIA) defined the new rules in a way that provides new impetus to the future of automotive development. As a result, they're accommodating the intentions of OEMs and automotive suppliers like Schaeffler to demonstrate their technological expertise and the viability of their visionary engineering designs to large audiences around the globe.

THE WORLD'S TOUGHEST TEST LAB

What makes Le Mans unique? Some key figures provide an answer: 5,300 kilometers. In 24 hours. An average speed of up to 240 km/h per lap and 220 km/h across the duration of the race. Le Mans demands top performance twice around the clock – from “man and machine” – and from the engineers in the deve-

URANCE MPIONSHIP



lopment laboratories. Revolutionary technologies have frequently stood up to their baptism of fire in the heart of France and then went on to establish their place in volume production. A brief summary: streamlined bodywork, lightweight design and hybrid powertrains.

For OEMs and suppliers, Le Mans is a paradise. The regulations deliberately allow freedom in many areas and durability plays a crucial part, just like it does in production. For Schaeffler, the legendary Porsche 917 for instance was a development demonstrator for valve train components that were subsequently produced by the millions. Turbocharger development benefited from Le Mans as well. Porsche, in 1976, achieved the first victory with a turbo engine there.

TEAMWORK, MOMENTUM, COMMITMENT

Success in motorsport is closely associated with the abilities of every individual but, above all, with teamwork. Motorsport demands innovative prowess and momentum, commitment and courage – which are of equal importance in the daily quest of Schaeffler's

ADDITIONAL INFORMATION ON THE WORLD WIDE WEB

-  [schaefflergroup](#)
-  [@schaefflergroup](#)
-  [schaeffler.com](#)
-  [Schaeffler](#)

-  [porsche.com](#)
-  [lemans.org](#)
-  [fiawec.com](#)

employees for maintaining their company's position as one of the world's leading automotive suppliers.

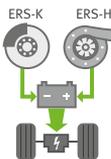
This is another reason why commitments in motorsport have been an integral component of Schaeffler's brand strategy for decades. Motorsport is emotional and while the WEC, DTM and Formula E racing series the company is involved in around the globe are highly diverse, all of them are challenging in terms of technology. ■

EFFICIENT MOTORING

Small engines save weight and with modern technology modern engines are genuine power plants despite having less cylinders – both on the race track and on public roads. Combined with systems to recuperate energy such as for example the recovery of brake energy (i.e. recuperation) the consumption level sinks significantly.

E-Boost through energy recuperation

The Porsche 919 Hybrid is equipped with two systems for energy recuperation. On one hand, braking energy is recovered on the front axle by recuperation, and on the other exhaust energy is used via an E-generator driven by the exhaust gas flow. This recovered energy is stored in the battery and used for boosting lap by lap.



Variable valve control

Enables variable control of the valves through camshaft regulation synchronised to the actual driving situation.



Turbocharger

In addition to vibration damping, the turbocharger is an important downsizing component. Ideally, friction-optimised by low-friction roller bearings.



Lower consumption



ERS-H

ERS-K

Hybrid module

Schaeffler offers different hybrid modules for the bespoke electrification of the drivetrain – from compact class to SUV.

History of downsizing

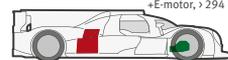
1970 Porsche 917
12 cylinders, 4.5 l displacement, 383 kW



1994 Porsche 962
6 cylinders, 2.9 l displacement, 500 kW



2016 Porsche 919 Hybrid
4 cylinders, 2.0 l displacement, < 368 kW
+E-motor, > 294 kW





“THE PERFECT STAGE”

Prof. Peter Gutzmer Deputy Chairman of the Executive Board and Chief Technology Officer of Schaeffler AG

Why are you involved in the FIA World Endurance Championship (WEC) with Porsche?

Peter Gutzmer The answer is simple: hybrid is increasingly becoming a hot automotive topic – both on the road and in racing. In the WEC regulations, energy efficiency and forward-thinking technology play a crucial role.

What do you intend to prove? Technological expertise. And

for that, the WEC including Le Mans provides a perfect stage. Particularly in endurance racing with its extreme demands on reliability, we continually improve our learning curve.

And, arguably, in Formula E as well – Schaeffler’s most recent motorsport commitment ...

