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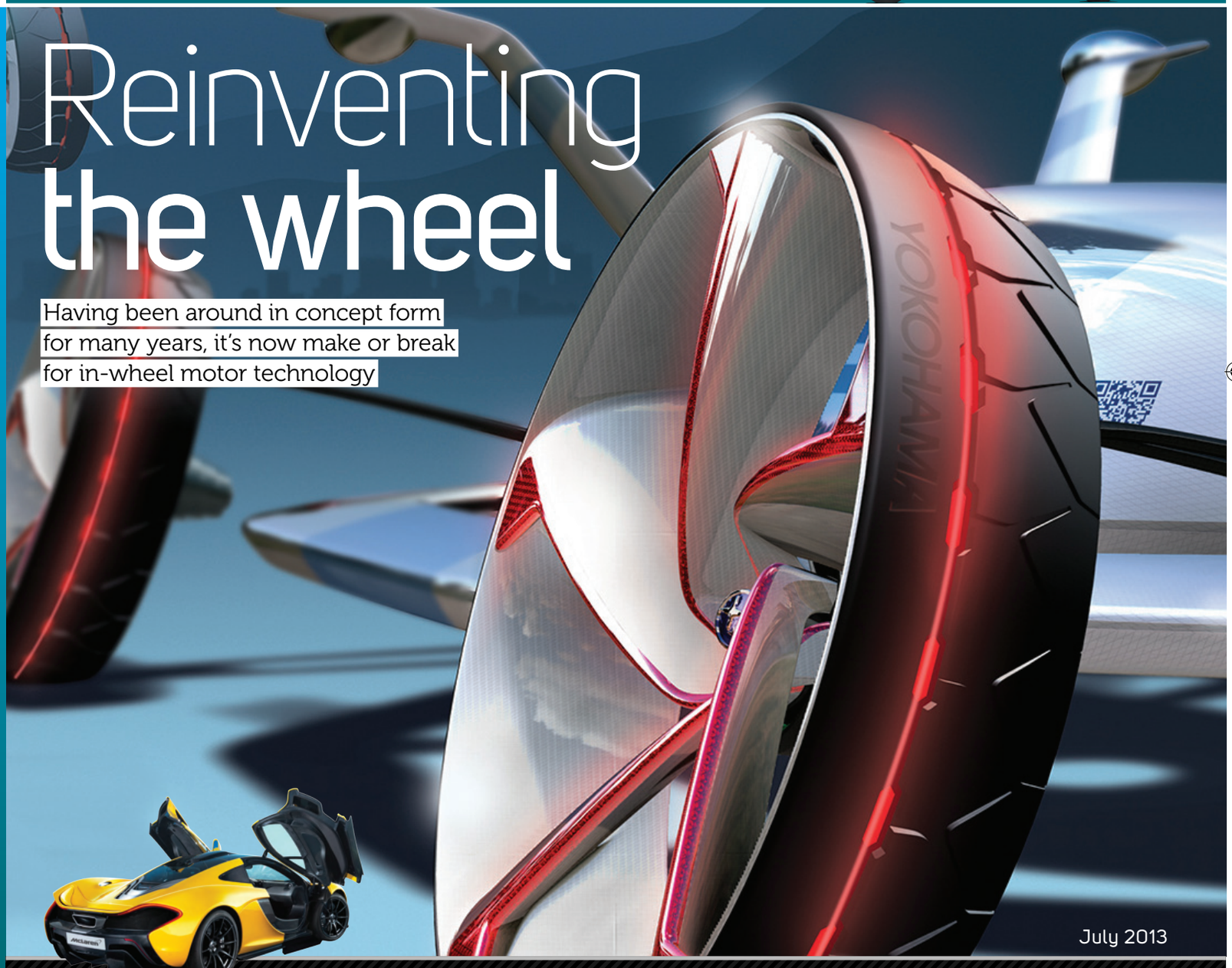

July 2013

HYPER ACTIVE

The inside story on the McLaren P1 – which pushes more than 900ps but has emissions on a par with a standard family hatchback

ELECTRIC EXTRAVAGANZA!

Exclusive features and interviews with senior engineers at Nissan, JLR, Qoros and General Motors

UNDER A CLOUD

Despite all the advances, does a continued lack of infrastructure mean that fuel cells are destined for failure?

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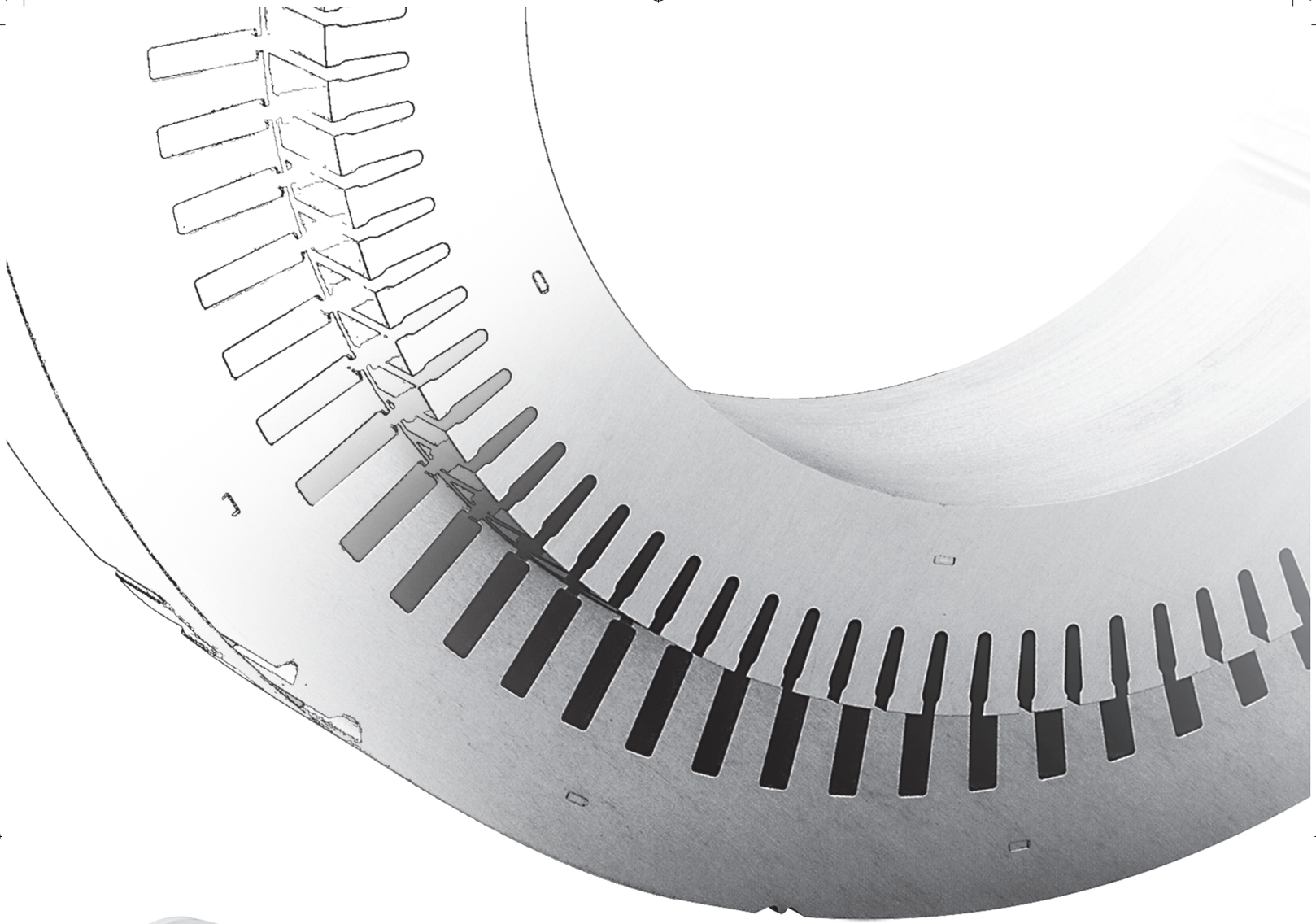

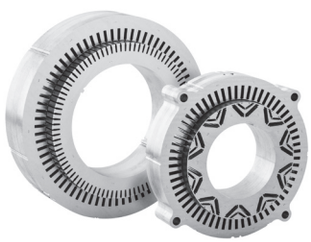

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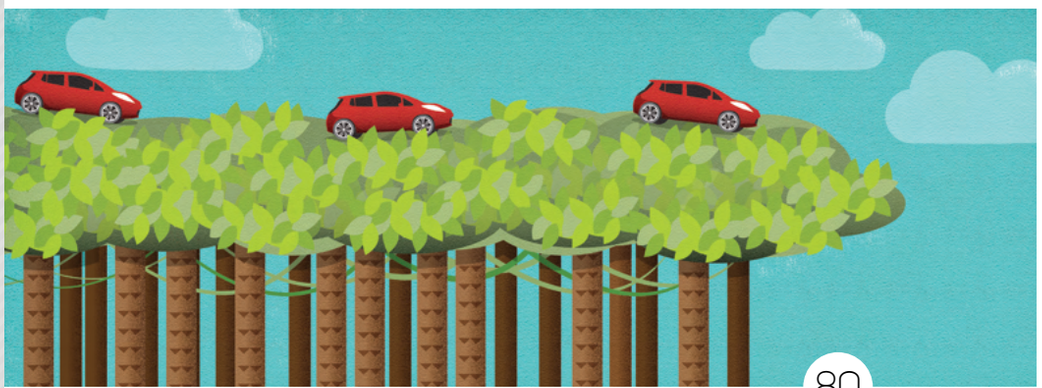

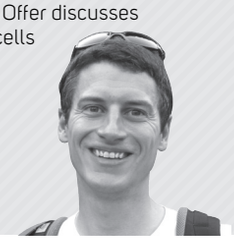

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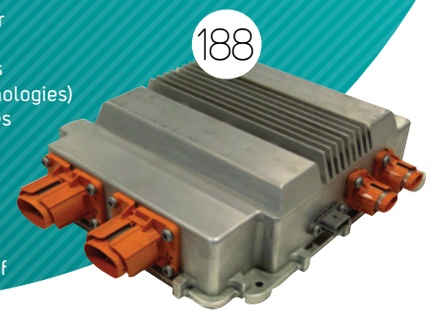

EDITOR'S NOTE

Two press trips that I have recently embarked upon have nicely encapsulated how different brands – and indeed varying automotive applications and subsectors – view the emergence of the all-electric powertrain.

At the supercar end of the spectrum, I was fortunate enough to visit the Ferrari factory in Maranello. It's only been in the past 10 years or so that bettering fuel economy and reducing emissions have come to the fore for Prancing Horse engineers during new development projects. This agenda started with applying direct injection to its IC engines – first seen on the V8 in the California, with now this technology gracing all of Ferrari's eight-cylinder and 12-cylinder designs – through to today's use of hybridization in the form of the LaFerrari creation. In fact, so important is this green mantra that Ferrari's charismatic president, Luca di Montezemolo, has safeguarded 50% of R&D budget across the next five years to focus exclusively on the development of emissions-reduction engine technologies.

How exactly this investment will shape up in terms of engine technologies is not clear, but di Montezemolo wanted to make two things clear: firstly, for now, hybrid technology will be limited to project LaFerrari only. Secondly, during his tenure – and there's no reason to suspect that di Montezemolo plans to call time on his very successful reign anytime soon – there will be no fully electric Ferrari development. In this part of the world, eight-cylinder and 12-cylinder designs (albeit in more environmentally friendly formats) are alive and well.

The message at Nissan couldn't be more different. Prior to turning up at Ferrari HQ, I was invited to Oslo to sample the new second-stage Leaf, which boasts more than 100 engineering changes to the model that was launched two years ago.

Why Oslo? Well, for Nissan, it's a leading European city that embraces EV driving, with electric vehicle users benefiting from tax breaks, free parking in the city center, free public charging and the use of the extensive bus lane network. While eight- and 12-cylinder engines sit in traffic, the Leaf (and its electric cousins) whizz by, beating congestion. Here, the EV is king – no country has sold more Leafs per capita than Norway.

Of all the engineering changes on the new Leaf, the greatest modification comes in the powertrain, which is lighter and more powerful, to the point that it can now cover a distance of 199km on a single charge. (Read more on p80.)

While I was with Nissan, I got chatting to Steve Groves, vehicle evaluation engineer for Nissan Europe, who mentioned a number of interesting things: a dirty grid doesn't necessarily equate to a dirty EV; fast charging is the key to the adoption of EVs on a mass-market scale; and that fuel cells are not the endgame but just part of a variety of solutions out there, which will also include hybrids, plug-in hybrids, third-generation full EVs, and further downsized diesel and gasoline IC engines.

The message stemming from these two car makers couldn't be more different. Yes, they occupy two ends of the automotive spectrum, and their culture, market expectations and heritage are poles apart, but it reiterates my personal outlook that this is the most exciting time to be a powertrain engineer. With so many solutions, so many technologies and so many innovations to pursue, the next decade – for all car makers, from Ferrari through to Nissan – holds much promise. I don't want to fast-forward through the next 10 years of my life, but personally speaking, I just can't wait to see how things pan out.

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"Our dilemma wasn't really 'should we go hybrid?' It was more 'should we go hybrid, if it makes the car slower?' And the answer to that will always be 'absolutely not'"

Dan Parry-Williams, chief design engineer, McLaren Automotive

Hyper active

WORDS: JOHN O'BRIEN

With the McLaren P1's power output exceeding 900ps, you'd be forgiven for thinking it is all about performance

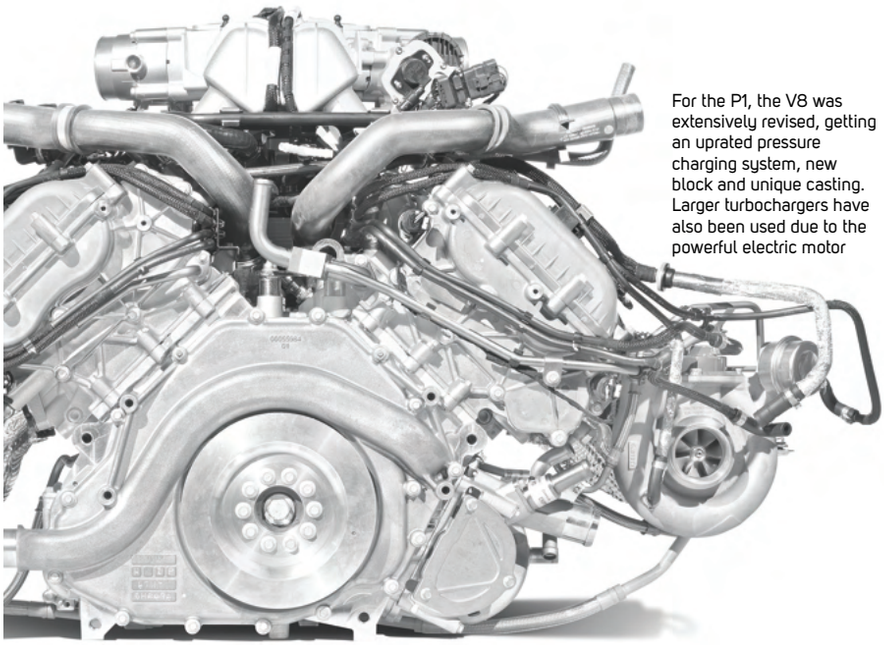
The new generation of hypercars is being sold on more than just top speed and peak power output. In fact, the latest figures touted by Ferrari and McLaren for their respective top-end creations are almost at odds with the very ethos underpinning the supercar idea. These machines are being marketed not on performance promises, but on their green credentials.

McLaren's P1 perhaps embodies this notion best, with the F1-inspired hybrid drivetrain that boosts power by an additional 179ps to a total of 916ps, while delivering emissions figures to rival a small hatchback. "We wanted to be pushing the technology, while reducing CO_2 emissions and wanting the technology in the cars to be relevant," explains Dan Parry-Williams, chief design engineer. "The world is changing, and just because we make supercars doesn't mean that we are immune to that fact."

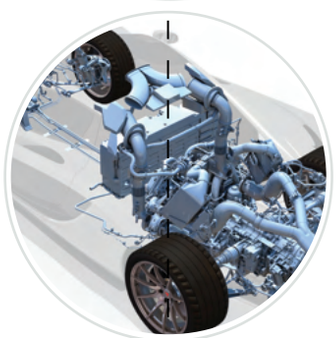
Hybrid judgment day

Core to the McLaren's powertrain is the internally developed electric motor, created by subsidiary McLaren Electronic Systems. The choice to go hybrid, however, was only finalized midway through the car's development. "The technology that was around when we started developing this car helped us to make an initial decision – we essentially said 'no' the first time," says Parry-Williams. "The specific power of the motors available at the time just wasn't enough. But when KERS took off in F1, the specific power of electric motors shot up, from 1-1.5kW/kg, to 10-12kW/kg."

As such, this F1-derived technology is key to the P1's ethos, with former McLaren F1 team member Richard Hopkirk becoming function group leader for the hybrid system and former Mercedes HPE team member, Axel Wendorff, also joining the P1's development program.



For the P1, the V8 was extensively revised, getting an uprated pressure charging system, new block and unique casting. Larger turbochargers have also been used due to the powerful electric motor



Above: The electric motor, created by McLaren Electronic Systems, is affixed to the V8 engine. The Axeon lithium-ion polymer battery is located within the P1's midpoint and weighs less than 100kg

Right: Initially the P1 was never intended to be a hybrid hypercar. That engine decision came much later during the development project, following enhancements made to KERS and electric motor technology

On the car itself, the electronics are perhaps the derived technology closest to motorsport. "We are closely related to F1 in the business and we knew the technology that had gone into the F1 car, so we revisited our original decision and thought we could push the technology further and make the car go faster too," Parry-Williams continues. "So we settled on 120-140kW as being the right size and decided that if it is going to be relevant it must have an EV capability as well. Those parameters pretty much outlined the system requirements."

These requirements mean that at the heart of the P1 is the M838T 3.8-liter twinturbo engine, as fitted to the 12C. Given the bespoke nature of the car, it is unsurprising to see a raft of revisions not only to the IC unit, but also in McLaren's relationship with development partner Ricardo. "It was somewhat different this time as we were pushing the envelope more with P1," says Parry-Williams. "This time we designed the engine and Ricardo simply builds it. So it is a little different in so much that they were carrying more of the warranty risk on the 12C than this time around, when we are."

The engine's revisions include an all-new pressure-charging system to optimize cooling and durability under higher loads, while the block has a new, unique casting to incorporate the electric motor and increase stiffness. "The motor bolts directly to the engine block," explains the chief design engineer. "The block is completely new for that reason. It also has an extra clutch on the back of it, which isn't needed normally, so that meant changing the back of the engine, while the block's ancillaries had to change to accommodate it too." Despite these revisions, the entire length of the drivetrain has only grown by around 50mm, enabling the P1 to maintain its squat proportions.

In achieving this goal, the packaging and positioning of the hybrid system gave McLaren's engineers a major challenge from the word go. "It's one of the first decisions you have to

POWER RANGER

While the McLaren's hybrid system is quite conventional in its fundamental principles, alternative solutions were considered in the early stages of development. "Normally the received wisdom is that batteries have better energy density than supercaps, but worse power density," explains Parry-Williams. "The cell chemistry that we've chosen has the same power density as a supercap, so in that respect there was no benefit to choosing those. The things that drove the system specification were a significant, so around 10 or 11km of range in electric vehicle mode. We definitely wanted a big reduction in CO_2 emissions and to achieve that you need a good EV range anyway. So it was power that we needed to focus on for acceleration in EV mode, and we needed to realize a certain power density in order to fit it in the space we identified. The number of cells is just a function of the range. So you basically end up with a series of fixed points, and this really dictates the technology. There are a number of requirements that mean, at the moment, lithium-ion batteries are the only viable solution."

make," continues Parry-Williams. "There are a number of factors beyond first sight that you have to consider. Obviously, there is the car's center of gravity. There's also the safety case analysis, so we have to consider the location of the pack in relation to other components. Then we have to think about crash scenarios and the best position for the pack in terms of protecting it as much as possible. We also have to consider the heat transfer from the engine, because the hybrid system doesn't want to run at the same temperature as the engine or gearbox. In fact, that's another challenge, so you have to manage that temperature delta, thinking about heat transfer from the main drivetrain. We have our battery pack on top of the fuel tank, albeit in a separate, sealed box. It's not in the same space, but geometrically it's above it. There is a small penalty paid with center of gravity, as we could have put it lower in the car, but we would have suffered with some of the other considerations. As in most things when designing, wherever we put it, there would have been a compromise."

VITAL STATISTICS

Layout: Longitudinal mid-engine, RWD with integrated lightweight electric motor
Engine configuration: V8 twinturbo 3,799cc
Engine PS/rpm: 737 at 7,500
Torque Nm/rpm: 720 at 4,000
Transmission: Seven-speed SSG
Powertrain modes: E-mode/ Normal/Sport/Track/ Race
Dry weight: 1,395kg

In achieving the hike to 737ps, the Ricardo co-developed IC engine has had turbo pressure increased to 2.4 bar, up from the 12C's 2.2 bar, while a dry sump and flat plane crankshaft have been added to the engine to help lower the center of gravity. The addition of the hybrid drivetrain has also allowed McLaren to remove the alternator and starter motor from the engine, ultimately removing weight. "We use a high-voltage battery as a load leveler," explains Parry-Williams. "Then we have a DC convertor that supplies the 14V to the low-voltage system on the car, enabling us to use the EV motor to start the engine."

Electric motor expertise

Despite the idea of a hybrid, ecological supercar being oxymoronic, as seen in past greats of this genre, the P1 uses its green additions to help boost performance. "Our dilemma wasn't really 'should we go hybrid?'," admits Parry-Williams. "It was more 'should we go hybrid, if it makes the car slower?'. And the answer to that will always be 'absolutely not'."

Affixed to the V8 is the internally developed electric motor. Running at twice the engine speed, the singular unit produces the equivalent of 260Nm and can deliver an additional 179ps when in IPAS mode – a system similar to F1's KERS device. Under normal circumstances, the motor is used to smooth the car's torque curve, giving instant throttle response. As a result of this linear delivery, McLaren was able to fit larger turbochargers to the engine, often ruled out due to the increased spool time, but ultimately capable of delivering even more power.

"We now have instant torque in all gears. We also have good acceleration in electric mode. It'll do 0-100km/h in 10 seconds, which is spritely and makes driving an EV really fun."

By Parry-Williams' own admission, the 12C-derived V8 was already optimized to its lowest possible weight, so any additional gains in the area of power-to-weight would have to originate from the hybrid system. "Ultimately we tried to design the lightest battery pack we could," he adds. "We have 70kg worth of cells and the entire pack weighs less than 100kg – which we feel is good considering that the battery management, cooling systems and interfaces are all included in that total. The motor is very efficient in terms of the power it can produce for its weight, and what's more, it can produce more power than it currently does in the P1. We quote the steady state power as 130kW, but the motor can provide more than that for short periods."

> "This time we designed the engine and Ricardo simply builds it. So it is a little different in so much that they were carrying more of the warranty risk on the 12C"
>
> Dan Parry-Williams, chief design engineer, McLaren Automotive

Despite the similarities between the P1's hybrid system and the F1 technology, the two developments are very different. McLaren's road car uses an Axeon-sourced Li-ion polymer battery, and is cooled by a traditional water-glycol mixture. The design of the motor is completely different, thanks to the differences in durability requirements between the two. "We've developed a hybrid system that we foresee won't need any maintenance over its lifespan, whereas with F1 it only has to last a weekend," states Parry-Williams. "They can change the pack after a weekend, and the team is always inspecting them. It's a completely different environment for the system to operate, in terms of expectation and lifespan, so it's not surprising that they've wound up different."

Dealing with such a unique drivetrain meant that there was no real benchmark. "There wasn't anything to go against. The Toyota Prius and the like are around 1.5kW/kg. And even now, if you go out and buy any new hybrid car, and try and use more than 10 or 20% throttle, the petrol engine kicks back in," says Parry-Williams. "In the P1, I've done 160km/h in electric mode. There is no limit to how fast you can go in EV mode. It's the battery capacity that's the limiting factor."

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Bright spark

The all-electric **Chevrolet Spark** is General Motor's first foray into the pure EV realm since the EV1 in the 1990s. But what did Detroit's largest car maker do differently second time around?

The Chevrolet Spark EV, GM's first pure electric passenger car since the EV1, not only looks set to right the wrongs of its mid-1990s predecessor, but could even set a new benchmark in EV powertrain development altogether.

Based on the third-generation Spark IC derivative, the Detroit-based OEM says it has produced the most efficient production electric vehicle in the world; a bold achievement that is all the more impressive considering that it is also one of the most powerful EVs.

Power to the people

Developed over three years and powered by a GM-built coaxial drive unit and a modified version of the Chevrolet Volt's permanent magnet electric motor, the Spark EV boasts a peak system output of 132ps and 542Nm of instantaneous torque – that's more than the Ferrari 458 Italia and Porsche Carrera S – enabling 0-100km/h acceleration in 7.6 seconds. But why pack so much impressively powerful powertrain technology into a five-door urban mini vehicle? According to Larry Nitz, GM's engineering director for electric and hybrid powertrain development, the company is responding to consumer demand.

In an exclusive interview with *E&H*, Nitz explains, "The idea of understanding the customer was very clear, which in this case was the urban commuter. The price of the car after tax will be under US$25,000, so it has a value-oriented place in the market, and will save more than US$9,000 over five years in fuel costs. We wanted to deliver customer value in a segment that customers want, at a price they can afford, while also delivering something more than our competitors are offering in terms of performance."

The Spark is equipped with a 254kg, 336-cell, 21kWh lithium-ion battery supplied by A123 Systems – which declared bankruptcy during the EV's development and was subsequently bought by Chinese auto supplier Wanxiang Group. Nitz says his company is "now working with Wanxiang to provide these batteries and we've had no interruption in engineering, development, validation or production supply".

1

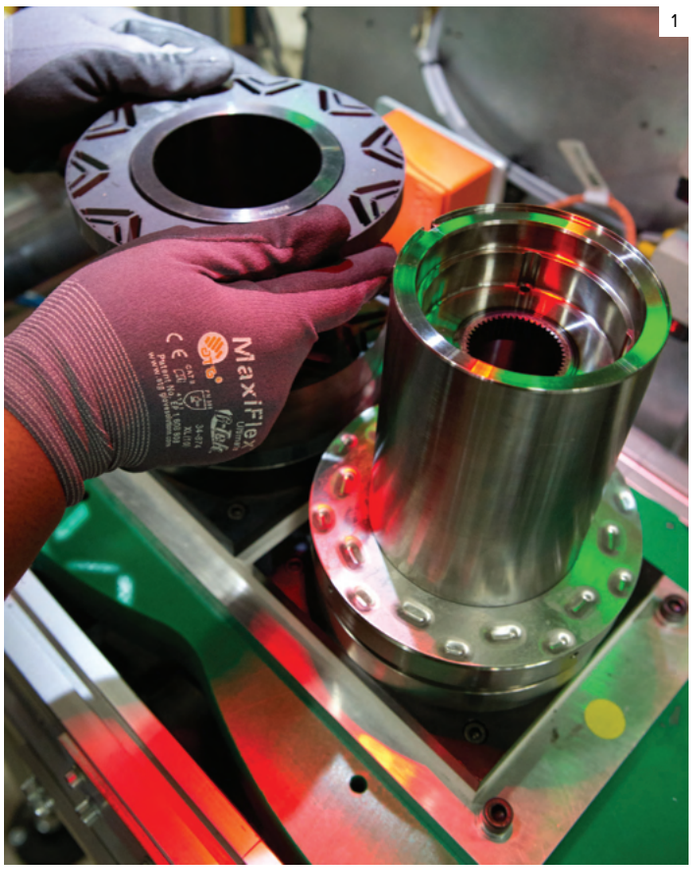
VITAL STATISTICS

Top speed: 145km/h
0-100km/h: 7.6 seconds
Torque: 542Nm
Power: 131ps
Battery: 254kg, 336-cell, 21kWh lithium-ion
Driving range: 132km (EPA estimate)
Fuel economy: 119mpge

2

1. With two reconfigurable, HD, full color LCD screens, the Chevrolet Spark EV features a customizable interface with confidence gauge

2. The Chevrolet Spark EV will go on sale initially in California, Oregon, Canada and South Korea later this year. European customers can expect it to arrive in selected markets in 2014



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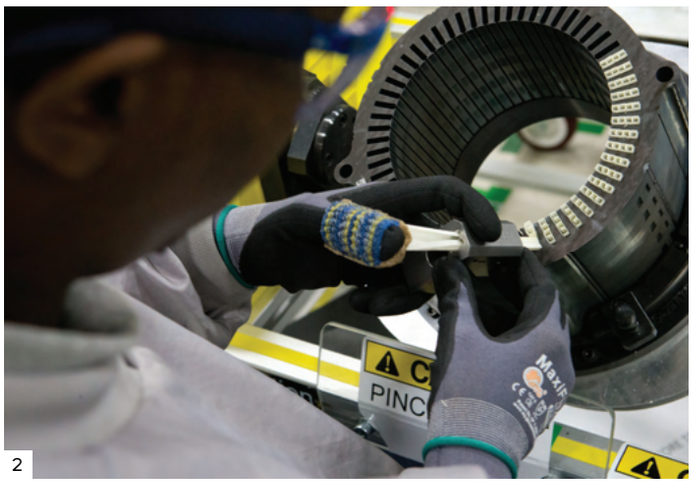

2

1. The Spark EV is powered by a modified version of the Chevrolet Volt's permanent magnet electric motor

2. GM manufactures the electric motors for the Spark EV at a facility in White Marsh, Maryland

3. The tiny GM city car can achieve a combined fuel economy of 119mpge

4. The Spark EV charges up to 80% in 20 minutes with SAE Combo fast charger

As such, this tiny city car can achieve a combined fuel economy of 119mpge (2.3 l/100km) with an energy consumption of 28kWh, and a US EPA-estimated range of 132km. This puts the Spark EV in the same range as the Honda Fit EV, but just under the Fiat 500e, which can go around 10km further on a full charge. However, the Fiat has a larger battery than the Spark and the Honda gets 118mpge – meaning that neither is as efficient overall as GM's new electric offering.

Of the impressive range, Nitz says, "We wanted to make sure the car delivered the range. The displays and gauges are specifically designed around a simple way of illustrating that drivers are going to have that range. If you listen to the feedback of some of our competitors, they have range that is fickle – it changes without driving much – and so we wanted a way to illustrate, based on how the customer is driving, what we think the expected range is and what it could be under different driving behaviors. Typically EV drivers only feel confident enough to take their car out when they know they can definitely get there and back. So we wanted to provide a means to extend the 'confidence limit' so that the customer would be more reassured when driving the car. And I think we've hit that."

3

4

Voltec crossover

The Spark also employs some of the same electrical power technology used in the Chevrolet Volt, such as regenerative braking, which harnesses and reuses energy otherwise lost while braking, decelerating or going downhill.

The battery, which operates with the help of an active liquid cooling and heating system, has been engineered to enable both regular AC and DC fast charging, and the Spark is the first EV in North America to offer the SAE Combo DC Fast Charging capability, which charges the battery to 80% capacity in about 20 minutes. However, a full charge using a dedicated 240V outlet takes around 7.5 hours with the 3.3kW charger – a disappointing aspect for some when considering the size of the battery.

Nitz, though, doesn't see much benefit in using a more powerful charger due to consumer habits. "We considered using a 6.6kW charger, but we have a lot of data from Volt customers about how they drive their vehicles and we've come to a pretty firm conclusion that if we can get an overnight charge – which is what people are depending on – down to around nine hours, then we're comfortable with that. It's simply a matter of not needing it to charge more quickly overnight."

Though Nitz says GM considered the Nissan Leaf as a benchmark, he claims "the Spark EV won't be a typical vanilla EV like a Nissan Leaf – it'll be a lot more fun to drive", and says they also benefited from using their knowledge acquired during the EV1 era. "The EV1 had very enthused customers. It didn't have as much performance as the Spark EV, but they loved the performance it did have. Times have changed but people generally haven't, and that understanding helped when benchmarking the Spark EV."

Details are sparse regarding testing of the Spark EV, with Nitz only willing to share that prototypes were put through a capture test fleet in different environments in Michigan and California. However, Pamela Fletcher, Chevrolet's executive chief engineer of electrified vehicles, says the battery "has undergone more than 200,000 hours of testing, and the same abuse tolerance testing as the Volt battery".

And the biggest engineering challenge Nitz's team faced while developing the Spark EV? Successfully keeping the vehicle's curb weight beneath 1,365kg, and producing an EV with the highest efficiency without sacrificing performance.

The Spark is set to go on sale initially in California, Oregon, Canada and South Korea later this year; European customers can expect it to arrive in selected markets in 2014.

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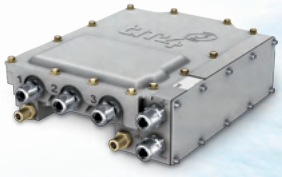

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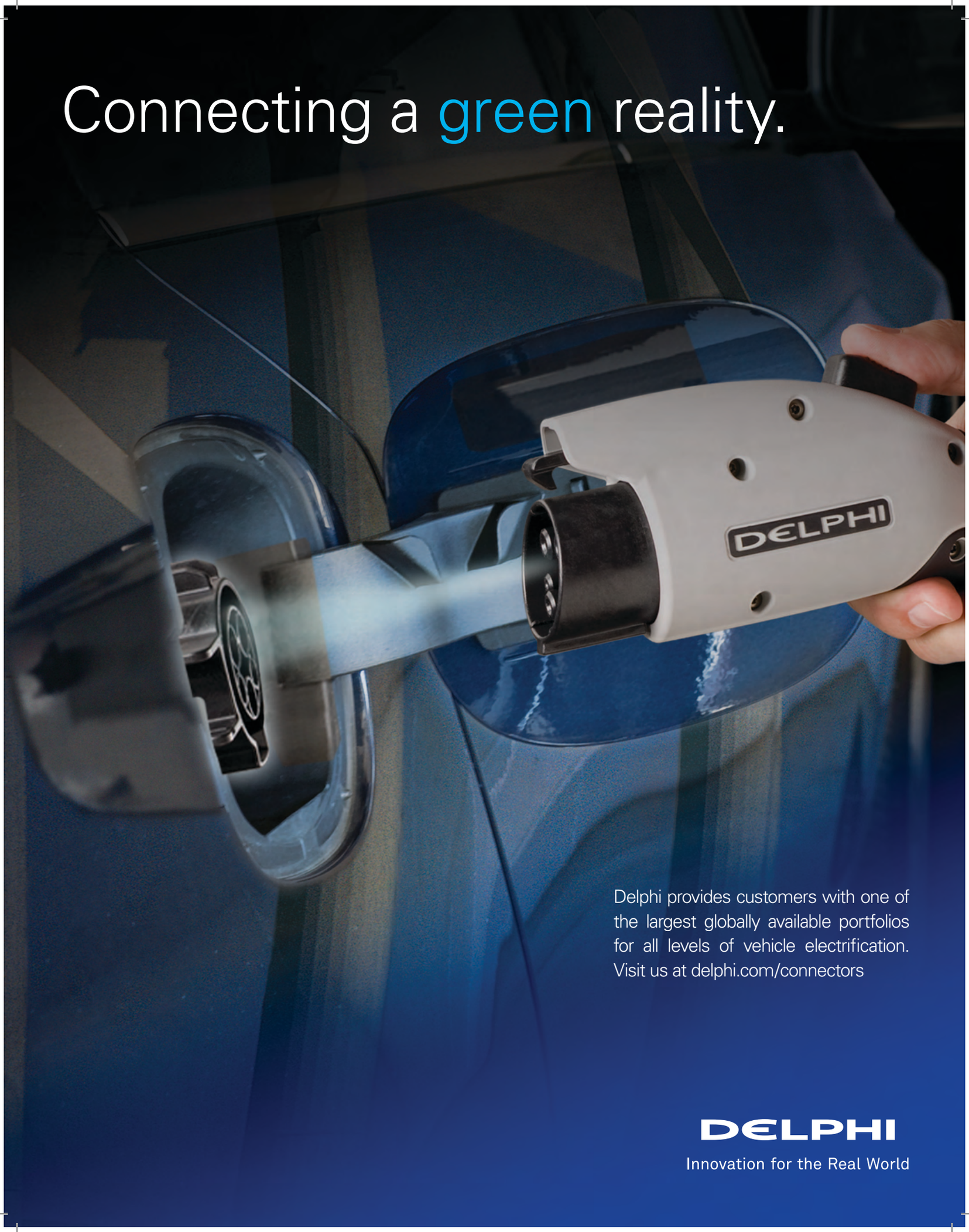
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Rite of passage

Audi has added a new chapter to its electric vehicle development program – the A3 Sportback e-tron

Audi continues to press ahead with the development of powertrain electrification following the latest installment of its e-tron project, which, at the Geneva Motor Show earlier this year, came in the form of the A3 Sportback.

Boasting an innovative parallel hybrid plug-in setup in combination with a slightly modified 1.4-liter TFSI engine, the A3 Sportback e-tron concept is home to numerous technical highlights, including a new disc-shaped electric motor that is integrated into a newly designed six-speed e-S tronic gearbox that transfers power to the front wheels of the vehicle. The TFSI unit has been tuned to deliver 150ps and 250Nm of torque, while the electric motor supplies an additional 75kW and 330Nm of power. The latter powerplant develops its peak torque output from start to around 2,000rpm, and the IC engine's maximum pulling power is available in a range from 1,750rpm and 4,000rpm.

Housed within a space-efficient, crash-protected location in the floor underneath the rear seats of the A3 Sportback e-tron is a high-voltage lithium-ion battery that offers 8.8kWh of capacity. The battery, which sits in a housing made almost entirely from aluminum, comprises eight modules with a total of 96 cells, and manages to maintain its optimum temperature range thanks to a liquid cooling system that boasts its own low-temperature circuit. Audi says this innovative setup is key to the total power of the A3's electric drive unit, which remains available at low ambient temperatures.

The concept's power electrics sit in the engine compartment of the five-door Audi, and these subsystems convert the direct current from the battery into alternating current to power the motor. The compact unit, with an integral DC-DC converter that supplies the 12V electrical system, shares the same cooling circuit as both the battery and the charging device.

Real-world data

Such technical and engineering innovations mean that the A3 Sportback e-tron offers a driving range of 50km in all-electric mode and 340km in total with the IC engine included.

Audi's latest e-tron tech demonstrator features a plug-in hybrid setup that consumes, on average, 1.5 liters/100km of petrol and emits just 35g/km of CO_2 emissions

FROM E-TRON TO G-TRON

Audi's sustainable transportation model not only includes powertrain electrification developments such as the A3 Sportback e-tron, but also the widening use of alternative fuels such as CNG.

Shown next to the A3 Sportback e-tron at the Geneva Motor Show 2013 was the A3 Sportback g-tron, a CNG-powered working concept that will be put into production later this year.

The design sees two tanks placed under the luggage compartment of the A3 g-tron that can hold 7kg of CNG at a maximum 200 bar pressure. Thanks to a new intelligent type of matrix, each tank weighs an impressive 27kg less than conventional counterparts currently on the market. The inner layer of the tank consists of gas-impermeable polyamide polymer, while a second layer of carbon fiber-reinforced polymer adds strength to the subsystem. Finally, a third layer of glass fiber-reinforced polymer provides the tanks with protection against everyday damage from the outside.

A second technical highlight of the A3 Sportback g-tron is its electronic gas pressure regulator – a lightweight and compact component that reduces the high pressure of the gas flowing from the cylinders down to around 5-9 bar in two stages. This clever subsystem also ensures that the right pressure of gas is always present in the gas rail and at the injector valves – with low pressure for efficient driving in the lower speed range and higher pressure when the driver calls for more power and torque. If the pressure in the tank drops to below 10 bar, the engine management system automatically switches to gasoline operation.

As such, the A3 Sportback g-tron, which boasts very impressive CO_2 tailpipe emissions of less than 95g/km of CO_2 in gasoline mode, offers a total CNG driving range of 400km, while the modified 1.4-liter TFSI engine provides an additional 900km of driving – meaning that for Audi, CNG is on a par with TDI when it comes to range. The concept, says Audi, consumes on average 3.5kg per 100km of CNG, so the A3 Sportback g-tron boasts combined CO_2 emissions of 30g/km. Power is rated at 110ps and 200Nm of torque, allowing the CNG Audi to have a top speed of 190km/h (118mph) and a 0-100km/h sprint time of 11 seconds.

For the A3 Sportback g-tron project, Audi powertrain engineers have had to make key modifications to the new EA211 1.4-liter TFSI unit, with major changes relating to the cylinder head, turbocharging, injection system and the catalytic converter subsystem.

1

1. From behind the wheel of the A3 Sportback e-tron, there is decent performance to be had thanks to the 150ps and 250Nm of torque from the TFSI unit, plus the additional 75kW and 330Nm being developed by the e-motor

2. The concept A3 Sportback e-tron features a high-voltage 8.8kWh lithium-ion battery pack that's located in the floor beneath the rear seats

When drive is powered from the electric motor, a top speed of 130km/h (81mph) is possible. Using power from both drivetrains, the A3 e-tron's top speed is rated at 222km/h (138mph) and the 0-100km/h sprint time takes 7.6 seconds. According to the ECE standard for plug-in hybrid automobiles, the Audi concept consumes on average 1.5 liters/100km (156.8mpg) of fuel, which translates to CO_2 emissions of 35g/km.

Interestingly, the A3's vacuum brake servo has been designed to have an additional supply connection that is served by an electric vacuum pump. Audi says that the hybrid management is tuned to be responsive with the electric motor. Up to moderate braking forces, the electric motor – which in this guise operates as an alternator – supplies most of the retardation and recovers much of the energy expended so that it can be channeled back into the battery. The wheel brakes only become active if and when the driver presses the brake pedal more forcefully.

In addition to the all-electric mode, the A3 concept can also be driven with just the IC engine providing power or in a hybrid combination. The vehicle's charging socket is located behind the four rings of the Audi in the radiator grille. The battery can be fully charged in around two-and-a-half hours with a 3.6kW charger.

2

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Comfort zone

Can an eco-friendly range-extender vehicle also be luxurious, sporty and upmarket? That was the challenge GM faced when developing the powertrain for Cadillac's latest product offering

Following its debut under the guise of the Cadillac Converj concept at the 2009 North American International Auto Show, GM's long-time-coming plug-in range extender application for its luxury brand finally returned to the annual Detroit event in production form earlier this year, sporting a new name and some intriguing powertrain technology developments.

Now dubbed the Cadillac ELR, the 1.4-liter luxury coupe is powered by GM's first derivative of the Chevrolet Volt's Voltec electric propulsion system. Manufactured and re-engineered at the company's Detroit-Hamtramck assembly plant, the unit encompasses GM's T-shaped, 198kg, 288-cell, 16.5kWh lithium-ion battery pack and a four-cylinder naturally aspirated gasoline-powered IC engine that acts as a generator. However, the main difference is a reprogrammed electric-drive controller that allows more current to flow from the battery, resulting in 210ps and 400Nm of torque – boosting system output by 59ps and 30Nm over the Volt. Add to this an estimated 0-100km/h acceleration time of around eight seconds – more than one second faster than the five-door Chevrolet hatchback – and GM's intentions for the ELR's powertrain become clear: this is a sportier, sleeker and more dynamic range-extender vehicle.

"It's an all-new vehicle upper and we've increased the power and performance of the electric drivetrain to give the type of performance that we expect from a Cadillac," states Larry Nitz, GM's engineering director for electric and hybrid powertrain development.

1

VITAL STATISTICS

Energy supply: T-shaped battery, 288-cell, 198kg, 16.5kW, lithium-ion

IC engine displacement: 1,398cc

Bore & stroke (mm): 73.4 x 82.6

Compression ratio: 10.5:1

Output: 85ps at 4,800rpm

Motors: Drive motor 117-135kW; generator motor 55kW

Transaxle: Voltec electric drive system

Evolution not revolution

But has the technology really progressed all that much? According to GM, the ELR can deliver about 56km of pure electric driving and a full driving range of 480km. That's 5km less than the Volt's all-electric driving capabilities and 131.6km less than the Chevrolet's overall range.

However, Nitz is quick to point to the addition of an all-new and exclusive powertrain feature to the ELR that demonstrates just how innovative the technology is. "Some of the improvements we've made enable the ELR to have some specific nuances that are unique to that vehicle, such as the paddle shifting capability," he says. "All Cadillacs have it, but we retrained it specifically for the ELR to become regen on demand – so an electrohydraulic regenerative brake system. When the driver pulls a paddle on the steering wheel, it sends a command to the software that helps to temporarily regenerate energy from the car's momentum into electricity that can be stored in the battery pack for later use."

Similarly, there are selectable drive modes, such as the hold mode, which puts energy back into the battery as the car slows down, while mountain mode allows the ELR to sustain a sufficient state of charge so that supplemental power is available from the battery when needed.

The ELR's battery can be fully restored in around 12 hours with a 120V electrical outlet or in just 4.5 hours using a dedicated 240V electrical charging station. In terms of fuel economy and emissions, Nitz says exact figures have yet to be released. However, ELR does feature a close-coupled catalytic convertor; 58x ignition system; returnless fuel rail; and fast light-off O_2 sensors. Crucially, its enhanced AT-PZEV emissions also meet California's criteria for single-occupancy access to high-occupancy vehicle lanes.

When asked whether the reason that the original Converj concept was cleared for production in 2010 but then canceled by top management a year later was an inability to create an acceptable balance of luxury appointments and battery range, Nitz flatly denied the claim, and posits that the Converj was only ever a concept vehicle.

In any case, subsequent real-world testing of the ELR has been extensive. Since mid-2012, prototypes have been exposed to extreme weather conditions, including 101mm of snowfall in Michigan's Upper Peninsula, and temperatures reaching -40°C in cold chambers in northern Ontario, Canada. This has enabled engineers to test the performance of the ELR's extended-range generator and finesse the traction control, antilock brakes and electronic stability control technologies.

"We're very proud of what we're putting together here for the Cadillac brand," adds Nitz. "It's a car that balances electric driving and uninhibited range; a car that's very dynamic and right in line with the Cadillac brand image."

2

1. GM's Voltec propulsion system, which debuted in the Chevrolet Volt, has been revised for the Cadillac ELR

2. The new range-extender setup in the ELR offers 59ps and 30Nm of torque over the Volt powertrain

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Range: 210km
Standard consumption: 146Wh/km
Top speed: 135km/h
Acceleration 0-100km/h: 13.5 seconds

Viva la Zoe

Flagship to Renault's revised line-up is the Zoe. Not a luxury sedan or thoroughbred sports car, but a C-segment, all-electric hatchback that is aiming to kick-start the mass market electric vehicle revolution

Renault took a bold move when it decided to radically overhaul its model line-up, canning familiar and well-established names and models in favor of an all-new range with an emphasis on electric power. The jewel atop the crown is the all-new Zoe, a C-segment hatchback that Renault hopes will capitalize on the current efficiency trend, on both sides of the Atlantic.

Development of the Zoe began in 2008 and followed a very similar pattern to that of an IC engine, closely mirroring the Clio 4 program. "That was a deliberate choice," explains David Twohig, Renault's deputy technical director for the Zoe project. "As the product was going to be extremely innovative, we didn't want to also reinvent the process of how to design a car."

Sticking to traditional timing schedules, and using existing tooling and machinery, meant that the Zoe's development easily hit the first of three main criteria outlined by Renault – cost. "We didn't want it to be a niche product, or for it to be exclusive for the wealthy," explains Twohig. "It had to be affordable and that meant we had to count the euros from day one."

ZOE'S NEW SHOES

Enhancing the range of new technologies on board the Zoe are the car's new tires. The Michelin Energy E-V tires are specifically designed to complement the car and optimize range. In most instances, tires account for up to 30% of the energy consumed by an electric powertrain. The complex formulation that makes up the carcass of the Energy E-V tire prevents deformation in the tire body. This reduces rolling resistance through heat build-up. However, rather than simply make the sidewalls incredibly stiff and encroach on ride comfort, the special compound is capable of flexing under braking – heating the contact patch and ultimately reducing braking distances when needed.

Maximum expression

The two other main criteria Renault outlined were desirability – with Twohig stating that Renault didn't want "a glorified golf cart" – and range. Despite an alleged equal weighting between the three points, range is still one of the biggest discussion topics when it comes to electric vehicles. To combat this, Renault has ensured that the Zoe has one of the best ranges in its class.

This is, in part, thanks to the continuously evolving powertrain from supplier, Continental. A 22kWh NEC lithium-ion battery sits under the floor and powers a 65kW (88ps) AC electric motor, which drives the front wheels. The highly efficient drive motor, power electronics, and hardware for the electric vehicle controller are all supplied by the German tier 1, and have been tried and tested in Renault's Kangoo and Fluence Z E models.

The 5Agen2 powertrain in the Zoe takes this basis and adds an all-new, fast-charge power electronics module. This fast-charge system is capable of adapting to the power supply available, be it single or three-phase, up to 43kW. As a result, the Zoe can charge its battery to 80% in just 30 minutes.

This puts it far ahead of the cars Renault benchmarked for range and charge time. "The benchmark when it comes to electric vehicles is the Leaf," explains Twohig. "We obviously have the advantage of having that in the family, so we took the good parts of that car, and improved on them. We also looked at other cars such as the Polo for quality, the Fiesta for ride and handling, as well as the small Korean competitors."

It is this split approach to the Zoe, as both a new car and a new EV, that provided Renault with its biggest headache. "The technical challenge was managing to keep those two strands going at the same time," Twohig adds. "It was almost like doing two cars in one. Doing that while bringing several worldwide innovations was a hell of a stretch for the team."

Setting the bar

There are two further major firsts aboard the Zoe: a second-generation regenerative braking system, supplied by Bosch, and the revival of the heat-pump – a technology that has laid dormant since the disbandment of GM's EV1 program.

Bosch's second-generation regenerative braking system differentiates itself from earlier versions by allowing the driver not to directly influence the hydraulic braking system when the brakes are applied. "When you operate a regular system, it just wastes energy that becomes heat," explains Twohig. "In the Zoe, you're sending a signal to the ECU, which talks to both the motor and the brake system. If the motor can supply more generative force and slow the car down more, the system will ask the motor to do so, blending the brakes in as necessary to finish the braking maneuver."

This live electronic control constantly blends the two systems to give the maximum braking force, and helps achieve a 10% gain in range as a result.

The heat-pump system on board the Zoe was inspired by concepts used in housing, and lays claim to being the first fitted to a mass-production vehicle. The system has had special control algorithms developed to take account of the thermal inertia of the cabin. To cool the cabin, the system works in the same way as a normal electronic air conditioning arrangement. But to heat the car, the system simply reverses the cycle of operation; trapping calories in the ambient air outside the vehicle, compressing and heating them, before directing the heat into the car.

The inclusion of these two innovations has resulted in the Renault Zoe being the first production electric vehicle to have a NEDC homologated range of over 200km. And Renault states that the innovations that make up its 'OptimiZEr system' are responsible for an overall increase of 25% in range.

The Zoe is a key car for Renault, and it has been embraced early in its native France – outselling the Nissan Leaf eight to one in its first few months of sales. Renault is adamant, thanks to increasing fuel costs and ecological awareness teamed with advances in technology, that the dawn of the electric vehicle is now upon us.

"There will be a moment of catalyst where the car is there, the infrastructure will come, and the conditions are suddenly right for this to take off," concludes Twohig. "We genuinely think Zoe will be the car to tilt the balance and allow the EV market to take off."

The 5Agen2 powertrain in the Zoe consists of an AC electric motor capable of producing 88ps and 220Nm of torque

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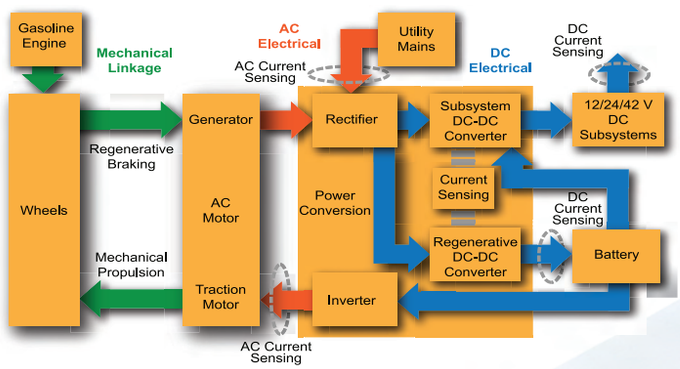

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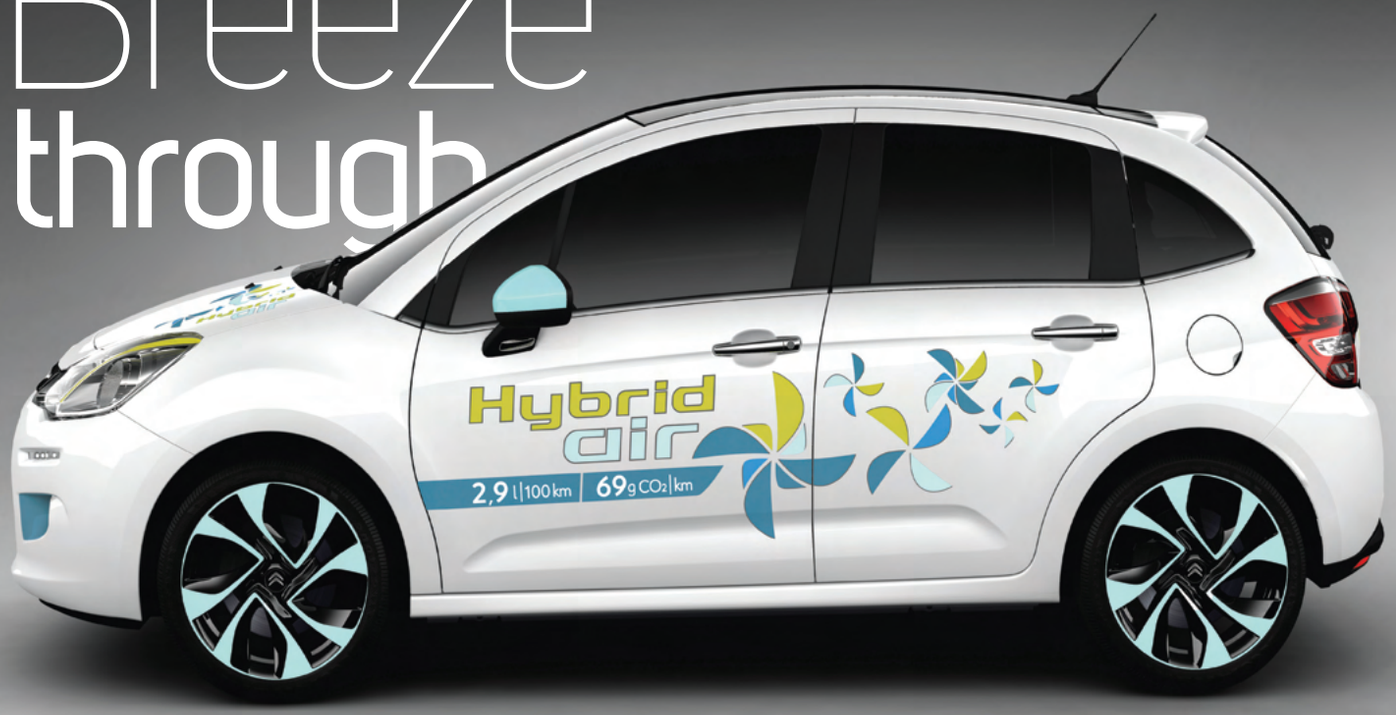

Advanced in terms of its design, yet simple to apply, PSA's latest hybrid powertrain innovation – which promises to drastically slash emissions – could be the right solution at the right time for the automotive industry

Now for something different: a groundbreaking powertrain solution that dramatically reduces emissions and improves fuel economy, but does not need high-tech battery technology or expensive rare earth materials and is not reliant on some sort of new refueling infrastructure or service maintenance network. Welcome, then, to the world of Hybrid Air, an interesting innovation from PSA Peugeot Citroën and its supplier partner Bosch that in many respects could be the holy grail of powertrain developments.

Housed in Peugeot 2008 and Citroën C3 tech demo vehicles, Hybrid Air combines drive from PSA's latest 1.2-liter VTi three-cylinder petrol engine and compressed air to realize fuel economy of 2 liters/100km (140mpg), which the French OEM hopes will help it to reduce its average fleet CO_2 emissions to 116g/km by 2015/16.

The entire setup comprises an energy tank that contains pressurized air and is housed under the body of the vehicle in a central tunnel; a low-pressure tank at the rear suspension crossmember acting as an expansion bottle; and a hydraulic unit consisting of a motor and a pump that is installed under the hood and on the transmission.

The electronic gearbox control drivetrain, says Dr Karim Mokaddem, executive manager for the change acceleration process and disruptive innovation at PSA, plays a crucial role in the arrangement of the technology, managing the dual-sourced energy from the IC engine and compressed air tank in the most efficient way. "The gearbox is something we have worked a lot on in-house – it really is the brain of the system," he adds.

Fourth-generation prototype

Mokaddem says his team started working on the Hybrid Air in 2011, but development has been fast paced. "It has been a short time-cycle, for sure – we started from a blank sheet of paper only two years ago."

But in those short 24 months, the team has managed to develop – and fully analyze in the real world – four prototype generations of Hybrid Air, in the process making sure that they control any potential negative factors that could detract from PSA's pursuit of the technology long term. For Mokaddem, it's a failsafe strategy that ensures the French car maker doesn't lose out in a monetary sense: "We decided we're not going to lose money [with this development]. So each time we hit a milestone, we assessed the technology and then proceeded." As an example, early on during the program, the team had to make the technology more competitive against current powertrain solutions, so the system's architecture was fully revised.

In just 24 months, PSA's Hybrid Air team has assessed four prototype generations of the technology on Peugeot 2008 and Citroën C3 concept tech demonstrator vehicles

TEAM PLAYERS

A new technology such as Hybrid Air could not have come about from a conventional program, says Mokaddem, who adds that the project brought together 200 specialists from many different strands from within PSA Group. "We have tapped in to competencies on the IC engine side, which is obvious, but we have also used competencies for the system management of the hybrid unit, which comes from the capability we have amassed from the Hybrid4 project. In addition to this, we have competencies coming from the hydraulic world – and this is a key point. We have mixed all these different engineers and many others who, in normal situations, would not work together so closely. That's a challenge – but also an advantage – to developing this technology."

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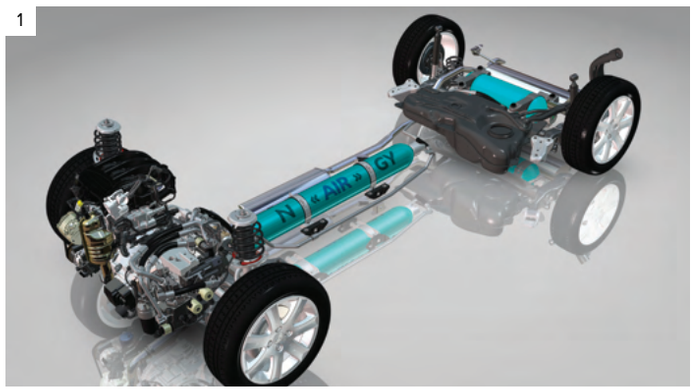

1. PSA has so far filed 80 patents for Hybrid Air. The aim is for the technology to hit the market by 2016

2. Mokaddem says Hybrid Air is easily applied to existing architectures, with crucial factors such as occupant space, modularity and fuel tank capacity remaining unchanged

The PSA executive manager continues, "One of the key points during the creation of these four generations of technology is that we have increased our knowledge and competitive advantage of system control."

For Mokaddem, this last point is very important: "What is behind this technology is not only that we are able to control the energy that is coming from the engine, but also the energy coming from the hydraulic components, and much of this is down to the very intelligent gearbox that we have designed."

Hybrid Air has been created to offer three states of driving in the real world. In Air (ZEV) mode, only energy contained in the compressed air tank will drive the vehicle. As it depressurizes, the air occupies an increasing amount of space in the energy tank and thus displaces a corresponding volume of oil. This "energy carrier", as Mokaddem terms it, supplies the hydraulic motor that is coupled with the drivetrain. With the IC engine not operating at all in this mode, the vehicle moves without consuming fuel or emitting CO_2 emissions. In petrol engine mode, the 2008 and C3 prototypes are powered solely by the three-cylinder engine, while in combined mode, the third state of driving that's available with Hybrid Air, the IC unit and hydraulic motor operate simultaneously to move the vehicle in its optimum state with regards to specific driving conditions. For this latter mode to happen seamlessly, Hybrid Air has been designed to supply energy to the hydraulic motor from two sources: the pressurized air tank, which PSA says contains plenty of energy to fulfill the needs of the driver, as well as using the hydraulic pump directly.

The technology, says Mokaddem, has great potential, particularly in the B- and C-segments of the automotive industry. PSA reckons driving in Air mode can be realized 80% of the time when commuting in urban areas, resulting in a 45% reduction in fuel economy. In fact, one recent homologation cycle test resulted in a figure of 2.9 liters/100km (97.4mpg) for Hybrid Air and CO_2 levels of 69g/km. What's more, Mokaddem adds that there are other important aspects to Hybrid Air, including smooth driving due to the automation of the transmission and the fact that the technology is compatible with existing platforms – to the point that occupant space, modularity and even fuel tank capacity remain unchanged.

2

New suppliers

For now, though, the further development of Hybrid Air is the focus for Mokaddem and his team, who have so far filed 80 patents relating to the inner workings of the system. However, there are challenges that fall beyond the scope of PSA that Mokaddem is fully aware of: "The great hurdle that we have is linked to industrialization. The components that we have in our prototypes are components and subsystems that come from aeronautics and other such industries, which means that today they do not fit in terms of the current needs of the automotive market for mass production. This is a hurdle that we need to work on, but it's something that we can't do on our own, and that's why we are partnering with Bosch in order to overcome this issue."

In a telling final statement, Mokaddem adds, "To get this technology to market by 2016, we need to work with the only supplier that has mass production control competencies, but also competencies when it comes to hydraulics for the mass market, and the only supplier that can play those cards is Bosch. But if – as we expect – this technology is to be deployed in the mass market, then there will be a new set of players in the automotive supplier pool very soon."

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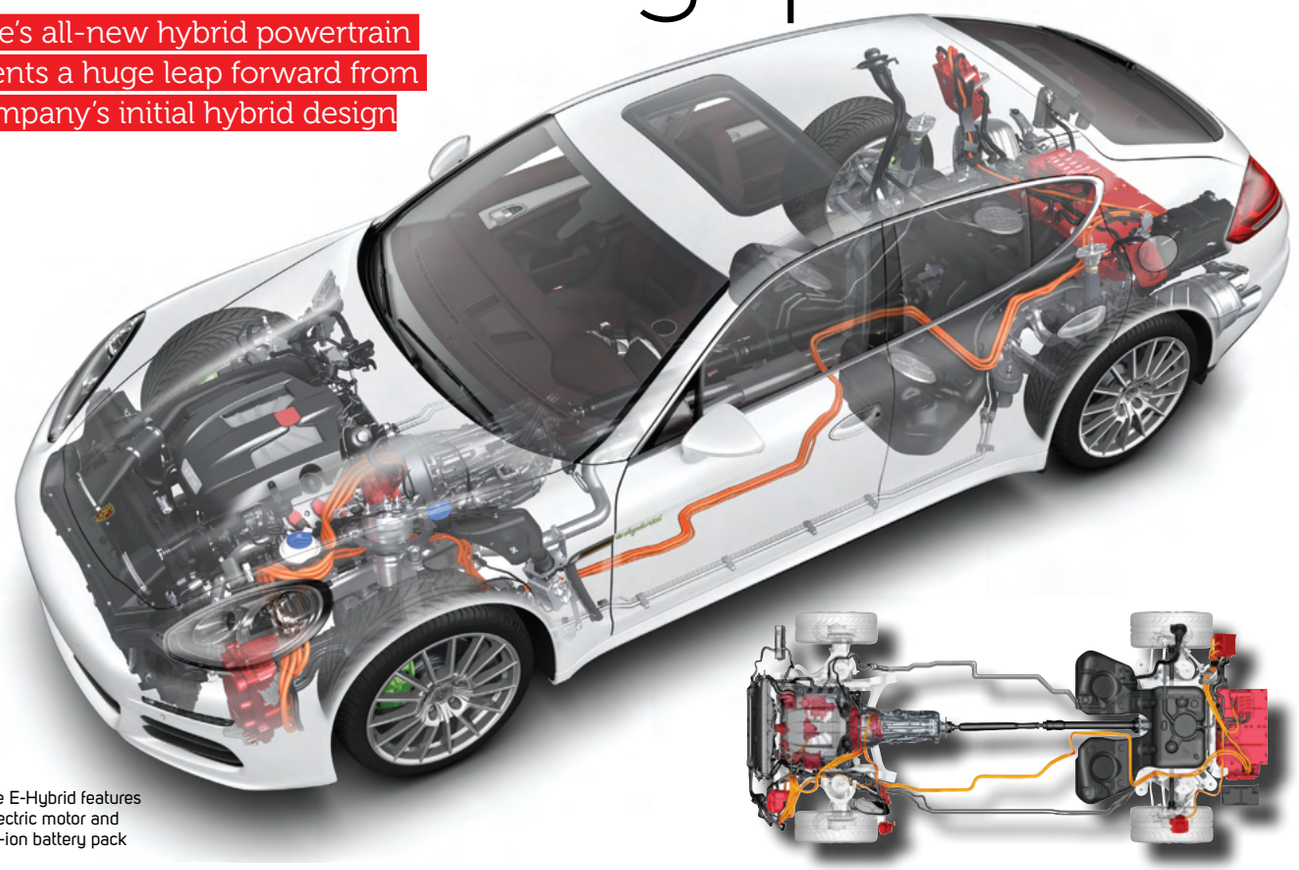
Generation gap

Porsche's all-new hybrid powertrain represents a huge leap forward from the company's initial hybrid design



The Porsche E-Hybrid features a revised electric motor and new lithium-ion battery pack

'Fewer revs for more miles' is the new mantra at Porsche. The previous Panamera Hybrid was launched in 2010, but the new E-Hybrid, based on the facelifted Gen2 Panamera, takes the basic concept much further, offering not just increased performance from the revised electric motor and battery pack, but also a plug-in charging facility. In doing so, it undoubtedly broadens the appeal of the model beyond specific markets.

Once again, Porsche has stored the battery pack under the boot floor, but replaced the nickel metal hydride setup with a lithium-ion type, which can store 9.4kWh – five times that of the old batteries – and 384V, although at 129kg the weight is virtually the same (but with enhanced power density).

A synchronous electric motor is packaged with the IC engine and the integration of the two systems is handled by a 'decoupler' clutch; drive is then performed by ZF's ubiquitous eight-speed torque converter automatic gearbox, although Porsche has integrated the system with its own PDK twin-clutch gearbox for the forthcoming 918 Spyder supercar (more on that later), and the company even says there is no reason why the new hybrid setup would not work with a manual – not that customers would particularly want such a combination.

Daniel Semmler, team leader of hybrid drivetrains, further explains the hybrid changes in the new Panamera: "The power-to-weight ratio of our electric motor has doubled, thanks to more windings within the casing." The result, he adds, is a much more serious contribution from the electric motor – now 70kW and 310Nm – which means on electric power alone the E-Hybrid can get from rest to 48km/h in 6.1 seconds, and unusually, has a top speed of 135km/h. In other words, high-speed electric-only running on the autobahn is now a reality. Porsche's next-gen electric motor will be seen first in the 918 Spyder, and in a development sure to make Porsche enthusiasts smile, it switches from water cooling to part-air cooling, assisted by a fan when the car is stationary. This new motor will produce 95kW and 400Nm, and it should weigh around the same as the E-Hybrid's subsystem.

Supercharged

Once again, the hybrid Panamera uses Audi's 3-liter Supercharged V6, ostensibly as hybrid developments will be rolled out across the Volkswagen Group, particularly with Audi. The E-Hybrid technology is classified as Euro 6 compliant, but on its own the engine would be Euro 5: the additional group higher compliance is due to the warming of the cats in E-Power mode (which takes 30 seconds).

The E-Hybrid has four individual driving modes, three of which are selectable, and all influence the behavior of the Panamera far more than in a conventional car. From the turn of the key, the E-Hybrid is in E-Power mode: the hybrid manager software – according to the team, one of the biggest challenges of the project – tries to prioritize electric-only running at all times, but gearshifts remain like a conventional car (and can be carried out manually). The new power meter (instead of a rev counter) has a direct relationship with the driver's right foot, to aid judging how to accelerate without summoning the IC engine; kick-down automatically brings in the latter.

Switching the car out of E-Power automatically places it in hybrid mode, which is the default setting. In this mode the hybrid manager automatically switches between electric driving, hybrid driving with load-point shift, coasting (with IC engine off), electrical system recuperation and boosting. Basically, the car attempts to maintain the battery reserves at the same level.

E-Charge mode increases the load on the IC engine, turning the electric motor into a generator to charge the batteries (it takes 30 minutes to recharge 80% of the battery). Finally, Sport mode causes the IC engine and electric motor to boost continuously: in this mode the E-Hybrid musters 416ps and 590Nm for a 0-100km/h time of just 5.5 seconds, with accompanying stats of 3.1 liters/100km (91mpg) and 71g/km CO_2 – a formidable combination.

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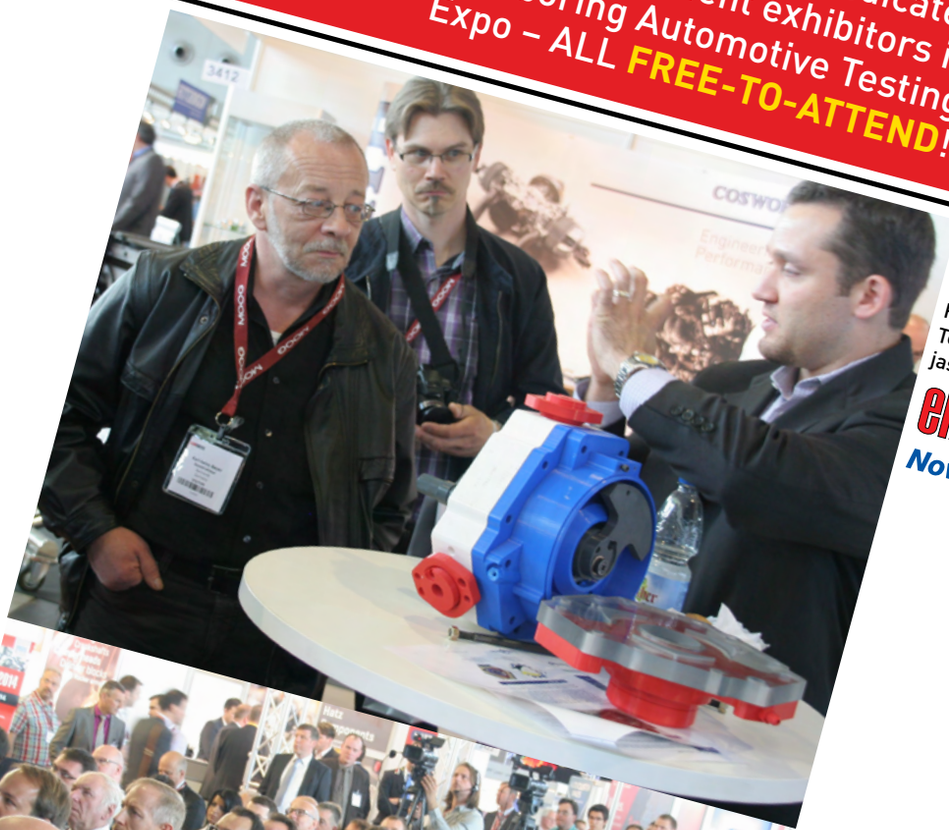

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Fuel for thought

While powertrain engineers continue to make great strides in the development of fuel cell electric vehicles, a lack of infrastructure, sociopolitical challenges and financial restrictions are inhibiting the realization of a hydrogen-powered future

WORDS: **KEITH READ**

One of the two major obstacles facing car makers around the world on their drive toward fuel cell powered, zero-emissions vehicles could be removed by an innovative solution pioneered by ACAL Energy. The UK company, based in premises once the home of ICI (Imperial Chemical Industries, before it was taken over by Dutch and US organizations) has developed FlowCath, a low-cost liquid catalyst solution that replaces 75% of the costly platinum cathode. A stationary demonstration installation is working in a chemical plant in the UK, where it has been producing a consistent 3kW of power for almost two years. "The trial has gone as well as we could have hoped for, with continuous, reliable power output coupled with zero degradation of the fuel cell performance," says Greg McCray, CEO of ACAL Energy.

Vehicle makers around the world are said to be enthusiastic about the technological breakthrough. "OEMs and Tier 1 suppliers are

Illustration by Ben Miners

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CELL COLLABORATIONS

At the start of the year, news out of Ford's Yokohama base in Japan revealed that the Blue Oval had signed a unique three-way agreement with fellow OEMs Daimler and Nissan to accelerate the commercialization of FCEV technology with the aim of launching the world's first affordable, mass-market FCEVs as early as 2017.

Seen by the three OEMs as an effective way to develop a common fuel cell electric vehicle system while reducing costs associated with the engineering of the technology, each company will invest equally in the project so as to maximize design commonality, leverage volume and derive efficiencies through economies of scale.

The partners plan to develop a common fuel cell stack and fuel cell system that can be used by each company in the launch of highly differentiated, separately branded FCEVs.

The collaboration has sent a clear signal to suppliers, policymakers and the industry to encourage further development of hydrogen refueling stations and other infrastructure to allow such vehicles to be mass-marketed.

Keen to get the ball rolling in its home market, Daimler has joined with industrial gas producer Linde to install 20 hydrogen filling stations in Germany. However, fuel cells face a chicken-and-egg problem that has also blighted electric cars: buyers remain wary until a refueling network is rolled out, but infrastructure investors are waiting for the vehicles to become widespread first.

1. Ford's HySeries Drive powertrain delivers a combined city/highway gasoline equivalent fuel economy rating of 41mpg

2. Mercedes has developed a fuel cell engine that is the same size as an IC unit, meaning fuel cell vehicles don't need to accommodate bulky and oversized powertrain designs

3. Ford's HySeries Drive plug-in hybrid is powered by a 336V lithium-ion battery pack and has a range of 40km on full electric charge. With the hydrogen-powered fuel cell, the range increases to a total of 490km

4. The combined volume of the hydrogen tanks equips the Toyota FCV-R with a driving range of around 700km while generating zero CO_2, NOx or PM

Current manufacturing costs for the vehicles are still more than twice those of equivalent lithium-ion battery models – but may come down much faster, some analysts say. And while fuel cell vehicles remain limited today, with no passenger cars on sale and primarily demonstration-driven roll-outs of buses, the fuel cell vehicle market value should grow to US$1.8bn by 2030 at a compound annual growth rate of 22%, according to a Lux Research report published in January.

"Fuel cell EVs are the obvious next step to complement today's battery electric vehicles as our industry embraces more sustainable transportation," says Mitsuhiko Yamashita, executive vice president of Nissan, supervising R&D.

Engineering work on both the fuel cell stack and the fuel cell system will be done jointly by the three companies at several locations around the world, including the site of a joint venture between Daimler and Ford in Vancouver, Canada. The partners are also studying the joint development of other FCEV components to generate even more synergies.

"We are convinced that fuel cell vehicles will play a central role for zero-emissions mobility in the future," says professor Thomas Weber, member of the Daimler board of management for group research and Mercedes-Benz development. "Thanks to the high commitment of all three partners, we can put fuel cell e-mobility on a broader basis."

The trio also hopes that the unique collaboration across three continents will help define global specifications and component standards, an important prerequisite for achieving higher economies of scale.

4

"Working together will significantly help speed this technology to market at a more affordable cost to our customers," says Ford's Raj Nair, group vice president of global product development. "We will all benefit from this relationship as the resulting solution will be better than any one company working alone."

BMW and Toyota are also pursuing their own strategic long-term cooperation in the field of sustainable mobility, having signed binding agreements in January aimed at long-term collaboration between the two companies for the joint development of a fuel cell system.

The companies are convinced that fuel cell technology is one of the solutions necessary to achieve zero emissions. BMW and Toyota are to share their technologies and to jointly develop a fundamental fuel cell vehicle system, including not only a fuel cell stack and system, but also a hydrogen tank, motor and battery, aiming for completion in 2020. The companies are to collaborate in jointly developing codes and standards for the hydrogen infrastructure that are necessary for the popularization of fuel cell vehicles.

looking for cost reduction and durability, and their response has been incredibly good," reveals McCray. "We're now engaged with almost all the major OEMs."

Inexpensive innovation

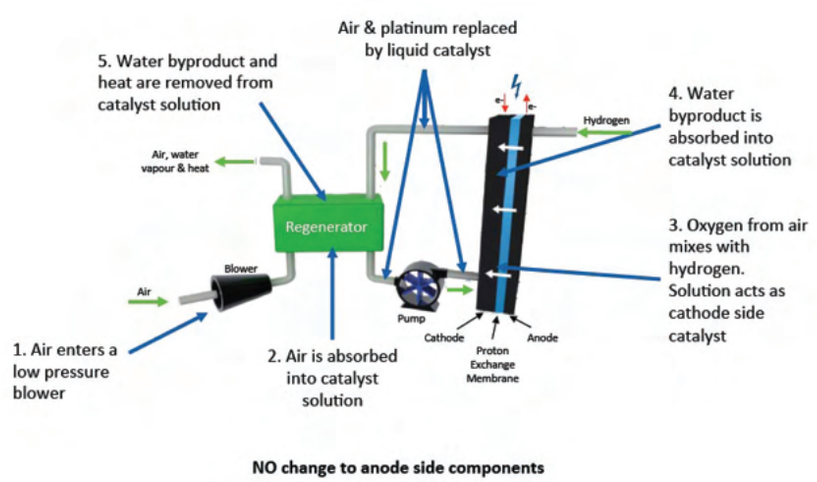
Honda, together with the Sumitomo Corporation, two UK government organizations and Belgian company Solvay Chemicals, is financially backing the FlowCath development. "Our system reduces the cost without OEMs having to throw out their existing investment. We focus on re-engineering the cathode side of the fuel stack, where we remove 75% of the platinum and replace it with a poly-oxometallate liquid chemical solution," explains McCray. "As well as enhancing durability, the design can further reduce cost by decreasing some mechanical elements." A prototype has been bench tested for 9,000 continuous hours – the equivalent of 300,000 road miles – on a cycle designed to mimic typical car journeys.

Automotive prototypes will be running within a few months – well before the end of the year – but will not be installed in a vehicle for some time. "Our business model is more of a licensing model, and while we do build prototypes to demonstrate the viability, OEMs would be building the installations for their own vehicles," outlines McCray. "They can use the same stacks [as they have now] and just modify the cathode side, which is only 30% of the system, but 80% of the cost and 99% of the durability issues. I'd expect to see OEM prototypes running with our system within a couple of years, while production vehicles could be on the roads within five to seven years."

But what are the drawbacks to this promising breakthrough technology? "There aren't any disadvantages – except that it's new!" he says. "And that's not exactly a disadvantage because we've proved the science works and we've built prototypes. But in terms of flaws, there aren't any. The chemical solution is very inexpensive to make using commodity chemicals. What's more, OEMs will be able to drive even more cost out of the system because that's what they do for a living."

McCray sees the all-important hydrogen infrastructure for wide-scale take-up of fuel cell powered vehicles – flagged by many within the industry as a serious challenge – as less of a problem. "My background is in

The ACAL Energy Solution – FlowCath



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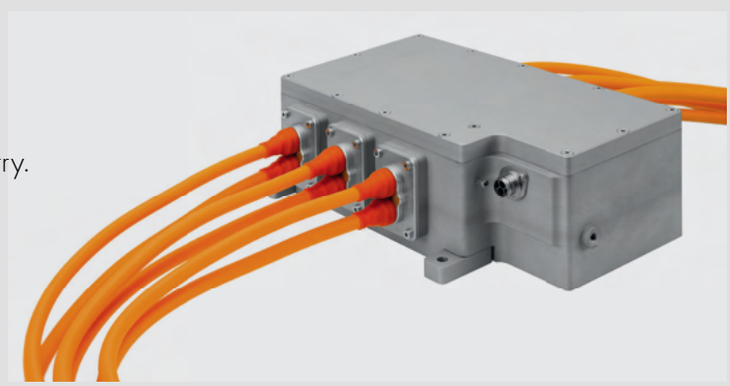

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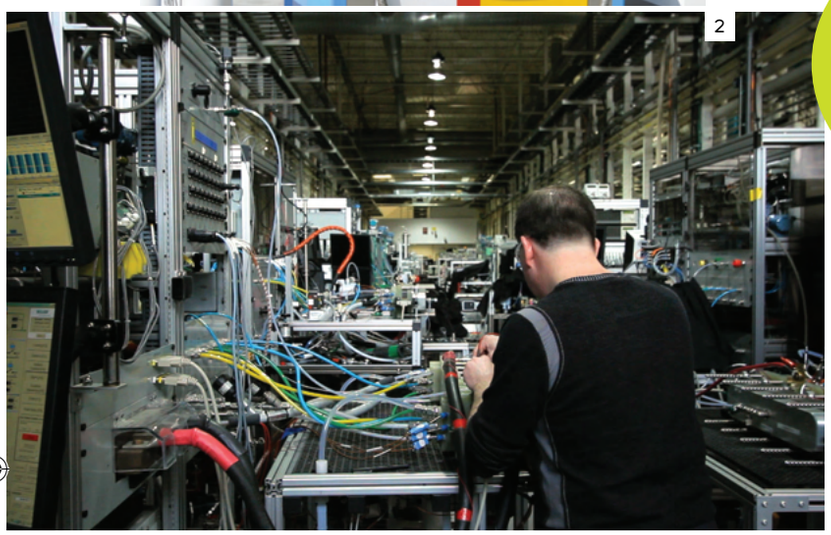
1. A Shell hydrogen refueling station. One of the two major challenges that hydrogen fuel cells currently face is a lack of refuelling infrastructure

2. Ballard Power Systems has been researching and developing fuel cell technology for more than 25 years and maintains high-tech fuel cell R&D facilities near Vancouver



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Sabina Russell, director of product engineering at Ballard Power Systems, says in addition to creating an adequate infrastructure, cutting total cost is also an important part to ensuring fuel cells break the mass automotive market globally

telecommunications and I remember the agonizing debates we had over issues like putting in broadband and fiber optics – projects that cost billions and billions. But it was amazing how quickly the telecoms infrastructure was built once the consumer need was identified. In some cases, governments stepped in and helped out. It all happened surprisingly fast; and if auto makers come out with affordable hydrogen-fueled cars that customers really want, you'll be amazed how quickly the hydrogen infrastructure will come about. I'm sure some governments will, again, help subsidize it. I'm not saying it'll happen tomorrow – but it won't take 100 years! When there's a need, the infrastructure comes pretty quickly."

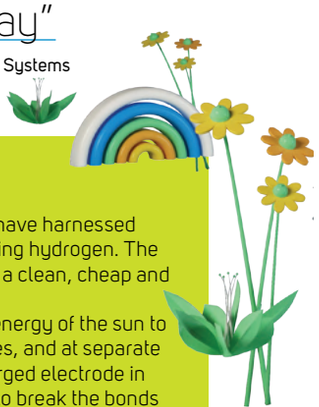
Cost reduction is a key element of Vancouver-based Ballard Power Systems' current activities. Sabina Russell, director of product engineering for the company that has been researching and developing fuel cells for more than 25 years, says significant progress has been made: "We have achieved an average product cost reduction of approximately 60% since 2009." Reducing platinum loadings, using fewer parts, negotiating deals with suppliers and increased volumes have made savings. More than 3,500 fuel cell forklift trucks are in use with companies such as Walmart, Sysco and FedEx Freight; more than 40 Ballard-powered fuel cell buses are in daily use; and back-up power systems are in use by telecom networks around the world, and global telecom networks rely on more than 2,000 of the company's power back-up systems.

"Our focus is on cost reduction to enable more aggressive competitive positioning versus incumbent technologies, including IC engines and lead-acid batteries," says Russell. "The primary remaining challenge for commercialization of automotive fuel cells relates to achieving the aggressive cost goals, while maintaining durability under the harsh vehicle duty cycles." However, she highlights the lack of fueling stations as a big obstacle to the introduction of hydrogen-fueled vehicles. "With the first fuel cell vehicle, purchasers will need to have confidence that sufficient fueling is available. The reality is that it will take many years for hydrogen fueling stations to become as prevalent as gasoline and diesel stations are today."

Team effort

Kia recently reiterated its commitment to fuel cell vehicles and the South Korean company's principal research engineer for its No.1 FCEV vehicle team, Dr Sae Hoon Kim, is convinced hydrogen-fueled vehicles have a sound future. "FCEV technology is advancing very rapidly. Cold-start was not common 10 years ago, but now they can be started at temperatures as low as -20°C to -25°C," he says.

> "The reality is that it will take many years for hydrogen fueling stations to become as prevalent as gasoline and diesel stations are today"
>
> Sabina Russell, director of product engineering, Ballard Power Systems



GREEN SCIENCE

Scientists experimenting at the University of Glasgow in the UK have harnessed the principles of photosynthesis to develop a new way of producing hydrogen. The technique is being heralded as the key to unlocking hydrogen as a clean, cheap and reliable power source – including as a fuel for road vehicles.

Plants' powers of photosynthesis enable them to harness the energy of the sun to split water molecules into hydrogen and oxygen at separate times, and at separate physical locations in the plant's structure. With a negatively charged electrode in a process known as electrolysis, scientists have long been able to break the bonds between hydrogen and oxygen, thus releasing them as gas. But industrial processes to produce pure hydrogen from water require expensive equipment and rigorous supervision to ensure that the gases do not combine, which can lead to potentially dangerous explosive mixtures.

In a paper in the journal *Nature Chemistry*, published in April, professor Lee Cronin and Dr Mark Symes outlined how they have managed to replicate, for the first time, plants' ability to decouple the production of hydrogen and oxygen from water using what they call an electron-coupled proton buffer (ECPB). Says Dr Symes, "What we have developed is a system for producing hydrogen on an industrial scale much more cheaply and safely than is currently possible. Currently, much of the industrial production of hydrogen relies on reformation of fossil fuels. But if the electricity is provided via solar, wind or wave sources, we can create an almost totally clean source of power."

A BMW team member at the car maker's plant in Spartanburg, South Carolina, USA, drives a hydrogen-powered fuel cell material handling train

BMW EXPANDS USE OF HYDROGEN FUEL CELLS

In March, BMW announced the successful expansion of the company's hydrogen fuel cell materials handling equipment across its 371,600m² production facility in South Carolina. In 2010, the car maker completed the installation of a hydrogen storage and distribution area near the plant's energy center to power around 100 pieces of fuel cell materials handling equipment. Since that time, the company has more than doubled its hydrogen fuel cell fleet to approximately 230 units to service the entire plant's production and logistics functions.

The additional usage of the hydrogen fuel cell system was executed by adding two new higher-capacity compressors, new storage tubes and distribution piping and eight new hydrogen dispensers. The expanded system will deliver at least 400kg of hydrogen per day, and BMW estimates that the new arrangement will save 4,100,000kWh per year, up from 1,800,000kWh per year for the initial hydrogen fuel cell system.

BMW also released a project update to the Landfill Gas-to-Hydrogen Pilot Project. The first phase of the study, which validated economic and technical feasibility, began in July 2011. The project has now successfully moved to the second phase of methane-to-hydrogen conversion. The project team, led by the South Carolina Research Authority, is implementing and testing equipment that will monitor the hydrogen purity. To do this, BMW has installed a clean-up system that takes a stream of landfill gas (post-siloxane removal), removes the sulfur and trace contaminants, and ultimately produces hydrogen via a steam methane reformer.

"BMW is very pleased with the progress we have been able to achieve over the past 18 months," says Cleve Beaufort, BMW Group's energy manager for the USA and Canada. "The objective of generating renewable hydrogen from methane is proving to be a possible option for BMW and will be transformational for the fuel cell industry."

The final phase of this project is scheduled to begin in late 2013. At that time, BMW will conduct side-by-side trials of materials handling equipment fueled by landfill gas derived hydrogen versus commercially sourced hydrogen.

"The expected durability is about 10 years (5,000 hours in bench tests). The ultimate goal should be much longer – so there is still much work to do"

Dr Sae Hoon Kim, principal research engineer, Kia

"We don't know exactly where FCEVs will be in 10 years' time, but within the market for hybrid vehicles, FCEVs will be one of the powertrain options available in showrooms. Their performance today is very similar to conventional IC engine vehicles, with a driving range [between refueling] of 400-600km and maximum speed of around 160-180km/h. But one of the more attractive features [compared with battery-powered EVs] is that it takes three to four minutes to refuel."

With that said, Dr Kim accepts there is more to do on durability. "The expected durability is about 10 years (5,000 hours in bench tests). The ultimate goal should be much longer – so there is still much work to do."

He says the hydrogen-fuel infrastructure problem can be solved – but only when governments work with the energy, automobile, oil and gas industries. "A good example is the H2 Mobility initiative, which we can see in Germany. But while this sort of government-industry cooperation has started in a number of countries – the UK, Japan and Switzerland – we do not expect the [full] infrastructure will be ready in the short term." Hydrogen will, he says, become more important within the overall energy system, and he predicts that countries such as Denmark, Norway, Germany and the UK will be the early markets for FCEVs.

"Although not a direct challenge for the car industry, commercial availability of the fuel is a very slow process in a few countries – and not progressing at all in most"

Uwe Deller, manager of European technology , Vauxhall/Opel

During 2012, General Motors consolidated its global fuel cell R&D at its powertrain engineering HQ in Pontiac, Michigan. Uwe Deller, manager of European technology for GM's Vauxhall/Opel brands, says huge progress has been made in the problem areas of hydrogen storage, propulsion systems and low-temperature starting in fuel cell electric vehicles. "Nevertheless, following the slow uptake of electric cars across Europe – which includes the issue of low volume/high price for the advanced nature of the technologies – the industry has learned there is still a long way to go to getting to a meaningful price level for the fuel cell propulsion system and, therefore, a sensible price proposition for the customer. Further work on the fuel cell stack is necessary before further vehicle integration programs can be pursued.

"But GM will continue to refine its fuel cell system technology so it can be ready to commercialize the technology at a point when the market and business conditions make sense," says Deller.

Back to the drawing board

On the hydrogen infrastructure issue, Deller has strong views: "Although not a direct challenge for the car industry, commercial availability of the fuel is a very slow process in a few countries – and not progressing at all in most. It needs much clearer direction from governments in terms of how we want to achieve both sustainable mobility, and a sustainable energy system, based on renewable energy sources. The automotive industry needs a much higher confidence level for its fuel cell planning."

So while those involved in FCEVs are optimistic that zero-emissions cars fueled by hydrogen definitely have a future, the consensus is that – despite several technical advances – that future is still some way away.

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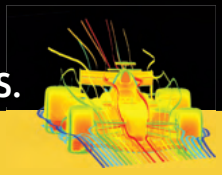

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Not only is this the world's most powerful hydrogen vehicle, it also has been created to shatter records in the most demanding of motorsport environments. The question is, has Aston Martin's Rapide S fulfilled its brief?

WORDS: **DEAN SLAVNICH**

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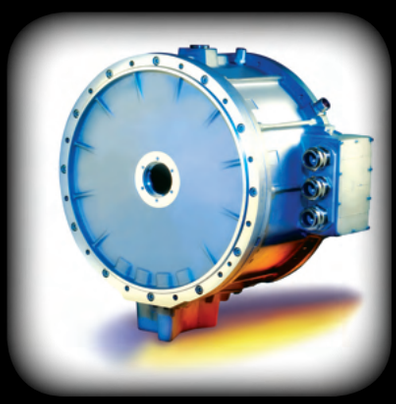

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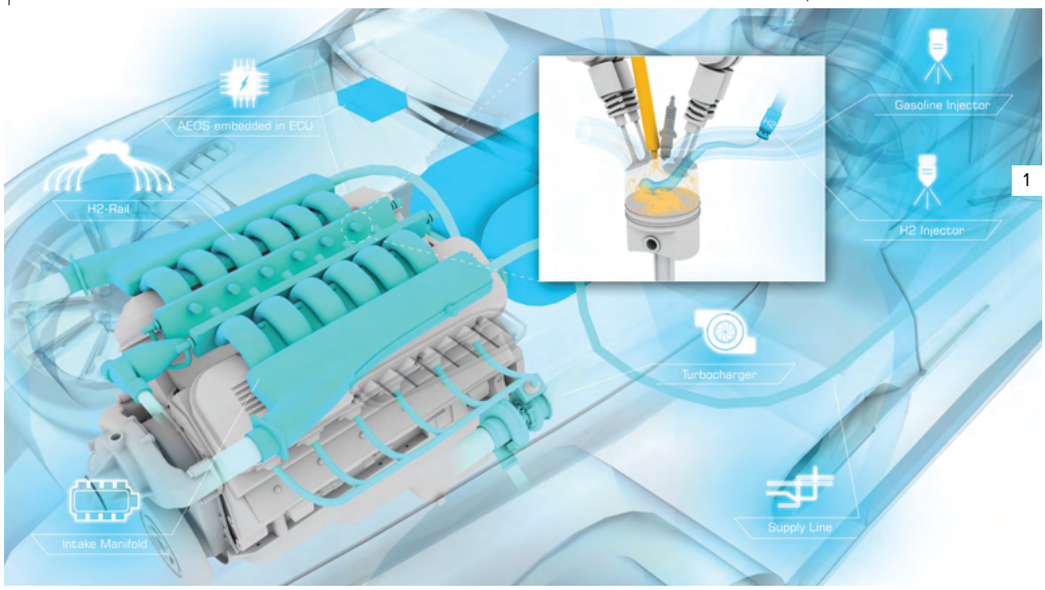

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1. The main development focus for the Aston Martin project was on software and control, with components such as the intake manifold and mixture formation system redesigned to allow a hydrogen rail, injectors and a turbo unit to be integrated

Sometimes there can just be too much at stake. Whether said scenario relates to a company takeover, the creation of a new type of vehicle or the development of an expensive technology, there comes a tipping point when it's easier to take the chips off the table and walk away.