Here, we can explore extremes. At Schaeffler, we

have and continue to gather a wealth of know-how in the combination and interaction of components. In Formula E, it’s between the e-motor and the transmission or, in the case of hybrids, between the internal combustion engine and the e-motor. In addition, motorsport is emotion – and that’s what we need in electric mobility as well. That’s another reason why Formula E is an ideal field to be active in. ■

EXTREMELY RELIABLE

Extreme loads necessitate absolutely reliable components. This applies not just to motorsport, but also for everyday road traffic or energy generation by wind power. Schaeffler does not only offer comprehensive expertise in the field of bearing technology, but always has an integrated view for the entire system. Because the result is often more than only the pure sum of its parts.

1. Centrifugal pendulum absorber

Modern centrifugal pendulums absorb oscillations. They sit between engine and gearbox and are the key to low revs and therefore low consumption.



4. WPOS spherical roller bearings

The durable bearing for all wind turbines guarantees the greatest reliability. Ingenious know-how ensures low friction and lowest wear.



2. Twin tandem wheel bearing module with spur gear teeth

Low-friction ball bearings combine low resistance with increased cornering rigidity. The spur gears combine increased strength with maintenance optimised mounting.



3. Ball bearing mounted balance shaft

Small engines need modern assistance such as balance shafts. With their low friction and lightweight, they have a positive influence on consumption, emissions and service life.

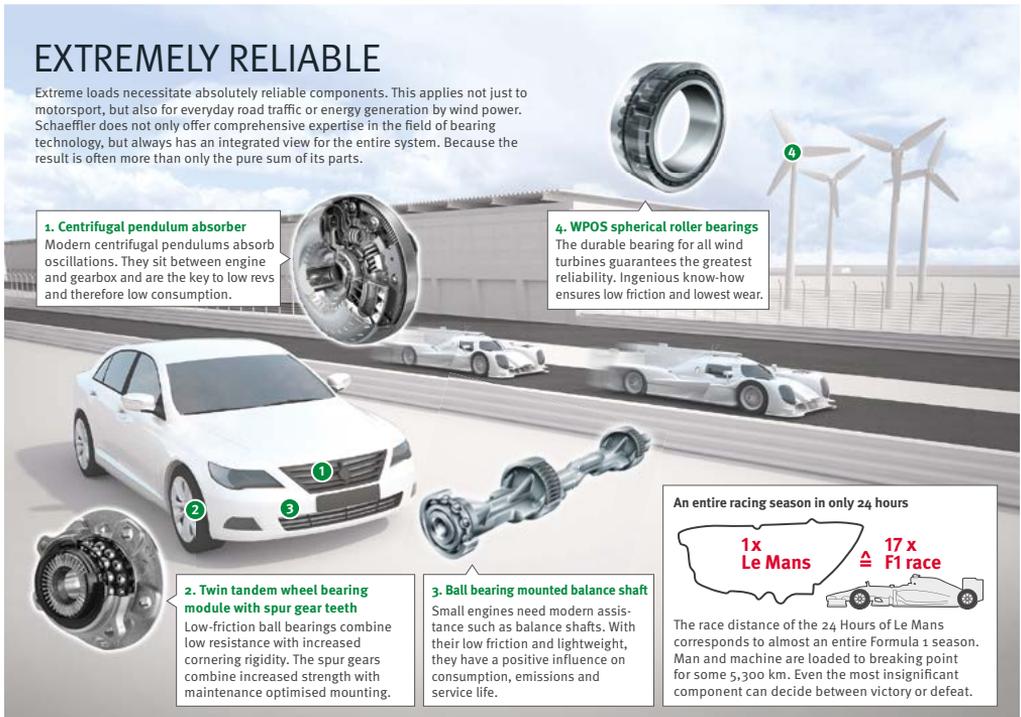


An entire racing season in only 24 hours

1x Le Mans $\hat{=}$ 17x F1 race



The race distance of the 24 Hours of Le Mans corresponds to almost an entire Formula 1 season. Man and machine are loaded to breaking point for some 5,300 km. Even the most insignificant component can decide between victory or defeat.



VOLTAIC DRIVE

Hybrid is the magic word for the future of the automotive powertrain. But not all hybrids are created equal. Schaeffler's research and development activities are focused on various concepts. While each of them is justified in its own right, they all pursue a common goal: efficiency and lower CO₂ emissions

First, the meaning of “hybrid” in the language of automotive developers should be explained. Put simply, it means adding a second power source for propulsion to complement the conventional internal combustion engine. Today, this refers to electric motors.