It's a situation which many sustainable transportation pioneers, be they OEMs, suppliers or specialist developers, regularly find themselves in. And for one particular recent piece of groundbreaking technology – a very clever hybrid hydrogen setup in an Aston Martin Rapide S – the ante could not have been higher. Up for grabs was proving the technology's reliability, performance, flexibility and environmental credentials, but this would have to be done on one of the biggest motorsport stages of all: the grueling and unforgiving Nürburgring 24h race (N24). Added to the mix was the fact this technology has been at the very core of Alset Global, Aston Martin's development partner for this project for nearly a decade, as well as it being the British car maker's 100-year anniversary – and no company wants a forward-thinking tech demonstrator like this to break down on such an esteemed occasion, and one soon gets a flavor of just how important this exercise is, not just for Alset and Aston Martin, but for the wider use of hydrogen in motorsport and automotive environments.

For Thomas Korn, Alset vice president of product management and technology, the objectives in taking part in the N24 could not have been clearer leading up to the race. "We wanted to show the world that a cost-efficient solution doesn't have to compromise performance," he says. "And since we're not using any fancy or rare materials, durability can be achieved, even in such extreme conditions as this 24-hour race."

Powering the dream

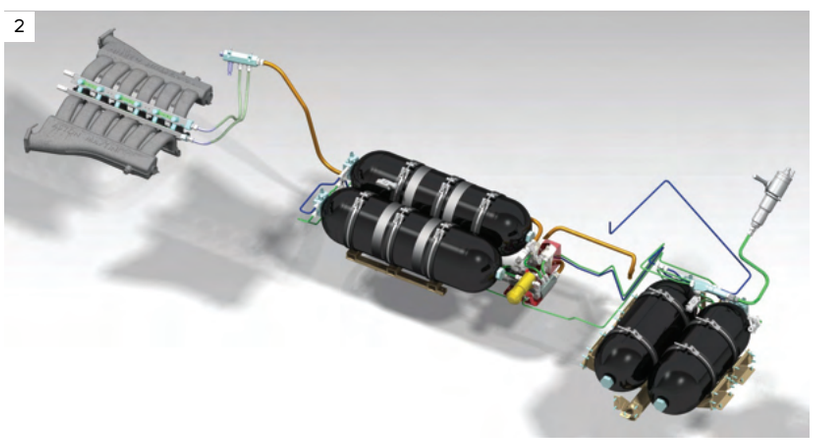
At the heart of such lofty objectives is an emissions-free, high-tech powertrain driving the No. 100 Aston Martin Hybrid Hydrogen Rapide S – the most powerful hydrogen car ever built. The system, which enables the Rapide S to run on hydrogen, gasoline, or a blend of both, comprises a hydrogen storage unit, a hydrogen supply and injector arrangement, a safety system and a Pectel motorsport ECU from Cosworth that contains proprietary Alset Engine Operating Software optimizing the fuel compound and combustion process across all driving situations.

An important development goal, not only for this Aston Martin project but for the technology in general, was that in order for the hybrid hydrogen system to be integrated into an existing application, little modification needed to be undertaken to the IC powertrain, which in this one-off motorsport example was a 6-liter V12.

"The advantage to our technology is that the engineering effort we need to undertake on the base engine is minimal – that's really important to us," states Korn, who joined Alset from BMW, where he was a senior project manager for the German car maker's hydrogen program in California. "There have been several hydrogen combustion engine developments in the past from very well-known companies, like BMW and Ford, that developed hydrogen in a combustion vehicle, and these examples worked perfectly, but the efforts to modify the base engine [in these projects] were incredible. I think our strategy – and this was one of the major goals of the Aston Martin project – to come up with a cross-platform that can be easily and quickly adapted to any existing gasoline engine, is the right strategy."

> "We had less than a year to do the entire engine, engine calibration and other such development"
>
> Thomas Korn, vice president of product management and technology, Alset Global

As such, the main development focus for the Aston Martin project was on software and control, with components such as the intake manifold and mixture formation system being



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2. The Rapide S is equipped with four carbon-fiber hydrogen storage tanks that have an aluminum liner with a 15mm thickness. Two of the tanks are placed next to the driver while the other two are located in the trunk, holding a total of 3.2kg of hydrogen. For this project the hydrogen is stored at 350 bar

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1. Matthew Marsh was selected as the driver of the Rapide S for the N24

2. The race car exceeded expectations by reaching a speed of 250km/h on pure hydrogen power alone

3. Alset's engineers developed the hybrid engine in less than a year

redesigned to allow a hydrogen rail, injectors and a turbo unit to be integrated. This work was undertaken by Korn's engineering team and was mostly in response to a reduction in engine power when operating in pure hydrogen mode, due mainly to the lower volumetric energy density of hydrogen fuel.

The hydrogen injectors, which are sourced from AFS, are similar in design to injectors found in CNG engine applications developed at OEM level, but key differences include high-durability seals and materials. For the V12, the injectors are of a solenoid type and are fitted to the intake manifold, upstream of the regular gasoline injectors. The hydrogen is delivered to the fuel rail in constant flow, at 4-5 bar.

The lack of lubrication properties of the hydrogen fuel also means that the valves and valve seats in the Rapide S have been changed, with Inconel alloy added for robustness and improved temperature resistance.

The hybrid hydrogen drivetrain uses two small exhaust-driven turbochargers when the car is burning hydrogen to improve the mixture heating value of charge, forcing more air/fuel mixture into the combustion chamber. A knock-on effect to the modified turbocharger operation is that the engine's compression ratio has been reduced from 11.5:1 to 9.5:1 thanks to a new piston crown design. The integration of the turbochargers has also led to an alternative cylinder head gasket being used.

Surprise package

Korn's team equipped the Rapide S with four carbon-fiber hydrogen storage tanks that have an aluminum liner with a 15mm thickness. Two of the tanks are placed next to the driver while the other two are located in the trunk, holding a total of 3.2kg of hydrogen. For this project – and unlike a production car – the hydrogen is stored at 350 bar (rather than 700 bar) for simple and quick refueling purposes, which came courtesy of a Linde mobile refueling station at the actual race.

The storage system, developed with Magna Steyr, weighs around 100kg and covers all components, including valves, holding brackets, tubes, the pressure regulator unit and the actual cylinders, two of which weigh 21kg each, and the other two 17kg each.

Having to integrate the hydrogen tanks and fuel lines into the Rapide S meant packaging was a tricky engineering hurdle for Alset engineers to overcome. "It's never easy to package new components in an existing car," admits Korn, who says that today's CNG vehicles were an important reference point for the project. "Natural gas vehicles have two fuel systems – the natural gas tank and the gasoline tank – so it's a 200- to 300-liter package that needs to be made available. This is the same kind of size we need to make available for hydrogen cars, but for Aston Martin we needed not a series production solution, but a race car solution. This meant we had requirements to integrate the gas system inside the roll cage, which of course wouldn't be the case for an automotive market product – for that we'd package the system outside the vehicle, like the designs on natural gas vehicles."

Another specially created feature for the Rapide S is an additional ECU developed with Gigatronik that not only monitors and manages the hybrid hydrogen tank, but also ensures safety at all times. This hydrogen ECU is connected to four hydrogen sensors that continuously assess the gas system. The setup also connects the ECU to crash sensors within the vehicle so that in the event of one of the sensors detecting a trace of hydrogen, or if there is a crash, the hydrogen supply shuts off immediately thanks to a valve between the tank and the pressure regulator.

UNLIKELY PARTNERS

According to Gonzalo Auil, Alset's vice president of administration, the racing tie-up with Aston Martin came about following an initiative from Alset to work with the wider automotive industry in an effort to further the company's hybrid hydrogen technology. "We've been developing our technology for quite some time and last year we started our pre-commercial efforts, approaching several OEMs, specifically trying to focus on the premium segment."

Having submitted a tender to top-end car makers, Aston Martin, says Auil, was one of the first to show interest, but only if the eco-friendly powertrain technology could be used in the motor racing arena: "Aston Martin basically said we had to do it their way, which is through racing, because it's the best way to see how the technology works, especially under the extreme conditions that motorsport brings."

Auil says Aston Martin's response to house the technology in a racing application always led the way, despite holding "several conversations with other OEMs". Auil adds, "We really like the challenge presented to us by Aston Martin because it's a very big engine to apply our technology, so we put talks with other OEMs on hold to focus on this project."

For when the V12 turns to gasoline power, the Rapide S has a 100-liter motorsport-specified gasoline tank located in the vehicle's regular OE-level position.

Rather than one specific part of the program presenting a particular engineering headache for Korn, the greatest hurdle, says the VP for technology, was tight deadlines: "We had a lot to do in not a lot of time. We had less than a year to do the entire engine, engine calibration and other such development. I think this shows just how quickly this technology can be implemented."

Back, then, to the prize: did the hydrogen bubble fly high at the N24 or burst in failure?

In extreme weather conditions, the hybrid hydrogen technology, the revised V12 and hydrogen storage tanks made it possible for the Rapide S to be the first car ever to complete one full lap of the 25km-long Nordschleife track on pure hydrogen, although during the race the team used mainly a blend of the two fuels. But that was just the start. The Rapide S also became the first hydrogen-powered car to compete in, and to undertake zero CO_2 emissions laps of, an international motor race. In fact, the eco-friendly racer, and the technology within it, ran faultlessly throughout the race, demonstrating the system's reliability and durability, with the Rapide S even reaching 250km/h on pure hydrogen power alone.

For Korn, the engineering effort was worth it, and the aim now is for the hybrid hydrogen system to be applied to a production vehicle very soon. "Our technology can run on both fuels, so if you have just one hydrogen refueling station in your city – and many cities today have only a basic hydrogen refueling infrastructure – our technology will allow an average of 150km to 250km of hydrogen driving and then a back-up of gasoline driving. So, I think 90% of your traveling can be done with carbon-free fuel, but then, if there needs to be a back-up, we can run on gasoline fuel, so we think this is a brilliant solution."

In a telling final comment, the victorious and proud Alset VP adds, "If we have one million hydrogen cars on the roads, then the technology will really take off. In my opinion, hydrogen is indispensable – it's just a question of when, and I feel we're on a very good path."

1

1. A Linde mobile refueling station was sited at the Nürburgring 24h race

2. The TrialH2-gas mobile refueling unit from Linde

3. The hybrid hydrogen drivetrain uses two small exhaust-driven turbochargers when the car is burning hydrogen to improve the mixture heating value of charge, forcing more air/fuel mixture into the combustion chamber

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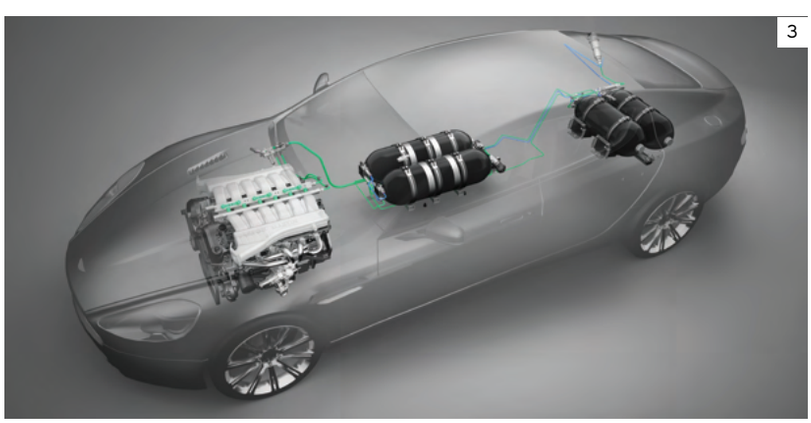
"We wanted to show the world that a cost-efficient solution doesn't have to compromise performance"

Thomas Korn, vice president of product management and technology, Alset Global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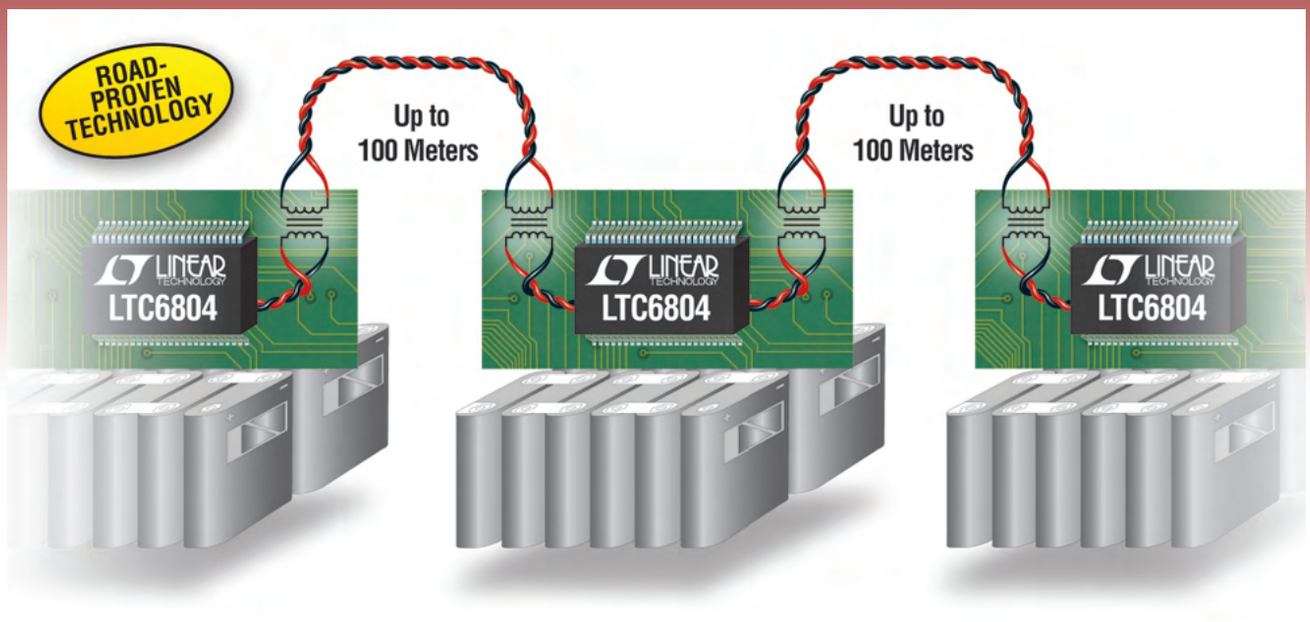

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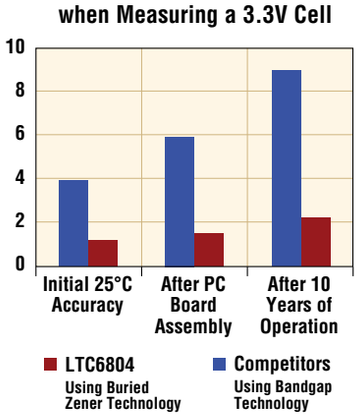

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Circular precision

For the past decade, in-wheel electric motors have been widely touted as the alternative propulsion system for future powertrains, but with the adoption of battery electric vehicles and the rebirth of hydrogen fuel cells, *E&H* examines whether this conceptual technology will ever make it to the fore

WORDS: **JOHN THORNTON**

Depending on who is asked the question, the use of in-wheel electric motors as a production-ready propulsion system in future electric and hybrid passenger cars is either just around corner, five years away, or simply too technologically flawed to make it past the testing lab.

There's no denying that the technology promises much – and most agree with that statement – but whether in-wheel motors (also referred to by some as hub motors) will ever make an impact on production vehicles is a question that really divides opinion in all quarters of the automotive industry.

The list of manufacturers working on the technology reads nearly as long as the amount of time being taken to develop it, with the likes of TM4, Schaeffler, Protean Electric, Siemens, Michelin and several Japanese suppliers and OEMs, including Mitsubishi and Sim-Drive, privately cultivating their own products and tech demonstrators for at least the past decade.

The Honda Air concept vehicle was created as part of the design challenge at the LA Auto Show. It shows how a vehicle with hub motor technology could look like in the future

1

1. Protean Electric's production-version of its in-wheel electric drive system debuted this year in a Mercedes Brabus sedan

2. The 2008 Protean Ford F-150 all electric pickup truck used four in-wheel motors, offering 454ps combined power

3. Rear view of the Protean drive in-wheel motor with a mechanical braking system

And each organization is quick to extol the virtues of in-wheel motors – especially versus IC engines – regarding power and efficiency gains, improved packaging options and environmental friendliness.

"A permanent magnet motor can be placed anywhere in a vehicle, and if the design is correct it will always provide around 97% or 98% mechanical power efficiency, while IC engines achieve only around 30%," states Christian Pronovost, senior product manager at TM4, a Canadian company that has invested over 20 years in optimizing the technology. "With a typical in-board electric motor on the market today – in a Nissan Leaf, for example – the motor goes through a gearbox and then a differential before getting to the wheel. As much as 8% efficiency can be lost when power passes through all those components. With in-wheel electric motors directly connected to the wheel, the 98% efficiency is going right to the wheel, with no loss. You can't get better than that."

Slow burner

As impressive as that sounds, the technology has so far only been deployed in a raft of demonstrator/concept cars, and been put into production only in certain applications, such as bicycles and buses. Subsequently, a perceived slowness-to-market of the technology has led to a growing number of critical voices casting doubts over the reliability, safety and durability of in-wheel motors, as well as concerns regarding the detrimental effects of increased unsprung mass on vehicle performance dynamics.

So what exactly is taking so long and when can the market expect to see production-ready in-wheel motors?

According to Dave Greenwood, head of hybrid and electric systems at automotive engineering consultancy Ricardo, the hold-up stems from technological immaturity. "The penetration of electric vehicles is generally still quite low, and hub motors aren't necessarily the easiest form to create," he says. "Typically, organizations that have moved to market with electric vehicles have tended to do so with a single-traction motor because they tend to be lower cost and lower risk. There are also challenges in physically packing a motor inside a wheel along with a good-quality braking system and a good-quality suspension system, as well as having a vehicle with good performance and good ride characteristics at the end of that."

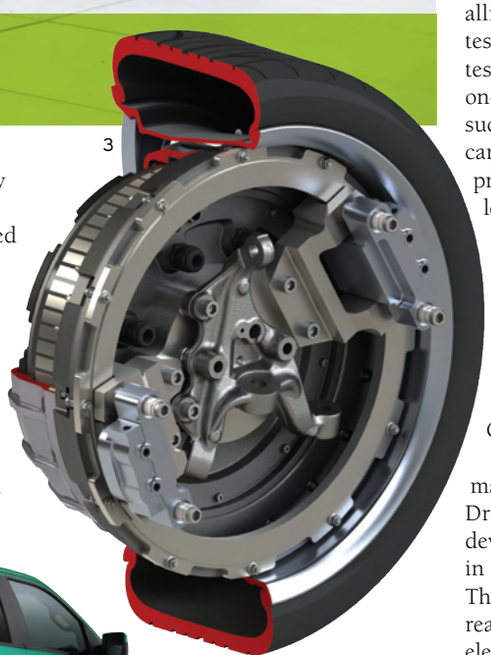
For OEMs specializing in developing high-performance vehicles, such as McLaren Automotive, cost and lack of testing with high specific outputs mean they're not jumping to install in-wheel motors in their vehicles anytime soon. "It's definitely a technology for the future, in terms of the architecture it brings to the car. But for us at the moment, the penalties outweigh the advantages," says Mark Vinnels, program director for new vehicle projects at McLaren Automotive. "At the price point for which we operate, cost is still an important factor. And so, although we can probably – in terms of the technologies that are appropriate for our cars – push the commercial aspect of some of the components, at the moment the overall costs are still relatively high. Also, some of the questions we've asked of the technology, particularly in relation to the durability of bearings and brushes, is something that we would need to have more confidence in before

"Is the technology as mature as centralized drive systems on the market today? No, it's not, but is any electric and hybrid technology as mature as IC engines? Clearly, the answer is 'no'"

Andrew Whitehead, director of strategic alliances, Protean Electric

making in-wheel motors a fundamental part of any development program we begin."

With that in mind, it has become widely accepted that electric derivatives of bicycles and buses are easier to equip with a similar technology due to both types of applications enjoying better economies of scale. Compared with cars, bicycle wheel motors are low-tech, low power, have fewer safety implications, and are therefore more cost-effective to develop. Buses, meanwhile, tend to be manufactured in relatively smaller volumes per year than cars and are used in more controlled cycles by operators. Critically, buses aren't sold to the general public, and because of that, the depth of engineering required to validate the product isn't quite as much as that needed on a passenger car.



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Driving force

One company that appears to be on the threshold of possibly changing this perception is Protean Electric. At Auto Shanghai 2013, the Michigan-headquartered company unveiled the production-version of its latest in-wheel electric drive system. Used as part of a hybrid powertrain system housed in a Mercedes Brabus sedan, the two rear-wheel motors are paired with a traditional IC engine and each offer 101ps peak power and 1,000Nm peak torque – representing a 25% increase in total torque compared with the previous generation's design. Weighing in at 31kg each, Protean claims the motors can improve fuel economy by up to 30% in hybrid configurations, compared with the existing vehicle, and depending on battery size. The company says the drive system also offers superior regenerative braking capabilities that allow up to 85% of the available kinetic energy to be recovered during braking.

"We are at the end of our concept validation phase and are about to go into design verification," reveals Andrew Whitehead, Protean Electric's director of strategic alliances. "We've carried out a multitude of testing, from subsystem tests to motor bench testing and motor unit testing, and also on-road vehicle testing at proving grounds such as Millbrook and Idiada. We're also carrying out an accelerated vehicle life testing process, where a multitude of surfaces and load conditions are used. The next step is to start putting it into tooled-up production toward the end of this year.

"So, no, I don't think 'immature' is the right word. Is the technology as mature as centralized drive systems on the market today? No, it's not, but is any electric and hybrid technology as mature as IC engines? Clearly, the answer is 'no'."

Slightly behind Protean in terms of market readiness is Schaeffler's E-Wheel Drive system. Now in its beta stage of development, the technology was presented in a new concept Ford Fiesta earlier this year. The compact vehicle is driven by two rear-wheel motors that house not only the electric motor but also the power electronics, controller, brake and cooling system. The wheel hubs provide an output of 111ps per drive, with a continuous output of 91ps, and deliver torque of up to 700Nm.

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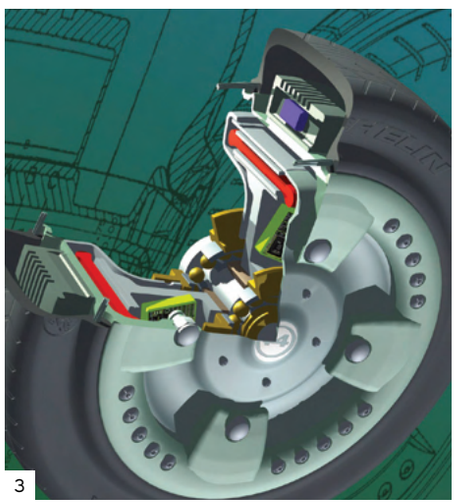


Dr Raphael Fischer, director of the wheel hub drives product group in Schaeffler's e-mobility systems division, claims that with a weight of 53kg per wheel motor they were able to reduce vehicle weight thanks to integrating the components and thus omitting much complex wiring.

However, quantifying exactly how much vehicle weight electric in-wheel motors can save isn't so cut and dried. "You've got to look at it from a whole vehicle point of view," explains Phil Barker, chief engineer of hybrid and electric vehicles at Lotus Engineering. "If you're putting wheel motors in, then that suggests it's got to have an onboard electrical storage system of some sort, such as a battery – and a battery's going to be heavy. So, if you take out a conventional powertrain, which weighs around 200kg, maybe more, and replace it with a couple of in-wheel motors that weight around 30kg each, then you could say you're saving some number of kilograms, but what about the battery you're also adding in? The weight is probably going to go up."

Weight matters

Greenwood at Ricardo concurs: "The issue isn't with the weight of the motors, it's the weight of the batteries. The challenge with electric vehicles is to package sufficient batteries to give an acceptable range, thus the mass of the battery is relatively high. The weight of four in-wheel motors compared with a single traction motor is probably slightly higher, but not dramatically so. But that's almost irrelevant in the context that there are going to be several hundred kilos of batteries on board the vehicle to enable it to have an acceptable range."

Another weighting issue, which has become something of an albatross for in-wheel motor manufacturers, is the unsprung mass of the wheel. While there is no disputing that the weight of a wheel increases once a motor is added to it, the consequences of doing so are hotly contested. "If you increase the weight of the wheel too much, the wheel won't drop into the contours of the road as fast as it would do usually, meaning some traction is lost," states TM4's Pronovost. "You'll also lose grip when accelerating or cornering. If you're cornering on a bumpy road, the higher the weight of the wheel, the more the vehicle will skid on the sides. So, the main drawback is losing the patch to the ground."

However, the results of a six-month study into the dynamic implications and opportunities of an unsprung-mounted drivetrain, conducted by Lotus Engineering, Protean Electric and Dunamos in 2010, challenge such assertions. A 2007 1.6-liter Ford Focus was evaluated for ride, handling and performance around corners and over bumps. The vehicle was then modified with

> "With in-wheel electric motors directly connected to the wheel, the 98% efficiency is going right to the wheel, with no loss. You can't get better than that"
>
> Christian Pronovost, senior product manager, TM4

1. The E-Wheel Drive wheel hub is small enough to fit inside a standard wheel rim

2. The concept Fiesta has undergone extensive winter testing in Scandinavia

3. TM4 began development of its 4-wheel motor system and control software in 1991

4. TM4 supplied four electric wheel motors to the Peugeot Quark quad-bike in 2004

added static and rotational mass to the front and the rear – to simulate the added weight of the wheel motors – and retested. According to Protean Electric and Lotus Engineering, there was a difference, but that difference was minimal and could be recovered with traditional ride and handling techniques.

"The myth surrounding the issue of unsprung mass is a pure misconception," states Barker. "There were some downsides to the vehicle dynamics behavior, but you'd have to be a specialist in vehicle dynamics to notice them. The average man in the street wouldn't notice the difference at all."

In fact, Whitehead even goes so far as to compare the effects of unsprung mass on the tested Focus to "a car in the middle of a development process, as opposed to a car that was undriveable or a car that needed new suspension geometry". The Protean Electric director suggests that "there are actually probably more benefits to using in-wheel motors in terms of ride and handling" once advancements such as torque vectoring are taken into account.

Ford has also undertaken testing in this area with the Fiesta E-Wheel Drive development vehicle. Roger Graaf, Ford Europe's project manager for research and advanced engineering, claims, "Test drives have clearly shown that the driving behavior of this test vehicle in terms of comfort and safety has remained at virtually the same level, despite the higher wheel-sprung masses compared with the conventional basic vehicle."

Applying the brake

However, while the ability to independently control the amount of torque at each wheel can improve the maneuverability, driving dynamics and active safety of the vehicle, the lack of friction braking associated with in-wheel motors continues to leave some within the industry skeptical. Jon Hilton, co-owner and co-founding director of Flybrid Automotive, is a staunch critic of in-wheel motors. "I can't see the technology taking off, to be honest. I've seen people offer wheel motors in packages that appear not to have friction brakes, which I don't know how you'll get past the DFMEA [design failure mode and effects analysis]. The brake itself is very hot, and magnets in motors can't stand very high temperatures – 180°C will kill most magnets. You'd be better off with a pancake style motor, mounted on the inboard end of the driveshaft by the differential. Or back-to-back pancake motors with no diff."

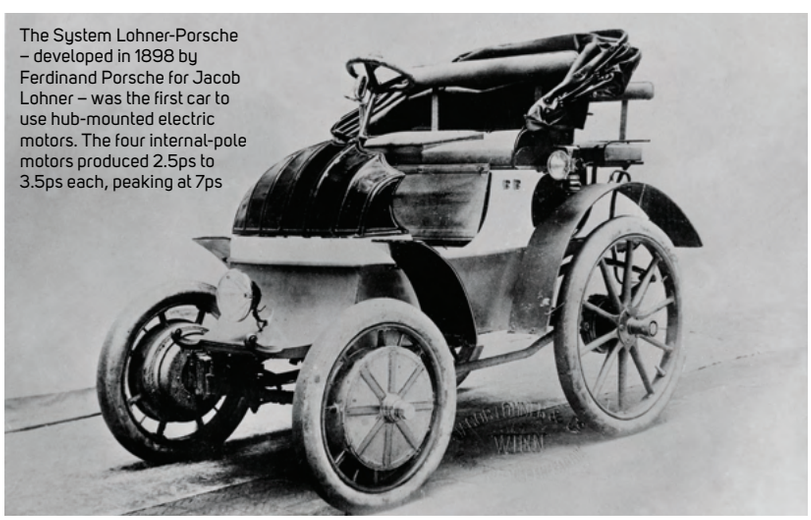
> "I can't see the technology taking off, to be honest. I've seen people offer wheel motors in packages that appear not to have friction brakes, which I don't know how you'll get past the DFMEA"
>
> Jon Hilton, co-owner and co-founding director, Flybrid Automotive

The 2006 Honda FCX has three electric motors: one front-drive motor with an output of up to 108ps, and two smaller motors with a maximum output of 34ps driving each of the rear wheels

Likewise, Barker believes supporters of the technology will fall short on a regulatory and technical basis. "Current braking regulations do not allow completely non-friction braking systems, and regulations take time to catch up with technology," he says. "To change the actual regulations is probably a three-year process. There's a customer expectation as to how quickly the vehicle can slow down, and regenerative braking simply cannot move the energy around quickly enough. We're talking about megajoules of energy in a 1g deceleration. A standard vehicle decelerating from 1g at 100mph [160km/h] has to get rid of 1.8 megajoules of energy, and 75% of that is at the front wheels because of the weight transference. So it might be possible not to have friction braking from the rear axle, but certainly with current and near-term technology you'll still need friction braking on the front."

Despite such drawbacks, a huge perceived benefit of all electric motors, including in-wheel variants, is the environmental gains that the technology realizes, but even this issue is being debated. While vehicles that run on an EU-average electricity mix will show somewhere between 20% and 30% net CO_2 benefits over IC vehicles, the way in which the electricity itself is sourced ultimately determines how green the technology truly is. "If we can get to a point where the electricity we use is genuinely zero carbon, then clearly our form of transport becomes zero carbon," says Greenwood. And while Pronovost cites that 90% of Canada's electricity is sourced from clean hydroelectricity, Barker says that in the UK, "the tailpipe equivalent grams per kilometer of CO_2 for a pure EV is around 70-80g just because electricity is generated in a dirty way. In France it's far less because a lot of their electricity generation is nuclear. So, you can't just say that a pure EV emits fewer emissions than a combustion vehicle – you've got to look at the bigger picture."

So, it would seem in-wheel electric motor technology still has much to prove, not only to OEMs potentially interested in adopting it, but also to the suppliers developing the technology. What's certain, however, is that in-wheel motors will one day become a legitimate method of propulsion in light passenger vehicles. When that day will arrive is yet to be determined.



The System Lohner-Porsche – developed in 1898 by Ferdinand Porsche for Jacob Lohner – was the first car to use hub-mounted electric motors. The four internal-pole motors produced 2.5ps to 3.5ps each, peaking at 7ps

Protean in-wheel motors are actually in wheels… and on the road.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Testing and development cycles for new electric vehicles are still evolving. Pictured here is VW's XL1 diesel hybrid offering being inspected by powertrain engineers

Double standards

Manufacturers of IC-engined vehicles have had more than a century to fine-tune development programs for new powertrain designs. For the EV arena, however, it's a very different story, with new standards and testing procedures all being up for grabs

WORDS: **JOHN CHALLEN**

Vehicle manufacturers, automotive analysts and battery developers the world over have, for some time, been talking up the impact that all-electric powertrains will make on the global automotive market. Yet while such favorable rhetoric is all well and good, there's little doubt that when it comes to actual development, electric vehicles have a long way to go – especially when compared with their IC-engined brethren.

The thinking is that specialist vehicles need specialist test equipment, and one supplier that's running with this mantra is Sakor, which has recently introduced a high-voltage battery simulator and test system designed specifically to meet the need of electric and hybrid powertrain development.

"One of our typical advanced systems involves one or more dynamometers driving the motors in the electric vehicles, and we are also providing a battery simulator to drive the inverter and electric motor, simulating the battery at the same time," explains Sakor president, Randy Beattie. "But testing the battery is just one piece of the jigsaw, and more often than not we are evaluating it in more than one dynamometer, instead of testing the entire electric motor, inverter and gearbox as a whole."

The problem with the development of EVs, says Beattie, remains with the batteries, specifically the rates of power density. "Electric vehicles have been struggling with the same problems they've had for 20 years, and a lot of these issues are to do with power density," he maintains. "Trying to come up with smaller, lighter, higher density batteries has been a very slow process so far. There have been incremental improvements, but nothing revolutionary. In this respect, our battery simulator and test system is very useful, and we have undertaken a lot more testing, but so far we haven't seen any major changes in the technology."

Power rangers

Unsurprisingly, vehicle manufacturers are also keen to see improvements in battery performance, and it's in this area that testing and further development will play a key role. "One of the challenges we have in testing is actual vehicle range," outlines Ben Boycott, CEO of Detroit Electric, which recently showed its first entrant into the EV world, the SP:01. "Achieving a sign-off for durability work is easier in a car that is quick to refill because you can simply do more kilometers in one shift. With SP:01, for example, we've spent more time on development because we can only do a certain number of kilometers before we need to recharge the vehicle, which takes a number of hours, not minutes."

Boycott recognizes that the challenge is getting the road testing and miles done in the time that the project permits, which, he says, means being inventive with shift patterns. "For a transmission test cycle, it would be maximum acceleration at low speed, medium speed, and finally high speed. Then we would do it all over again in another gear, and go through all the gearchange cycles," he explains. "We would normally get 100 miles of testing, give or take 25% depending on how aggressively we're driving the car."

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1. Johan Konnberg, project manager for Volvo's C30 Electric program, says creating the right durability cycle for an EV is not an easy task

2. At present there are 250 C30 Electric vehicles being trialed with select customers

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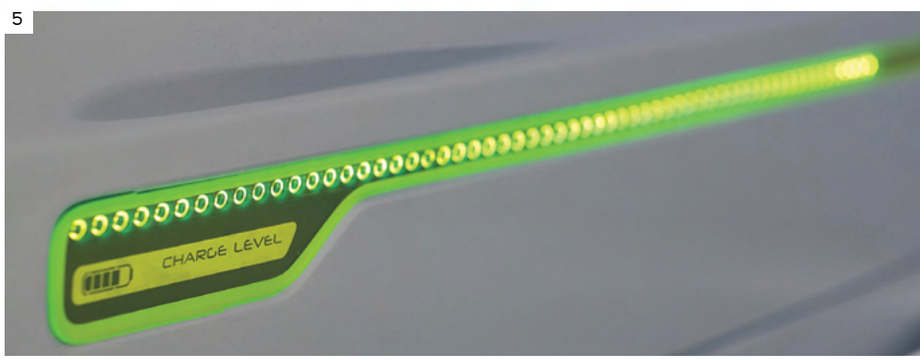

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3. Unveiled earlier this year, the SP:01 from Detroit Electric has been created with performance in mind, with a 0-100km/h time of 3.7 seconds

4. SP:01's electric powertrain gives a 290km (180 mile) driving range

5. Battery charging time is creating many challenges during EV testing

6. Underneath the skin of the frontal area of Volvo's C30 Electric creation

7. Crash testing of the C30 Electric is undertaken at Volvo Cars' test labs

"One of the challenges we have in testing is actual vehicle range. Achieving a sign-off for durability work is easier in a car that is quick to refill because you can simply do more kilometers in one shift"

Ben Boycott, CEO, Detroit Electric Engineering

COMPARE AND CONTRAST

Volvo's Konnberg and Detroit Electric's Boycott admit that a lot of their EV testing work marries up with that of a traditional vehicle test schedule, but there are obvious differences surrounding the powertrain. Not surprisingly, a large degree of the effort in the development of SP:01 was concentrated on battery safety systems. "This is a critical part before we step up to vehicle safety systems such as regenerative braking, ABS and calibration of the motor in respect of battery safety as a whole," reveals Boycott. "The battery management system plays a key part in how the vehicle behaves, because the battery is the significant entity in the vehicle.

"We use MIRA and Millbrook, but also some other smaller companies. They typically have smaller chambers that can be set up or adapted to our specific needs. We tend to need a bit more specialty in how we test, so the smaller, more flexible operators are very useful to us."

As well as range, charging speeds remain an issue, says Boycott. "Our system can charge up to 18kW, but most facilities don't have that kind of charging system available. All we need is a lot of amps, but at most facilities, such as Rockingham in the UK, you can only get around 16A, which gives you 3.7kW. If we used that system it would take us 10 hours to charge the car!" For any OEM, this is hardly a desirable situation when the testing teams are under the same time and cost pressures as standard vehicle development groups. "Hopefully, in the future, there will be a range of charging equipment available at these test facilities," the Detroit Electric CEO continues. "For us, it needs to be high current, single phase, but maybe in the future, three-phase or DC offerings would be more readily available."

Boycott believes the challenges facing electric vehicle manufacturers when it comes to testing will reduce in the near future. "The main benefit is going to be that we will have a set of proven test procedures and know where the critical paths are in the technical development of, let's say, battery thermal management systems," he maintains. "We already know, from the testing we've done, the type of tests we need to focus on, and from the simulations we are doing now, it will be more sophisticated from the first round of testing."

This level of sophistication is key, as is the role that simulation will play. "We should be able to do more on the test bench to simulate the vehicle," he maintains. "With our first electric vehicle, we didn't know how it behaved, despite the simulation work. The first time we did our crash analysis, it wasn't very good, but now you can rely on it. This, as well as better availability of test equipment, means that we can streamline some of the development activities and test procedures."

Another challenge that Detroit Electric has faced is general skepticism toward electric vehicles, which has produced some interesting testing scenarios. "Some companies are quite nervous about having EVs on their rigs or chambers. It's irrational really, because there is much more energy in a tank of diesel or gasoline than there is in a battery, but they worry because they haven't had an EV in a chamber before," says Boycott, highlighting the lack of safety systems in place as the cause of the anxiety in some independent testing facilities. "We were using a climate chamber at one company, and it insisted that we had another vehicle connected to our vehicle. So we had a chain coming out through the chamber door, and if our vehicle had a problem, the other test car could immediately tow it outside, thus protecting the chamber." It turns out that the company, having had no experience testing EVs, thought that the high and low temperatures that were being tested could cause the batteries in the Detroit Electric prototype vehicle to become unstable.

Clearly there is a long way to go for some areas of the industry to fully understand the needs of manufacturers when it comes to testing electric vehicles. Boycott says he and his colleagues are working hard to try to educate the people that need to know. "We speak to them, and explain about the safety systems the car has on board. We tell them that long, long before the battery reaches a critical point, the whole system will shut down automatically. Other than showing them our test data there isn't a lot more we can do."

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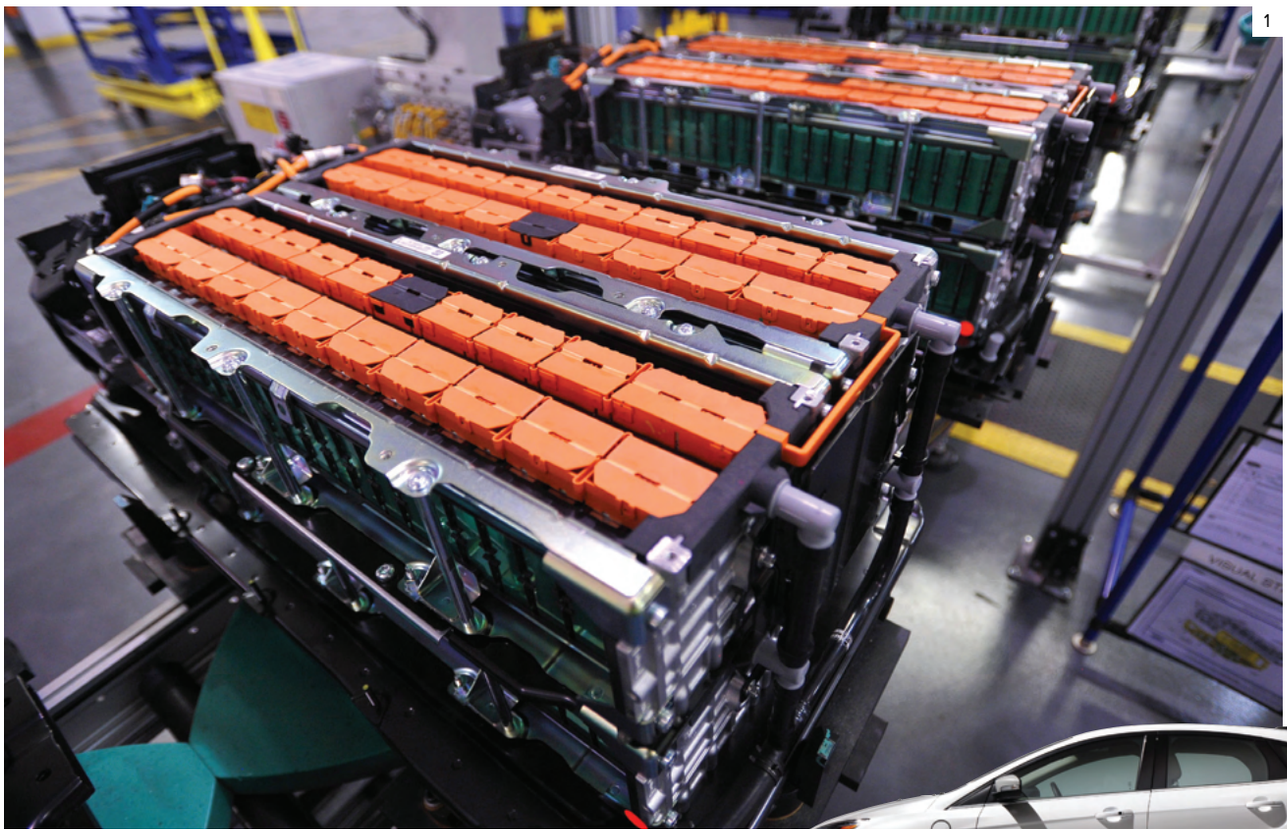
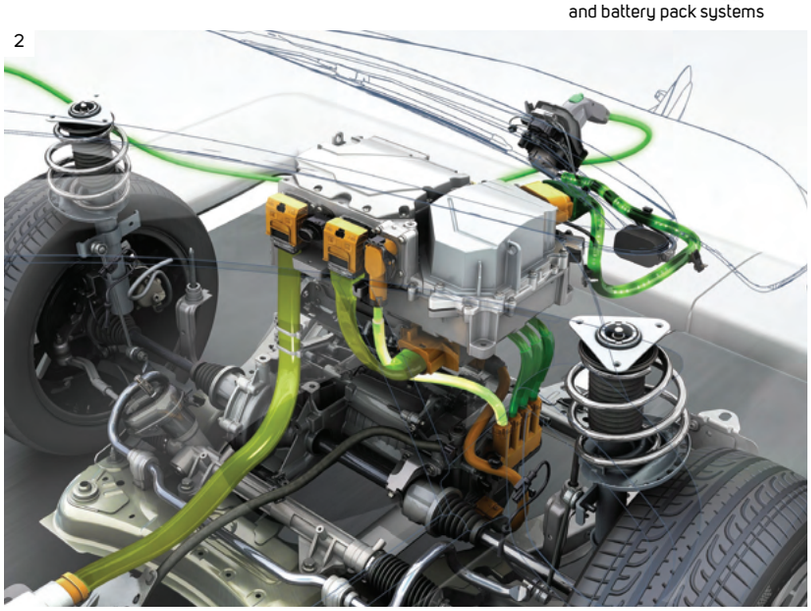


1. Ford has ramped up battery development work as its EV range has expanded, first with the C-Max hybrid and C-Max Energi plug-in hybrid models and then with the all-electric Focus (right)

2. The Renault Lardy R&D center has played a key role in the French car maker's advancement of electric powertrain technology and battery pack systems

"Testing the battery is just one piece of the jigsaw, and more often than not we are evaluating it in more than one dynamometer"

Randy Beattie, president, Sakor



A break from the norm

Volvo, in many respects a leading pioneer when it comes to automotive development – especially in the areas of safety and forced-induction IC engine designs – has encountered numerous new issues in its electric vehicle development evaluations. Johan Konnberg, project manager for Volvo's C30 Electric project, says that while the company's 250 vehicles are not strictly prototypes, they are not production-ready either. This puts Konnberg's team in the interesting position of placing cars in the hands of potential customers and project partners before they are signed off. While Volvo's project manager is quite happy for this select group to conduct their own form of testing – especially if it helps the broader development of the Swedish car maker's EV portfolio – Konnberg has witnessed, first hand, what can go wrong.

"At one point during assessment of the C30 Electric, we had to stop the project and redesign the vehicle heating system because we found it was too weak for the Nordic climate we were testing in," he recalls. "The car had a range of 120km, but at -20°C, our test team could reach only 70km – there was just not enough power, because a lot of the energy was being taken by the heating system to keep the occupants warm."