ONE NAME, VARIOUS CONCEPTS

Automotive OEMs and their suppliers are testing and offering various hybrid systems. Schaeffler is among the companies at the forefront of this technology. As a pioneer in this field, Schaeffler – see right-hand page – has been testing a wide range of systems and gathering in-depth experience of high value to the automotive industry.

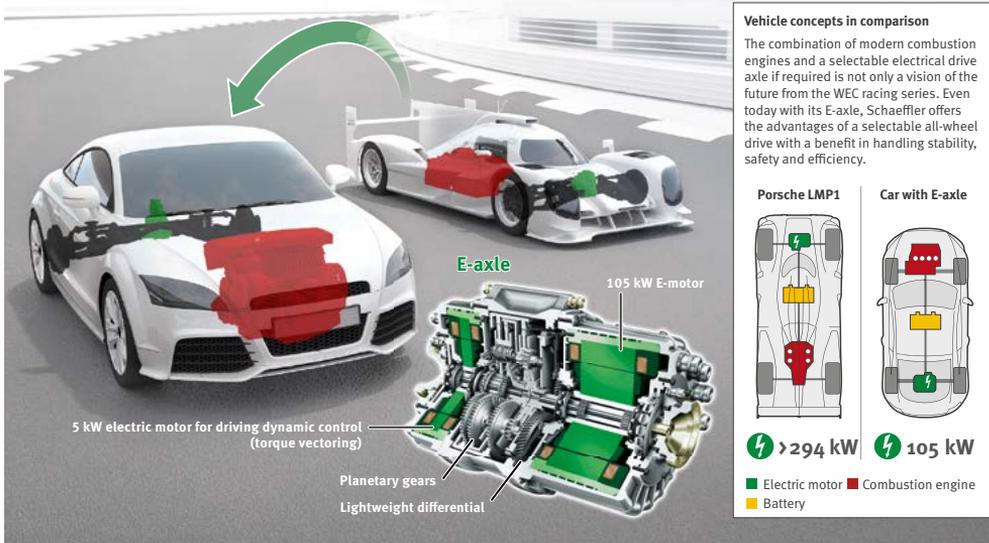
Every one of these innovative and intelligent concepts is justified in the marketplace. Not least because “more electric power on board” makes it possible to replace other conventionally used mechanical or hydraulic components with electrical ones.

OPTIMIZATION IN MANY AREAS

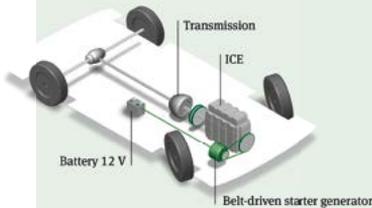
Obviously, the energy with which hybrid technology is pursued within the Schaeffler Group is matched by the company's intensity to drive the optimization of the internal combustion engine forward in many areas – Uni-Air, the first fully variable electrohydraulic valve timing system (see page 14) for instance is a Schaeffler invention. ■

ELECTRIC FOUR-WHEEL DRIVE

The connection of the combustion engine with an electric drive provides new opportunities. In motor racing, hybrid cars with four-wheel drive concepts represent the pinnacle of the technically feasible. In conventional road cars, the electrification of the drivetrain with increasing hybridisation plays an important role. With its E-axis, Schaeffler provides an innovation that combines the electric drive with the possibility of wheel selective controllable driving power. All-wheel drive in connection with combustion engines is available to the driver when required.



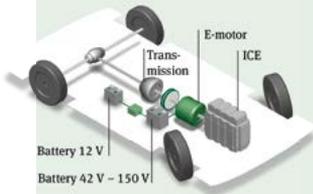
5 HYBRID CONCEPTS IN COMPARISON



MICRO HYBRID (12 VOLTS)

THE PRINCIPLE *Micro hybrid describes cars equipped with start-stop automatic and which recover braking energy via recuperation through a generator, meaning the battery is constantly recharged. The starter-generator – the electric machine – cannot be used for propulsion.*

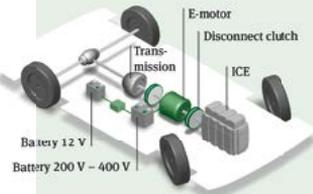
IN A NUTSHELL *Braking and coasting charge the classic battery to relieve the engine of this ‘work’. This saves fuel. Exactly like the automatic stopping and starting of the engine when the vehicle is stationary, at traffic lights for example.*



MILD HYBRID (42–150 VOLTS)

THE PRINCIPLE *Combined with start-stop automatic, the electric machine in a mild hybrid supports the conventional engine (internal combustion engine/ ICE) by increasing power (boost function). The braking energy can be partially retrieved in a regenerative brake (recuperation) and serves to recharge the battery.*

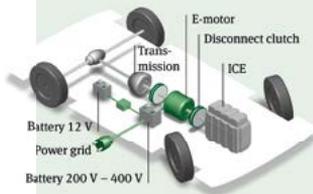
IN A NUTSHELL *A second battery and a small electric motor generating about 16 kW support the internal combustion engine.*



FULL HYBRID (200–400 VOLTS)

THE PRINCIPLE *Full hybrid vehicles can be propelled either electrically, only using the internal combustion engine or combined.*

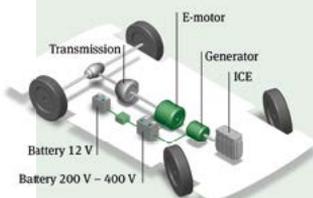
IN A NUTSHELL *A significantly more powerful battery as well as a larger electric motor in this concept enable pure electric propulsion with a low range.*



PLUG-IN HYBRID (200–400 VOLTS)

THE PRINCIPLE *While the mild and full hybrid solutions recharge the accumulator via braking energy or the internal combustion engine, the accumulator in a plug-in hybrid can also be charged externally by plugging into the mains electricity supply. For this reason a larger accumulator is used, with which significantly longer distances can be covered in pure electric mode.*

IN A NUTSHELL *Battery (accumulator) and electric motor are suitable for longer distances, the system can be charged via the mains plug/charging station.*



RANGE EXTENDER (200–400 VOLTS)

THE PRINCIPLE *Electric vehicles with a range extender have an efficient electro drive and make pure electric driving possible over a comparatively long range. Internal combustion engines are used most frequently as range extender, which power a generator that in turn supplies the accumulator and electric motor with electricity.*

IN A NUTSHELL *The vehicle runs purely on electricity. The ‘small’ internal combustion engine is not connected to the wheels and only helps to charge the accumulators for the ‘large’ electric motor.*

ELECTRIFYING FUTURE

Energy efficiency, environmental concerns and the resulting strong growth in the number of hybrid and fully electric vehicles – the automotive industry is about to step into a new era. And Schaeffler is a pioneer

FORMULA E DEVELOPMENT PLATFORM

The innovative FIA Formula E electric racing series has evolved into an important test bed for the development of advanced automotive drive technologies in just its second year. As its exclusive technology partner Schaeffler, together with Team ABT Schaeffler Audi Sport, designed the powertrain for the race cars. The experiences gathered in Formula E will be benefiting future technology for electric mobility on the road as well



In times of scarce resources, fine dust pollution and emission scandals, the agenda, more than ever before, has been set for alternative powertrains. Hybrid and electric drive are the most advanced and widely spread systems. Schaeffler supports this game changer with forward-thinking technologies. In the light of this trend, the company is in the process of doubling its global capacities in the field of electric mobility. In total, the team dedicated to electric mobility and mechatronics will increase to 2,400 members within the next five years.

The speed at which headcount is growing is matched by the expansion of Schaeffler's electric mobility product portfolio. From hybrid modules, to the electric axle, to wheel hub motors the company offers solutions for hybrid

and fully electric vehicles – covering both 48-volt and high-voltage systems.

GTC II: NEW FUEL ECONOMY BENCHMARK

The second generation of the Gasoline Technology Car, GTC II, created in close cooperation with Continental and Ford, is a fine example of Schaeffler's innovative spirit. The car that is based on the Ford Focus shows the potential of intelligent state-of-the-art 48-volt hybridization. The most notable difference between the latest version and its predecessor model, GTC I, is the fact that the electric machine has been integrated between the internal combustion engine and the transmission in a highly efficient manner. "The GTC II, like the GTC I, marks a milestone achievement because highly efficient hybrid operating strategies have been successfully implemented in a vehicle with a manual transmission," says Prof. Peter Gutzmer, Member of the Executive Board and Chief Technology Officer at Schaeffler. "The electrified clutch in the GTC II additionally creates the prerequisite for functions such as electrical starting from rest, electrical stop-and-go, plus recuperation nearly up to the point of rest." ■



25%

fuel savings are promised by the GTC II from Schaeffler, Continental and Ford

EURO 6 C

The GTC II already complies with the strict emission standards for 2017/2018

PARTNERS



PORSCHE 356 THE BEGINNINGS

The Schaeffler brothers invent the cage-guided INA needle roller bearing, a fundamental invention at the end of the 1940s. It reduces friction and can also tolerate high speeds. These bearings make many transmissions suitable for highway use for the first time. Porsche is one of Schaeffler's customers.