The solution the team came up with is a compromise, and something not regularly seen in standard vehicle developments. "We now have an external heater, running

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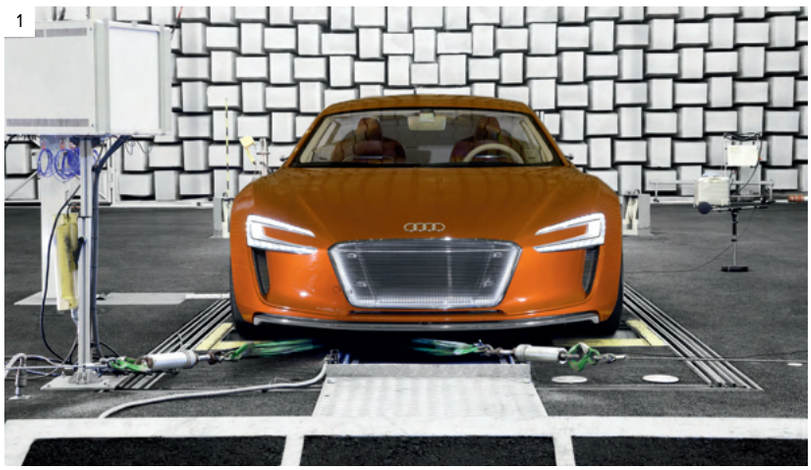

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on E85 fuel, which takes care of the problem to an extent," reveals Konnberg.

"We also found out early on in the C30 Electric program that we needed two safety systems on most of the electronic features, so if something happens to one, you always have another to work with. If the systems fails, you are dealing with 400V, so ensuring safety all around is a priority."

Yet creating the right durability cycle is not easy given the combination of low and limited driving range and relatively long charging times for these new electric vehicle creations. For Konnberg, the challenge is running the vehicles as close to 24/7 as possible. "We have a few vehicles recording high concentrated mileage and from these tests we have proved that there is no battery degradation," he says, adding that he initially feared that the charging cycles would have a negative effect on the battery power available.

However, such a cycle is not without its drawbacks: "The range available from one charge is 120-140km, and with our 22kW fast-charging system, the vehicles can be back out and on test in under two hours. But the batteries, connectors and cables are restricting charging times," the Volvo project manager adds. "We cannot put more than 22kW into the vehicle because it will not store more energy than that. Even though the market is talking about 50kW, we have to evaluate that to see if it is worthwhile and find out the costs involved."

1. Audi's upgraded EV development facilities in Ingolstadt underpin the company's e-tron program

2. An Audi engineer connects lithium-ion cells to an electrical testing unit

3. Mercedes-AMG is also stepping up electric engine developments. Shown here is the technology that underpins the SLS AMG

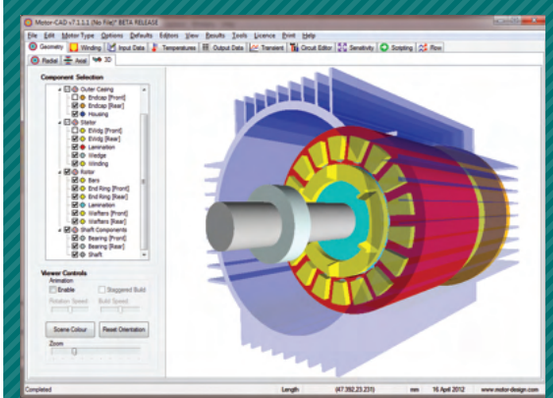
ELECTRIC MOTOR MODELING

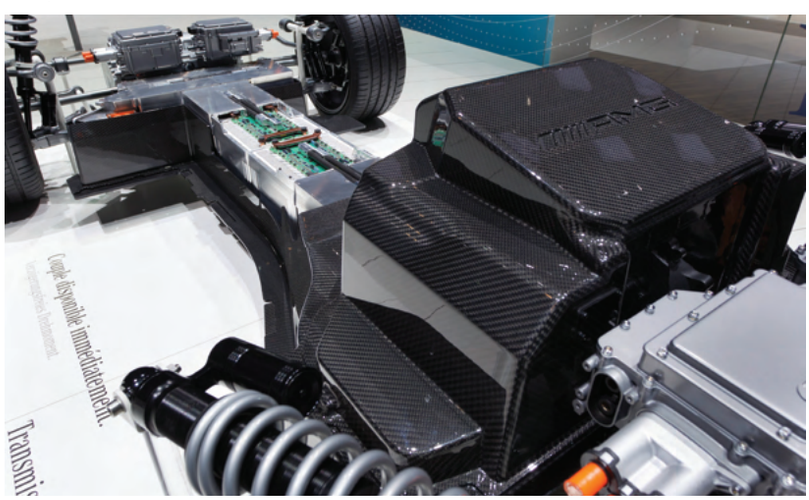
In the area of electric motor simulation software for electromagnetic and system cooling, Motor Design has developed Motor-CAD, a sophisticated and easy-to-use software simulation program that is helping many OEMs when it comes to new-generation electric vehicle developments.

Dr David Staton, director at Motor Design, says the development package is used to predict motor thermal performance with different duty cycles, thus optimizing the cooling system for the expected load cycles. He adds, "Motor-CAD v7.1 has some exciting new features to make cooling system optimization even easier to carry out and produce more accurate results. It also has new visualization features to aid understanding of the cooling system performance."

One of the new visualization features is a 3D geometry viewer, which makes it easy for engineers to visualize the cooling system as a whole. Another feature that has been integrated into the package improves accuracy in calculating the heat transfer through conductors.

Staton says it only takes a few seconds to construct a mesh and undertake calculations. He adds, "Not only does Motor Design provide software to motor designers, but we also provide extensive consultancy and training services. And our customers always get expert motor design advice and full support."





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Cell formation

A new pioneering program could result in more accurate safety and durability testing for the battery packs in hybrid and electric vehicles

WORDS: **GRAHAM HEEPS**

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In the young, fast-changing field of hybrid and electric vehicle development, test methods and standards are evolving as quickly as the experience being massed by OEMs and specialist suppliers. In the case of durability testing, developers of IC-engined vehicles can rely on mature testing procedures that have been correlated to decades of data from real-world use. However, that data simply doesn't exist yet for electrified drivetrains, so there is a far greater risk that components and subsystems will be under- or over-engineered.

To help fill the gap, a team at the Millbrook test and development facility in Bedfordshire, UK, decided to research the typical vibrations to which a car's battery pack is exposed, as a first step toward establishing new standards for battery durability testing – an essential strand to any EV development program.

The project's impetus came from a customer who wanted Millbrook to devise a vibration testing system for battery packs. "When we reviewed the academic literature, we found very little published research or publicly available studies with regard to the vibration testing of electric-vehicle energy storage systems," outlines senior engineer Jim Hooper.

1. The Smart ED was one of four electric or hybrid cars used to gather data by the team at Millbrook, plus the IC-engined benchmark

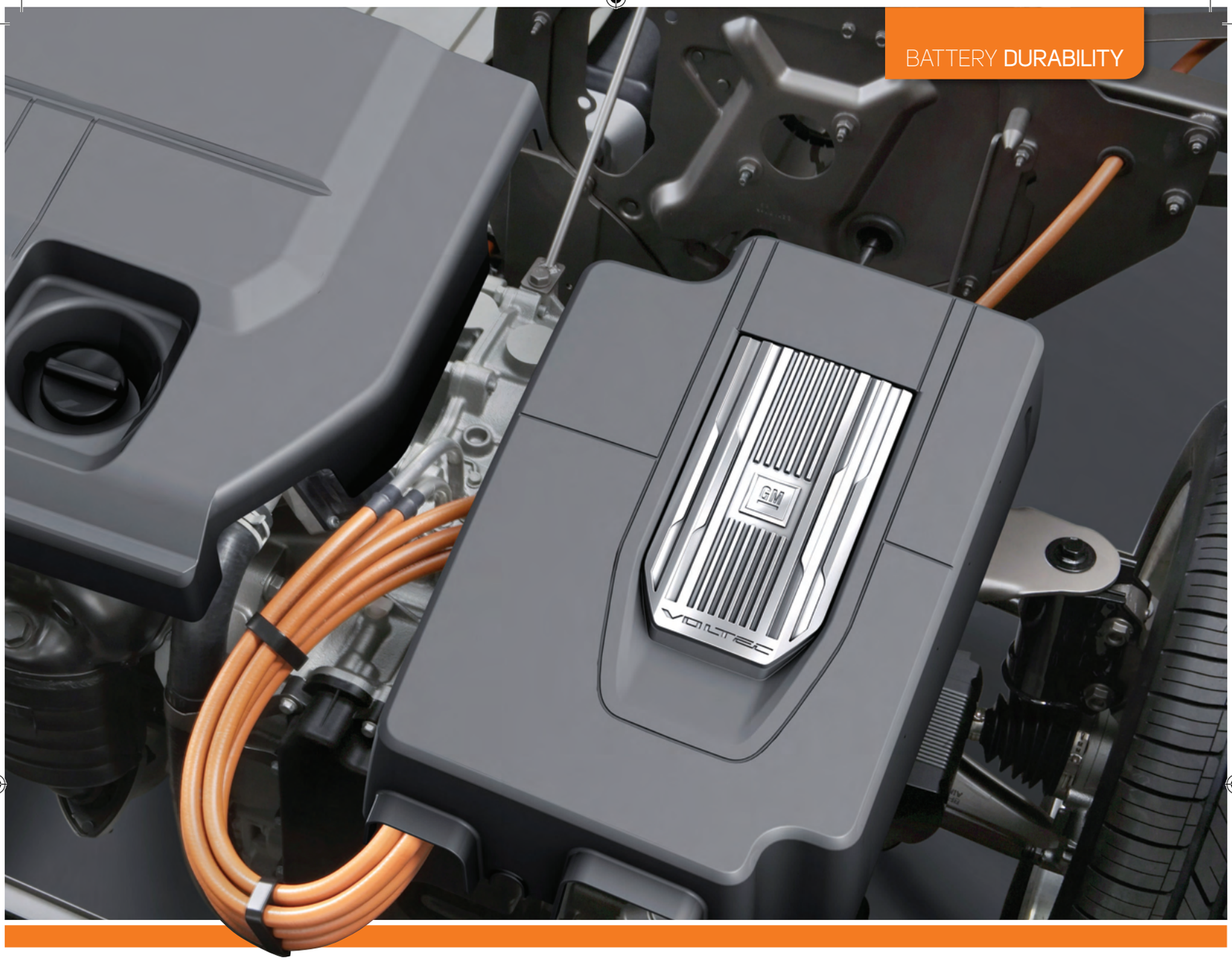
2. The Nissan Leaf's air-cooled, pouch-cell battery pack. Future test standards may need to take account of different cell constructions

3. GM's Voltec range extender powertrain in the Vauxhall Ampera was also assessed by the team

Vehicle manufacturers have their own test specifications for battery packs, but there are some industry standards that OEMs have to adhere to. Hooper identifies SAE J2380 and a similar US Advanced Battery Consortium specification for vibration testing, as well as British standard BS62660 (an abuse test for battery-pack cells) and the new ECE-R100, which also has a requirement for the vibration testing of battery packs.

"However, if you start looking in further detail at the existing specifications, you see they suffer from a number of limitations," Hooper continues. "Most of them haven't been devised to represent a given vehicle's durability life. The majority have only been devised as a short-term abuse test, just to determine the failsafe performance of the pack, as opposed to a durability-based procedure to determine whether the pack would survive a warranty period. One of the biggest uncertainties for battery-pack suppliers is how long to guarantee them for."

Hooper's team found that specifications have often been based on data from consumer electronics, which will have a completely different life and service operation from a battery pack in a vehicle application.



"There are little anomalies that haven't been considered and that we have identified"

Jim Hooper, senior engineer, Millbrook

"Another limitation we've found is that some of the specifications only test in the *z*-axis," he says. "And when there are specifications that want you to evaluate in the *x*- and *y*-axes, they want you to use the same vibration profile, which is not realistic at all, because you get different *x* and *y* behavior."

A further shortcoming is that the majority of specifications treat an EV battery the same way regardless of the vehicle it's going to go into, with no discrimination between a battery EV and a hybrid, which will have very different vibration characteristics due to its onboard generator.

"There are little anomalies that haven't been considered and that we have identified," Hooper adds. To gather some realistic vibration data, Millbrook obtained a group of different electric and hybrid vehicles including a Smart ED, a Vauxhall Ampera, a Nissan Leaf and a Mitsubishi i-MiEV. Data was collected from triaxial accelerometers at six locations on each vehicle: both A-pillars, the front and rear of the battery packs, and the front and rear of the chassis.

"We looked at the different vibrations to establish durability cycles," explains Hooper. "We used surfaces from Millbrook's structural durability test procedure as a

basis, which simulates a 10-year life of a typical European passenger car. That test specification has been correlated to real-world data. Granted, the limitation is that it's going to be 10 years of an IC engine because that's where the correlation has occurred, but it's a starting point.

"There is scope for us to do future research – because there isn't any data out there at the moment – on what the typical life is for a battery electric or hybrid EV. Early studies that have reviewed the use of battery EVs, even though they took place over only two years, have seen changes in customers' usage behavior. Customers are adapting their behavior to be more in line with how they used their IC-engined vehicles."

The test team recorded each surface separately using the same speed, vehicle setup and arrangement, and number of passengers. An IC engine vehicle was used as a baseline so that any differences in characteristics between EVs and IC engine vehicles could be highlighted. The results made interesting reading, as Hooper explains: "All vehicles displayed significant vibration energy from 0-5Hz, derived from primary ride behavior. That was interesting because the specifications we reviewed typically evaluated EV vehicle batteries from 7Hz upward. So there is a big chunk of vibration that is being ignored in the specifications.

"We also found on the Leaf and the i-MiEV that at frequencies above 300Hz there were some reasonably high vibration energy spikes. This is subject to further research, but we think those resonances could have three sources. They may be a function of powertrain vibration – the vibration being transmitted from the EV motor to the pack. They could also be a function of the cooling strategy, because we saw these vibration spikes occurring only at high speeds of around 80-112km/h (50-70mph), which is when the cooling fan will activate. Finally, they could be a function of the power electronics with the transformers cutting in.

"If it is the cooling system, then there are implications for test standards and how engineers are going to have to develop their products," he continues. "The packs in vehicles destined for a warmer environment will be subjected to more vibration input than a vehicle in a more temperate climate such as the UK."

Interestingly, the Nissan Leaf displayed a unique vibration spike that could be a result of its battery pack being air cooled rather than water cooled, a setup dictated by the pack's pouch-cell construction. Other spikes from 7-20Hz in all tested vehicles – including the IC engine-equipped Ampera – could stem from the powertrain, such as the gearbox and engine rolling or bouncing on their mounts, or from vibration induced between the suspension and the road surface, such as hop. In this respect, there is some correlation between EVs and normal IC-engined vehicles.

"Something we found that was EV-specific was vibration spikes from 20-70Hz," adds Hooper. "We believe this is a function of the body torsion mode being introduced into the pack. In EVs, the pack usually forms part of the chassis or body assembly because it's such a large item. We noticed that in these frequencies there were differences in the isolation strategy for the pack being employed by the OEMs. There are different forms of mounting and different NVH as a result, so that's another factor that needs to be considered when you're developing test standards."

The Millbrook team sequenced the recorded data using nCode vibration analysis software. A power spectral density plot for a 10-year life of the vehicle was created and overlaid against the J2380 and BS62660 test profiles.

"Whichever way we sequenced the data, we came to the conclusion that the J2380 standard is too harsh for a simulated life test of a European passenger car," says Hooper. "We also evaluated against BS62660. As with J2380, we came to the conclusion that it was too severe from a vibration point of view."

For the future, Millbrook would like to work with battery makers to help devise specifications that would be more realistic to the application of their automotive packs, and with other bodies to try to improve pack specifications.

"We have a chance for this study to snowball," says Hooper. "We are working with Dr James Marco at Cranfield University in the UK to publish the results because we don't think they should be hidden away."

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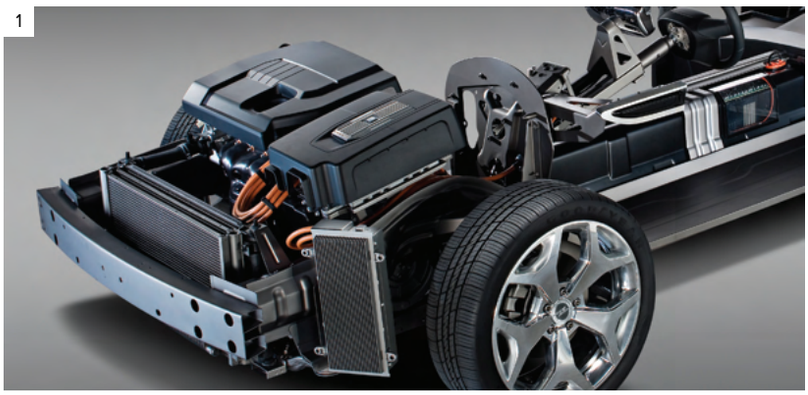

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1 and 2. The Ampera being assessed at Millbrook as part of the program. Millbrook is now aiming to work closer with battery makers to help devise specifications that would be more realistic for the automotive industry

MOVING GOALPOSTS

Hooper acknowledges that the field of EV testing is evolving rapidly and, inevitably, having completed the study there are areas he would like to revisit.

"We'd like to instrument a vehicle to understand what the cooling system is doing and establish what impact different temperatures have on vibration with regard to the cooling systems of different vehicles," he says. "We can certainly do that at Millbrook because we have the large vehicle chambers, the tracks and also a dyno within a chamber. It might also be interesting to do a whole-vehicle modal analysis and see how the pack behaves with regard to the modes at which it resonates, from vehicle to vehicle. That will certainly give us more definitive answers for the impact of the various factors that we've identified."

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Material gain

In the ongoing debate over lightweight design, choosing the right material is moving ever higher up the EV optimization agenda. Are carbon fiber and its alternative material cousins the new black for this new-generation of eco-friendly automobiles? *E&H* investigates

WORDS: **MAX MUELLER** ILLUSTRATION: **BEN WHITE**

For designers of drivetrains that power electric and hybrid vehicles, important factors such as lightweighting, CO_2 reduction, efficiency gains, greater range and better performance are inextricably linked terms. As such, engineers are looking to further drive down weight through the use of carbon fiber, hybrid plastics and organic matrix composites. But do these new, promising materials really outperform traditional aluminum and steel when it comes to cost, weight and compatibility?

At Lotus, engineers can see the potential of new materials, but aren't predicting a revolution any time soon. "For high-volume applications, aluminum and steel remain the best compromise," says Phil Barker, chief engineer of hybrid and electric vehicles. "Even though alternative materials are continually being developed to offer increased benefits, the more conventional materials are also being improved.

"Motorsport frequently uses materials such as magnesium and carbon fiber for lightweight housings,


Organic Matrix Composites
Hybrid Plastics

titanium for lightweight and low-inertia geartrain components, and carbon fiber for lightweight and low-inertia shafts," he continues. "Because of the relatively high cost of the base materials and the manufacturing processes, they do not lend themselves to general use. But they can offer cost-effective benefits in specific applications such as carbon propshafts and driveshafts for higher rotational speeds, and in magnesium housings for weight-sensitive applications. But the standard materials are likely to remain dominant for the foreseeable future."

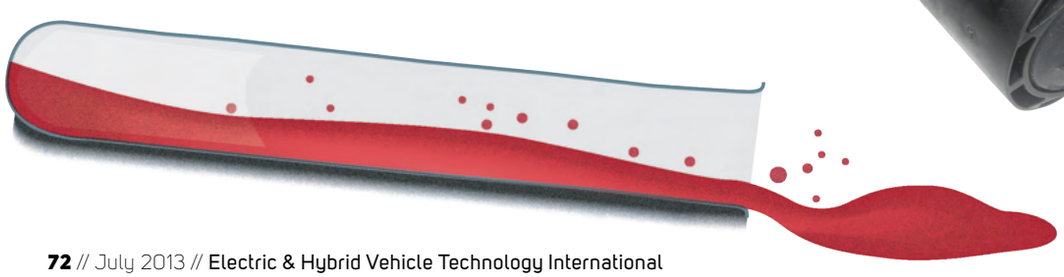
Barker is not the only one with this outlook. Engineers at Drive System Design, based in Warwickshire, UK, also advise caution: "The main challenges are to reduce cost and weight while improving refinement and efficiency," says the company's managing director, Mark Findlay. "These aims generally conflict with one another as NVH issues often require mass for them to be eradicated. The introduction of advanced materials requires an in-depth understanding of the manufacturing constraints and the differences in material characteristics. The use of plastics may migrate from unstressed covers to structural casings, but introduces concerns about heat rejection. Composite propshafts save weight but are susceptible to impact damage and have less inherent damping, so are more liable to excite rattle modes.

"There are interesting developments underway using plastic materials for gears and selector forks," Findlay continues. "Chopped carbon fiber mat used as a bulk material may have potential applications, and carbon nanotubes as part of injection-moldable materials will open up new possibilities. But for any new material to be successful, it requires thorough assessment of manufacturability, robust NVH modeling and an appreciation of its sensitivity to any production-generated variation in its properties. The next generation of highly efficient, downsized e-machines running at higher rpm will produce higher input speeds to the transmission, creating different running conditions and driving the selection of different gear steels. The low cabin noise levels, when running in electric mode, create additional NVH challenges for the transmission and driveline. For the latter, avoiding the power loss inherent in forced lubrication means that special oil formulations and surface coatings can be necessary to permit splash lubrication."

1. The Smart Forvision's seats are super absorbent and contain integrated fleece fabric to enhance seating comfort through its passive climate control

2. Hexagonal transparent solar cells on the roof of the Forvision transmit light and generate energy to various applications housed within the concept

3. Developed with BASF, the Smart Forvision concept vehicle combines a futuristic design with technologies relating to energy efficiency, lightweight design and temperature management



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4. The high-temperature resistant engineering plastic, Ultramid Endure, from BASF has found its first production application: German supplier Montaplast is using the polyamide specialty Ultramid Endure D3G7 for a heat shield in the charge-air manifold on Daimler's four-cylinder diesel powertrain product

5. A lower tie bar and lightweight fixing to an oil sump by BMW – two new lightweight designs

"Composite propshafts save weight but are susceptible to impact damage and have less inherent damping, so are more liable to excite rattle modes"

Mark Findlay, managing director, Drive System Design

Lubricants and their interaction with material surfaces is a subject currently being investigated at Romax, as CTO Barry James explains: "We're running a project funded by the Energy Technologies Institute in conjunction with Ansys and Castrol. We're aiming to cut parasitic losses in lower drivetrains by focusing on gears, bearings, lubricant flow and lubricant composition – and one key element is surface treatment. Gear materials still have to be durable and strong, but a better interaction of the surface with the oil can bring a substantial reduction in friction. Another interesting area within lubricants for EVs is a common coolant and oil system for the motor, electronics and gearbox. Because of the better thermal properties of water, we're looking at water-based lubricants – effectively, emulsions. They can transfer more heat, but the challenge is in the lubrication function – so far I haven't actually recommended use of water-based lubricants in any of my gearboxes," he laughs.

Replacing precious rare earth metals

"Looking at hybrid and EV drivetrains specifically, another hurdle is to develop electric motors with a reduced or zero content of rare earth metals to enable production without having to rely on potentially uncertain supplies," James continues. "The replacement materials are well known – conventional electromagnetically active ferrites – but the key is to use new structures and new ways to design motors that have enough power density and are sufficiently quiet, but can still deliver the performance of the permanent-magnet machines people are used to."

Another mainstay of the electric drivetrain is the battery, where new ingredients can play a major role. "In addition to developing advanced materials for lithium-ion batteries, we're researching future battery concepts such as lithium-sulfur and lithium-air," outlines Dr Martin Jung, senior vice president for global structural materials at BASF. "We need batteries that provide a greater driving range with lower costs per energy unit. To address this, we've partnered with organizations such as Sion Power in Tucson, Arizona, to develop lithium-sulfur technology with a mid-term goal of tripling the energy stored in the battery per weight."

Another focal point for the company is the development of engineering plastics. "The move toward electric and hybrid drivetrains is creating new demands on the characteristics of plastics," Jung explains. "On the one hand, entirely new properties are required in terms of temperature resistance, electromagnetic shielding and flame protection. On the other, a higher proportion of plastics in cars is needed to compensate for the battery's additional weight and ensure an adequate driving range.

"We have just expanded our assortment of polyamide grades optimized for the use of water-injection technology (WIT) in injection molding, to produce hollow plastic parts suitable for medium-carrying lines that require a very good inner surface," Jung adds. "For tubes that convey oil (for example, for dipsticks) or for other applications with high oil resistance that have specific stiffness and dimensional stability needs, WIT-processed materials offer great advantages.

"Copper can be replaced by aluminum for some electrical cables and we try to use silver instead of gold coatings for connectors"

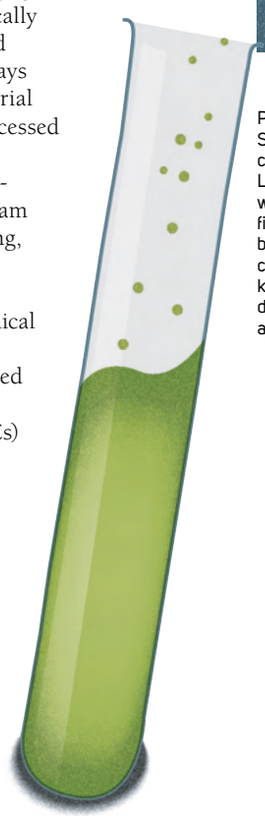
Martine Monin, material and process expert, PSA Peugeot Citroën

"In the motor compartment, integral polyurethane foam is particularly applicable. It shows outstanding temperature resistance, as well as high dimensional stability and excellent sealing characteristics. It can be used for the end caps of filters, for sheathing on cable bushings and harnesses exposed to high temperatures, and on engine covers. We're also developing solutions for glass or carbon fiber-reinforced plastics based on epoxy, polyurethane or polyamide chemistry. In this context we've launched new products for resin transfer molding processes," Jung concludes.

Counting the cost

In addition to the increased use of engineering plastics, developments at PSA Peugeot Citroën address environmental impact and cost reduction. "For highly mechanically and thermomechanically stressed parts we mainly use forged steels and aluminum cast alloys," says Olivier Delcourt, PSA's senior material and process expert. "These are processed through high-pressure die-casting without heat treatment, gravity die-casting with heat treatment, lost foam casting and low-pressure die-casting, using remelted alloys and recycled raw materials."

For parts exposed to less mechanical stress, the company uses technical plastics such as polyamide reinforced with short glass fibers (also called organic matrix composites or OMCs) in applications such as air hoses, air intake manifolds, water outlet housings, fuel rails and engine mounts. "These plastics can be green materials when combined with recycled nylon, bio-based materials such as Rilsan polyamide, which is made from castor oil, or in polymers reinforced with natural fibers," outlines Martine Monin, another material and process expert at PSA.

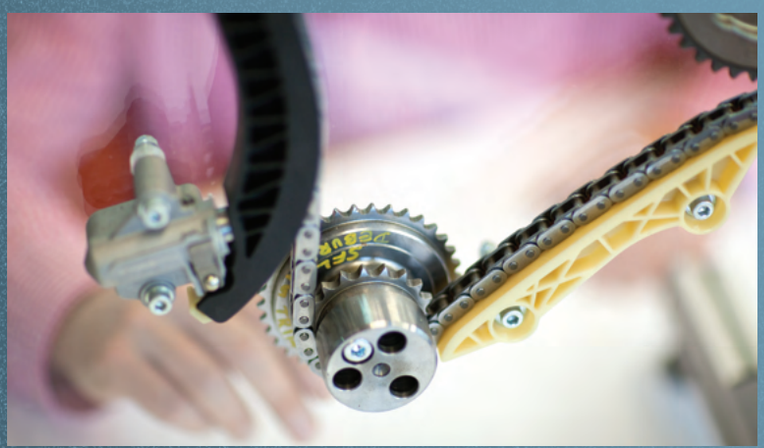


SMARTPHONE TECH TRANSFER

Laser direct structuring (LDS), a new production process previously used in mobile devices such as tablets and smartphones, promises to make small but worthwhile weight savings in EV and hybrid electronics.

"LDS fuses electronic tracks with plastic covers and other components used in the drivetrain without the need for a separate circuit board," explains Ralph Ramaekers, global segment manager for powertrain at Dutch materials company DSM. "The technology can deliver benefits by making parts more compact with higher functionality where electronics in automotive systems need input via sensors or generate output to activators and other components."

Further integration of electronic components or wire attachments soldered onto the tracks of the LDS part requires the use of high-temperature materials. For this purpose, DSM recently introduced a range of compatible Stanyl engineering plastic grades. Stanyl ForTii is suitable for the reflow soldering process because, unlike PC/ABS, it can withstand the high temperatures of lead-free reflow soldering without loss of its properties. The high strength and stiffness at room temperature and elevated ranges limit warpage during and after the soldering process.



Part of the BMW i8 Spyder's efficiency comes from the company's LifeDrive construction, which consists of a carbon fiber reinforced plastic body and mainly aluminum chassis, ensuring weight is kept to around 1,600kg, despite the heavy batteries and other EV subsystems

"One challenge is the complexity and expense of hybrid technology – we're constantly looking for savings. Copper can be replaced by aluminum for some electrical cables and we try to use silver instead of gold coatings for connectors.

"The second topic is durability," she continues. "Electrical components must not corrode with water or salt spray from roads, so electrical boxes must be sealed properly and electrical contacts protected. For this we're developing tests to characterize and validate new materials.

"Characterization tests are rather complex – for most parts, monotonic tensile tests alone are insufficient – and need to provide material data for the relevant simulation," she says. "Our CAD specialists keep changing behavior models and associated criteria so that the numerical simulation can improve the design's reliability. You need to know how to characterize and validate materials and associated processes, from metallic materials and plastics/OMCs, to hybrid metal-plastic solutions."

PROFILE: DICK GLOVER

Job title: Research director
Company: McLaren Automotive

What career did you want when you were growing up, and what was your first job?
As a youngster I dreamed about becoming an engineer a lot. In fact, the other day I was going through some stuff at home and I found my old *Shell Motor Book*, which must have been published in the 1970s. As an 11-year-old I read it all the time! I started my career as an engine engineer with Ricardo, focusing specifically on combustion, but before that I did mechanical engineering at university. I was always driven as much by a passion for technology as a passion for cars. I just loved – and still do love – engineering, hence my career as an engine engineer.

What was your career path to the position you currently hold?
Following my time with Ricardo as an engineer immediately after university, I moved into the oil industry to work for Shell. My time there further increased my passion for technology, helping me to gain a deeper understanding of combustion processes. I then started formulating racing fuels for McLaren, and that was a whole new area of chemical technology that I found fascinating. Following that I went into Formula 1, heading McLaren's vehicle dynamics team. I only truly joined an automotive company in 2007, when I became technical director of McLaren Automotive. Since then I have led the engineering team on the development of the 12C, which was an incredible challenge. It presented new technical challenges for me personally, but in addition it was also a totally new sector because I'd come from Formula 1. Now my job is director of research, so I'm looking at technologies for future products. In that respect I've had a very good grounding having worked on the 12C, but alongside that I am also now revisiting some of the things I learned years ago when I was working in other industries.

What are the best and worst elements of your job?
The best bit is how many good ideas and how much interesting technology I get the chance to look at – from an engineering perspective, that's just amazing. The worst bit is how little time there is.

> There will be lots of cars that have conventional IC engines that will be a lot more efficient than they are at the moment, and that trend is going well, but there will also be lots of electric vehicles

What car do you currently drive?
We get to drive fantastic cars at McLaren, so there's not much point in owning a sports car. My passion for getting kicks is motorbikes and I have a lot of them, which I need to transport, so I have a Mercedes Viano.

Emissions legislation aside, what would be your dream engine specification?
It's probably very unimaginative, but something very close to what we've already got in production: a highly rated turbocharged engine.

What would your dream engine specification be for today's eco-friendly world?
Again, it would be similar to what we've already got, but with a focus on pushing in that direction – making the engine smaller and smaller, with better turbocharging and increasing power output. So we end up with something that's very small, lightweight and efficient, but overall very exciting to drive.

In your opinion, what is the greatest engine that has ever been produced?
The Rolls-Royce Merlin engine that powered the Spitfires, Hurricanes and Lancasters during World War II. It was a 27-liter V12 that offered incredible performance for its time.

Which OEMs do you have engineering respect for in terms of engine development?
The Yamaha engine that's in the Lexus LFA is a very nice job. It's a normally aspirated V10 and it sounds sublime.

What could legislators do to make your working life easier?
The UK government initiative through BIS and TSB to have 'catapult' centers that bridge the gap between technologies coming out of universities and into industry is a great program. It's all quite new so we'll have to see how it goes, but it's something we're engaging with and that we're supporting.

In your opinion, what will be powering a typical family sedan in the year 2030?
It depends where it's going to be driven. Every market is very different. At McLaren Automotive we tend to think a lot about the UK and Europe, but there will be lots of cars driven in other parts of the world as well, and the answer is going to be different in each market. Then it will differ between city areas and rural areas. There will be lots of cars that have conventional IC engines that will be a lot more efficient than they are at the moment, and that trend is going well, but there will also be lots of electric vehicles.

Capital assets

Renault Twizy

Designed from the wheels up as a full electric vehicle aimed at revolutionizing urban mobility, the Twizy is a truly unique product. On that basis alone, much kudos is due to Renault for daring to come up with such an avant-garde creation, and in many respects the Twizy really does take the notion of future sustainable transportation and makes it available in the here and now.

The two-seater, 2.34m-long, 1.24m-wide eco-friendly vehicle is ripe for the bustle of congested urban centers, with its squat proportions allowing it to slip into the smallest of gaps and park in spaces that other four-wheeler applications – including the Smart Fortwo – can only dream about. What's more, weighing just 450kg means that there's sufficient city center performance to be had: zero to 45km/h takes no more than six seconds, which is on a par with a 125cc scooter over a distance of 50m. The Twizy's performance comes from a 13kW, 57Nm electric motor placed at the rear, while the 6.1kWh lithium-ion battery pack is at the front.

Critics of the Twizy have been quick to point out that the vehicle is not practical, lacks storage space, has a limited driving range and can be exposed to the elements (although Renault has since introduced a winter windows zip-on kit). While such points are valid, in many respects the bigger picture is being missed: this quadricycle-classified vehicle makes a lot of sense for those that live and work in the very center of densely populated cities, and that's especially the case when said urban dwellings are in countries that tend to be hot and don't suffer from year-round rain. Twizy has not been created for rural areas or even those living on the periphery of major towns.

A driving range of 80km is realistic on one full charge – and we tested our Twizy in some harshly cold conditions. A complete charge takes around 200 minutes. Finally, not only is it fun to drive and attracts attention like no other vehicle we've had on test, but it's also very affordable, with prices starting at US$9,200!

Propulsion system: A 6.1kWh lithium-ion battery pack at the front of the vehicle provides energy to the 13kW, 57Nm electric motor at the rear. Drive takes place through a single-gear transmission

Smart Fortwo electric drive

Now in its third-generation guise, the Smart Fortwo electric drive, like the Twizy, is an automotive product that makes sense for people who spend the majority of their time living and working in congested city centers.

Our time with the all-electric Smart was brief but telling. Far more practical and comfortable than its Renault counterpart but somewhat less fun to drive, the Fortwo's drivetrain consists of a 17.6kWh lithium-ion battery pack that's been developed by Daimler subsidiary Deutsche ACCUmotive, and a 55kW magneto-electric motor – the first product to come from the Daimler-Bosch EM-motive joint venture. This new setup means that out goes the 30kW electric motor that once graced the second-generation Smart Fortwo electric drive, together with the Tesla-developed lithium-ion battery pack.

The result of such technological upgrades means that the new Fortwo electric drive is even more impressive in the real world. The two-seater Smart can sprint from 0 to 60km/h in five seconds (1.5 seconds quicker than the previous electric model); offers a top speed of 120km/h (up by 20km/h), thus putting the EV on par with the IC-engined Smart models; and boasts an enhanced driving range of 140km. This latter point is particularly pertinent because, unlike the Twizy and other such smaller electric vehicles, this third-generation Smart Fortwo electric drive does have the capacity to venture out from the city center from time to time. It might not be the most pleasant of journeys – and indeed there will only be a limited amount of stuff you'll be able to take on a country retreat weekend (as well as having to plan carefully for recharging) – but a driving range that's nearly double that of the Twizy, as well as a far more comfortable cabin, means that the all-electric Smart does have more to it than just urban functionality. Just as important is that the new Fortwo electric drive also benefits from a 22kW onboard charger that enables a completely empty battery to be fully charged in less than an hour.

Propulsion system: A 17.6kWh lithium-ion battery pack underneath the body of the Fortwo supplies a rear-mounted 55kW magneto-electric motor. Drive takes place through a single-gear transmission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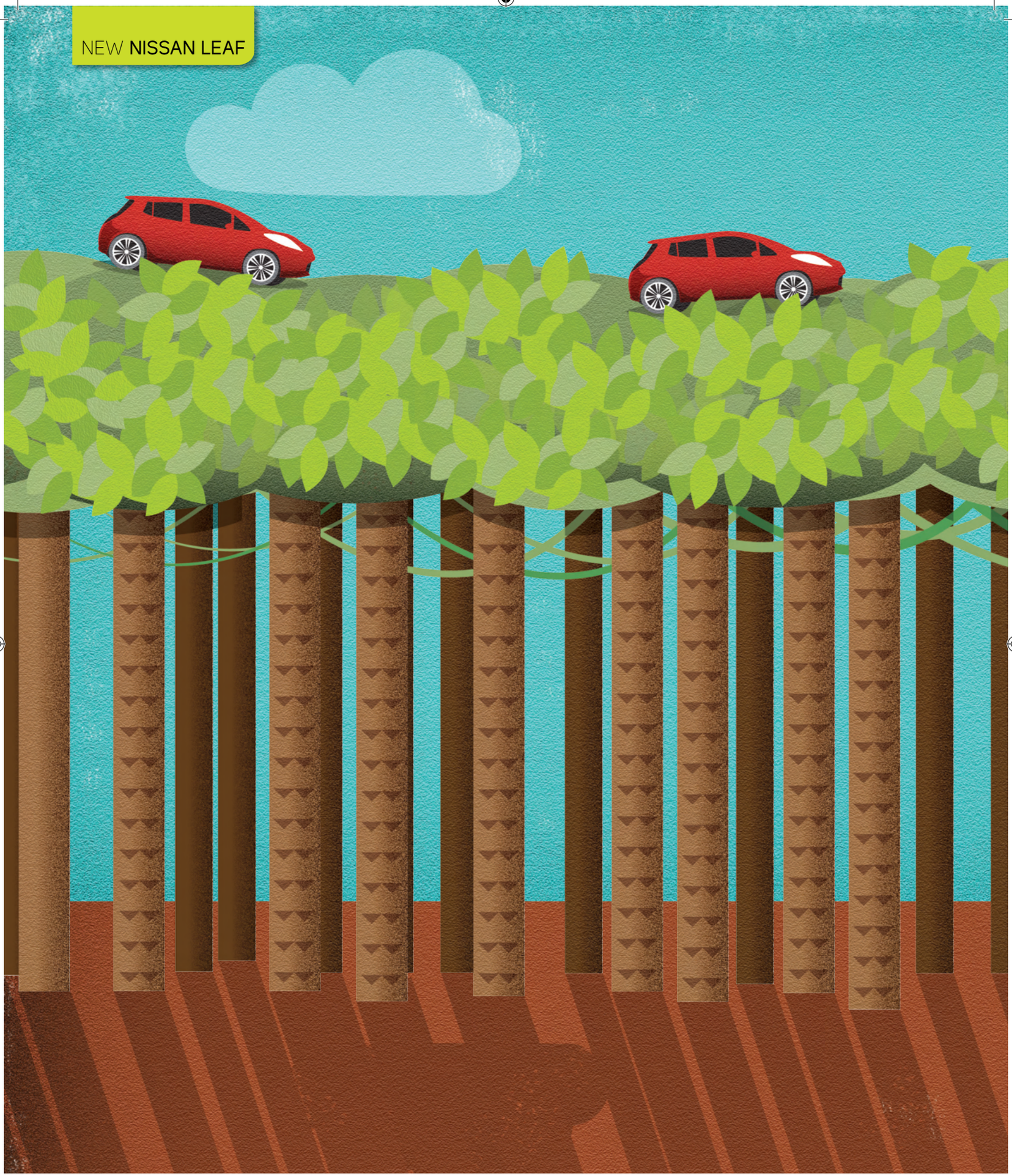
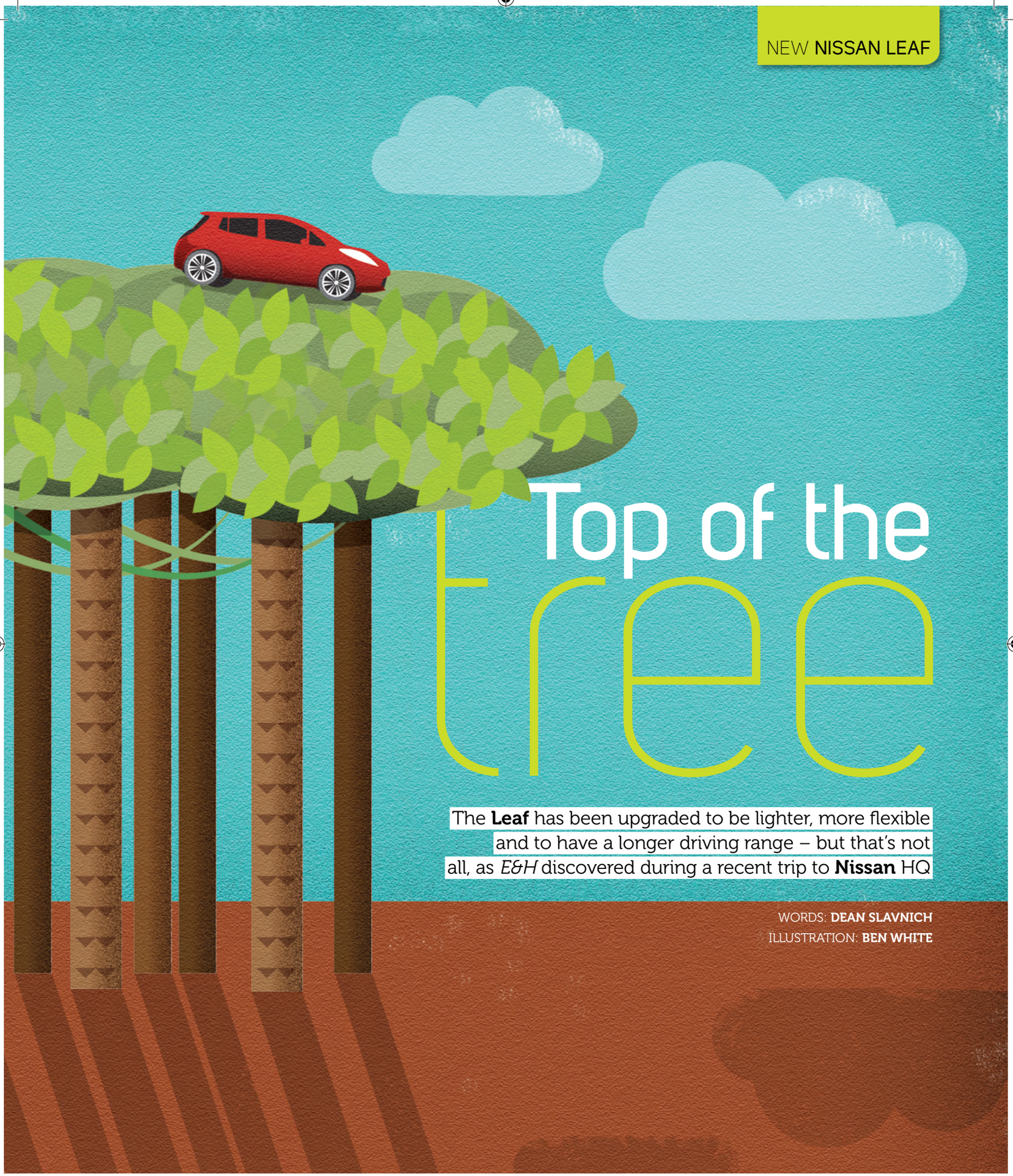

NEW NISSAN LEAF



Top of the tree

The **Leaf** has been upgraded to be lighter, more flexible and to have a longer driving range – but that's not all, as *E&H* discovered during a recent trip to **Nissan** HQ

WORDS: **DEAN SLAVNICH**
ILLUSTRATION: **BEN WHITE**

Two years ago, Nissan unveiled a product that took the industry by surprise: an affordable, family-friendly electric vehicle that boasted modern, comfort features and specs, was not unpleasant to drive – in fact, it was more engaging than many hybrid rivals – and offered a credible 175km-plus driving range.

Said car was branded the Leaf and the rest is history. Two years on, 60,000 units sold globally, numerous accolades (but interestingly not an International Engine of the Year Award) and feedback aplenty from early EV adopters, the time has come for Nissan to refresh the Leaf. Welcome, then, the second-stage Leaf, not a second-generation product, but more of a 1.5 version that's lighter, more accessible and offers far greater functionality than the original.

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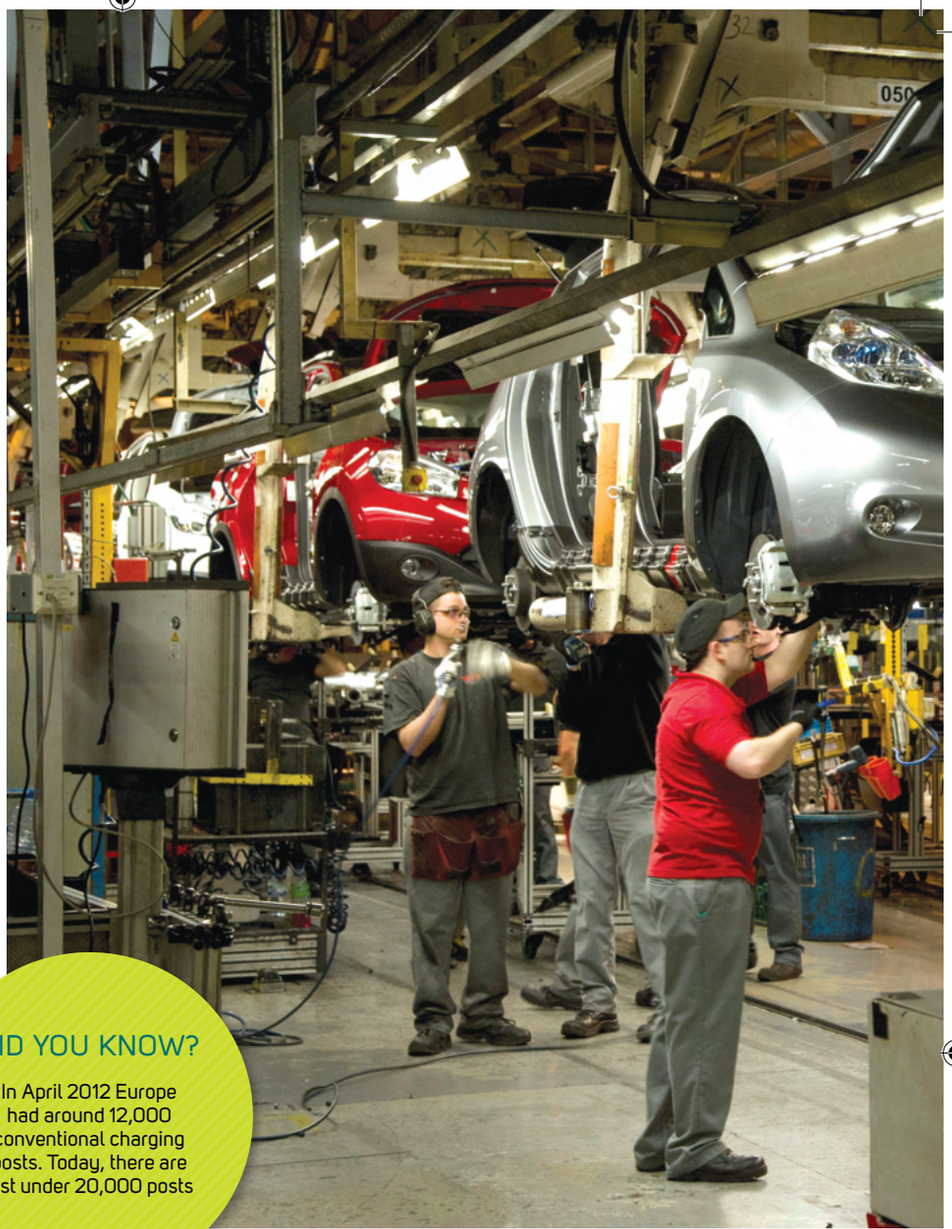

DID YOU KNOW?

In April 2012 Europe had around 12,000 conventional charging posts. Today, there are just under 20,000 posts

1. The second-stage Leaf features a fast 6.6kW charger option that reduces charging time by half

2. There are over 600 CHAdeMO standard quick chargers in Europe. It takes just 15 minutes to boost a battery from 30 to 80%

In total, the new Leaf boasts around 100 key changes over the outgoing model, with the main modifications resulting in an extended real-world driving range; a fast charge option; re-engineered motor and charger; upgraded European-like chassis; weight reduction across the vehicle, but especially the powertrain; and a larger and more practical trunk.

"For us, the journey really started shortly after we launched the first-generation Leaf," recalls Steve Groves, vehicle evaluation engineer for Nissan Europe. "From SOP, we had cars [Leafs] running with customers and we were monitoring the real usage of the cars. Because this was the first time we had a real electric car with customers in the market, we were very, very keen to get their feedback." That meant conducting a number of interviews with early Leaf adopters and then bringing together that information with data obtained from other key markets, including Japan and North America.

3

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DID YOU KNOW?

Nissan's Sunderland plant not only manufactures the new Leaf on Line 1 alongside the Qashqai and Qashqai +2 models, but is also responsible for battery production thanks to a new facility where more than 200 engineers are based

"Aside from the motor, the main change came about with the layout of the car," continues the Nissan engineer. "In the original Leaf we had the charger in the trunk and, for us engineers, that was just wrong – it wasn't a very good layout, to be honest. We knew we needed to improve the layout of the vehicle, so moving the charger from the trunk and into the bonnet area basically makes the car easier to build and avoids us having to run cables down the car." This change in layout also meant that there's no casing needed for the charger in the trunk, which helped the team to further reduce total mass. In fact, the second-stage Leaf powertrain is some 29kg lighter than the first-stage design.

"We have saved quite a lot of weight in the cabling area," expands Groves when pressed about how his team managed to shed so much weight. "We have very heavy 400V insulated cables that provide a completely durable solution – and these cables did run the full length of the car in both directions, what with the charger being located in the trunk. Putting the charger upfront automatically saved a lot of weight for us. Integrating the circuit boxes within the engine bay also helped us reduce the overall weight. And then there's no charger casing in the trunk either." Alongside the reduction in mass, this layout change also meant that there's an extra 40 liters of space to be found in the trunk of the new Leaf.

"From an engineering standpoint, another area we wanted to improve for the customer was the HVAC unit," he continues. "Our customers felt that the initial warm-up of the HVAC unit just wasn't good enough, but this situation partly came about through the layout of the original vehicle, where we used a carry-over HVAC unit from an IC car." The setup in the original Leaf meant that in order to heat the interior of the car, the vehicle had a PTC heater in the engine bay that heated the water circuit as if it were an IC engine vehicle, and then channeled the air through a heat exchanger into the cabin. "You can imagine that this wasn't the most efficient way to heat up

"Our customers felt that the initial warm-up of the HVAC unit just wasn't good enough, but this situation partly came about through the layout of the original vehicle"

Steve Groves, vehicle evaluation engineer, Nissan Europe

"We're lucky because Leaf owners tend to be technically knowledgeable and so through forums and blogs, we very quickly started to get feedback about what to do next. We didn't have people just complaining in the blogs, but actively suggesting solutions and customers finding solutions for themselves. We found a big interplay and community building up around the car and that really helped."

Core focus on powertrain and HVAC

The single-biggest engineering modification between first-stage Leaf and the second-stage iteration can be found in the powertrain, which now has the capacity to power the EV to 199km.

"From the point-of-view of range, we improved the inertia of the motor," explains Groves. For the record, the high response AC synchronous motor develops 80kW as before, but its inertia has been reduced by 5%.

3. Unlike the first Leaf, which was assembled exclusively in Japan, the new Leaf will be built in the UK and the USA as well as Nissan's home country. Pictured here is new Leaf production taking place at the Sunderland facility

4. At the Sunderland plant, the new Leaf is being built on Line 1 alongside the Qashqai and Qashqai +2. The smaller Juke and Note Nissan models are produced on Line 2

the car," admits Groves. So what the Leaf engineering team did was eliminate the water circuit, with the PTC heater being placed within the HVAC unit, allowing the system to heat air directly and giving increased warm-up time of the car. "This arrangement, coupled with the heat pump, which is essentially running the air-con circuit backward, as it would do in a modern house, results in a 70% improvement in the HVAC system.

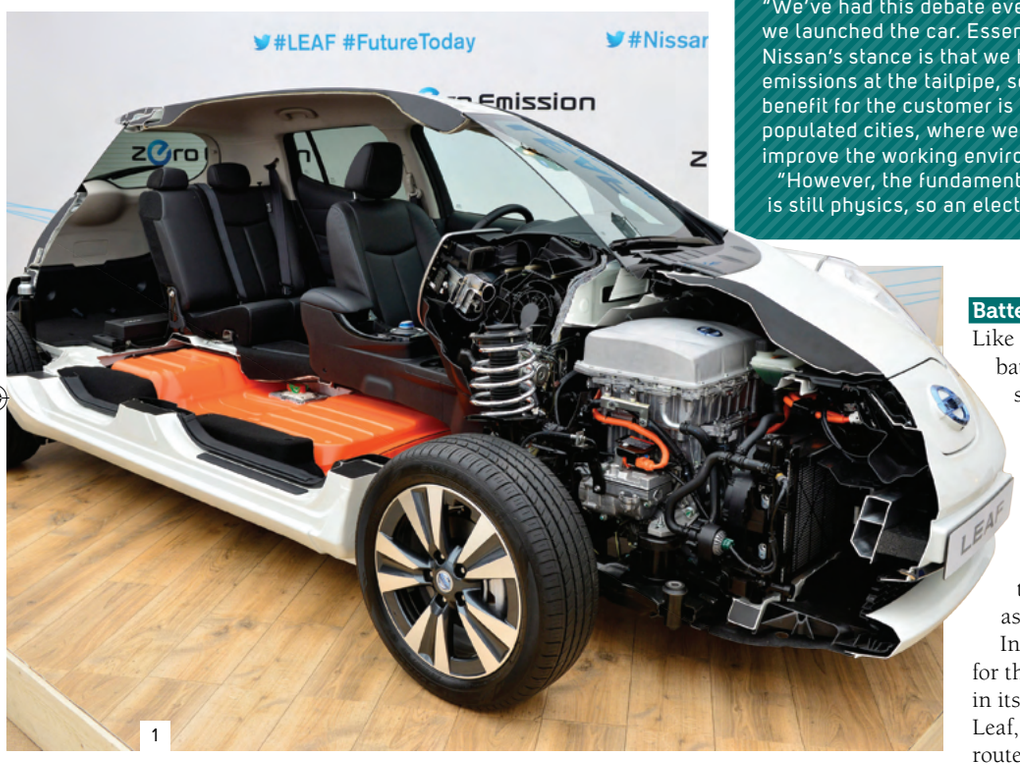
"When we developed the original car," he continues, "our focus was mainly on the electric powertrain and using as many carry-over components from our existing portfolio. Obviously, the benefit of two additional years, along with customer feedback, has enabled us to make improvements to the whole layout of the car, making it more efficient and cost effective."

DIRTY EQUATION

While EVs reduce emissions in nations that have a clean grid, such as France which is mainly nuclear based, an EV in Poland, for example, does little good as the grid is based mainly on coal, therefore simply moving the production of emissions from one cycle (in this case the vehicle) to another phase – in this instance, at grid level. In fact, critics of EVs have been very quick to point to the well-to-wheel performance of electric powertrains, citing the bigger picture as a massive flaw in cars that charge themselves on dirty grids. Groves, however, has a different take: "We've had this debate ever since we launched the car. Essentially, Nissan's stance is that we have zero emissions at the tailpipe, so the main benefit for the customer is in heavily populated cities, where we can improve the working environment.

"However, the fundamental thing is still physics, so an electric motor takes energy and can convert it from electric power to motive energy at 90% efficiency. With an IC vehicle you're looking at 35% efficiency, with a diesel being 45% at best. The main thing is that we can convert energy into motive power much more efficiently. So, even if we have the dirtiest grid in the world, we still benefit the environment overall because that transfer of energy into motive power is so much more efficient with an electric motor.

"There are figures quoted by journalists, in South Africa for example, where they mostly burn coal to generate electricity, which state that an electric vehicle doesn't have a CO_2 figure well-to-wheel that's much better than an IC engine vehicle. However, in the UK, we are right up there with the best of the hybrids well-to-wheel, and in Finland we can stand head and shoulders above the rest."



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1. There have been more than 100 engineering modifications to make the new Leaf a better product. Most of those changes came under the skin of the electric vehicle

2. The battery pack, which comes from Nissan's joint venture with NEC, is slightly lighter. Leaf customers have the option of either leasing the battery or buying the vehicle outright with the battery

Battery options

Like the old Leaf, the new EV benefits from Nissan's JV battery collaboration with NEC, with there being only slight changes made to the inside of the battery pack.

"From a layout point of view, the pack is the same as it was before and that's the same when it comes to assembly as well," says Groves. "There is, however, a slight decrease in weight, but that's it."

As before, the 48-module lithium-ion battery is mounted in a single pack under the cabin area of the vehicle to keep the car's center of gravity as low as possible.

In fact, perhaps the biggest change in terms of battery for the new Leaf comes not in its technological setup, but in its availability in the marketplace. For the second-stage Leaf, Nissan has gone down Renault's battery leasing route, but unlike its Alliance partner, the Japanese OEM is offering EV customers a choice between leasing the battery and buying the car outright with the battery. Groves explains the thinking: "With Renault, you can presently only lease the battery, but we have allowed for more flexibility. We want to make the product more affordable, so the entry starting price is a lot cheaper, making it a lot more accessible to the market. It comes down to customer choice." The leasing option, says Nissan, will enable customers to break even within six or seven years, depending on how the car is used.

During development, the Nissan engineering team benchmarked the new Leaf against the previous Leaf, but also against a few hybrid competitors. "We looked at all

cars on the market, and in terms of size, the Toyota Prius Plug-In Hybrid is an equivalent, as well as being a vehicle that is aiming to reduce emissions. In terms of the ride and handling of the vehicle, the Prius is quite heavy and we felt there were opportunities for us in this area with our new vehicle."

With the Leaf's battery pack being placed under the floor, giving the EV a low center of gravity, the aim for engineers at the Nissan Technical Centre Europe in Cranfield, UK, was to make the car as agile as possible, while also eliminating the 'floaty' feeling that hindered the first-stage Leaf. As such, damper settings, steering weight and brake performance have all been optimized for European tastes.

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1. The engineering changes mean that the Leaf's total range has increased from 175km to 199km

2. The new Leaf's electric engine is 29kg lighter than the first-gen powertrain

On the road, the new Leaf does feel firmer and its steering steadier. It is also true that the revised damper settings have reduced the floating feeling that was present in the original Nissan EV. In fact, the Leaf that we sampled is very much a European-developed product for Europeans. And while the original Leaf was built solely in Japan, the new Leaf is rolling off production lines not only in Nissan's home country, but also in the USA and UK.

Shaping tomorrow's transportation

Groves says that the experience and know-how gained from working on the original Leaf and subsequently the second-stage Leaf puts the company in good stead for future powertrain developments.

"The thing that we're stressing is that we've pioneered electric technology because electric technology underpins today's hybrid technology and in the future it will underpin fuel cell vehicle technology," he says. So, are tailpipes that emit water vapor the end goal for Groves? The Nissan engineer is not so sure: "We think it will be a combination of different solutions. So, at the moment you have people that buy a petrol engine car because of acceleration and that sporty drive, and then there are people that buy diesel because they tend to do long motorway journeys and want to get the maximum driving range. We think that in the future people will buy cars that suit their needs. So as a commuting vehicle, Monday through to Friday – and the type of mileage people tend to do to work – an EV will be the cheapest to run. The advantage of developing an electric powertrain is that it gives us the flexibility of offering many solutions in the future."

In the near term, however, the new Leaf will be followed by the e-NV200, a battery-powered LCV, an e-NV200 taxi, a compact luxury EV application from Infiniti, and then fuel cells from around 2017, the latter of which has been made possible thanks to a strategic alliance with partner Renault, as well as Ford and Daimler.

CHARGE AHEAD

While OEMs such as Nissan are racing away with electric powertrain technologies, the charging infrastructure, say some analysts, has struggled to keep up. Is inductive charging the optimum solution for Nissan? "Essentially, it's more of a reality if you're building a new metropolitan city," Groves says. "So, if you can put in that type of infrastructure from the outset – and it's standardized and it's available on vehicles – it will happen. But as you can imagine, it's costly. It's something we can envisage happening, but the cost of installing the infrastructure is quite big."

Groves continues, "As engineers, we have mid-term strategies and long-term dreams. Inductive charging is something we know can be made possible, but for the mid-term, we need to work with local governments to establish an infrastructure. The key thing is quick charging – that's very important; we need to work with governments to encourage the take-up of quick-charging infrastructure."

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Country pursuit

The iconic all-terrain Defender has got itself an eco-friendly, urban electric powertrain – and the EV innovation taking place at **Jaguar Land Rover** doesn't stop there, as *E&H* found out during a recent visit

WORDS: **NARGESS BANKS**

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"The way that we deliver any of LR's key off-road attributes and technologies needs to change"

Tony Harper, chief engineer for research and advanced engineering, JLR

1

VITAL STATISTICS

Total battery pack energy: 27kWh
Dimensions (mm): 1,080(L) x 780(W) x 590(H)
Weight: 410kg
Nominal voltage: 300V
Nominal capacity: 100Ah
Maximum pulse power: 144kW

Following successful trials of the Leopard 1, a Defender-based electric prototype vehicle, Jaguar Land Rover (JLR) has unveiled no fewer than seven fully electric concept Defender models, with the aim being to realize a prototype product that offers zero emissions while retaining the legendary SUV's core off-road capabilities.

While JLR is remaining coy about the possibility of mass-producing an electric Defender, the Leopard 1 and its offspring are forming an essential cog in JLR's powertrain electrification program. At an exclusive tech workshop and ride-and-drive event of the EVs, *E&H* caught up with Tony Harper, chief engineer for research and advanced engineering at JLR, to discuss electric Defenders, hybrid Range Rovers and future fuel cell applications.

What is the engineering significance of the electric Defender program?

The project is acting as a rolling laboratory for us to assess electric vehicles, even in the most arduous all-terrain conditions. It gives us a chance to evolve and test some of the technologies that may one day be introduced into future cars. Because the application areas are run in a controlled off-road environment, it acts like a laboratory without the need to have 200 cars on the road.

2

1. The electric Defender prototype vehicles use a high-tech SR electric motor in place of a diesel engine. The tech demonstrators weigh only 100kg more than their IC powered cousins

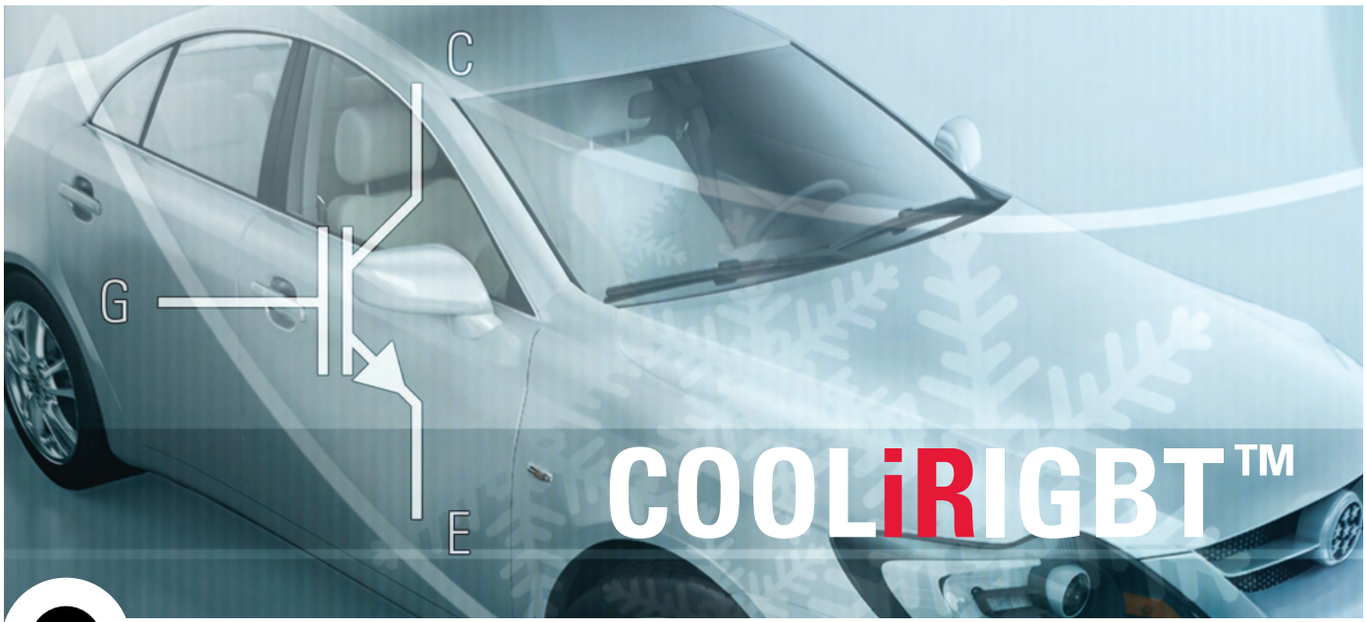
2. The Defender's Axeon Li-ion battery, which weighs 410kg and has a capacity of 27kWh, can be fully charged via a fast-charger in four hours

How does this specific project fit in to your electrification program?

Studying electric drive is important to our future no matter what solution we reach. The way that we deliver any of LR's key off-road attributes and technologies needs to change. Today, much of that is delivered through changing the electronic control of gearboxes, but in the future this is likely to disappear. So we need to learn how to do these through a different medium, and that is where this project fits in.

On an engineering level, how challenging was it to electrify the Defender?

It was quite simple: you take the diesel engine and replace it with an electric one (see *Electric Defender*, page 93). The devil is in the detail,



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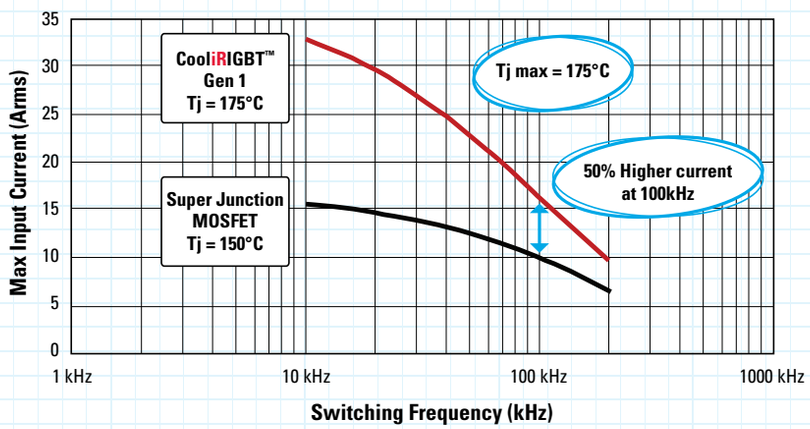

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Manufacturability	Complex	Simple
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COOLiRIGBT™ Gen 1 are designed to be used in a wide range of fast switching applications for electric (EV) and hybrid electric vehicles (HEV) including on-board DC-DC converters, and battery chargers.

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1

2

1. The absence of an air intake or exhaust system on the electric Defender has allowed for a 300mm increase in wading depth

2. JLR's Harper is unsure whether hydrogen fuel cells represent the future

though. With the throttle response, for instance, what we wanted to do was to get a lot of the regenerative braking because if you can get this, you regain much of the energy. In an off-road scenario, you drive up the hill and use a lot of energy, but with a diesel engine you lose all that energy, whereas with an electric engine you get the energy back. This gives us a lot more range.

How has the all-electric powertrain impacted the driving characteristics of a Defender?

On the prototype vehicles we have had to create what feels like more engine braking, so when you're driving and you lift your foot off the accelerator, it feels like the vehicle slows down more quickly. What we have discovered is that drivers find this [system] effective when driving in traffic or off-road.

JLR has confirmed a Range Rover hybrid model for 2014. Will this program extend to the Defender?

It is much simpler to design an off-road vehicle with a full electric powertrain; with a hybrid, you have two sources of power to mix together, which is more of a challenge.

ELECTRIC DEFENDER: THE INNER WORKINGS

For the electric Defender, Harper and JLR's electrification engineering team replaced the standard 2.2-liter four-cylinder turbodiesel and a six-speed manual transmission with a 70kW (94ps), 330Nm switched reluctance (SR) electric motor from Nidec SR Drives that is twinned with an Axeon 300V, lithium-ion battery with a capacity of 27kWh.

JLR says that this new electric powertrain solution enables the prototype Defender to have a driving range of just over 80km. Harper says that in typical, low-speed off-road use, the battery can last for up to eight hours in total. It can be fully charged by a 7kW fast-charger in four hours, or by a portable 3kW charger in 10 hours.

The smooth, low-speed capability of the SR electric powertrain makes the electric Defender well suited to climbing and descending inclines without causing unnecessary damage to ground surfaces. The drivetrain features wound, laminated steel stator and rotor, and as there are no magnets, there is no need for rare earth materials.

The battery system incorporates Axeon's proprietary BMS, which monitors the battery state, measuring and controlling key operational parameters, thus ensuring safety – particularly important for electric vehicles that may be subject to more challenging environments. The pack itself weighs 410kg and is mounted in the front of the Defender in place of the diesel engine. Total curb weight of the prototype is some 100kg more than a basic Defender 110 model, which varies from 2,055kg to 2,162kg depending whether the body style is a pickup, hard-top or station wagon.

High-tech subsystems, such as the battery and SR motor, ensure the electric Defenders have an 80km driving range

The electric Defender retains four-wheel drive capability and differential lock. Because the electric motor delivers maximum torque from the moment it starts, there's no need for gearshifting, and so the transmission is a single-speed, 2.7:1 reduction design combined with the existing Defender four-wheel-drive system. A modified version of Land Rover's Terrain Response System has also been incorporated.

All the major components and subsystems in the electric powertrain – including the battery, inverter and motor – are air-cooled, saving a considerable amount of weight and complexity, and adding robustness. What's more, the absence of an air intake or exhaust system has allowed for a 300mm increase in wading depth compared with a standard Defender. Regenerative braking has been optimized to such an extent that when using hill descent control, the motor can generate 30kW of electricity. Because the battery technology can be charged very quickly at a rate of up to twice its capacity of 54kW without reducing battery life, almost all of the regenerated energy can be recovered and stored. Up to 80% of the kinetic energy in the vehicle can be recovered in this way, depending on conditions.

JLR says the vehicles have been tested in extreme conditions, with the trials including pulling a road train weighing 12 metric tons up a 13% gradient, and wading to a depth of 800mm.

To get the best off-road capabilities, this setup has its advantages, but at this stage we are still gathering data and seeing whether there is a market out there for a Defender with a relatively limited range.

How far have you come with your fuel cell program?

There comes a point where you move to full electric drive and you either have a very big battery or you have something in the car that generates electricity to feed the drivetrain. That can be an IC engine connected to the wheels to generate electricity, or it can be a fuel cell. As a company, our view is that it is key to develop the electric drivetrain first. What then powers it can be separated – it almost becomes a generator in the technical arrangement. From a manufacturer's point of view, we don't know if fuel cell is the future – we just don't know if the hydrogen infrastructure will get there, and if it does get there, who will invest in it? What we can do is develop the things that are reasonably certain.

What kind of timeline is Jaguar Land Rover looking at for full electrification, including fuel cells?

If you'd asked any manufacturer, the answer three or four years ago would have been that fuel cell vehicles were coming very quickly, but what's actually happening today is that there is a lot of consensus around the value of plug-in parallel hybrids – at least in the medium term. And for all-electric vehicles or fuel cells, in order for these vehicles to make sense, the energy has to come from a sustainable source, otherwise you're just moving CO_2.

PLUG-IN POWER FOR JAGUAR

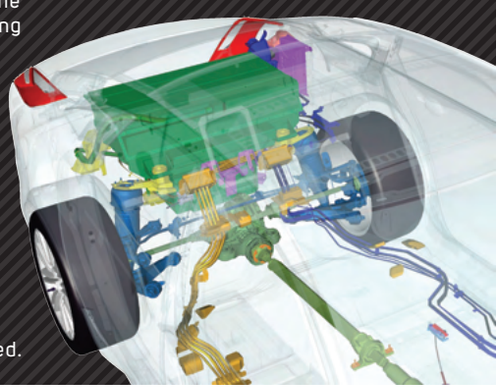
Land Rover's sister brand, Jaguar, is also hard at work on electric powertrain development. The XJ_e, an experimental plug-in hybrid vehicle based on the XJ sedan, offers a 0-100km/h sprint in under 6.5 seconds and a limited top speed of 250km/h, while achieving CO_2 emissions of less than 75g/km and a zero-emissions range of 40km on electric power.

The Axeon-developed high-performance, plug-in hybrid battery is a 12.3kWh-capacity 307V system that tips the scales at 159kg. The pack makes use of the latest lithium iron phosphate pouch cells in liquid-cooled/heated self-contained modules for optimum battery management and safety.

Axeon says there were two key challenges that needed to be overcome when developing the XJ_e's batteries: first, ensuring that the battery itself fitted into the compact space, which required tailor-made casing and precision design; and second, managing the impact of the liquid cooling and heating system on the vehicle's overall performance. As such, tighter control through thermal microgen software for cold and hot use – a new concept in this area – was used.

In addition to the innovative battery setup, the XJ_e also features a 69kW motor/generator, a Zytek custom DC/DC and inverter, an efficient 2-liter turbocharged DI petrol engine that powers the Range Rover Evoque and a hybridized ZF eight-speed automatic transmission.

Discussing the project, Bob Joyce, JLR engineering director, commented, "The XJ_e investigates how a 5-liter V8 engine could be replaced by an advanced 2-liter hybrid powertrain to deliver similar performance and refinement, but with CO2 emissions of less than 75g/km. While the XJ_e is an experimental project, it highlights that JLR customers can expect some exciting low-carbon products in the future."



DID YOU KNOW...

The electric Defender program first started in 2010, when an all-electric Defender was conceived for use as a safari vehicle at the Londolozi Game Park in South Africa. The vehicle, which also had Axeon-developed batteries, offered a top speed of 64km/h

The SR motor ensures that the electric Defender prototypes are well suited to all terrain driving, including climbing and descending inclines

"As a company, our view is that it is key to develop the electric drivetrain first. What then powers it can be separated – it almost becomes a generator in the technical arrangement"

Tony Harper, chief engineer for research and advanced engineering, JLR

So will we see the electric Defender entering production?

Although there are no plans for the electric Defender to enter series production, our seven EVs will go into service in specialist applications later this year. If we do an electric Land Rover, it has to be a product that offers all the things that our customers expect of us. What we're learning about low-carbon cars is that customers are not willing to sacrifice.

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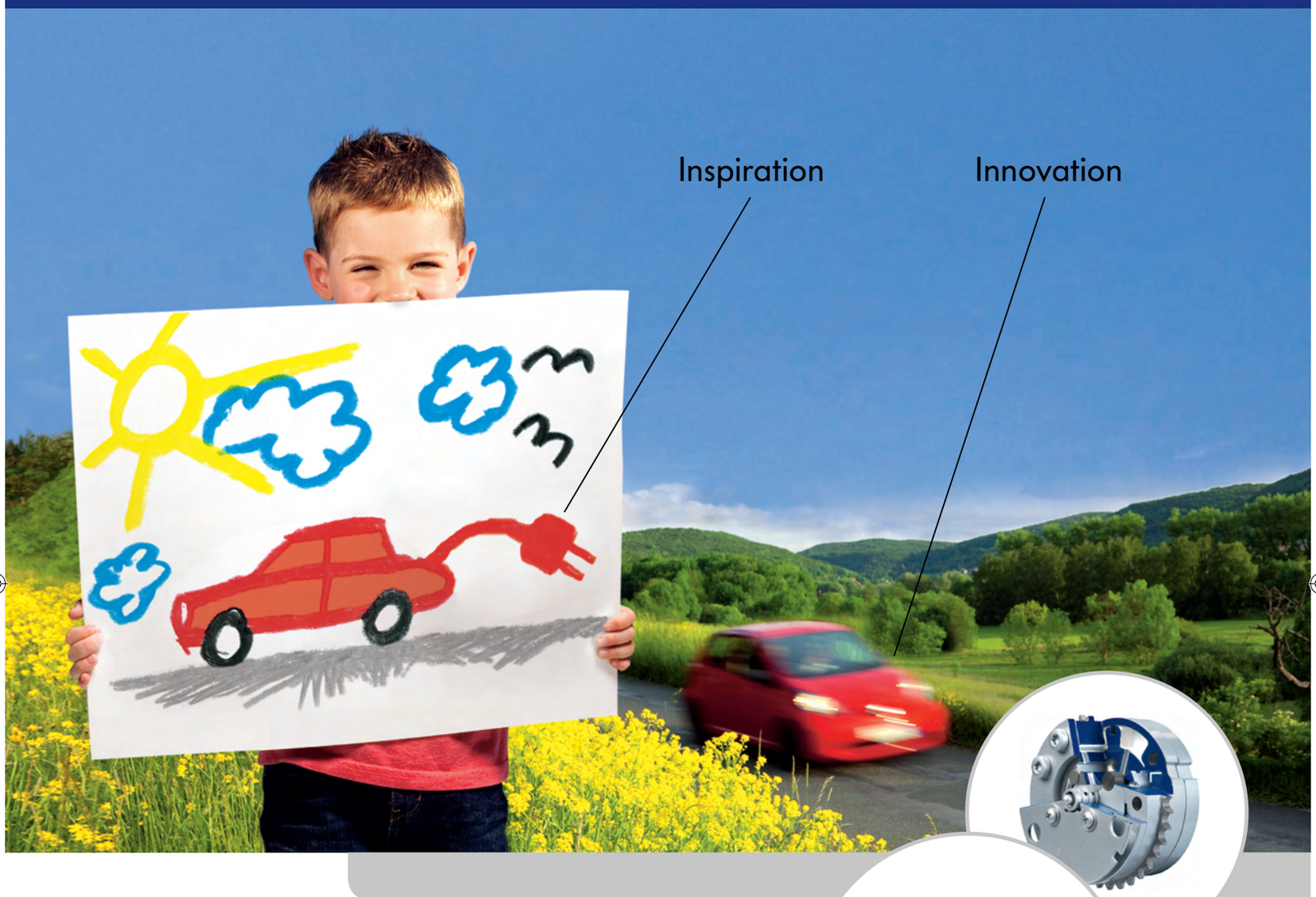

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Trading places

Not many people would swap their safe and secure senior position at a leading company to join a start-up during one of the most economically challenging times for industry, but that's exactly what one former BMW senior engineer did. Now his input is helping to realize a new way of doing business in the automotive world

WORDS: **DEAN SLAVNICH**

There's no doubt that the Qoros project is an interesting one. Completely brand-new developments, whether they are actual vehicles or powertrains, are rare, but the birth of a new brand – and one that's financially and logistically supported as well as Qoros – is almost unheard of in this automotive age. "For me, the most exciting aspect to all this is to be part of a start-up company – not a lot of colleagues of mine in this industry have this chance," proudly states former BMW senior engineer, Klaus Schmidt, who recently took the role of vehicle engineering director at Qoros. "It's a risk, for sure, but this company has grown amazingly over the past three years. We have a great future ahead of us."

Much of that future is underpinned by a unique business and engineering model that only a start-up such as Qoros can implement, allowing the company to efficiently bring to market new vehicles that will house a new family of gasoline engines, as well as a gasoline-hybrid powertrain.

"We create the concept, the idea and the requirements, and look for the right partners to support our vision – that's the model behind Qoros," outlines Schmidt. "Most suppliers are a step ahead of the OEMs, so if we use their full capabilities, we'll always have the leading solution. That's why we're focusing on this model – this is our business and engineering strategy."


QOROS

It is certainly an interesting setup and one that moves away from the traditional OEM-supplier relationship, but for Schmidt, it is an efficient approach and one that only a start-up company like Qoros can adopt: "Existing OEMs all have huge engine plants that they can't just stop – that's one major reason why they have to continue to develop engines themselves. At BMW, for example, part of the core DNA is the engine, but that's not the case for us. For us, our biggest interest is not who supplies or develops the actual engine, or if we develop it ourselves. We have a different approach to development and manufacturing from other OEMs – and that approach is finding the very best partners for our model."

The German spends his time more or less equally between China and his home country: "There are a lot of very good suppliers in Europe," he says – and this is a critical point for Schmidt, who argues that it is imperative for Qoros and its model to source technologies and subsystems from the likes of Bosch, Continental, Lear, Magna Steyr and Benteler. "If we want to fulfill our targets, we need to build cars to European standards. We need to have the same quality as European competitors and that means working with European partners." In the case of Qoros, transmissions come from Getrag, electronic parts bear Bosch's hallmark, brake systems are supplied by TRW and the turbochargers are from Garrett; top-end names that grace the finest of European cars.

1. Qoros is the first China-based manufacturer to create a mainstream automotive product designed with the European market in mind

2. European sales of Qoros vehicles, such as the 3 Sedan, are expected to start in 2014

"What is really helpful is that many of these suppliers are also based in China," continues Schmidt, "so that actually helps us a great deal with our engineering model. We use their R&D in Europe, but the factories in China for production."

Once all of the subsystems have been sourced and supplied by the Tier 1s and 2s, the business model then calls for Chery, one of Qoros's major shareholders and one of China's largest auto makers, to manufacture the engines and assemble the actual cars in a plant located in Changshu, China, which gives the start-up a massive and immediate scale of economy. The Qoros dedicated facility has the capacity to roll out 150,000 vehicles annually, with potential expansion to 450,000 units. However, Schmidt is keen to stress that the large Chinese OEM will build the powertrains and the vehicles to the high quality levels that Qoros demands for international markets.

Hybrid hope

The Qoros 3 Sedan will go on sale in China later this year, and sales in Europe are expected to start by mid-2014. The Sedan will be powered by efficient gasoline engines co-developed with AVL, but it's the 3 Cross Hybrid Concept, shown at the Geneva Motor Show, that has really caught the eye of many industry onlookers. It not only unofficially confirms that a tourer, compact hatchback and crossover will spin off the company's current architecture, but also that there is a hybrid offering as well, which at the time of writing was at the prototype testing stage.

"We are using an ISG at the front, then we have the IC engine and an additional electric motor on the rear axle of the vehicle," explains Schmidt, outlining the engineering setup. "At the moment we are thinking of 20kW at the front and 50kW at the rear. The target is for us to realize pure electric driving at up to 120km/h with a range of 4km."

The ISG is placed between the transversely mounted three-cylinder turbocharged engine, which will generate around 135ps in this format, and its transmission. Essentially, the use of the ISG is to start the IC engine more discreetly than a traditional starter motor, with the

DID YOU KNOW...

Qoros was founded in 2007 between Chery Automobile and Israel Corporation. The company's board boasts top-level automotive executives that have come from the likes of BMW, Volkswagen, Volvo, General Motors and Jaguar Land Rover. Qoros undertakes R&D at its sites in Shanghai, Munich and Graz, with the overall aim being to launch new models at intervals of six to eight months

1

technology boasting less noise and vibration. But in addition to that, the ISG provides charge to the rear motor's dedicated battery. And while the electric motor is at the rear, to be more specific, it is housed between the luggage compartment and the concept vehicle's rear axle, which has been supplied by American Axle, a Detroit-based Tier 1. The electric motor is powered by an LG Chem lithium-ion battery that has a maximum capacity of 1.9kWh.

Clever control software will ensure seamless transition between varying driving modes, says Schmidt, including gasoline engine front-wheel drive, electric motor rear-wheel drive, and an all-wheel-drive mode, depending on driver input and road conditions. The hybrid vehicle's high-voltage electronics are sourced from Magneti Marelli, and "the rest of the major components are from Bosch", adds the engineering director.

Schmidt admits that one of the current challenges to the hybrid project is weight: "Mass is an issue, that is clear, but integration is also a key challenge. As you know, we have an existing platform that gives us different models, so to integrate all of these hybrid technologies is a difficult task, but an interesting one too."

At the time of this interview, the first hybrid prototypes were being tested in Sweden. "Early feedback has told us that we need to do some modifications on the packaging, especially the rear axle. It is a problem, but we have some solutions and we are building prototypes and new subsystems as we speak."

1. The Qoros 3 Sedan will be powered by efficient gasoline engines co-developed with AVL. The naturally aspirated 1.6-liter unit generates 127ps and 155Nm of torque from 3,900rpm

2. Qoros sources its technologies and subsystems from leading European suppliers such as Bosch, Continental, Lear, Magna Steyr and Benteler

2

"If we want to fulfill our targets, we need to build cars to European standards. We need to have the same quality as European competitors and that means working with European partners"

Klaus Schmidt, engineering director, Qoros

1

Efficient families

On the gasoline IC engine side, Qoros products will eventually reap the benefits of belonging to two different families, both of which have been co-developed with AVL. From launch, the Qoros 3 Sedan will have two four-cylinder designs: a naturally aspirated unit that generates 127ps and 155Nm of torque from 3,900rpm; and a turbocharged derivative that offers 158ps and 210Nm of torque from 2,500rpm. The engines, both of which meet Euro 5 emissions standards in China, will come with a six-speed manual as standard or with a six-speed DCT as an option.

The second – and arguably more interesting – engine family is currently under development and comprises a three-cylinder 1.2-liter turbocharged motor – also used in the hybrid setup – but in this instance tuned for 131ps; and a brand new four-cylinder 1.6-liter turbocharged design that will offer 162ps. These powertrains will both benefit from direct injection and VVT, will be compliant with next year's Euro 6 emissions requirements and will be mated to a seven-speed manual as standard or be fitted with a seven-speed dual-clutch transmission as an optional upgrade.

On the three-cylinder, Schmidt says the powertrain has been benchmarked against smaller established IC designs from Volkswagen and Toyota. The larger, all-new four-cylinder currently in development is intended more for the European market as a first step, but "at the same time, we will also be thinking of using this larger engine for the Chinese market heading into the future".

Discussing particular engineering aspects of the new engine programs, Schmidt adds, "The performance we are getting at the moment is good, but there are some aspects we can improve upon. One of the biggest challenges is torque control because we are using a double-clutch transmission – so we have had to spend time there to optimize that issue. However, the shifting qualities of the transmission are perfect. Based on the ECU that we have used, we have managed to incorporate a lot of functionality into the powertrain." For the record, the ECU is sourced from a Bosch joint venture based in China.

Schmidt admits that the support from AVL is key to the powertrain development program as a whole. "They have been really good and it is a boost for us to have them as a partner. Without them, I don't think [the engine program] would have been possible because we have only a handful of engine engineers, and from that basis it is really not possible to develop a new engine."

Somewhat tellingly, though, there is no diesel engine yet in the Qoros powertrain line-up. "It is something we are thinking about, but there is just no demand for it in China," explains Schmidt. "But then if we want to be present in the European market, then of course diesel vehicles are something we will have to consider, but at the moment there is no decision on that."

In that case – and keeping in mind Qoros's unique business model, would it not be easier to license a clean diesel engine from an already established OEM such as PSA Peugeot Citroën, Daimler or BMW, rather than produce such a powertrain in-house? "We are looking at all possibilities, but it all depends on our final decision, which comes down to volume and costs," he replies.

With powertrain talk finished, there is time for just one more question for the engineering director, which neatly takes us back to the start of the conversation: does he regret leaving the engineering powerhouse that is BMW, where he spent 25 very successful years, for an Israeli-Chinese start-up? "I did think long and hard when they asked me to join, but I must say, each day has been just amazing, it really has," he says. "Not many colleagues can say they have been part of something totally new." Cynics will argue that Schmidt is simply toeing the company line, but speaking to him one-to-one, it is plain to see that he is reveling in his role at Qoros, helping to shape the future of this new and burgeoning car maker.

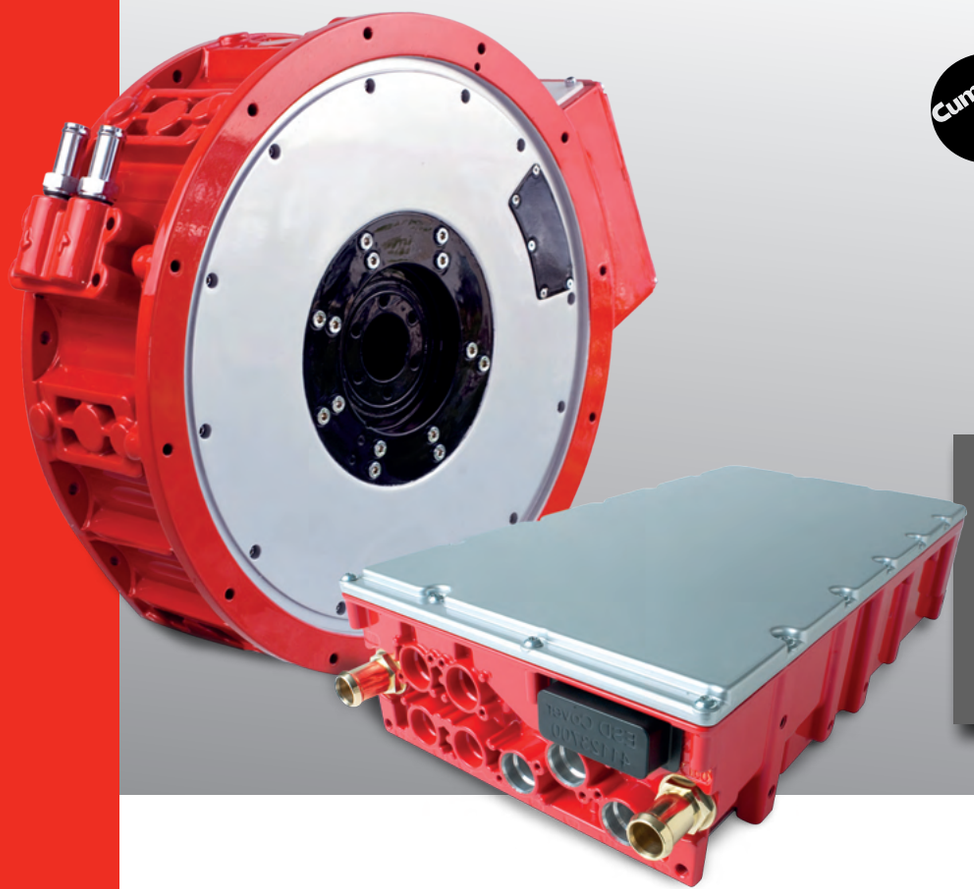
2

1. The Qoros 3 Sedan is engineered to achieve maximum European and Chinese crash test ratings. Occupants are protected by state-of-the-art safety measures, including front, side and curtain airbags

2. Qoros's naturally aspirated and turbocharged powertrains will be mated to a seven-speed manual as standard or be fitted with a seven-speed dual-clutch transmission as an optional upgrade

"We have a different approach to development and manufacturing from other OEMs – and that approach is finding the best partners for our model"

Klaus Schmidt, engineering director, Qoros



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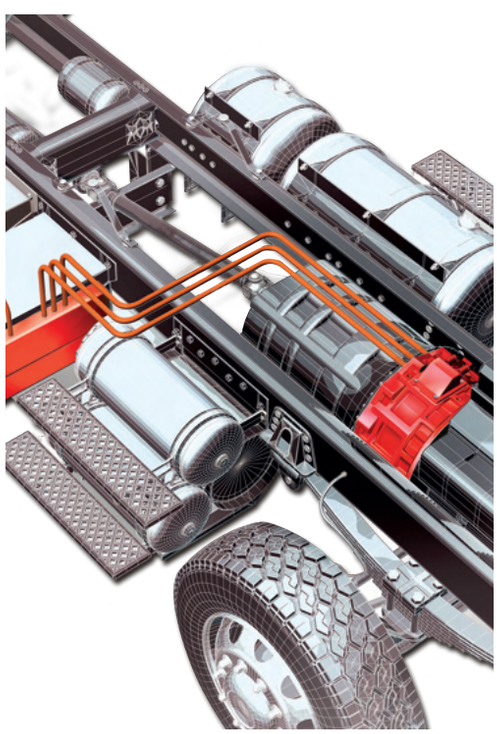

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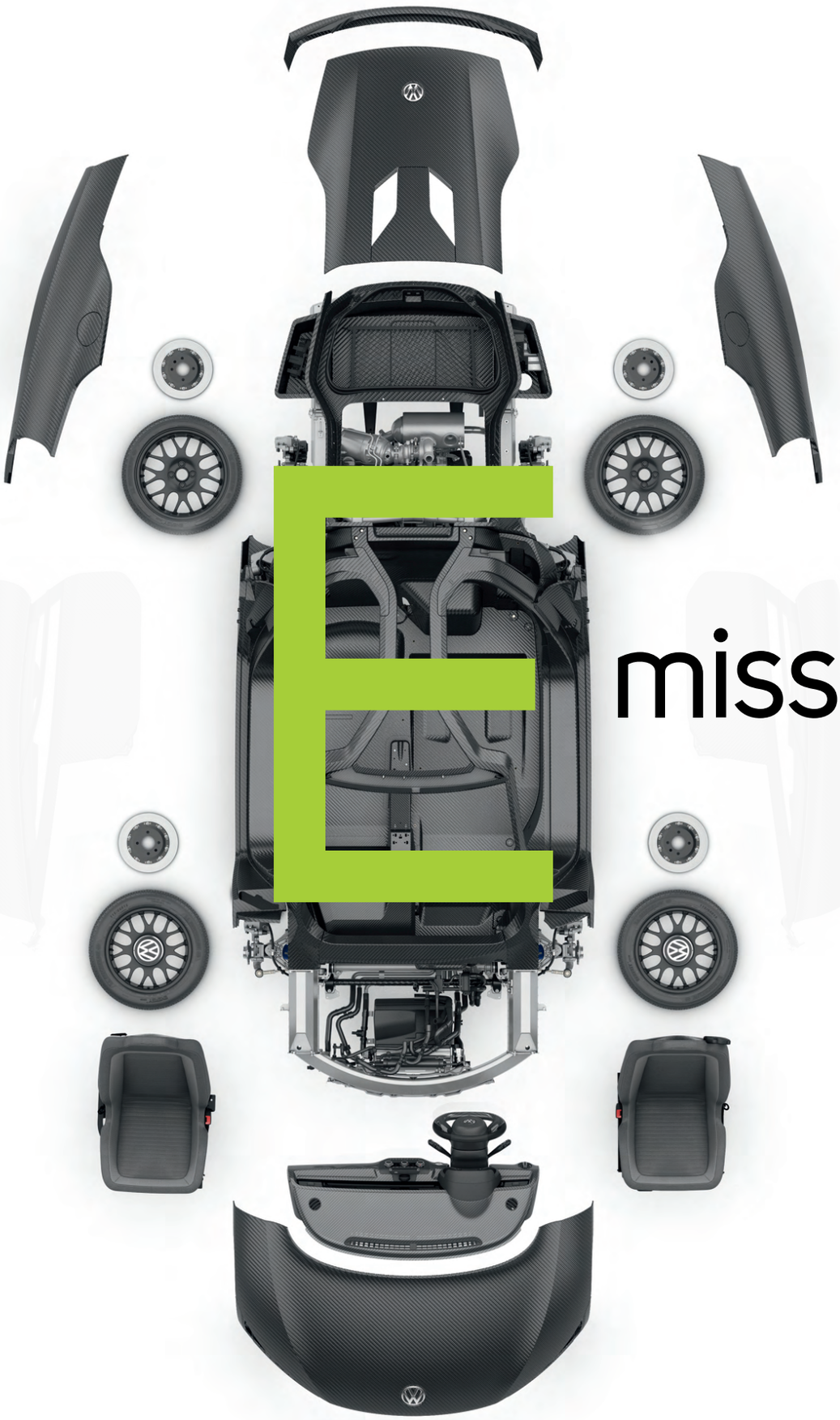


Emission.....

possible

The car you see here could quite possibly be the most significant automotive development in recent times – and much of its hype is to do with its layer upon layer of powertrain innovation

WORDS: **PHILIP BORGE**

It is quite a marketing statement to call a vehicle the world's most fuel-efficient production car, but creating such a machine is precisely what Volkswagen has achieved with the intriguing XL1. At first glance, the figures, which certainly back up such ambitious claims, make almost unbelievable reading: the XL1 is rated at 0.9 liters/100km (313mpg) for fuel economy and emits just 21g/km of CO_2. An astounding automotive development in every sense.