PORSCHE 911 LEGEND

Schaeffler founds the clutch manufacturer LuK in 1965 and puts the first diaphragm spring clutch on the market in Europe. This innovation is the start of a successful career. Today, one in three cars worldwide has a clutch from Schaeffler's LuK brand.



PORSCHE AND SCHAEFFLER FROM DAY ONE



The collaboration between the Stuttgart-based manufacturer and Schaeffler goes as far back as 1948 and the first Porsche. A summary of the most important joint projects to date

A comparative look at Porsche's model history – from the original 356 model to the current 918, the high-tech hybrid road-going sports car – impressively documents more than six decades of automotive progress: progress that Schaeffler has been helping to drive from the very beginnings. Automobile manufacturers around the globe rely on innovative and active assistance of this kind by suppliers that decisively influence automotive advancement, drawing on their production know-how and the innovative prowess of their development engineers.

SCHAEFFLER: GLOBAL EXPERT PARTNER

Schaeffler is one of these global expert partners of the automotive industry for sustainable mobility. The product portfolio encompasses technologies for the engine, transmission and suspension, plus hybrid elements and electric motors. It extends from single

PORSCHE 917 SUCCESS STORY

In 1970, Porsche is the overall winner at Le Mans. Tappets from INA bridge the gap between the camshaft and valves in the engine of the 917. Schaeffler uses the race track as a test laboratory. Today, Schaeffler has established itself as THE specialist for components and systems in the valve train.



PORSCHE 928 COMFORT DUE TO TECHNOLOGY

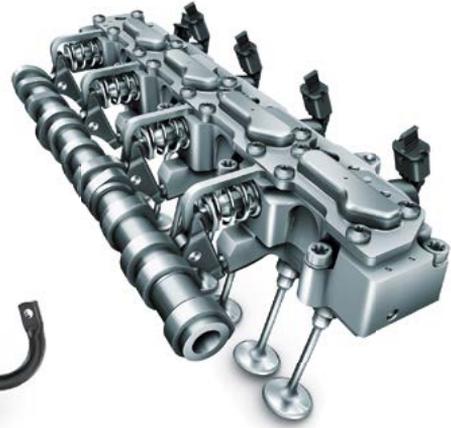
Schaeffler engineers introduce hydraulics into the valve train. Hydraulic tappets, as used for the first time by Porsche in the road-going 928 launched in 1977, are self-adjusting and mean that time-consuming garage services are a thing of the past.





Two innovative Schaeffler solutions

The electromechanical roll stabilizer is adaptive and, thanks to an electric motor that only draws power when the swivel actuator twists, operates very efficiently. UniAir, the world's first fully variable electrohydraulic valve timing system (left), is an important key to increasing the efficiency of internal combustion engines



components to complex systems, and energy efficiency is a focal topic in this context.

The CO₂ concept-10% concept car is a case in point. In 2009, Schaeffler used this technology demonstrator based on a Porsche Cayenne to show the optimization potential yet

to be tapped even by modern automobiles. Equipped with a large variety of coordinated Schaeffler products, fuel consumption and CO₂ emissions drop by ten percent. In addition, the prototype of the electromechanical roll stabilizer was tested in this concept vehicle.

PROGRESS AND COMPLEXITY

Today – seven years later – the components shown back then, including electromechanical camshaft phasers and roll stabilizers, have become volume products. Progress never ends. Accordingly, modern automobiles are distinctly more complex than their ancestors. No matter how long the road may have been from the Porsche 356 to the 918 Spyder hybrid sports car – it's a road Porsche and Schaeffler have always traveled together. ■

PORSCHE 959 HIGH-TECH LABORATORY

The 959 of the late 1980s represents cutting-edge technology with its four-wheel drive and tire-pressure monitoring system. This sports car with a top speed of more than 300 km/h also features hydraulic chain tensioners. A Schaeffler invention, which also benefited drivers of the Porsche 911.