Representing the third stage of VW's 1-liter car strategy, which began in 2002 with the first design and was revisited in 2009 with a second-generation concept, the XL1 is armed with sophisticated eco-friendly technologies, subsystems and production measures. In fact, it's not far-fetched to say that on every level, this creation is groundbreaking from initial design through to realization and manufacturing.

At the core of the XL1 is a plug-in hybrid setup that enables the lightweight VW – and in this case, the term 'lightweight' is quite an understatement as the entire car tips the scales at only 795kg – to cover a distance of 50km in all-electric mode. The hybrid powertrain consists of a two-cylinder TDI engine rated at 48ps, an electric motor that provides 27ps, a seven-speed DSG and an advanced lithium-ion battery pack. The electric motor delivers 140Nm of instant torque.

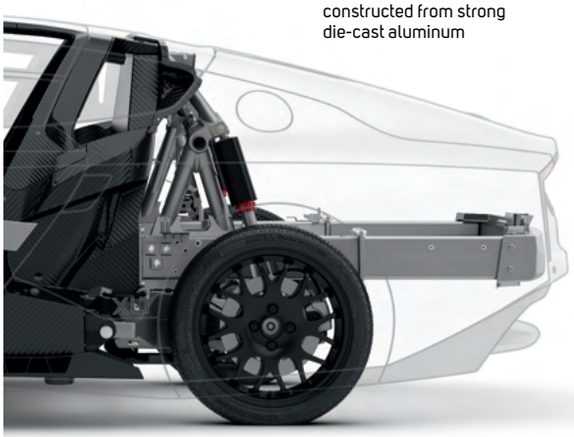
Just as important is the XL1's incredibly aerodynamic design (Cd 0.189), which gives the efficient VW creation the ability to cruise on the road at a constant speed of 100km/h (62mph) using just 8.4ps. And if that's not impressive enough, in all-electric driving mode, the two-seater needs less than 0.1kWh to cover a distance of 1km. At the opposite end of the spectrum, XL1 – which boasts a low center of gravity at just 1,153mm – has an electronically limited top speed of 160km/h (100mph) and a 0-100km/h acceleration time of 12.7 seconds.

But back to the heart of the vehicle – the very clever powertrain, which in total weighs just 227kg, including the battery pack. The entire hybrid unit is housed on the rear axle, while the hybrid module, electric motor and clutch are positioned between the diesel engine and the DSG. The module itself is integrated within the transmission base in place of the usual flywheel.

The lithium-ion battery, with its 5.5kWh capacity, supplies the electric motor with energy from its location at the front of the vehicle. For driving to be undertaken in all-electric mode, the diesel unit is decoupled from the drivetrain by disengaging a clutch, before fully shutting down. At the same time, the clutch on the gearbox side remains closed, therefore enabling the DSG to remain fully engaged with the electric motor. Operating at 220V, the power electronics system manages the flow of high-voltage energy from and to the battery or electric motor. The body's electrical system is supplied with the necessary 12V via a DC/DC converter and a small auxiliary battery.

As well as helping to realize an all-electric driving mode, the electric motor also supports the diesel engine when the driver accelerates. The IC unit, which is 800cc in displacement capacity, is derived from VW's four-cylinder 1.6-liter diesel base, meaning that the XL1 IC heart shares the same cylinder spacing of 88mm, cylinder bore of 81mm and stroke of 80.5mm.

The 0.8 TDI motor also shares key internal modifications with its larger diesel brother for reducing emissions, including specially formed piston recesses for multiple injection and individual orientation of injection parts. The IC setup within the XL1 makes use of a balancer shaft that's driven by the crankshaft turning at the same speed in an effort to improve NVH and optimize smooth engine running – a key feature for a two-cylinder arrangement such as this.

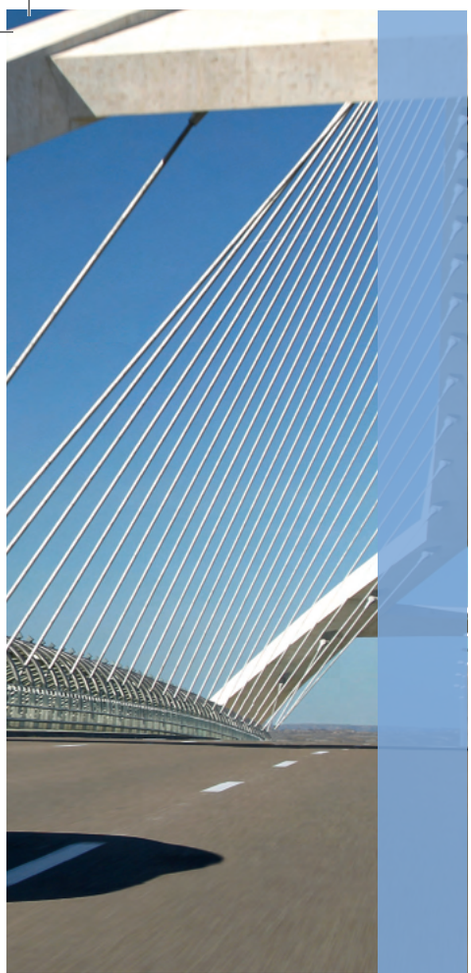


The XL1's hybrid unit is housed on the rear axle, which is constructed from strong die-cast aluminum

"The hybrid module, electric motor and clutch are positioned between the diesel engine and the DSG"

For this project specifically, the diesel engine's aluminum crankcase is constructed to achieve high dimensional precision, which in turn leads to low friction losses. EGR and an oxidation catalytic converter, as well as a DPF, make an appearance as the XL1 strives to keep emissions output as low as possible. The eco-friendly VW model also boasts battery regeneration capability to recover energy when the vehicle is slowing down and store as much of it as possible back into the battery pack for reuse. The result of such measures is that the XL1, unsurprisingly, easily meets Euro 6 emissions legislation.

In fact, every facet of the XL1 is seemingly tailored to emissions reduction – and that includes the vehicle's sophisticated cooling setup. For example, its engine management cools the TDI base by activating the regulated mechanical water pump only when engine-operating conditions require it. In addition, the car's advanced cooling system includes an automatically controlled air intake function at the front to drive down drag, and a second electric water pump – which is used only when needed – circulates a separate lower temperature coolant loop to cool the starter generator and power electronics.



Top: Volkswagem says the XL1, which weighs just 795kg, is the world's most fuel-efficient production car, realizing 0.9 liters/100km (313mpg) for fuel economy and emitting 21g/km of CO_2

Above right: The 800cc two-cylinder diesel unit is based on VW's 1.6-liter four-cylinder diesel engine. As such, cylinder spacing, bore and stroke are all shared

Left: Thanks a sleek aerodynamic design, the XL1 has the ability to cruise at a constant speed of 100km/h (62mph) using just 8.4ps

Material world

But there's more to the XL1 than just its innovative powertrain technology. Carbon fiber reinforced polymer (CFRP) is used lavishly, to the point that the body of the vehicle weighs just 230kg. For the record, CFRP is used for the construction of the monocoque, all exterior parts, and what VW terms the functional elements of the vehicle, including the anti-roll bars.

The German car maker has opted for a resin transfer molding (RTM) process to produce the CFRP components, which it says is a more economical route to market, enabling lower costs at higher part volumes to be realized mainly due to automation techniques. The RTM parts are produced in multi-shelled, heated and vacuum-sealed tools. This involves injecting liquid resin at high pressure into the tool containing the semi-finished carbon materials whose interior has the shape of the part that needs to be produced. VW says that the beauty of this setup is that CFRP's density is only around 20% that of a comparable steel exterior skin. This means that the XL1's skin is just 1.2mm thick, but in terms of stiffness and strength it is on a par with steel and aluminum.

Running gear weight is greatly reduced through the use of aluminum parts, including suspension components, brake calipers, dampers and steering gear housing. The brake discs are ceramic, the wheels are made of magnesium, and plastic is used widely for the steering wheel body. There are also friction-optimized wheel bearings and drive shafts, as well as low rolling resistance tires from Michelin.

Bespoke production

The XL1 is currently being manufactured by Volkswagen Osnabrück, which consists of former Karmann plants that are currently responsible for rolling out the VW Golf Cabriolet and Porsche Boxster.

However, a vehicle as unique and special as the XL1 needs carefully honed production processes. After all, this is no ordinary mass-production car, what with the lavish use of composite materials, the highly innovative diesel hybrid powertrain and the vehicle's aerodynamic styling.

As such, there are no fewer than nine production stages to go through before one XL1 is ready for delivery. VW says this rather detailed, level-driven manufacturing process will benefit the group long term, and especially as more models in the future make use of CFRP and other such advanced materials in an effort to shed total mass.

Stage one of the XL1's production process begins with the delivery of the CFRP monocoque from a supplier company in Austria that uses the RTM process. Once delivered to Osnabrück, the monocoque is mounted to an assembly support plate, where the body of the vehicle is constructed – but without doors and lids. Internally, VW refers to this stage as the bodyshell frame, and it's the point at which all parts are moved to their prescribed design positions by special fixtures, thus enabling the entire process to maintain tight manufacturing tolerances.

The various interior and exterior surfaces of the monocoque are pretreated in advance. VW says this technique enables tight gaps and smooth surfaces to be realized. Unlike welded metal parts, the XL1's roof can't simply be placed on the monocoque; instead, the strength of the adhesive material must compensate for all gaps in the monocoque-roof side-member structure and the different material thickness of the laminated roof. This means that on the production floor, the roof is made to hover over the monocoque before gluing. Once the roof's on, the XL1's first production stage then sees the boot pan being brought into position with the water channel, where it is then glue and screw fastened. All additional structural and exterior skin parts, including the rear cross members, are also positioned and screwed via a sled fixture.

In parallel to the first production stage, the XL1's two wing doors are produced in the

Tech spec: Drivetrain
Type: Plug-in hybrid, rear-wheel drive
IC engine: TDI, two-cylinder, 800cc, 35kW/48ps, 120Nm
Electric motor: 20kW/27ps, 140Nm
System power during boosting: 51kW
System torque during boosting: 140Nm
Transmission: Seven-speed DSG
Battery type: Lithium-ion
Battery energy capacity: 5.5kWh

Tech spec: Performance and fuel economy
Top speed: 160km/h (electronically capped)
0-100km/h: 12.7 seconds
Fuel consumption (NEDC, combined): 0.9 liters/100km (313mpg)
CO_2 emissions (NEDC, combined): 21g/km
Range in electric: 50km
Range with electric mode and diesel engine: 500km, 10-liter fuel tank

Top: The wide use of CFRP throughout the car – as well as an intricate production process – are two key ingredients in the XL1's eco success

Above: Despite the advanced technologies and production process, the XL1's interior has been styled so that it's comfortable and driver orientated

Left: The hybrid powertrain consists of a two-cylinder TDI engine, which is rated at 48ps, and a high-tech electric motor that provides 27ps

SURPRISE PACKAGE

Subsystem packaging was a particular challenge during the early design stages of the XL1 – and that was also the case when Volkswagen chiefs were planning the vehicle's nine production stages. As a result of such tight packaging margins, the XL1's air-conditioning system, which in most cars is typically mounted in the interior, is instead installed in a special insulated capsule in the car's front section.

second production stage of the program, which also includes crash reinforcements. For this, VW developed its own tool, which is used to fit the doors to adjoining body parts with millimeter precision.

The XL1's third production stage focuses on body assembly, and it's around this time in the early life of the VW model that all body parts are assembled to achieve specific gap dimensions and flush mounting precision. VW admits that a particular engineering challenge was accommodating the wing doors, chiefly because there needs to be a tight fit to the roof and the side body surfaces.

Ready for delivery

In total, 32 exterior skin parts are painted on the XL1, and this is largely what production stage four is all about. The fifth, sixth, seventh and eighth legs to this intricate journey see the XL1's front section/rear section and interior/windscreen, doors and wheels and final assembly of doors all being undertaken – and in that order. It's also during these stages that integration of the powertrain starts to take place. For example, during production stage six, the merging of the drive unit with the vehicle body occurs, shortly after assembly of the front end. This means that the entire drive unit is installed in the rear section of the vehicle, with the XL1's rear axle being made from strong die-cast aluminum. Prior to the drive unit joining the body, the prefabricated floor pan is integrated into the front end of the XL1. Also incorporated during this stage – and at the front of the vehicle – is the XL1's high-voltage battery for the plug-in hybrid drive. It's around this time that automatic testing of the vehicle's electrical system and preliminary start-up of all electronic components are also performed.

Before all XL1 models are signed off and ready for delivery, each car goes through the ninth and final production stage, also known as start-up. In the name of quality assurance, it's during this time that all electronic modules and their software and wire harnesses are double-checked. At the same time, control modules are interconnected with the vehicle's specific wire harness. For the final production phase to be completed, first the entire high-voltage subsystem is checked, and for this to happen, isolated faults are introduced by technicians to test the XL1's emergency shut-off functionality. That is then followed by starting up the IC engine, with all actuators and sensors of the TDI unit being assessed. The data gleaned from first start-up is compared with target data. All electrical equipment is then validated, and vehicle functions are checked during a test drive. Only then is the XL1 – the world's most efficient mass-production vehicle – ready to be delivered!

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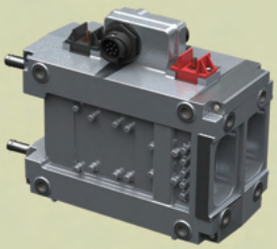
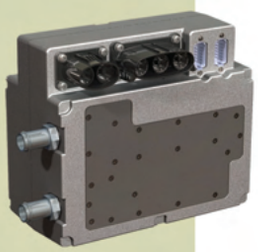
DC/AC Converters

- 6KW continuous
- Air or liquid cooled
- CAN communication
- Fully protected
- EMC compliant
- Group 31 size



DC/DC Converters

- 4KW continuous
- Bi-directional
- Air or liquid cooled
- CAN Communication
- Fully protected
- EMC compliant
- Group 31 size



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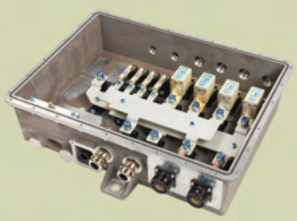
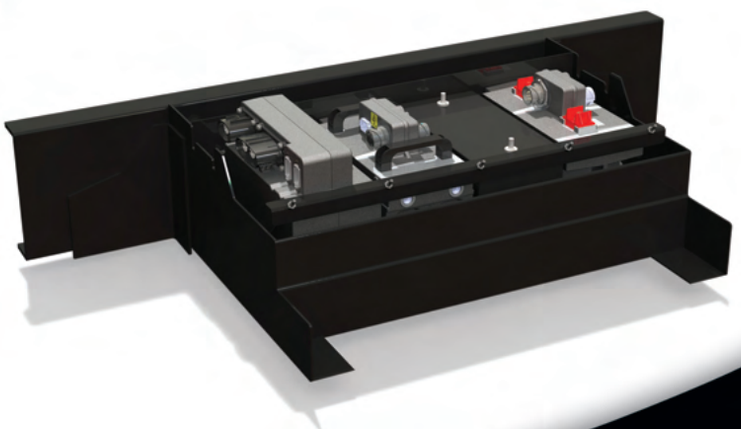
- IGBT based design
- Group 31 size



Power Distribution Modules

- High voltage version 750V, 750A
- Medium voltage version 360V, 300A

- 100KW Traction Inverter, 360VDC Nominal
- 6KW DCAC Inverter, 360VDC In (Nominal) / 115VAC Out
- Group 31 Battery
- 4KW Bi-Directional DCDC Converter, 360VDC In/Out (Nominal) / 13.8VDC Out/In (Nominal)



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Traction supply

Designing and manufacturing leading traction motor solutions, Chinese supplier Jing-Jin Electric is fast becoming a go-to brand for OEMs around the world

WORDS: **EDWARD KINGSLEY**

Founded by Ping Yu and Dr William Cai in early 2008, Jing-Jin Electric (JJE) has grown from a burgeoning start-up into a leading Chinese independent supplier of traction electric motors for EVs, HEVs and PHEVs. The company boasts a high-tech R&D center based in Beijing, a production facility in Shanghai, and has established a branch in Detroit for advanced technology development and sales support in North America.

Capable of manufacturing up to 100,000 units per year, JJE currently exports 90% of its products to blue-chip and start-up OEMs and powertrain integrators in the USA and Europe, thus achieving one of the highest volume of production and sales of traction electric motors in China. In its short life, the company has established a quality-first culture, and has built a quality-control system that covers every link throughout product development, manufacturing, supply chain and logistics. Certified to ISO9001/TS16949 and a consecutive winner of the Electric Motor Supplier of the Year award by *China Automotive News*, JJE has come a long way in a short time.

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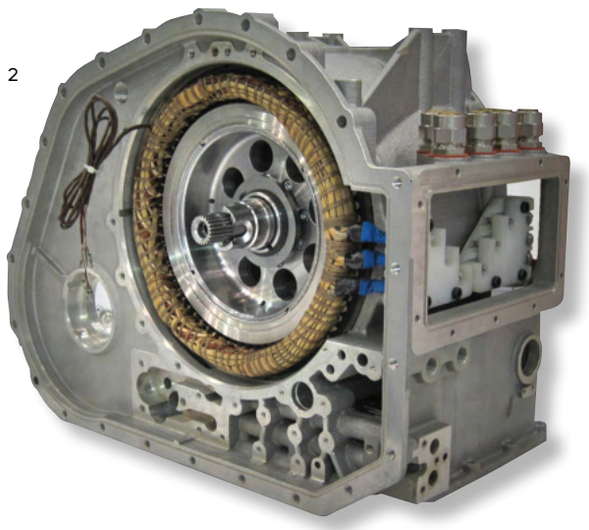


1. JJE's 150kW motor on the Fisker Karma range-extended electric vehicle

2. JJE's advanced dual-motor system for a power split transmission operation

3: Co-founder and CEO Ping Yu says that looking ahead, JJE wants to become a leading e-motor supplier

Solid foundations

The seeds of the company were sown several years earlier when both founders honed their craft at top-tier OEMs and suppliers. Yu worked for General Motors' powertrain group as a manager for global hybrid planning and strategy, while Cai was director of hybrid technology at Remy, leading the development of multiple HEV electric motors for the likes of GM, Daimler and BMW. Their union is underpinned by a shared passion for innovation, as JJE chairman and CEO, Yu, explains: "Innovation is our core strength. Everything is developed in-house because we believe that owning key technologies is critical to a company's success.

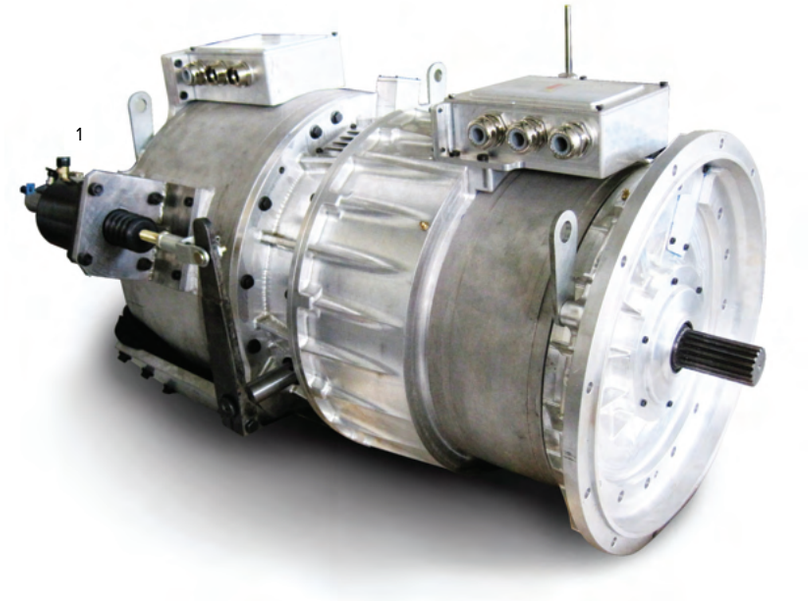
"The major trend in the electric machine industry is greater output density, higher efficiency and low NVH. JJE has the ability to develop innovative electromagnetic design, and synthesize multiple engineering disciplines – mechanical, thermal, fluid, noise and vibration, and testing and validation – to create designs that meet the unique requirements of customers."

These technologies include an array of highly efficient torque- and power-dense electric motors with low NVH, the first of which was delivered in December 2008. As the company grew in strength, the first Fisker Karma electric motor had rolled off the production line by the end of December 2010 and achieved a full run rate just six months later. Built for the Karma model, a plug-in hybrid luxury sports sedan produced by Fisker Automotive, JJE's two traction motors – 150kW, 650Nm each – produce a combined 300kW, and the generator delivers 175kW peak power and over 120kW continuous power at 336V. Designed to improve the vehicle's overall power-to-weight ratio, the motor weighs only 80kg. The motor's ultra-thin shape also greatly reduced the length of the powertrain, thereby enabling the Karma to meet frontal and rear crash requirements.

3

"Everything is developed in-house because we believe that owning key technologies is critical to a company's success"

Ping Yu, chairman and CEO, JJE



By mid-2013, JJE had launched a full array of traction electric motor products for the automotive and commercial vehicle markets, including a 32kg, 170Nm, 92kW high power-density water-cooled traction motor that features an innovative stator winding and rotor design; a 60kW dual-motor drive for a single-mode, compound-split hybrid transmission; a 120kW high-power motor system for parallel-hybrid bus applications; and a series-hybrid, direct-drive, dual-motor system with automated clutch for full hybrid or extended-range hybrid drive for commercial vehicles. "JJE is a recognized electric motor technology leader in China and has the fortune to work with leading global OEMs to create the motors for advanced electrified powertrains," adds Yu. "On one hand, JJE's own R&D constantly creates new technologies and we push them into the market. On the other, the ever-demanding requirements of leading OEM customers drive JJE to create innovative solutions."

These solutions are developed at the company's Beijing R&D center, which features a multitude of advanced testing and validation equipment, including multiple 10,000 or 20,000rpm motor dynamometers, and – according to Yu – "the industry's largest array of durability test benches with 2.4MW total installed power, and vibration, temperature, humidity and corrosion cycling testers". The JJE CEO says the company plans to add to its current portfolio over the next 12 months with the release of a number of products into the market, such as a high-voltage (300V) ATF pump motor and drive for full/plug-in hybrids; a 5kW electric AC compressor motor; 2,000-3,500Nm direct-drive motors that can propel an electric bus without a transmission; and wheel side dual motor axles for low center floor electric and plug-in buses.

1. JJE provides leading and high-tech motor solutions for commercial vehicle markets

2. JJE operates advanced R&D facilities, which include a total 2.4MW of durability dynos

3. JJE co-founder, William Cai, has 30 years of experience in electric motor development

"JJE's revenue has grown rapidly since the company was founded"

Ping Yu, chairman and CEO, JJE

Big ideas

As such, the company has, in an economic sense, fared well over the past five years. "The global recession in the second half of 2008 through 2009 had no impact on JJE," states Yu. "JJE's revenue has grown rapidly since the company was founded, and has maintained profitability every year since 2009."

Yu reveals that JJE's target is to grow its revenue stream to US$100 million in the next three years. In order to achieve this, Yu says the company must increase its sales in China to at least 50% of its world total in 2013. "China will become the largest market for electrified powertrains in five years, so it is absolutely critical that JJE grows its domestic sales to a substantive portion. Fortunately, we've won several large contracts for the top Chinese automotive and commercial vehicle OEMs, so we're in a good position to achieve our goals."

And yet, amid all the prosperity, Yu is still wary of the potential pitfalls. "Business uncertainty is our greatest challenge and hurdle to overcome. This is still a new market, and despite the overall high growth, customer demand may go down as well as up. Customers may even suspend or cancel programs, so the forecast is always unreliable. JJE needs to deal with these uncertainties by establishing a diversified customer base and product portfolio, a lean, agile production system, and supplier partners who share a similar outlook to JJE."

Looking even further ahead, Yu hopes to build on momentum that the company has already created for itself and transform JJE into "the technology and market leader in the electrification of powertrains" by 2020. With JJE already an influential supplier of traction electric motors, the CEO may well just see this hope become a reality.

We've found the missing piece

Motor-LAB

MDL's unique combined electromagnetic and thermal modelling tool

- couples with various software tools such as Motor- CAD SPEED, Flux and FEMM
- Specifically designed for Brushless AC motors in traction applications
- Fast, accurate and easy to use with experimentally verified techniques
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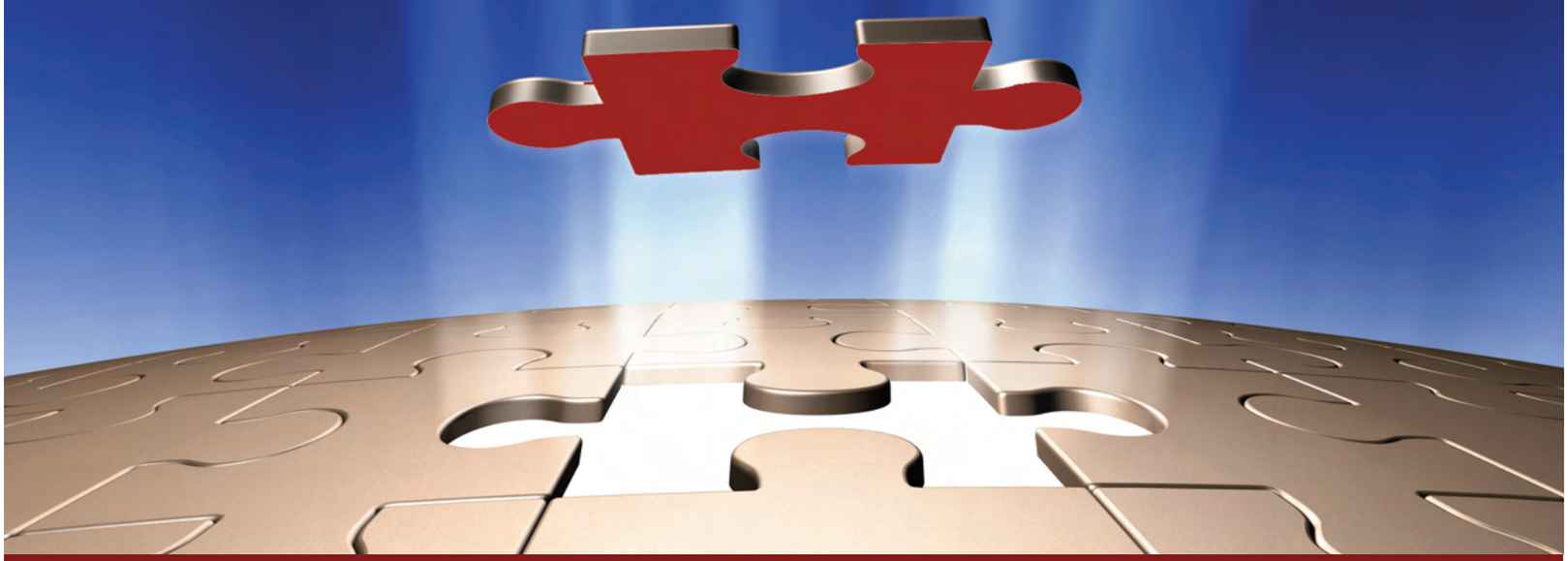

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Work in progress

As OEMs and aftermarket converters bring advanced, eco-friendly commercial vehicle solutions to market, *E&H* examines the blossoming powertrain electrification trends sweeping the service and utility sectors – important business areas that many argue are ideally suited for all-new fully electric propulsion technologies

WORDS: **FARAH ALKHALISI**

Electrification and hybridization are having an impact in the commercial vehicle world, from microvans through to full-scale refrigerator trucks, and this phenomenon is showing no signs of slowing as fleet operators, under mounting pressure from rising fuel costs, taxation regimes, urban low emissions zones and other national and local legislative measures, are increasingly looking for powertrain alternatives to the trusty diesel engine.

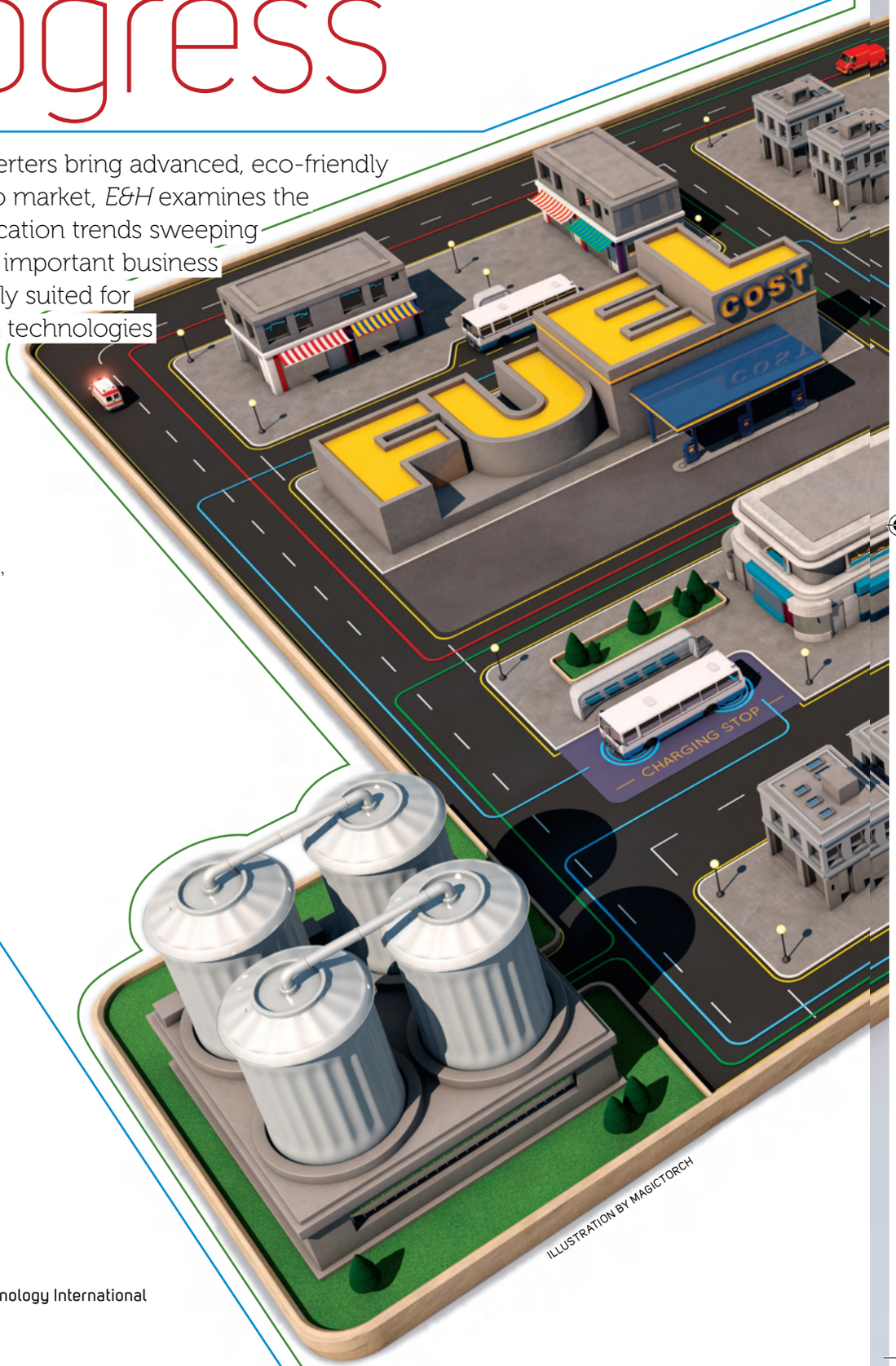

ILLUSTRATION BY MAGICTORCH


TAX
EMISSION

Numerous major orders and commitments have recently been made as a wider variety of new products come to market. Mercedes-Benz, for example, is to deliver 50 battery-electric Vito E-Cell panel vans, its largest European order to date, to the Danish postal service. The Vito E-Cell, which has a 60kW electric motor producing 280Nm of torque, a 36kWh lithium-ion battery and a range of up to 130km (NEDC), recently took part in field trials with Post Danmark on the island of Bornholm in the Baltic Sea, and was judged to be well suited for the short delivery rounds and frequent stops of a postal service vehicle.

Over the Atlantic, UPS has announced the deployment of 100 electric trucks in California, where Governor Edmund Brown has issued an executive order for the widespread deployment of zero-emissions vehicles to tackle the state's smog problems. It is thought that these electric UPS trucks, built by Electric Vehicles International (EVI) of Stockton, California, will save around 572,796 liters (126,000 gallons) of fossil fuel a year. EVI is working on further pilot trials with companies including Frito-Lay and Pacific Gas & Electric for its medium-duty and walk-in vans, and UPS is also taking delivery of 40 hydraulic hybrid walk-in vans this year from the Daimler Trucks subsidiary Freightliner Custom Chassis Corporation (FCCC) of South Carolina.

1

1. Mercedes has recently delivered 50 Vito E-Cell vans to Post Danmark

2 and 3. The functional Vito E-Cell features a 60kW electric motor, 280Nm of torque and an advanced 36kWh lithium-ion battery pack

2

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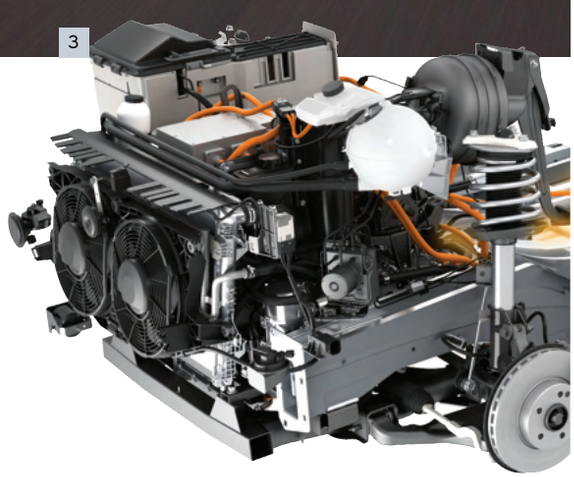


FedEx Express is one of many courier organizations that is electrifying its fleet of vehicles. Pictured here is the Nissan e-NV200 battery-electric van

Nissan, meanwhile, has trialed its e-NV200 battery-electric van in the UK and Japan with fleets including British Gas, FedEx and the Japan Post Service, and there are further programs underway in Singapore, the USA and Brazil. FedEx Express has stated that by the end of the 2013 fiscal year, it will be running 200 electric vehicles and 360 hybrid-electric vehicles, with its fleet including the Navistar eStar, the FCCC eCell and the Ford Transit Connect Electric, as well as retrofit conversions of existing vehicles by Enova Systems and FCCC, and the FCCC-Eaton hybrid-electric pick-up and delivery vehicles.

Moving people

However, it's not just the postal and courier industries where powertrain electrification is making an impact; this technological revolution is also happening in other hard-working sectors.

As transit buses follow defined routes and operate around a fixed depot, plug-in models (all-electric or hybrid) can be easily charged,

"At transfer stations, smaller electric vans would take over delivery. Their predictable travel routes and fixed depots would simplify battery charging and equipment maintenance"

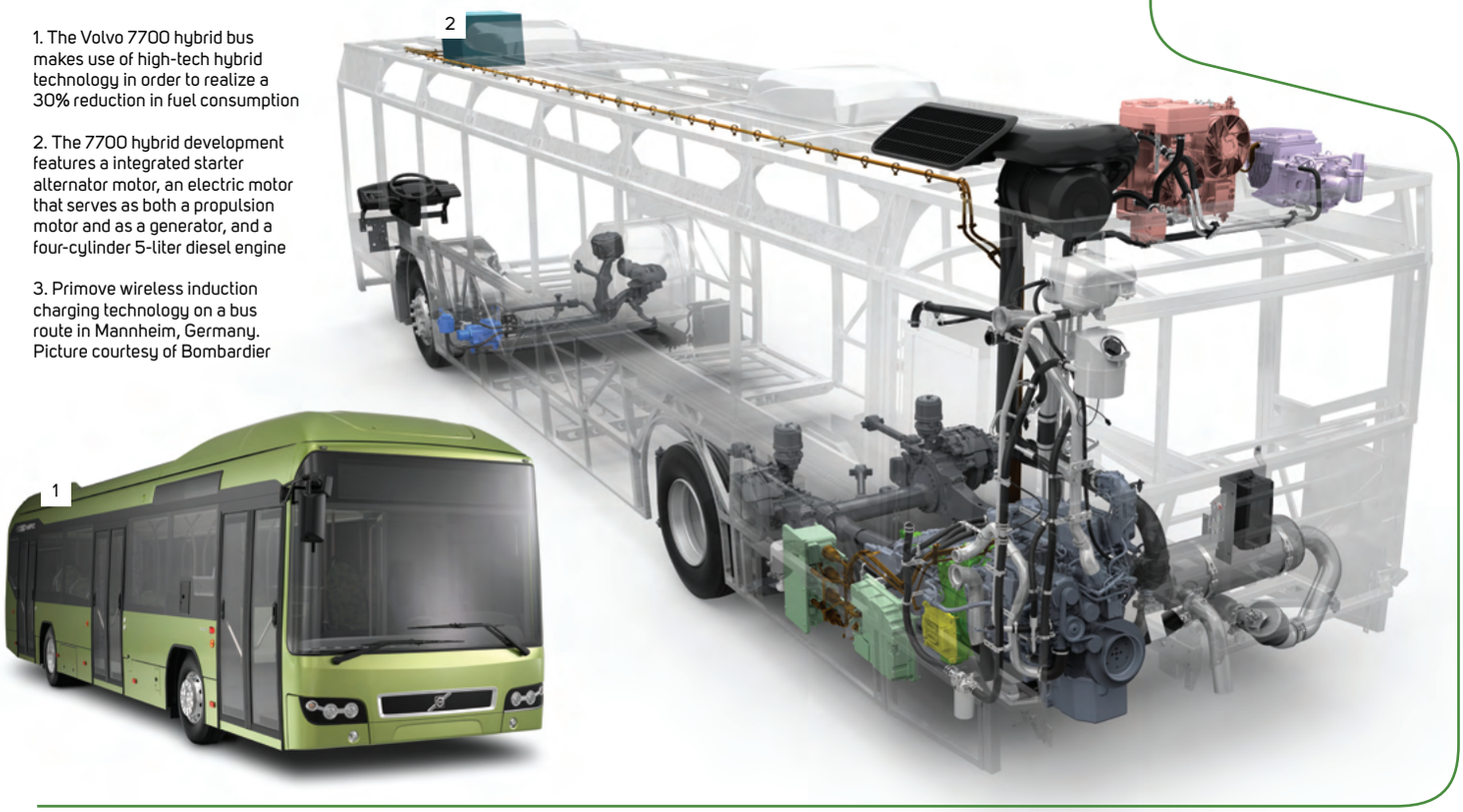
Dr Eckhard Scholz, speaker of the brand board of management, Volkswagen

FUTURE THOUGHTS

Part of the electrification process in the freight and service sectors are smarter logistics: different ways of scheduling, more focused deployment of vehicles, better integration with other forms of transportation and even vehicle-pooling or sharing. Management software using mapping to optimize an electrified powertrain, sophisticated route planning, automation, platooning and RFID tagging to create an internet of vehicles, could all facilitate the operation of EVs.

Volkswagen's Dr Eckhard Scholz, speaker of the brand board of management, said at the unveiling of the e-Co-Motion electric transporter concept that electric mobility could play a crucial role in meeting the growing transport needs of the world's megacities. "Freight trains and conventional or hybrid-powered high-capacity lorries would deliver goods up to the city limits," he explained. "Then, at transfer stations, smaller electric delivery vans would take over. Their predictable travel routes and fixed depots would simplify battery charging and equipment maintenance."

Postgraduate Vehicle Design students at London's Royal College of Art recently took part in a Citroën-sponsored project to visualize the global urban van of the future, and some of the concepts created illustrate the potential of digital communication. The prize-winning Equippe by Alexander Ibbett involves a team of networked Segway e-scooters for retrieving items in a warehouse and for local deliveries, following a larger EV in a platoon, but able to peel off from the convoy and join another. Another interesting idea was Selim Benhabib's iPick, an automated post office/vending machine/delivery unit on wheels to circulate in a designated neighborhood, summoned by smartphone app.



1. The Volvo 7700 hybrid bus makes use of high-tech hybrid technology in order to realize a 30% reduction in fuel consumption

2. The 7700 hybrid development features a integrated starter alternator motor, an electric motor that serves as both a propulsion motor and as a generator, and a four-cylinder 5-liter diesel engine

3. Primove wireless induction charging technology on a bus route in Mannheim, Germany. Picture courtesy of Bombardier

and many today are working worldwide as a result. China's BYD claims to be the world's largest maker of electric buses, and has exported its 12m-long eBus model – with iron-phosphate batteries and a range of 250km – to Europe and North America, and has just signed a deal to manufacture it in Bulgaria as well as in Shenzhen.

Many see opportunity charging via wireless induction as being the next stage for the electric bus operation, and already there are field trials underway, including the EMOSS program in s'Hertogenbosch, Netherlands, which uses a 120kW inductive power transfer with magnetic resonance coupling that connects a primary grid-powered coil in the road and a pick-up coil beneath the vehicle. The test bus, a Volvo conversion measuring 12m and weighing 18 metric tons, is mainly charged overnight, but is 'topped up' at the induction-equipped stops and can run for 18 hours or nearly 290km per day. EMOSS suggests that this allows for a downsized battery pack, saving weight, space and cost. Bombardier Transportation, meanwhile, is to trial its Primove wireless induction charging system on a bus route in Mannheim, Germany, and the Wright Group, maker of the Streetlite EV, is working with partners on a wireless charging project in Milton Keynes, UK.

Battery-swapping experiments continue nonetheless, and feature in a two-year, five-city trial e-bus project in Poland led by the Beijing Institute of Technology, the Warsaw Institute of Technology and Polish energy supplier Tauron Polska Energia. Fuel cell buses are in operation in numerous locations – 15 so far in California, according to the California Fuel Cell Partnership – and suppliers including Ballard have confirmed deals to deliver advanced fuel cell modules for bus applications.

Yet despite such enroads, diesel-electric hybrid buses are, at the moment, the predominant alternative powertrain option. Popular models in action in Europe include the Volvo B5LH, 44 of which are about to be delivered to operator Arriva North West in the UK. Volvo Buses's North American subsidiary, Nova Bus, has also just taken the group's largest ever hybrid order: 475 LFS buses for the operator ATUQ of Quebec, which has an option for 1,200 more. Volvo is also to start field trials of three plug-in diesel-electric hybrid buses in Gothenburg this summer, and is installing charging stations at its route termini.