PORSCHE 911 (TYPE 996) EFFICIENCY

Porsche sets new standards in terms of efficiency and performance with the VarioCam Plus variable valve control system. The engine's characteristics can be matched to the relevant driving situation with this technology supplied by Schaeffler.



THE FUTURE TODAY

SCHAEFFLER CONCEPT VEHICLES



System 48 Volt

Schaeffler demonstrates the performance capabilities of 48-volt hybridization in a range of concept vehicles. The "System 48 Volt" based on the Audi TT is one of these variants. In this prototype, an electrified rear axle assists the internal combustion engine acting on the front axle. In addition, the concept uses a belt-driven starter-generator, which operates with 48 volts as well, combined with the internal combustion engine. This package is an attractive alternative to the complex high-voltage hybrid.



eWheelDrive

The wheel hub motor is a highly intriguing option resulting from the electrification of the powertrain. In the "eWheelDrive" concept vehicle based on the Ford Fiesta, an electric unit is used on the rear wheels. It features highly integrated wheel hub motors, with all the components required for propulsion, deceleration and driving safety arranged within the wheel rim: the electric motor, power electronics and controllers, the brake and cooling. This compact design enables all-new vehicle architectures.



ACTIVE DRIVE

This concept car operates as a fully electric vehicle and is even equipped with four-wheel drive. Two E-Axles sit underneath the body shell. They have two motors each and in between there is a transmission with an equally innovative lightweight differential. The larger of the two electrical machines provides the test vehicle with sporty performance. The smaller electrical machine enables torque vectoring, in other words, wheel-selective power distribution. This results in vehicle dynamics on the highest level. Equipped with this high-tech E-Axle, modern hybrid vehicles have electric four-wheel drive as well.

PORSCHE CAYENNE S HYBRID TWIN POWER

Porsche's first hybrid car. The hybrid module with an integrated electric motor sits between the internal combustion engine and the transmission. A hybrid clutch from LuK harmoniously modulates the interaction of the individual components.



PORSCHE 918 SPYDER HYBRID SPORTS CAR

The Porsche 918 as a hybrid sports car marks the top end of what is technologically feasible. This applies to the selection of the materials as well. The wheel bearings from Schaeffler are a case in point: here, ceramic balls replace the rolling elements normally made of steel. This saves 640 grams of weight.



FACTS AND FIGURES ABOUT THE LE MANS 24 HOURS



 **3m 17.475s**
Track record
(André Lotterer, Audi, 2015)

 **75 km/h**
Slowest turn

Arnage

Mulsanne

Indianapolis

Porsche curves

 **260 km/h**
Fastest turn

Ford chicanes

Hunaudières straight

-190 km/h
Longest breaking phase
(220 m)

Dunlop curve

Dunlop chicane

340 km/h
Top speed

+120 km/h
Longest acceleration phase
(1,930 m)

Esses

Tertre Rouge

21 turns

 **9** left

 **12** right

 **50** gear changes
per lap

TIMETABLE (CEST, LOCAL TIME)

Wednesday, June 15

16:00 Free practice 1

22:00 Qualifying 1

Thursday, June 16

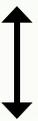
19:00 Qualifying 2

22:00 Qualifying 3

Saturday, June 18

09:00 Warm-up

15:00 24-hour race

 **13,629 m**
Track length



#1

 Timo Bernhard (35)
 Brendon Hartley (26)
 Mark Webber (39)



PORSCHE 919 HYBRID (LMP1)

 @porsche_team

- ▶ **Combustion engine** V4, turbocharger, 2,000 cc, <500 hp
- ▶ **Hybrid system** KERS at the front axle and exhaust gas energy recuperation, >400 hp via motor-generator unit (MGU)
- ▶ **Hybrid class** 8 MJ
- ▶ **Drive system** rear-wheel drive via internal combustion engine, temporary front-wheel drive via hybrid system (see above)
- ▶ **Energy storage system** Lithium-ion-battery cells
- ▶ **Minimum weight** 875 kg
- ▶ **Fuel tank capacity** 62.5 l
- ▶ **Height** 1,050 mm, **Width** 1,900 mm, **Length** 4,650 mm

#2

 Romain Dumas (38)
 Neel Jani (32)
 Marc Lieb (35)