BYD EBUS TECH SPEC:

Motor: AC synchronous motor (brushless) – BYDTYC90A
Maximum power: 180kW (2 x 90kW)
Rated power: 150kW (2 x 75kW)
Maximum torque: 700Nm (2 x 350Nm)
Battery type: FE
Capacity: 324kWh/600Ah (3 x 200Ah)
Charging time: Five hours
Top speed: 70km/h
Maximum gradeability: 15%
Minimum ground clearance: 140mm
Range: 250km
Curb weight: 13,300kg
Seats: 25 plus driver
Front axle: BYD low floor front-axle
Rear axle: BYD in-wheel drive rear-axle
Suspension: Air suspension and ECAS system

Above and right: The HybriDrive Accessory Power System 2 from BAE Systems provides both DC and AC power in support of the full electrification of truck subsystems, including engine cooling and the air conditioning unit

Even the iconic US yellow school bus has gone green: the Kentucky Department of Education claims to run the largest hybrid school bus fleet in the USA, with more than 160 now operating in the state and giving a claimed 34% average fuel efficiency improvement. These feature a diesel-electric Eaton hybrid powertrain mated to a chassis from International Bus and the Daimler subsidiary Thomas Built. Bus makers including Wrightbus are also looking at saving weight by adopting battery-free KERS, which is said to be particularly suitable for stop/start urban routes.

Green garbage run

Electrification is equally well suited to municipal duties such as waste and recycling collections, which also entail stop/start, low-mileage routines around fixed bases. Nissan built a small batch of electric garbage trucks in the late 1980s for its home city of Yokohama, but most electrified trucks in this sector have been, until recently, aftermarket conversions, often one-offs for small-scale local contractors rather than large fleet procurements. Purchase price is a particular barrier for public authorities, especially against a backdrop of cost-cutting by local councils in many recession-hit regions.

Above: RCA students were tasked recently with designing and creating a new form of service vehicles. Image courtesy of the Royal College of Art

Left: EVI will deliver electric trucks to UPS, which is expected to save the organization around 572,796 liters (126,000 gallons) of fuel a year

However, French manufacturer of industrial vehicles and producer of the Gepebus Oreus e-buses, Power Vehicle Innovation, has built an 11-strong fleet of 26 metric ton, all-electric garbage trucks for the city of Courbevoie, and further large all-electric municipal waste models in production include the Motiv Power Systems/Detroit Chassis/Loadmaster truck, with a fleet of 20 units destined for Chicago. Numerous small, lightweight and light-duty trash collectors and tipper trucks are available too, many Chinese-built, but there's also a heavy-duty hybrid offering from Volvo – the FE Hybrid – which combines a 7-liter diesel engine with a 120kW motor to give a claimed 30% cut in fuel consumption and carbon dioxide emissions against a diesel-only counterpart. The FE Hybrid has only recently been delivered to its first customers and the early feedback has been positive.

EVs on call

From neighborhood electric vehicles and buggies for low-speed urban or parkland patrols to mainstream OEM products such as the Nissan Leaf, first adopted by the

Portuguese police force, EVs are also today increasingly working in police, ambulance and fire services, albeit mostly in routine non-emergency capacities. BYD signed a deal earlier this year to supply 500 e6 police cars to the city of Shenzhen, and European police forces have been trialing small EVs such as the Mitsubishi i-MiEV and Smart Fortwo electric-drive. Others feel that higher-speed and longer-range REEVs are more appropriate for emergency response work, like in the UK, where the Vauxhall Ampera has joined the rapid-response team of the Yorkshire Ambulance Service and is in action in the Police Service of Northern Ireland as an incident response vehicle. Not to miss out, GM's Chevrolet Volt has been delivered to the Norfolk Fire Service.

Many agree that greater opportunity for EVs and HEVs will come in this sector as services seek to 'right-size' and purpose-design the vehicles deployed, especially with attention to quick responses in congested urban conditions. Francesco Binaggi, a student on the world-leading MA Vehicle Design course at London's Royal College of Art (see *Future Thoughts*, p117), worked on a project with the London Ambulance Service and created a concept for a cleverly packaged, compact, narrow vehicle that bridges the gap between a paramedic's motorbike and an estate car, capable of carrying the service's 'life pack' for heart attacks – including defibrillator and ventilators – plus two paramedics and a stretcher. "Congestion affects the reaction times of emergency services," he explains. "I looked at agility, and packaging, what an ambulance needs to carry, and asked: why not a small ambulance for specific problems?"

> "We want to continue contributing to the reduction of pollution in large urban centers, and the introduction of the 100% electric Nissan Leaf sets a new benchmark for our fleet"
>
> Paul Gomes Valente, national director, PSP

Above and below: Emergency services are increasingly looking to pure electric vehicles and range-extended models. Picture above is the use of the Nissan Leaf by the Polícia de Segurança Pública in Portugal and below is the Vauxhall Ampera that is being supplied to the Police Service of Northern Ireland

Questions such as the one posed by Binaggi are not only valid, but are also being considered by local municipalities, national governments and nationwide emergency services across the world. It would seem that the electric powertrain of today is shaping not only how car makers meet stringent emissions targets, but also the mobility of tomorrow's society.

DRIVING FORCE

Local police forces are increasingly looking to powertrain electrification to reduce fleet vehicle costs. Earlier this year, West Midlands Police confirmed the UK's largest-ever corporate order of the Nissan Leaf all-electric vehicle. The plan is for no fewer than 30 Leaf models to be used across 10 local policing units (LPUs) as 'diary' cars, meaning that the Nissan EVs will be used to attend pre-arranged meetings with victims of crime and locals who have contacted the force. The diary cars average 64-72km per day, making the 199km range of the new-stage Leaf perfectly suited for the LPUs' day-to-day needs. What's more, dedicated charging points installed at each LPU will be used to charge the Leaf electric vehicles, and with the bill for a full recharge being a mere US$2.6, total costs are kept under control too – a crucial factor for local governmental services in Europe looking to cut costs.

Meanwhile, across the Irish Sea, the Police Service of Northern Ireland (PSNI) is trailing General Motors range-extender Voltec powertrain in the form of the Vauxhall Ampera. "We're looking forward to putting the revolutionary Ampera through its paces when responding to incidents, while also reducing our emissions and providing significant savings on fuel costs," says Marcus Belshaw, head of transport for PSNI. GM's UK arm, Vauxhall, says that the range-extender technology in the Ampera, which won the Green Engine accolade at last year's International Engine of the Year Awards, makes it a good option for use in the emergency services as it benefits from both an electric motor and a petrol engine – thus eradicating range anxiety. Furthermore, charging point infrastructure is well developed in Northern Ireland, with EV owners currently being no further than 16km (10 miles) from a charger.

However, the Leaf and Ampera deliveries to UK police forces – which happened over the past few months – were not the first of their kind. For that, one needs to go back to July last year and to Portugal, where the Polícia de Segurança Pública (PSP), the security force responsible for policing the large urban areas of the country, became the first such service to take on a full fleet of electric vehicles – in the form of the Leaf.

The zero-emissions cars are being used mainly as part of the PSP's safe school action program, but with flashing blue lights, sirens and clear 'Polícia' markings, they can be called upon to perform other police duties at any time.

"We pride ourselves in being very the first police force in the world to incorporate cars with zero-emissions technology as part of our 5,000-vehicle fleet," says superintendent Paul Gomes Valente, national director of PSP. "We want to continue contributing to the reduction of pollution in large urban centers, and the introduction of the 100% electric Nissan Leaf sets a new benchmark for our fleet." The move by the PSP should come as no surprise – Portugal was one of the first countries to install a network of EV chargers in its major cities.

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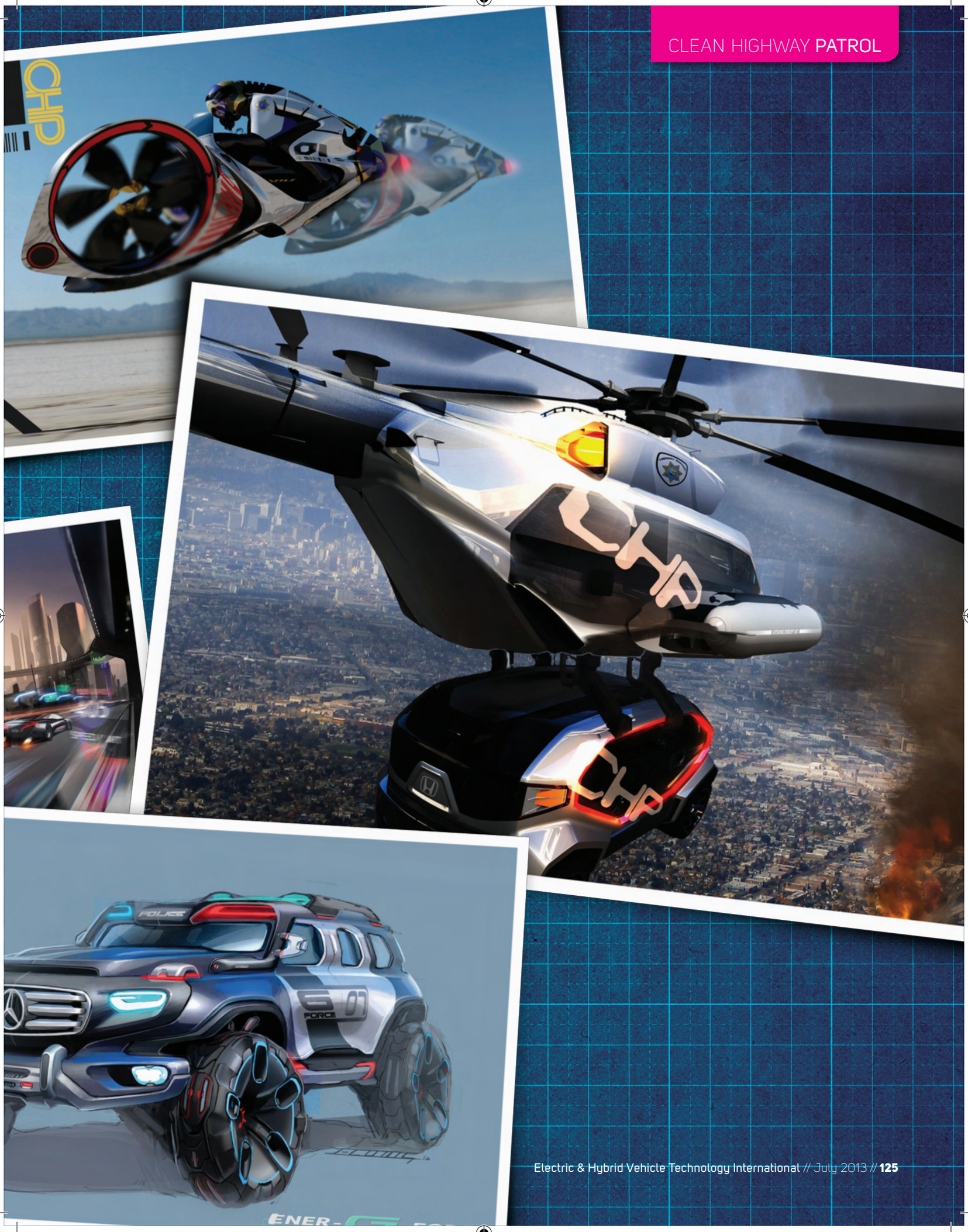
Thought police

Each year, the LA Auto Show holds its much-coveted Design Challenge – a competition that gives studios from across the world the chance to sketch tomorrow's automotive visions, usually relating to sustainable transportation. For the most recent Design Challenge, the theme was highway patrol vehicles that deal with the problems related to a specific region's transportation and societal conditions in the year 2025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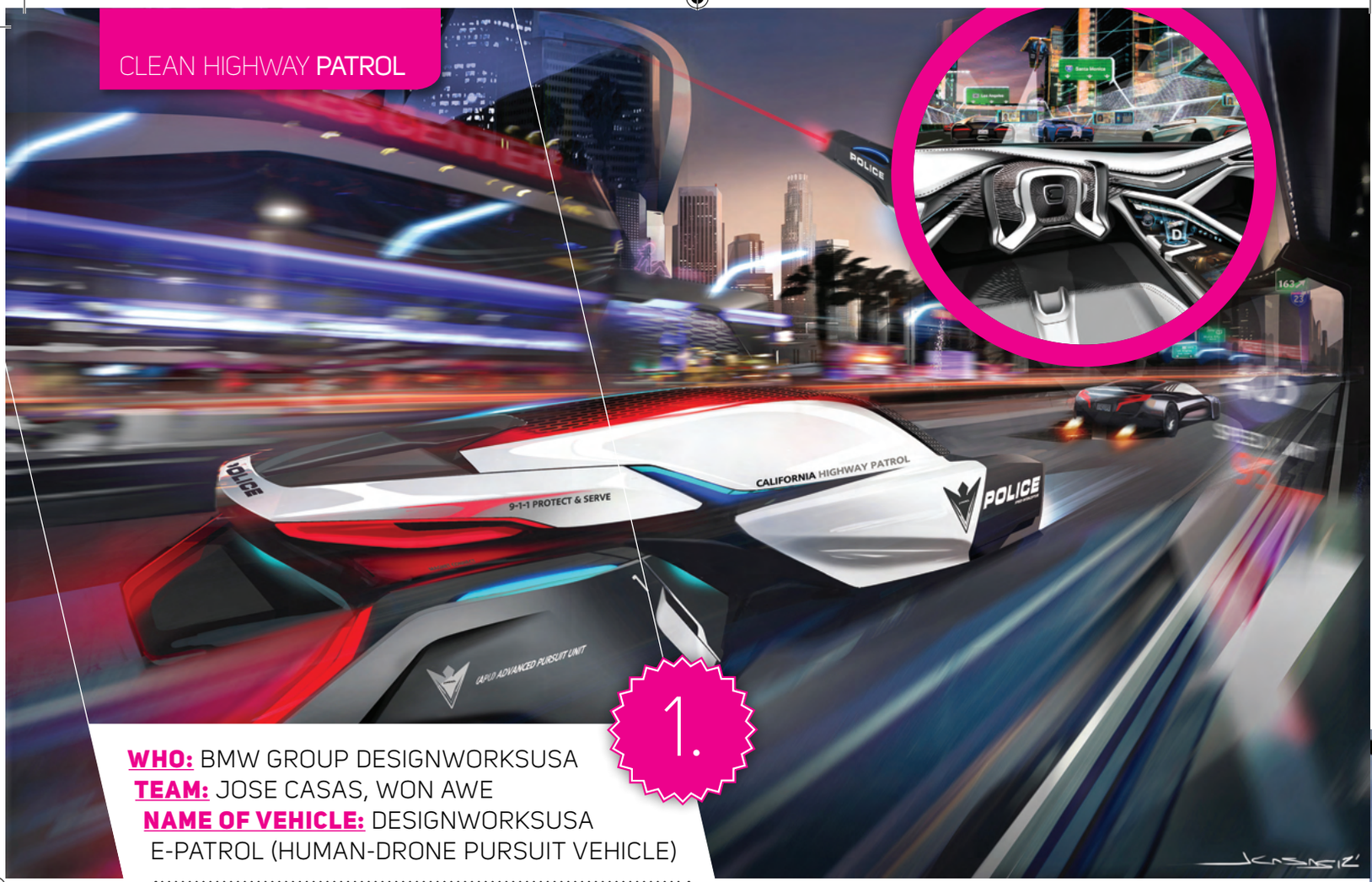
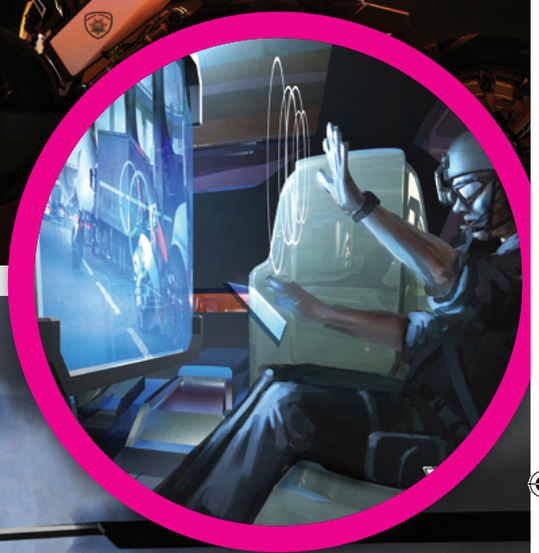


1.

WHO: BMW GROUP DESIGNWORKSUSA
TEAM: JOSE CASAS, WON AWE
NAME OF VEHICLE: DESIGNWORKSUSA E-PATROL (HUMAN-DRONE PURSUIT VEHICLE)

The BMW Group DesignworksUSA team chose Los Angeles as the region to create a 2025 scenario for its E-Patrol vision. The team's research predicated that the city by that point would have more traffic, faster vehicles and vehicles with alternative fuel sources. The main structure of the E-Patrol can deploy three drones. In the case of a pursuit during heavy traffic within the inner city area of LA, the patrol officer sitting within the two compartments of the main structure of the E-Patrol can deploy either the flying drone or one of the single-wheel drones to chase the criminal.

WHO: HONDA R&D AMERICAS INCLUDING THE ADVANCED DESIGN STUDIO CALIFORNIA
TEAM: JASON WILBUR, EDDIE BIRTULESCU, RAJ RIHAL
NAME OF THE VEHICLE: HONDA CHP DRONE SQUAD



2.

The CHP Drone Squad is a vehicle-based system for 2025 specifically designed to work efficiently and seamlessly in the harsh environment of Californian highways without the need for a new transport infrastructure. The Squad comprises a two-vehicle system. The Auto-Drone subsystem operates as a manned or unmanned mission control vehicle that has the capacity to deploy Moto-Drones while on the move. The Moto-Drones are unmanned motorcycles that are capable of being rigged for multiple responses or rescue missions.

3.

WHO: GENERAL MOTORS ADVANCED DESIGN CALIFORNIA
TEAM: FRANK SAUCEDO, BRENT WICKHAM, CHARLES LEFRANC, SHAWN MOGHADAM, DARREN LUKE, THAMER HANNONA
NAME OF VEHICLE: VOLT SQUAD

The GM Advanced Design team has created a new electric vehicle system that meets the challenge of a highway infrastructure that by 2025 will be brimming with cutting-edge technologies. Named the Volt Squad, the creation is essentially a three-vehicle fleet that's designed around the concept of observe, pursue and engage, with each vehicle having a clearly defined situational role, delivering superior flexibility, presence and capability. At the core of the vehicle's architecture is an advanced electric propulsion system whose roots can be traced to today's Volt powertrain.

4.

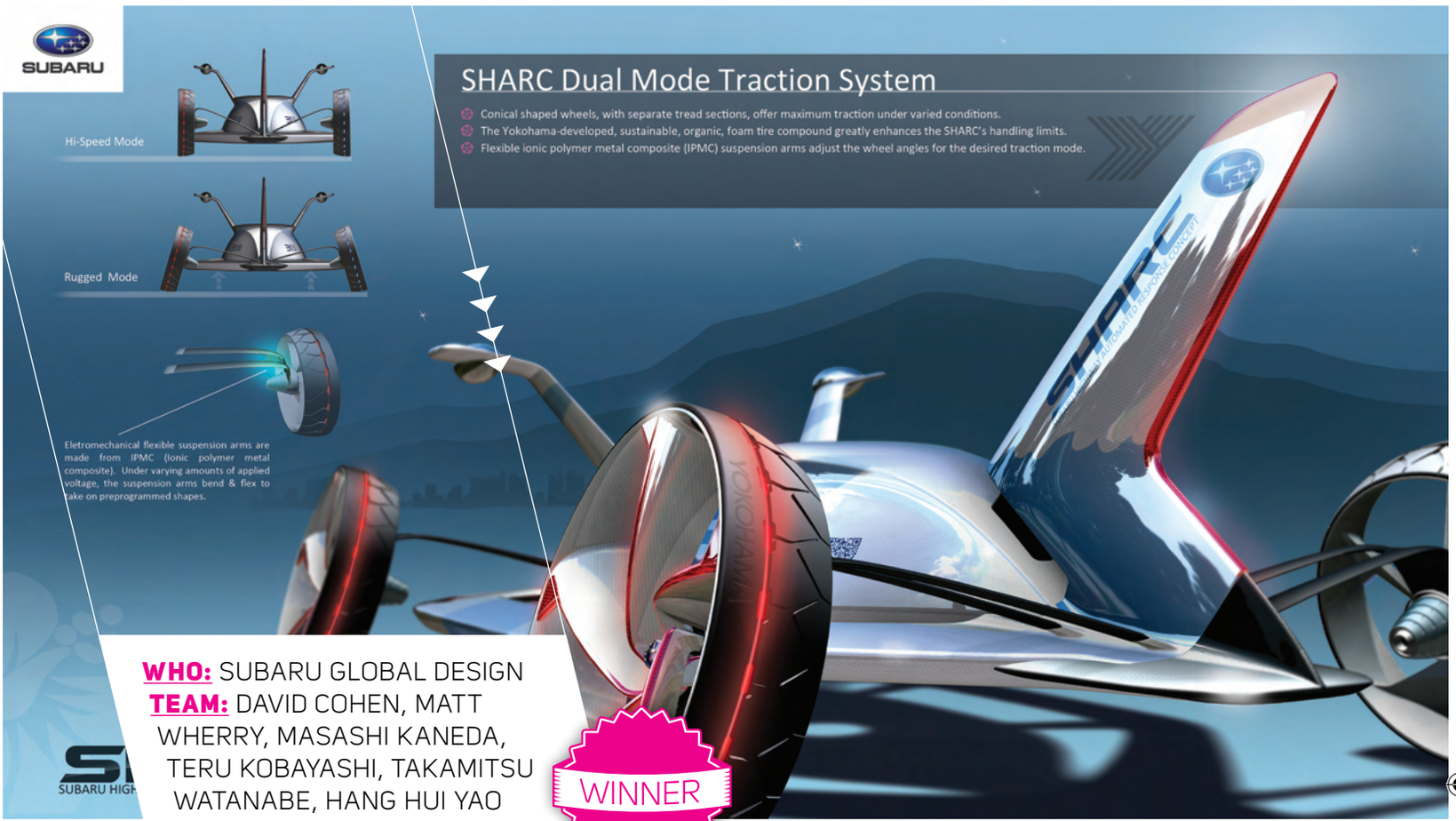
WHO: HONDA R&D COMPANY INCLUDING ADVANCED DESIGN STUDIO TOKYO
TEAM: RYO NAKAYAMA
NAME OF VEHICLE: HONDA CHIPS 2025 TRAFFIC CRAWLER

Honda Japan's Traffic Crawler concept offers key features that meet the needs of the California Highway Patrol central office as it adjusts to the ever-changing traffic environment in 2025 where, in addition to mounting conventional traffic problems, vehicles freed from environment constraints are getting larger and heavier. Despite the transitional period to safer automated driving, the traffic environment in 2025 is more challenging, especially as the state of California starts to re-establish its car culture. In response to the need for strict traffic enforcement, Honda has created an eco-friendly vehicle that will help enforce the law.

5.

WHO: MERCEDES-BENZ RESEARCH & DEVELOPMENT NORTH AMERICA INCLUDING ADVANCED DESIGN CENTER, CALIFORNIA
TEAM: HUBERT LEE, JACKSON LUTTIG, SYLVAIN WEHNERT, ARMIN SINICKI, DR GORDEN WAGENER, STEFFEN KOEHL
NAME OF VEHICLE: MERCEDES-BENZ ENER-G-FORCE

By 2025, the Mercedes-Benz design team says law enforcement officers will need to adapt to even more crowded roads with electronically monitored and controlled traffic, a much larger population, and changes in human behavior. As the most eco-friendly SUV, the Ener-G-Force has an innovative powertrain setup that gives it the capacity to store recycled water in tanks on the roof, and transfers the water to a hydro-tech converter, where natural and renewable resources are converted into hydrogen for operating the fuel cells. The storage units for the electricity generated in this process are housed in easily accessible striking side skirts that also house the battery packs. As a result, the Ener-G-Force emits nothing but water and has an operating range of around 800km. Four wheel-hub motors, whose output for each individual wheel is adapted precisely to the respective terrain by high-performance electronics, provide the pulling power.



WHO: SUBARU GLOBAL DESIGN **TEAM:** DAVID COHEN, MATT WHERRY, MASASHI KANEDA, TERU KOBAYASHI, TAKAMITSU WATANABE, HANG HUI YAO

NAME OF VEHICLE: SUBARU HIGHWAY AUTOMATED RESPONSE CONCEPT (SHARC)

WINNER

With the grand opening of Hawaii's sparkling new inter-island Paradise Highway, Subaru debuts its cutting-edge Subaru Highway Automated Response Concept (SHARC). The SHARC highway patrol vehicles provide an innovative, affordable and environmentally conscious solution for 24-hour highway monitoring, protection and rapid emergency response.

Meeting Hawaii's strict UltraGreen carbon-neutral environmental regulations and reflecting a trend for reduced highway patrol budgets worldwide, zero-emission SHARC vehicles are powered by renewable energy and operate autonomously, eliminating the need for a large full-time highway patrol staff.

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Charged with success

WORDS: **FRANK MILLARD** ILLUSTRATION: **BEN WHITE**

The race is on to expand EV charging infrastructure, integrate it with ITS and encourage customer take-up. However, this is currently driven by legislation and OEMs' long-term strategies rather than consumer demand

Provision for electric and hybrid vehicles is fast becoming a priority in transportation departments around the world. Car makers need to sell their vehicles to customers, who in turn need to keep their vehicles charged and in motion, but it's up to governments to provide the necessary infrastructure to ensure this happens in everyone's interest, as well as in accordance with increasingly stringent emissions regulations.

Siting charge stations in the best locations and making them convenient and accessible aren't the only factors to consider. As more drivers turn to electric and hybrid vehicles, there will be a fall in revenue from gas taxes – already a diminishing resource for DOTs – with the potential for dire financial consequences. With this eventuality looming, DOTs are busy looking for alternative models of funding.

A further factor to be considered is how these increasing numbers of EVs and their hybrid cousins will fit in with intelligent transportation systems as they, too, evolve and become more sophisticated. Does, for instance, the technical evolution of EVs jibe with ITS technology and strategy – or are we placing brand-new dinosaurs on 21st century roads? Many believe that the time to address the convergence of EVs with ITS is now, otherwise repentance and monumental expense will likely ensue.


SAT NAV
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CHARGE LEVEL

Time for an oil change?

Of all the countries in Europe that are actively promoting plug-in technology and its associated infrastructure, Germany is in the vanguard, not least when it comes to hydrogen. "It's the better oil for today," feels Dieter Zetsche, chairman of the management board of Daimler. "And that's why it's time for an 'oil change'." Daimler and Linde are currently working together to deliver a hydrogen fuel infrastructure for Germany.

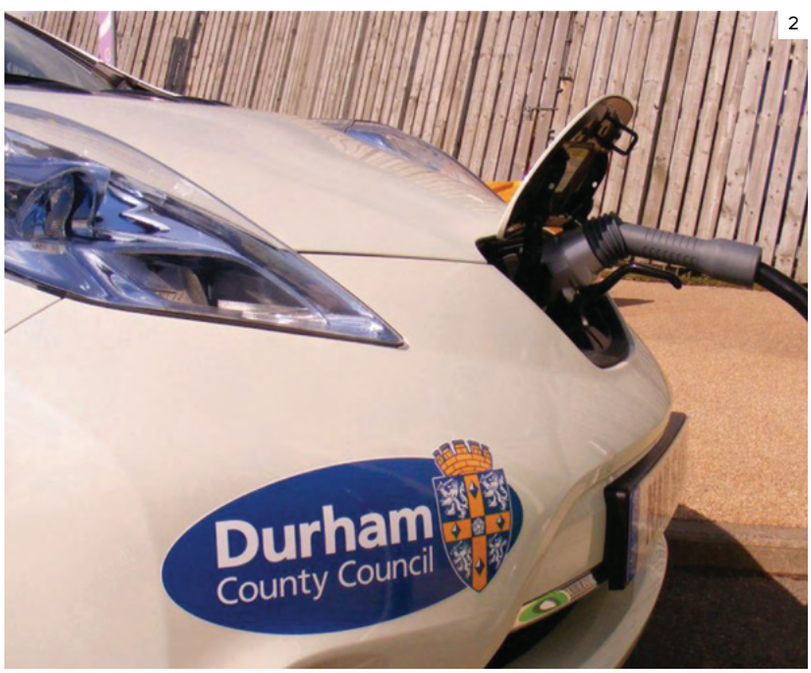
"EVs equipped with a battery and fuel cell will make a considerable contribution to sustainable mobility in the future," agrees Zetsche's colleague, professor Thomas Weber, who heads up Daimler group research and Mercedes-Benz Cars Development. "Because it is very customer-friendly, with a great range and fast refilling, fuel cell technology has enormous potential for greatly advancing Germany on its path to becoming the lead market for electric mobility."

In a joint venture comprising BMW, Bosch, Daimler, EnBW, RWE and Siemens, Hubject of Berlin is developing an interoperable Europe-wide public charging infrastructure to facilitate e-roaming. It will enable EV drivers to access all public charging points throughout the continent. "In the future, e-mobility customers will be able to use the charging infrastructure of all Hubject's partners across Europe under a single provider's contract," says Andreas Pfeiffer, managing director at Hubject. "This will help make charging an electric car as simple as withdrawing cash from an ATM."

Fuel Britannia

In June 2011, the UK's Department for Transport (DfT) published *Making the Connection: the Plug-In Vehicle Infrastructure Strategy*, which outlined its vision of an extensive charging infrastructure around the country. The UK government expects there to be tens of thousands of plug-in vehicles on its roads by 2015, and hundreds of thousands by 2020, so it wants to be in a position to deal with the demand. The DfT Plugged-in Places (PIP) program is the main initiative to kick-start a UK-wide ultra-low-emission vehicle (ULEV) plug-in charging infrastructure. A recent government *Spending Review* also announced provision of more than US$619m to support growing the market of ULEVs in the UK to 2015. Of this, the government has made US$46m available to match-fund the eight PIPs to install and trial recharging infrastructure as part of a commitment to make available up to 8,500 charge points.

1



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Continental shift

Enthusiasm for plug-in technology is also growing in the USA – plug-in.com lists 1,625 stations – although it is largely confined to states on the east and west coasts. California leads the way with 1,056 EV, 140 natural gas, 18 liquefied natural gas and 33 biofuel stations – but only four hydrogen points.

In November 2012, the California Energy Commission announced an increase in funding to expand the Golden State's charging infrastructure in line with Governor Jerry Brown's Executive Order of March 2012 to provide the infrastructure to support an estimated one million zero-emissions vehicles on the state's roads by 2020.

"We need better understanding of charging behavior and must work out how to manage charging more strategically with more targeted investment"

Phil Blythe, professor of ITS, Newcastle University

3

1. In May 2011, the Mayor of London, Boris Johnson, launched the Source London charge point network – publicly accessible charge points located at supermarkets, on the street and in parking lots all over the UK capital

2. Thousands of new charging points for EVs are being installed in the UK to try to boost the market for zero-emissions cars

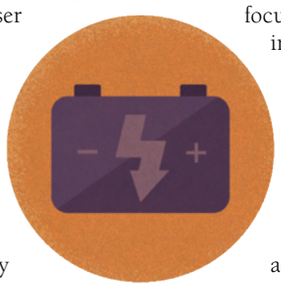
3. Linde and Daimler intend to more than triple the number of public hydrogen refueling points throughout Germany

At the same time, Oregon's DOT has been actively encouraging EVs onto its roads. Yet it has also been concerned about ensuring sufficient funding to replace dwindling gas-tax revenue, a small percentage of which can be attributed to EVs slipping through the taxation net. As the fairest and most efficient solution to the funding conundrum, the DOT has turned to a road-user charge in the form of a per-mile (1.6km) fee.

Funding outlook

In 2001, the Oregon Legislative Assembly introduced the Road User Fee Task Force to "develop a revenue-collection design funded through user-pay methods, acceptable and visible to the public, that ensures a flow of revenue sufficient to annually maintain, preserve and improve Oregon's state, county and city highway and road system".

After considering more than 20 options, the taskforce decided that a road-user fee held the most promise and a pilot scheme was introduced in the Portland area, which consequently proved the feasibility of the project. In late 2012 a second pilot study began. It concluded in January 2013, with a report being presented to the Legislature.



Participants selected their choice of MBUF technology from a number of plans and their mileage was recorded, reported, and an invoice subsequently generated. A smartphone option featuring device compatibility with EVs was also tested.

"Our updated Road Usage Charge Pilot Program focuses on achieving public approval by introducing new concepts such as motorist choice, open systems and a private sector administration option," explains Oregon DOT's James M Whitty, manager of the Office of Innovative Partnerships and Alternative Funding.

And Oregon could just be the start, with Whitty highlighting how several other states are considering a similar policy. "Minnesota is currently completing a pilot program as well, which began in 2011," he reports. "Other states such as Washington, Nevada and Colorado are taking active steps, too."

This all leads Jack Opiola, the managing partner and president of D'Artagnan Consulting, to believe that the gas tax has had its day: "We're at a point where we have highly efficient IC engines, efficient hybrid vehicles, plus a

new-generation of plug-in hybrids and EVs. The newer-generation IC engines are pushing 60-80mpg (3.5-4.7 liters/100km). When the fuel efficiencies are in these ranges, you can't possibly fund transport infrastructure through a consumption tax," says Opiola.

A more direct source of funding of transportation infrastructure is the way forward, Opiola advises, which is why he also supports a distance-based tax on the user-pays principle. "Any urban environment should address its transport funding through a three-part revenue stream: a portion of property taxes; fare box collection revenues for public transport improvements and fleet maintenance; and a distance-based tax on all vehicles. In the case of commercial vehicles, light and heavy trucks, it would be proper to charge them by their distance and the mass or weight they are rated to carry. This three-part funding stream helps provide a direct connection to affordable transport infrastructure."

The USA isn't alone in looking at gas tax alternatives. Opiola points out that the steady reduction in fuel tax revenue is a concern for governments the world over. In 2004, the Australian government envisaged an eventual 24% drop due to the improved fuel efficiency of vehicles, and two years later New Zealand produced another study suggesting a similar decline. Back in the USA, Washington State recently increased fuel tax by US$0.095 in an attempt to stabilize a downward trend in revenue, while in Vancouver the transportation authority Translink currently identifies an approximate US$488m funding shortfall between 2013 and 2015 as a result of these cleaner cars.

Phil Blythe, professor of ITS at Newcastle University in the UK, and director of the Transport Operations Research Group in the School of Civil Engineering and Geosciences, sees PAYD as the only logical solution to the impending hole in road-related tax revenue in Europe. "Charging infrastructure here has been installed to 'encourage and support' the take-up of EVs, largely without a clear business case, particularly when co-funded by the Office for Low Emission Vehicles (OLEV) through its Plugged-in Places initiative," he says. "We need better understanding of charging behavior and must work out how to manage charging more strategically with more targeted investment. We have more than 500 public charging posts in the Northeast of the UK through our existing Charge your Car initiative, for example."

Intelligent transportation

Art James, senior project executive of Innovative Partnerships, also sees the imminent convergence of EVs and their associated technology and infrastructure with ITS as having almost limitless possibilities. "A proliferation of EV car-sharing programs is exploding on the west coast of the USA," he enthuses. "There are also experimental projects using inductive charging – possibly even embedded into the roadway itself – that could fundamentally change how we perceive everything from driving, fueling and even owning vehicles in the future." (See *Dynamic Trials*).

DYNAMIC TRIALS

Dr Anthony Thomson from charging pioneer **Qualcomm** reveals how a wireless infrastructure could unlock the potential of the EV market

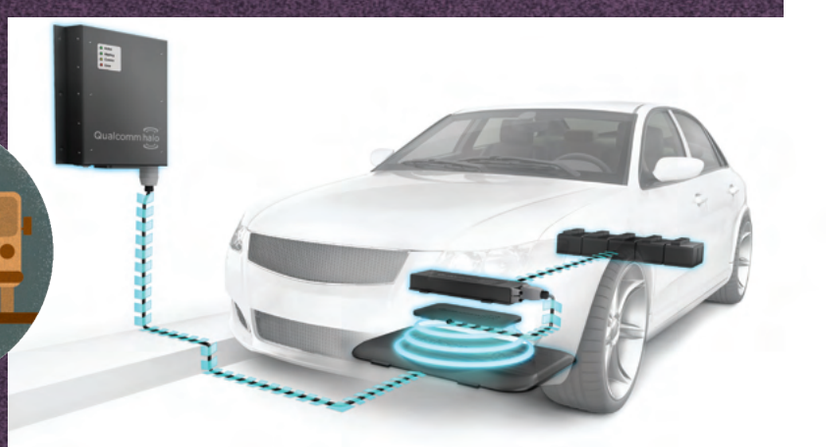
The vision of Qualcomm's Dr Anthony Thomson is for EVs and their charging infrastructure to be not only ubiquitous but also wireless-enabled. Qualcomm is currently working on wireless EV charging (WEVC), the natural extension of which will be dynamic electric vehicle charging (DEVC) – in other words, charging on the move. The latter, though, is at the R&D stage and some years away from fruition, according to the company's vice president of business development and marketing.

A next step will be to build a full-scale test track. "This will provide us with experience of the deployment criteria needed to test our unique DEVC design," Thomson reveals. And while major infrastructure upgrades would be necessary for dynamic charging to be realized, Qualcomm is working with industry and the public sector to highlight the potential that the Qualcomm technology could have in opening up the EV market. "This will come first with stationary charging, then semi-dynamic charging, and then dynamic charging on the move," Thomson predicts.

Qualcomm's immediate aim, however, is to commercialize WEVC into series design and EV production. "We're running a WEVC trial in London this year that will provide us with some good insight into how EV drivers will charge wirelessly, as well as the user benefits of WEVC over plug-in technology," Thomson adds.

The Qualcomm Halo WEVC technology is ideally suited to densely populated urban environments such as London, and it is hoped it will also help drive EV adoption which, in turn, will reduce city pollution levels. WEVC could even complement existing plug-in schemes. Qualcomm feels the technology is viable for any city, though, especially given the trend toward growing urbanization as well as the pursuit of 'smart cities' initiatives. One of these has the backing of UK Prime Minister David Cameron, with Qualcomm's large-scale pre-commercial trial of WEVC in London seen as the perfect megacity environment. This will involve up to 50 passenger and light goods vehicles, from passenger cars to taxis and car-share schemes, and is supported by stakeholders such as Delta Motorsport, Addison Lee, Renault, Transport for London and Chargemaster.

The objective is to enable partners to better understand how WEVC can be deployed in a dense urban environment and to gain feedback from WEVC drivers about their overall experience of wireless charging. Results are expected later this year. Further into the future, early dynamic trials will take place in what Thomson anticipates will be the 2016/2017 timeframe. Still some years away, the Qualcomm man is nevertheless adamant that dynamic charging will be a reality within the next 20 years.



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1. Charge Your Car in the UK is expanding from a regional subscription-based EV recharging network to a national pay-as-you-go network, with a target of 10,000 charge points

A new generation of mass-produced plug-in vehicles is also being equipped with advanced onboard telematics that inform drivers of everything from energy use to the location of the nearest charging stations. "ITS solutions that incorporate value-added services for drivers could help convince potential buyers to invest in these new vehicles," Blythe adds.

"The EV is what others have conceptualized as the 'connected vehicle' – it has to be!" Opiola continues. "I need the finer details built in to the vehicle itself. I need a navigation system to not only plan my most direct route, but my most energy-efficient route – not the same thing!

"Our updated Road Usage Charge Pilot Program focuses on achieving public approval"

James M Whitty, manager of the Office of Innovative Partnerships and Alternative Funding, Oregon Department of Transportation, USA

I need that navigation system to indicate charging stations and parking lots. Real-time data will tell me that I am fourth in line to recharge at the nearest station with parking, so I can opt to go to a different location. All of these 'features' are ITS features that are not simply value-added services as we think of them today, but essential services for an electric-powered world."

2

2. The 2011 all-electric Ford Focus was the first car to use Microsoft Hohm program, a web-based home energy management application that manages how and when to charge electric vehicles

Opiola concurs with other industry insiders who don't see much of a long-term future for pure IC engines. "I see the 'connected vehicle' of the future as the 'ITS' vehicle," he says. Further, he considers EVs and advanced hybrid vehicles as data-rich platforms. "As connected vehicles, they can anonymously feed their trip times, weather data, road conditions and other key data into our transport management centers," Opiola says. "Just think of the cost savings. If we had direct feeds from all these vehicles that were on the road, we'd be able to know and understand the exact conditions on the entire road network without spending billions of federal dollars installing loop detectors, cameras and all our current suite of traffic detection sensors.

"More importantly, we could manage traffic more effectively with dynamic speed controls and navigational data to steer vehicles around problem spots and accident sites. In short, I think the future of ITS, traffic management, incident detection, modal choice and so on is firmly tied to the future generation of EVs and advanced hybrid vehicles."

Blythe is equally energized as to how ITS could influence the eventual success of this electric powertrain movement: "In order for EVs to succeed, we're going to need smart range estimators and navigation, and charging post pre-booking and management. Smart urban traffic management and control will also be a must," he stresses. "I'm thinking about systems that take into account the performance of EVs – stopping them, for example, at the front of a traffic signal because they accelerate away better than IC vehicles, hence can clear the queue quicker when lights switch to green. Eco driving assist is also critical for EVs and can extend range by 30%."

And in the end...

The traffic challenges we face in 2013 are unlikely to have disappeared by 2073 just through the replacement of IC powered vehicles with electric-powered variants. And an aging population, population growth and the expansion of urban sprawl will exacerbate this scenario. "Sixty years ago, who would have predicted the worldwide use of cell phones or the information age of the internet?" says James, who finds it hard to concede that the planet could end up in zero-emissions urban gridlock half a century or so from now. "I am confident that we have the ability to apply technologies such as crash avoidance systems and GPS routing to avoid worse traffic conditions due to demographic fluctuations," he says optimistically.

Opiola, meanwhile, links funding strategy with the avoidance of traffic problems, believing that if we apply the 'user pays' principle and tax motorists by the distance they travel rather than the fuel they consume, we can provide the right price signals for people to make smart choices for their travel. "The right answer may be a car trip in an EV or advanced hybrid," Opiola says. "But the cost of the trip should be comparable to going by train or bus."

A stark warning from Opiola serves as an ideal caveat to the topic. "If we make dumb transportation policy and tax hotels, hair salons, restaurants and other services not directly related to travel choices, then congestion, accidents and other economic consequences will continue to sap our economic vitality and drag down the economic engines driven by transport."

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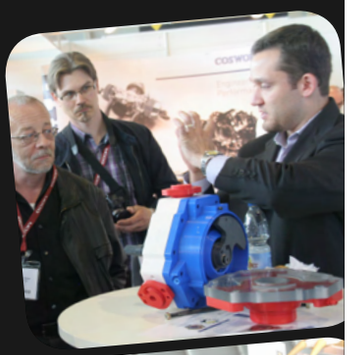
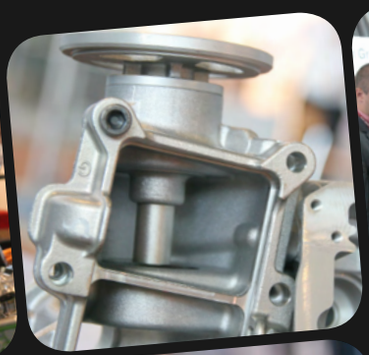




The European expo of specialist engine technologies, materials, coatings and engine concepts

Engine Expo will provide the industry with an ideal platform to meet the world's leading companies as they exhibit their latest powertrain breakthroughs, which will include state-of-the-art designs, cutting-edge components and subsystems, as well as innovative new materials, manufacturing technologies and services.

www.engine-expo.com

Battery extravaganza

The largest energy-storage meeting in the USA returns for a fourth year, giving leading industry figures the opportunity to showcase the latest innovations, developments and initiatives in the supply chain

THE BATTERY SHOW
The Expo for Advanced Batteries

Coming to Novi, Michigan, on September 17, 18 and 19, Electric & Hybrid Vehicle Technology Expo, the official exhibition of *Electric & Hybrid Vehicle Technology International* magazine, is an opportunity for technical leaders, executives and engineers from OEMs and tier 1 suppliers to meet the entire electric vehicle supply chain. Manufacturers of a range of hybrid and electric vehicles, including e-bikes, passenger vehicles, courier vans, buses, trucks, lift-trucks and off-highway industrial vehicles, will be in attendance.

A dedicated, three-day conference will run alongside the exhibition and will explore the latest challenges and opportunities relating to electric and hybrid powertrain engineering.

Running at the same time as Electric & Hybrid Vehicle Technology Expo, The Battery Show annually attracts thousands of battery professionals and buyers, enabling the entire supply chain to be on display, from materials suppliers and assembly equipment manufacturers, to cell producers and battery-pack assemblers.

The Battery Show will also feature a multitrack conference that will bring together the leading minds in the industry to discuss the latest innovations, developments and initiatives. Each year, The Battery Show has grown, and this year, combined with Electric & Hybrid Vehicle Technology Expo, organizers expect around 300 exhibitors to welcome over 4,000 visitors.

Before then, take advantage of this year's co-located event preview, detailing what some of the exhibitors will have to offer. For a full and regularly updated list of exhibitors, visit **www.evtechexpo.com/exhibitor-list**.

Testing solutions of the future

Horiba offers the tools and expertise to meet clients' e-motor and e-motor system testing requirements. A variety of dynamometer torque/speed combinations are available in both single- and double-ended configurations. These safe, durable, low-vibration systems are designed to withstand up to 18,000rpm for e-motor testing. Engineers also offer customized mechatronic testing solutions when DUTs are transmissions, axles, differential modules, electric drive subsystems and driveline components.

A full complement of simulation capabilities is available to achieve real-world test results. Virtual testing options range from battery, environment, track, engine (including engine torque pulsation) and driver simulation. Full vehicle simulation, including wheel-slip events, is also possible. Equipment and services are offered for purchase or on a contract basis through the company's labs in Michigan.

FROM RACE CARS TO ROOFTOPS

Electronic product design and manufacturing services company Nuvation will showcase its innovative battery management system (BMS) technology at this year's Battery Show.

In 2010, a team of engineers from Nuvation became involved in an after-hours project designing a fully electric vehicle for the Progressive Automotive X Prize competition. They installed 363kg of lithium batteries into a road vehicle chassis, and developed a race car capable of a top speed of 257km/h, and a 0-100km/h acceleration time of five seconds. Nuvation is an electronic design services and product development company, so when the team was unsuccessful in their effort to find an off-the-shelf solution to balance and monitor their battery stacks, they took matters into their own hands and built one themselves.

The result was a vehicle that reached over 200mpg, had a range of more than 322km and used a highly effective BMS design. Realizing that there was a promising future for next-generation battery systems and very little technology available that could handle the complex performance requirements, the team continued the research and development on its design. Since then, Nuvation has expanded its prototype into a customizable BMS platform, designed to monitor, balance and protect large-scale battery stacks in a variety of applications.

This development platform uses a PCB to manage each battery pack (coined the 'packman' boards), and a 'tank' controller board to monitor the complete system. The platform can be easily scaled to hundreds or thousands of battery cells, using most battery chemistries. The BMS monitors the temperature and voltage of each cell, and performs complex cell-balancing to maximize the system performance.

The Nuvation BMS addresses the needs associated with today's complex systems, including safety, accuracy, noise immunity, compliance with standards and competitive cost. Applications include electric vehicles, grid storage, solar and wind power conversions systems, and much more. Nuvation has seen an improved ROI and accelerated time-to-market for its customers.

WAY TO CONNECT

Huber+Suhner has drawn on its years of experience in the connectivity of high-voltage systems to develop the RADOX Automotive Connection System (RACS). The system is used in conjunction with high-voltage distribution units (HVDUs) in electric vehicles.

Thanks to its direct connectivity, the system ensures a safe and more efficient connection between HVDUs and high-voltage units, while being a space-saver. The design means the system can be manufactured using fewer individual parts, reducing sealing work requirements and fault probability. The high-voltage connectivity system is a customer-specific assembly that comes in a single-, two- or three-pin design. It is supplied with Huber+Suhner RADOX cables and a connection plate developed in-house. Customers can specify the type of connections and cable length/cross-section.

RACS has a shielded high-voltage connection and is protected to IP69K. The system has a low electrical resistance of <10mΩ between the connector and the HVDU, and a high current capability.

Watts the range?

Zytek Automotive will be on hand at The Battery Show to highlight how it can provide state-of-the-art, cost-effective turnkey solutions for EVs and HEVs. Its class-leading motor and power electronics products cover the range from 25kW to 250kW.

The company's specialist engineering teams have developed a variety of electric and hybrid vehicles, from light-duty passenger cars to heavy-duty commercial vehicles. Its newly developed systems have been designed to ISO 26262/ASIL D requirements and provide a very high degree of torque accuracy and control.

Advanced automated manufacturing

ATS is a world leader in the design and building of automated manufacturing equipment, with over 15,000 systems installed worldwide. It has experience in motor assembly electrified drivetrains, electronics assembly, and EOL testing complement automation projects in the hybrid and full electric vehicle market.

The company supports electric motor winding and assembly, battery assembly and production, new drivetrain manufacturing solutions and various electronics and peripheral component production systems that are integral to the overall electric or hybrid vehicle.

ROARING POWER

Axeon, part of the Johnson Matthey group, is a producer of lithium-ion battery systems for EVs, HEVs and PHEVs, and will showcase some of its latest battery technologies used in a plug-in hybrid supercar. Members of staff will also be keen to discuss the company's cell-agnostic strategy.

Axeon's battery and charger systems are designed and manufactured to full automotive standards, incorporating all the exacting requirements of packaging design, thermal management, electronics and vehicle integration. Currently, the company's EV batteries give a range of up to 225km from a single charge, with stored capacity ranging from 5kWh to 180kWh.

ACCLAIMED KNOW-HOW

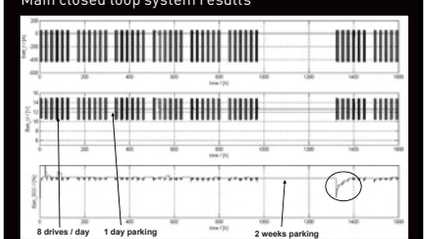
Bosch Engineering now offers its extensive systems know-how to auto makers to support their development of hybrid and electric vehicles. The services focus on systems, function, and software engineering for drivetrain concepts and vehicle dynamics solutions, alongside the associated electrical and electronic integration. These engineering services relate primarily to prototypes and small-scale series production.

Bosch Engineering has been an engineering partner for vehicles with IC engines and alternative drives for over 12 years. "We are now also offering our service portfolio to transform existing drivetrains into hybrid ones and to develop purely electric drives," says Bosch Engineering president, Bernhard Bihr.

These products, which will be under discussion at Electric & Hybrid Vehicle Technology Expo, include electric motors and power electronics that Bosch already has in series production. At a customer's request, components from third-party suppliers can also be integrated into an overall system.

Bosch Engineering can provide the entire drivetrain configuration to a customer's specifications.

Main closed loop system results



Better binder

Ashland Specialty Ingredients will showcase its anode binder and cathode binder process solvent-technologies at The Battery Show.

Aqualon and Bondwell sodium carboxymethylcellulose (CMC) products have been developed to meet the stringent needs of the lithium-ion battery market. These products provide effective rheology control, enabling an aqueous process to be used and ensuring efficient coating of the copper foil at high speed.

In addition to CMC, Ashland will promote its Micropure EG high-purity grade of N-methyl-2-pyrrolidone, which is used to prepare solutions of polyvinylidene difluoride for use as a cathode binder. Cathode slurries produced with Micropure EG solvent have ideal characteristics for coating on aluminum foil.

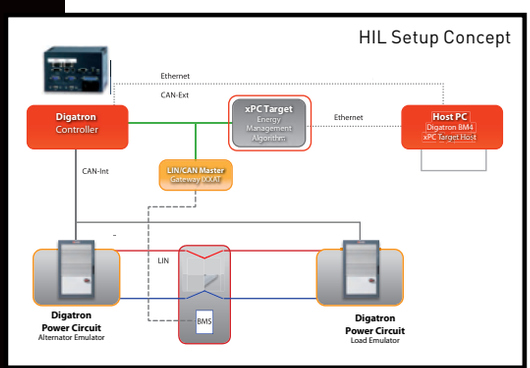
Time to test

Digatron Firing Circuits is an international group of companies with engineering, manufacturing and service facilities in Germany, the USA and China. Staff will demonstrate at The Battery Show how it develops and manufactures computer-controlled test and formation equipment for all kinds of batteries, including automotive starter batteries and EV batteries, as well as test equipment for other kinds of electrical energy storage devices, such as fuel cells, supercaps and hybrid systems.

Digatron's hardware-in-the-loop system for stop/start battery testing is just one example of its competence as a complete solution provider. Ralf Hecke, test and load simulation system developer, has successfully helped a major OEM reduce its development time while simultaneously optimizing fuel efficiency through this single verification system for all components, including the software algorithms.

Solutions can be provided for any other R&D case that involves one or more electrochemical energy storage devices.

HIL Setup Concept



SMART THINKING

Dr Peter Harrop, chairman of IDTechEx, which offers independent market research, business intelligence and advice on emerging technologies to companies across the value chain, has been researching the EV market and related technologies for more than 10 years. He also lectures and consults internationally on supercapacitors, energy storage, RFID and printed/organic electronics.

At The Battery Show, Dr Harrop will discuss supercapacitors and their potential to replace batteries. Also speaking at Electric & Hybrid Vehicle Technology Expo, Harrop will cover the profitable new markets for electric vehicles beyond cars. Looking at land, water and airborne hybrid and pure electric vehicles, he'll explain these growing sectors and why the electric powertrain market shouldn't just focus on cars.

IDTechEx has a catalog of over 80 market research reports and a highly valued intelligence portal covering key topics such as electric vehicles, energy harvesting, printed electronics, RFID and other such emerging technologies.

BATTERY BREAKTHROUGHS

East Penn Manufacturing will showcase its groundbreaking Deka UltraBattery technology.

Today, two moderate hybrid UltraBattery cars are proving that advanced lead-acid technology has a seat at the table of hybrid electric vehicle technology. One of these cars, supported by the DOE and the Advanced Lead Acid Battery Consortium, is on the brink of reaching 16,093km in some of the hottest conditions in the USA

A second UltraBattery car is undergoing road testing and battery system analysis at the company's manufacturing complex in Pennsylvania. The battery pack in this car is currently at 104,604.5km. In evaluation at 80,465km, the pack showed no performance degradation, and its individual battery voltages converged as they aged, proving UltraBattery technology can diminish the complexity and expense of other battery technologies and their BMSs..

Electromechanical endeavors

KOSTAL Kontakt Systeme specializes in the development, manufacture and sale of electromechanical components, with the main emphasis being on connectors. The company will demonstrate why electromobility is the future of the automotive industry. It offers high-voltage solutions that are based on standard products.

The KOSTAL high-voltage solution offers optimum electrical safety, high temperature resistance, large variety and good shielding characteristics. The terminal systems cover the complete power range, from signal current (HV-interlock) to full power currents through electric motors.

KOSTAL's prominent PLK 14.5 terminal, which will be on display at Electric & Hybrid Vehicle Technology Expo, is powerful and versatile. The materials used permit operating temperatures of up to 170°C, with short-term currents of over 2,000A being handled. Versatility includes the possibility of insertion into any of the three planes, therefore permitting extremely compact housing systems with 90° and 180° cable exits using single contact variant.

HIGH-VOLTAGE PROTECTION

TE Connectivity is a partner for OEMs developing hybrid and electric vehicles. It will showcase its expertise in high-voltage battery solutions, electrified powertrain connectivity and charging infrastructure that defines hybrid and electric mobility. Customers rely on TE Connectivity to optimize their unique systems for size, weight and cost, helping to safely and reliably protect people in close proximity to high-voltage power.

The company specializes in: battery systems with cell and module connectivity for power and monitoring, and protection of electrical power flow (BDUs with contactors, sensors and circuit protection devices); HV connectivity for the electrified powertrain, including reliable and touch-safe connectivity solutions (from battery to the E-motor); and bridging technology between the automotive and energy industries, with its smart-charging solutions for PHEVs and EVs.

ORIENTAL ORIENTATION

Tridus provides customers with a low-cost and high-reliability path to China magnet manufacturing. The company's technology and magnet solutions result in millions of magnets and magnet assemblies being shipped globally every year.

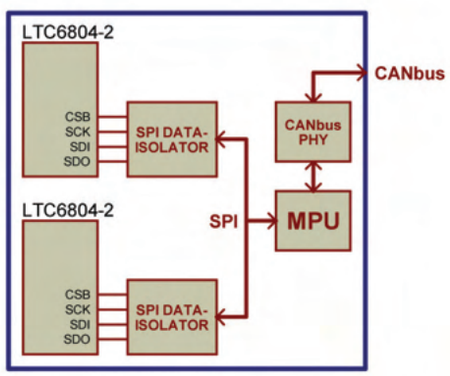
With a reliable and quality embedded supply chain that spans from rare earth smelting and separation to complex value-added assembly products, Tridus aims to use The Battery Show to demonstrate high standards of quality, exceptional levels of service, competitive pricing, on-time delivery performance, effective after-sales support, and efficient supply chain management.

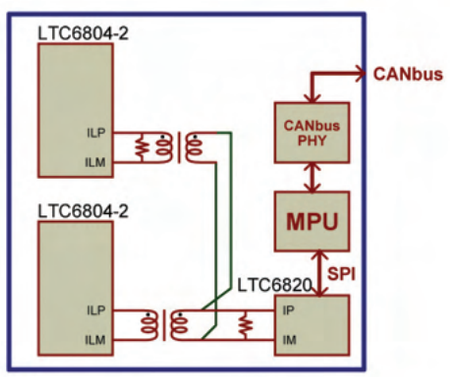
Wiring wizardry

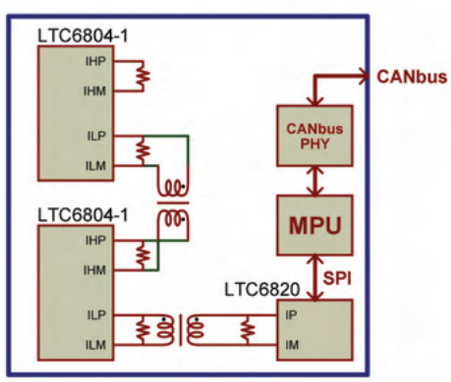
Linear Technology Corporation will present its isoSPI, a physical layer adaptation of standard chip-level serial peripheral interface.

It offers error-free transmission while subjected to the rigors of bulk current injection interference testing. Besides its ability to provide inter-module communication, isoSPI is also less expensive than other on-board isolation methods that are needed for safety and operation around battery systems' high voltages.

As the isoSPI structure enables the minimization of electronics that are resident within cell modules, new directives such as ISO 26262 are more easily and cost-effectively addressed.

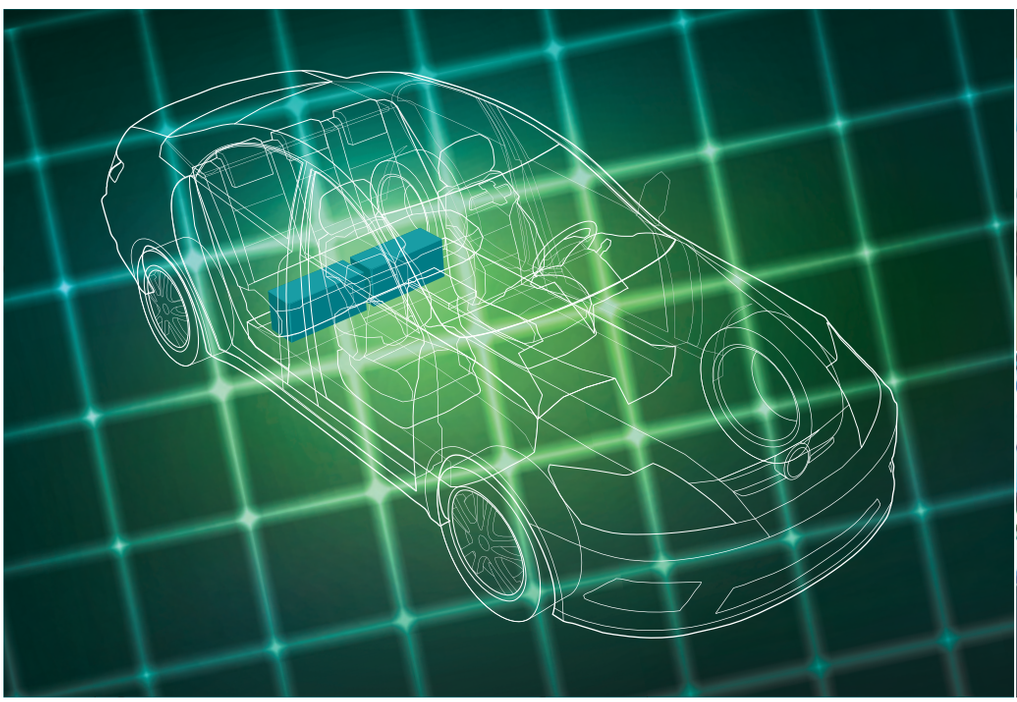






Goodwolfe Energy – setting new standards in Lithium battery systems

Goodwolfe Energy is a major international partner in the supply of lithium battery systems. We deliver solutions for hybrid electric vehicles, plug-in electric vehicles and full battery electric vehicles – including cars, buses, trucks, scooters and motorcycles.



Totally integrated, totally engineered

Goodwolfe Energy – accelerated performance

Goodwolfe Energy's modular system allows for designs from 12V to 800V in any capacity. This, combined with our proven cell management, CANbus communication and modular battery system technology, ensures that our products meet the ever-demanding safety and performance criteria of Europe's OEMs.

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Advanced powertrain testbeds

The successful execution of hybrid development projects has been boosted by the creation of a high dynamic powertrain testbed that links testing and calibration

Vehicle and powertrain development are affected by the number of vehicle variants and the technical complexity of hybrid powertrains. Traditional vehicle targets such as performance, fuel efficiency, emissions and driveability must be achieved, while robustness and reliability have to be guaranteed over a vehicle's lifetime. Additionally, functional safety drives organizations to review and revise their development processes to comply with new industry norms and standards. All of these challenges need to be structured and managed utilizing limited resources very quickly.

For these reasons AVL has established specific engineering methodologies and applied advanced tools to successfully execute hybrid development projects. A systematic, structured approach links different engineering disciplines and demonstrates how efficient execution helps achieve targets and offers new possibilities to save development time.

This systematic testing approach is based on a structured system description, which is either already completed during the development phase or set up before testing. The focus of hybrid functional testing is to confirm that the hybrid system operates safely, predictably and reliably in all possible driving situations over a vehicle's lifecycle.

As such, various test methods and test environments have been established. Component testing and integration testing, including hardware-in-the-loop (HIL) testing, are state-of-the-art for control systems, not only in hybrid powertrain development. New components such as high-voltage batteries, DC/DC converters and various actuators add to this complexity. However, the installation and maintenance of full integration HILs is complicated and time-consuming. Therefore, effort and result need to be considered to find an efficient testing method.

The large number of interacting components and internal states of hybrid functions, as well as interfaces to other vehicle systems, show that a traditional testing approach using HIL might not provide the expected benefits, especially when real interaction of all physical vehicle systems and components is required.

Figure 1: AVL's high dynamic powertrain testbed tests all interfacing vehicle systems including climate control, chassis controls and driver assist systems

AVL has therefore taken an all-new approach, using a high dynamic powertrain testbed for the functional testing of hybrid vehicle systems (Figure 1). The test covers all interfacing vehicle systems including climate control, chassis controls and driver assist systems.

In this specific vehicle HIL setup, the driving environment is simulated in closed loop with AVL InMotion. The AVL PUMA testbed control initiates the driver's inputs and generates the speed and torque at the four wheels as reactions to the environment. AVL InMotion also serves as a test manager system that runs through the test sequences, initializes the test maneuvers, injects stresses or failures and records test data from various sources, including different vehicle communication buses (Figure 2). Furthermore, the tests are automatically verified according to pre-defined acceptance criteria.

As such, about 6,000 tests are executed in just six weeks to prove that the hybrid system functions as expected under normal, stress and failure conditions. Such a large number of tests can only be achieved in a test environment that allows automated test execution during two to three shift operations.

While vehicle test departments usually try to reach similar test coverage with vehicle fleets driven all around the world, some test conditions are difficult to record and require numerous attempts, which increases the required test time, respective of the number of test

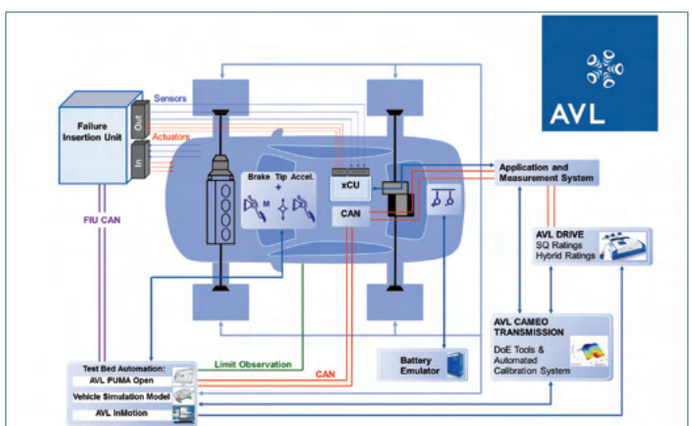

Figure 2: AVL's PUMA testbed control initiates the driver's inputs and generates the speed and torque at the four wheels as reactions to the driving environment

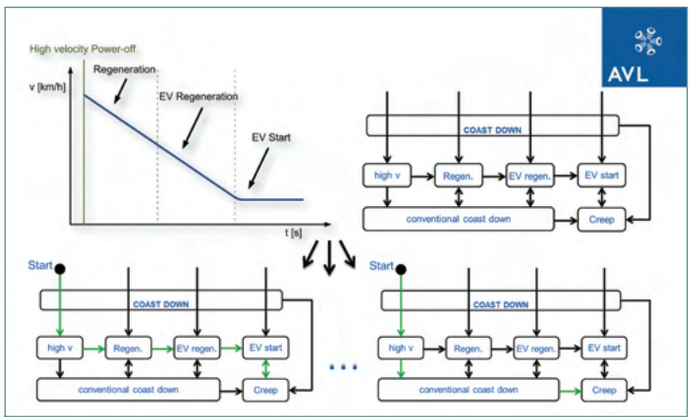

Figure 3: The initial system review analyzes and structures the hybrid functionalities and interactions to other control systems and subsystems with the aim of fully identifying all possible internal states and transitions

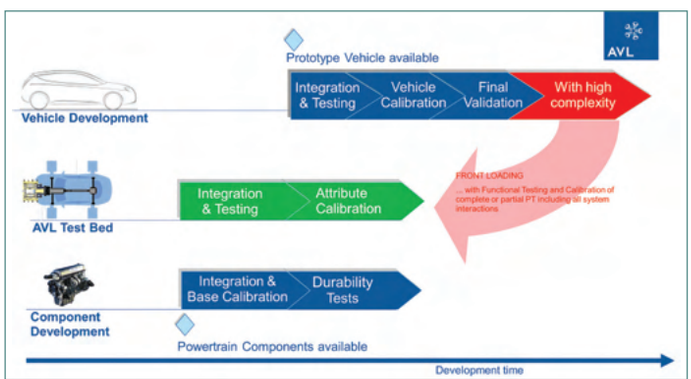

Figure 4: Beyond functional testing to confirm that the hybrid system is reliable or robust, the application of the test methodology also provides further opportunities towards speeding up the hybrid calibration process

vehicles. In a controlled environment the test will be repeated until confirmation is recorded. Otherwise the initial test condition is varied and the test is repeated. This is not only more efficient, but the safest way to protect both the driver and vehicle.

Questions regarding the appropriate hybrid testing maneuver catalog are frequently asked. Working on hybrid systems for different vehicle manufacturers provides a wider perspective and, therefore, the experience AVL engineers have acquired is used to define and prioritize test cases. That experience is now applied in the initial system review to analyze and structure the hybrid functionalities and interactions to other control systems with the aim of identifying all possible internal states and transitions (Figure 3). The analysis also generates information on control and noise factors affecting the hybrid functions intentionally or unintentionally. While some of these values could be established during testing, it has proved more efficient and effective to generate them during the system review. Additionally, some customers appreciate a fresh review from experienced engineers not involved in the specific hybrid design, knowing that it might reveal critical points or opportunities to reduce risks before testing commences.

After the hybrid system has been analyzed, a step-by-step approach is used to prioritize the tests, confirm the test catalog and to define the test plan. Verification of initialization conditions and a first check of the test results are performed during testing. A further data review to confirm a pass or fail is undertaken daily using AVL CONCERTO. Following test completion, critical conditions are reviewed and evaluated together with the customer before the final report concludes the hybrid functional testing.

Beyond functional testing to confirm that the hybrid system is reliable or robust, the application of the test methodology also provides further opportunities towards speeding up the hybrid calibration process (Figure 4).

The hybrid calibration focus is to achieve the desired vehicle attributes such as driveability, performance, comfort and legal targets. Considering the large number of internal states and associated calibration parameters, a more effective and efficient calibration process is required to achieve the targets while avoiding negative effects on reliability, robustness and safety. The basis for this process is generated during system analysis and testing. Additionally, both hybrid testing and hybrid calibration use similar test tools. Linking hybrid testing and calibration on powertrain testbeds to deliver a hybrid powertrain that satisfies all requirements is a work in progress at AVL.

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IGBT gate drivers

The availability of digital gate drivers offers a new realm of efficient possibilities to meet the safety targets of future inverter systems

E-mobility is becoming reality and EVs and HEVs are now being produced and commercialized on a large scale. This has a tremendous effect on all electrical systems in a car, presenting new efficiency, size, safety and cost challenges. This means that new concepts have to be developed at both component (microscopic) and architectural (macroscopic) levels. Infineon's broad portfolio of complementary components for e-mobility applications, including microcontrollers, gate drivers and IGBT power modules, supports the development of optimized system solutions for EVs and HEVs.

Typically, an inverter consists of a high-power IGBT module, controlled by a logic device operating in the low-voltage (12V) battery domain (Figure 1). Today, one single device manages the very specific demands of highly integrated logic technology and high power technology: this is the gate driver IC.

The primary function of the gate driver is to provide the necessary voltage and current signals to turn the IGBT on and off efficiently. Output current limitations of driver ICs are usually overcome with an external post-driver (or booster) stage. Infineon's automotive EiceDRIVER family (1ED020I12FA2, 1ED020I12FTA and 2ED020I12FA), for instance, can source or sink up to 2A, which means it can already drive MOSFET and smaller IGBT power modules.

Additionally, the low- and high-voltage domains need to be electrically isolated, and for this purpose Infineon developed a coreless transformer technology (CLT). CLT integrates the two coils of a transformer into one integrated circuit. Inductive-based data transfer is enabled bidirectionally: the PWM control signal from the microcontroller can be sent across the galvanic isolation barrier to the IGBT, and feedback signals can be sent back to the LV side of the device. The CLT offers multiple advantages over other isolation technologies: it does not show the degradation over lifetime that is typically seen with optocouplers; it shows high immunity to electromagnetic interferences and transients; and it can be easily implemented within standard chip production processes, which leads to significantly lower system costs than for discrete solutions. A monolithic process also supports integration of additional functions on the device.

Introduction of the ISO 26262 standard means that future traction inverters will have to meet the highest safety standards up to ASIL

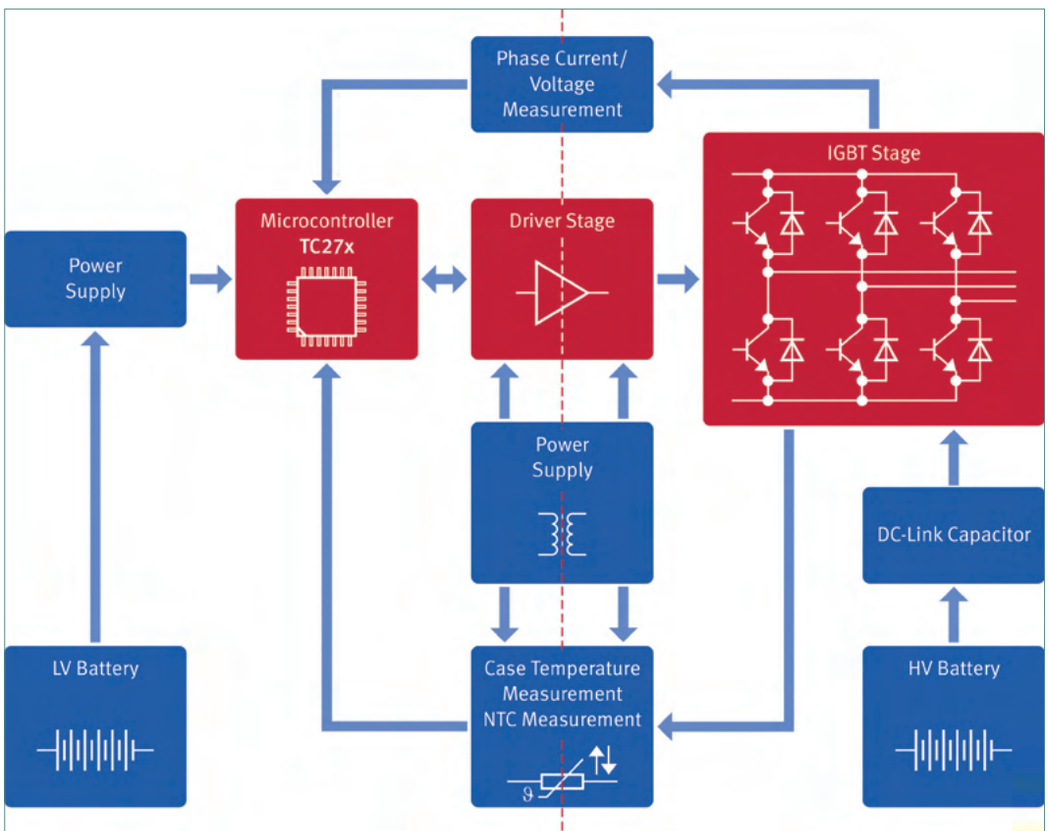

Figure 1 (above): A detailed graphic outlining an inverter that consists of a high-power IGBT module that in turn is controlled by a logic device, which operates in the low-voltage (12V) battery domain. Figure 2 (below): The I/O monitor of Infineon's new AURIX microcontroller family compares the IGBT state with the original PWM command in real time

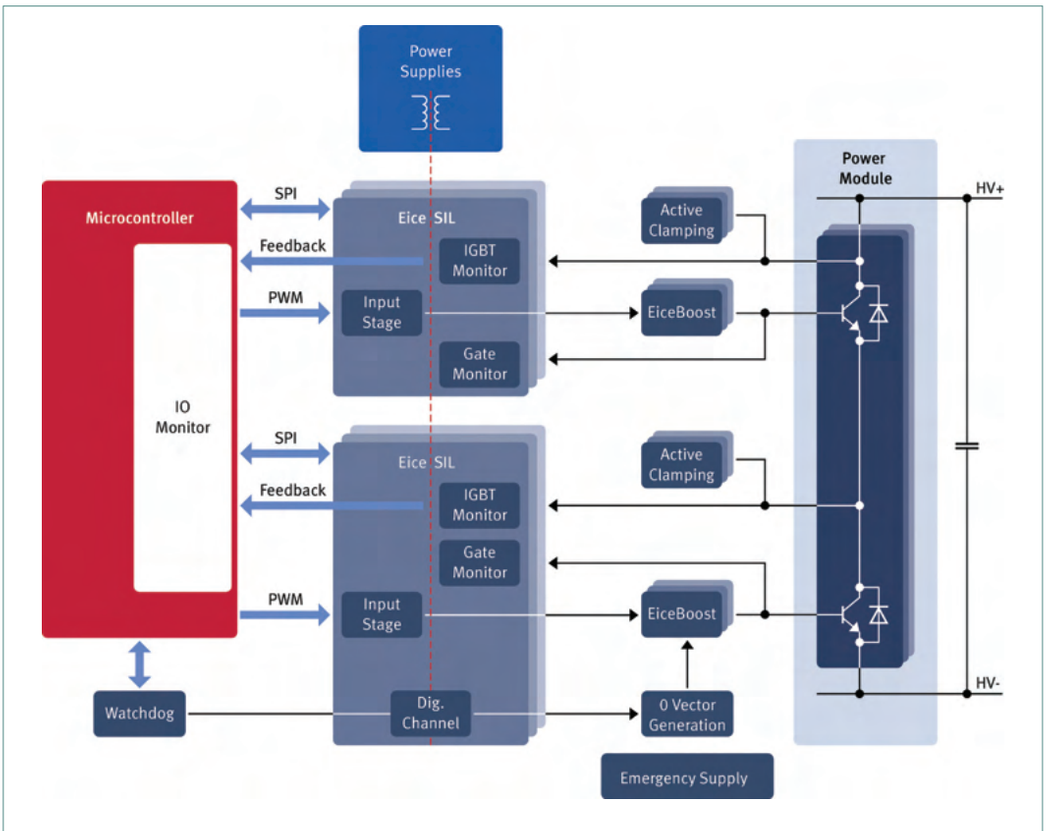

Figure 3: The above detailed information graphic showcases a prime example of an optimized inverter architecture

C or D. One of the main safety requirements stipulates that in the event of failure, the system shall prevent or limit the generation of unwanted torque at the wheel. This top-level requirement has a direct impact on the components used. To meet these evolving needs, Infineon has developed a new generation of gate drivers and boosters: EiceDRIVER SIL (1EDI2001AS, 1EDI2002AS); and EiceDRIVER Boost (1EBN1001AE).

The EiceDRIVER SIL marks another significant step toward functional integration. It includes a standard middle speed (2Msps) serial peripheral interface (SPI) bus. This link to the LV main logic block is used to configure the device during system power-up and provide status information during runtime. The SPI does not have to control the switching behavior of the IGBT directly; it is a parallel channel to the regular PWM command.

Part digitization of the gate driver enables the designer to implement several layers of diagnostic functions. At the lowest level, all internal key functions are monitored, such as oscillators, power supplies and internal data integrity. The second level is related to interconnection of the device. Here, signal consistency can be checked by reading the levels of the signals sent and received by the device over the SPI. One level higher, the device supports the injection of 'dummy' failures (e.g. false DESAT event). In this way, latent 'sleeping' failures can be detected. Correct failure responses of the system can therefore be guaranteed over the complete vehicle lifetime.

The next level involves ensuring that the PWM command is correctly received by the IGBT. The extended DESAT function supports continuous monitoring of the IGBT VCE voltage. The result of the comparator is sent continuously to the LV side, and the information is available in the form of a digital signal. The I/O monitor of Infineon's new AURIX microcontroller family can then compare the IGBT state with the original PWM command in real time (Figure 2). Programmable delays compensate for the latency time introduced by the galvanic isolation barrier and the physical IGBT switching time.

A commonly used approach is to delocalize a dedicated function over several components in order to achieve a cost-optimized solution. This is especially beneficial when implementing active short circuit (ASC) strategies. For a permanent magnet synchronous machine, such strategies may be complex to implement. The IGBT is a normally-off device, so the natural default state of the inverter is all switches open. However, at high rpm, the magnet excitation may lead to over-voltage, which could result in the destruction of the inverter. Therefore, the safe state of the inverter is, with some exceptions, the 0-vector, or ASC. Figure 3 shows an example of an optimized inverter architecture.

The EiceDRIVER Boost is an advanced and thermally optimized post-driver stage. It has a dedicated input, which means the IGBT can be turned on directly whenever a PWM command signal is sent by the gate driver. The control signal activating this pin comes from a watchdog IC and is transferred through the galvanic isolation barriers via the low-latency digital channel of the EiceDRIVER SIL. Several monitoring functions, such as the gate monitor and the output stage monitor, guarantee reliable activation of the safety path.

Over the years, automotive systems have become increasingly integrated. The exponential rise in microcontroller computational power is leading to the gradual shift of hardware functions into software; similarly, digitalization is increasing functional integration and enhancing diagnostic capabilities. The availability of digital gate drivers offers a new realm of efficient possibilities to meet the safety targets of future inverter systems. This is the first milestone on the journey toward smart actuation in automotive inverter systems.

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ONLINE READER ENQUIRY NO. 502

SR tech breakthrough

High-tech Land Rover research vehicles are powered by an innovative electric drivetrain system that retains the off-road vehicle's rugged driving characteristics

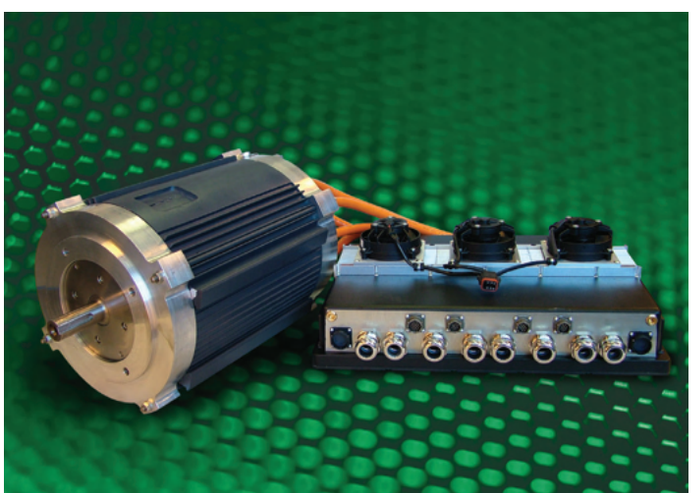
At this year's Geneva Motor Show, Land Rover unveiled seven electric Defender research vehicles that are directly powered by an electric motor and drive system developed and built by Nidec SR Drives (NSRD). The Harrogate, UK-based company, together with other project partners, worked with Land Rover's advanced engineering team on the development of the all-electric vehicles, designing and manufacturing their switched reluctance (SR) motor and power electronics.

The electric Defender was originally conceived as an eco-friendly game-viewing vehicle for the Londolozi game reserve in South Africa, fulfilling the requirement for a dependable off-road vehicle that has clean and near silent operation. For this latest project, however, Land Rover specified the use of magnet-free SR technology to achieve the higher performance required for this new breed of electric Defenders with four-wheel-drive capability.

As NSRD's technical director, Mike Turner, explains, "The benefits of SR technology in traction-type applications have greatly enhanced the performance of the electric Defender compared with the original Londolozi concept vehicle. The fundamental robustness is ideally suited to the arduous environments seen by the Defender."

The SR technology developed by NSRD is exceptionally well suited to the Defender's arduous all-terrain traction needs, being able to deliver full-rated power over a wide speed range. The EVs retain the Defender's four-wheel-drive system and differential lock. But, because the SR motor delivers full-rated torque from standstill, there's no need for gear shifting and the transmission comprises a single speed, 2.7:1 reduction gearbox, combined with the existing Defender's four-wheel-drive system.

Land Rover electric motor and power electronics on dynamometer test



With no need for liquid cooling, both the motor and power converter are air-cooled

In the electric research vehicles, the standard diesel engine and gearbox of the Land Rover 110 Defender was replaced by a 70kW (95ps) SR electric motor that delivers torque levels of up to 330Nm and speeds up to 7,000rpm. Regenerative braking has been optimized to such an extent that, when using hill descent control, the battery can accept up to 30kW of regeneration from the drive system. With no requirement for liquid cooling on the EV, both the motor and the power converter are

In its 65th year, Land Rover unveiled seven electric Defender research vehicles at the 2013 Geneva Motor Show. These Defenders deliver zero emissions while retaining their tough and durable go-anywhere capability

air-cooled. In addition, SR motors do not use permanent magnets and, being able to deliver full-rated power over a wide speed range, are exceptionally well-suited to traction applications. They are constructed using conventional materials such as copper, steel and aluminum, resulting in the motor being fully recyclable at end of life – an important consideration for automotive applications.

"This project has been an excellent opportunity for us to transfer our proven traction technology from heavy-duty mining and construction vehicles to a passenger car vehicle. The marriage of our rugged and high-performance technology with the Defender vehicle is an excellent pairing, and aligns well with Nidec's plans to place SR technology at the heart of its EV traction developments," says Roy Blake, managing director of NSRD.

Twinned with a 300V lithium-ion battery with a capacity of 27kWh, the Defender EV has a range of more than 50 miles (80km). It has a top speed of 70mph (130km/h) and, in typical low speed off-road use, can run for up to eight hours before recharging is required. And compared with the earlier game-viewing vehicle, which is equipped with an induction motor, the enhanced torque-speed characteristics of the SR motor provides improved climbing ability and acceleration from rest, substantially better 0-60mph (0-100km/h) performance, and an increase in vehicle top speed by an impressive 35mph (55km/h). The smooth, low-speed capability of the SR electric powertrain makes the electric Defender especially well suited to climbing and descending inclines without causing unnecessary damage to ground surfaces. The vehicle has been tested in extreme and environmentally sensitive conditions – with trials including pulling a 12 metric ton road train up a 13% gradient, and plowing through water up to 800mm deep. As such, the absence of an air intake and exhaust system enables the vehicle to handle a 300mm increase in water depth compared with a standard Defender.

Although Land Rover has no plans for the all-terrain electric Defender to enter series production, the seven EVs will continue to be deployed in ongoing trials in real-world conditions.

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ONLINE READER ENQUIRY NO. 503

Optimal connection

High-voltage connector and charging plug developments are central to the creation of more advanced electric and hybrid vehicle applications

High-voltage wiring assemblies are crucial to electric vehicle makers when it comes to designing new powertrains

The successful creation of viable powertrain electrification solutions by the automotive industry has required intensive research and development across a wide range of individual components and assemblies. Connectors and charge plugs are no exception. Given Delphi Automotive's extensive track record in the development of automotive connection systems and wiring assemblies, it is no surprise that the company is at the forefront of efforts to address these challenges. Many challenges are directly related to voltages and operating currents that are many times higher than those employed in conventional vehicles. Most notably, this has meant dealing with challenges such as the safety of consumers and the service industry; electrical interference; and considerations relating to reducing weight, minimizing demands on space, and simplifying the overall assembly process.

To meet the exacting demands of high-voltage EV and HEV applications, Delphi has worked closely with OEMs to create a full product portfolio for the global market. With a diverse array of EV and HEV vehicles now in full production, important lessons have been learned. These encompass not just the real-life performance of EVs and HEVs in the hands of motorists around the world, but also the efficiency with which they can be manufactured. In particular, attention is being focused on creating vehicles that combine technical excellence with greater affordability. Delphi's comprehensive global portfolio of connectors, wiring assemblies and charge plug systems are playing a key role in meeting the design objectives of OEMs in the Asia-Pacific region, Europe and North America.

J1772 inlet that complies with SAE J1772 and the IEC 62196-2-1 standards

Designed specifically for applications up to 250A/600V, Delphi's high-power connectors incorporate a host of innovative features, such as finger-proof/touch-safe designs, assured mating, two-stage timed delay disconnect, external IP67 sealing and internal IP2XB electrical protection. Delphi's comprehensive portfolio of charge plug solutions enables electric and plug-in hybrid vehicles to be powered safely and efficiently at home. Products are available that provide full compliance with established global standards: GB/T 20234, IEC 62196 and SAE JI772, as well as a fast-charge DC combo inlet (Combo 1 and Combo 2) with an interface compliant with IEC 62196-2-2.

To meet the wide range of customer and market requirements, available parts include portable cordsets, EVSE and inlets. Furthermore, reflecting the fact that charge plugs represent a key point of contact between the motorist and the vehicle, a range of user-friendly features is offered. These include ergonomic handles and push buttons, drain holes to eliminate water that might otherwise collect in terminal cavities, built-in flashlights and the option of a hinged cover for the inlet.

While the company's high-voltage range is extensive, Delphi remains fully committed to creating new solutions that anticipate the rapidly

evolving demands of powertrain electrification. At present, key areas of interest include the use of 48V-based systems as a means of powering modules such as active suspension and A/C units, and facilitating the development of competitive mild hybrid products. The logic of this approach is clear, as it minimizes the additional safety and shielding features required on high-voltage connectors, thus reducing the cost. However, if issues such as electrical interference are to be avoided when using 48V, designers must use an architecture-level approach rather than simply downsizing from high-power components. Around the world, Delphi engineering teams are currently working in partnership with OEMs to ensure that the implementation of 48V designs are realized without compromising system performance or reliability.

Reflecting and supporting this determination to deliver groundbreaking products for OEMs, Delphi maintains dedicated development centers in China, Europe and North America, all of which are close to key customers and the markets they serve. Production and manufacturing facilities are similarly located, optimizing responsiveness to OEMs and eliminating any unnecessary supply chain costs. Delphi's extensive harness assembly capability provides yet another important resource in terms of successful connector development, thereby offering an opportunity to generate immediate feedback on the viability of proposed new products in terms of the ease with which they can be implemented on a production line.

A charging cable for AC mode 3 charging on plug-in hybrid and electric vehicles

Portable cordset available for 110V or 220V charging on PHEVs and pure EVs

"The EV and HEV market has come a long way in a short time," says Randy Sumner, director for global hybrid vehicle development and innovation at Delphi. "Across a range of vital product technologies, Delphi leads the way in delivering innovations that are essential for this new era in automobile design and manufacturing."

However, the pace of change in this technological arena shows no sign of abating and in such a fast-moving environment it is vital that OEMs and suppliers work together to apply the lessons being learned from the first generation of mass-market electric vehicles and hybrid electric vehicles. In particular, the emphasis of the industry is switching toward reducing total applied costs and maximizing consumer appeal. The continuing development and improvement of connectors, wiring assemblies and charge plug solutions has an important part to play in achieving these wider development goals, and Delphi remains fully committed to accelerating the momentum behind the creation of more efficient and environmentally sensitive automotive designs.

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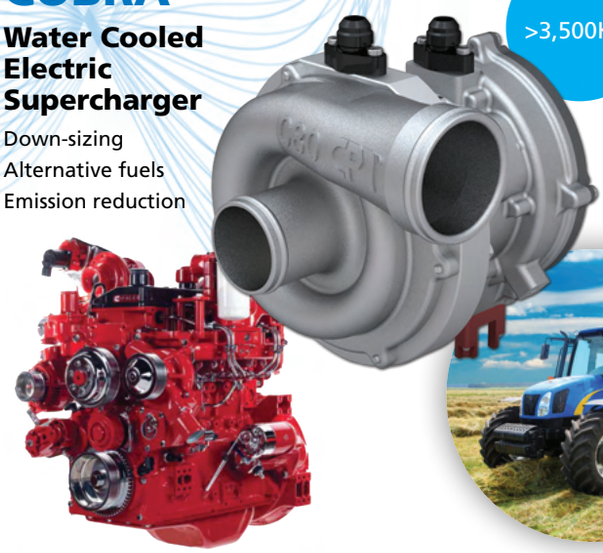

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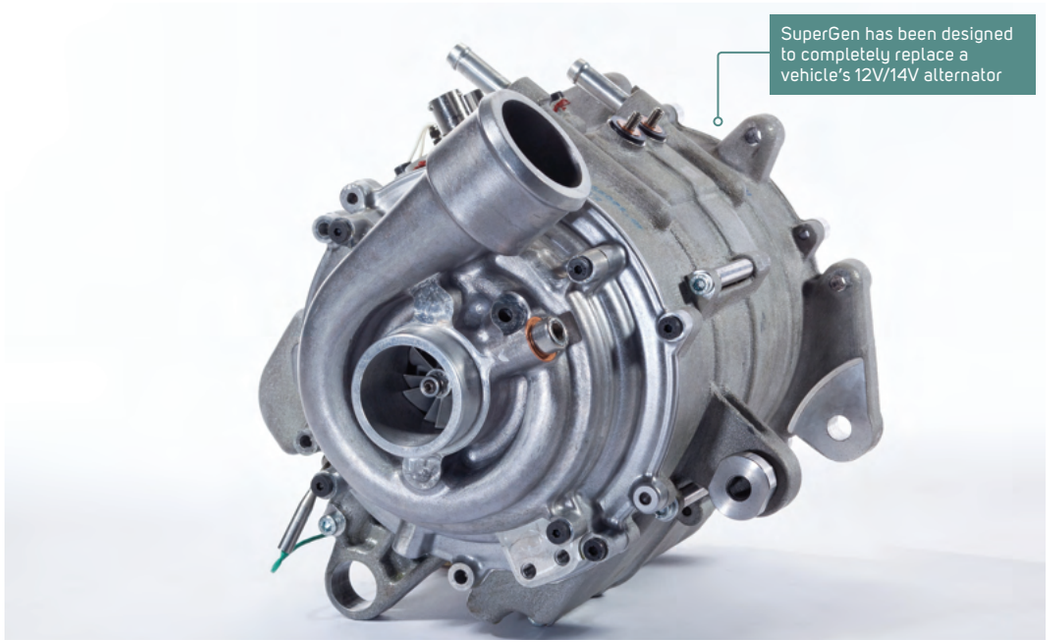
Integrated boosting

The second-generation SuperGen electromechanical supercharger offers advanced mild-hybrid and electrically augmented boosting in a single 14V compact solution

Integral Powertrain and NexxtDrive, co-inventors of the SuperGen integrated supercharger and mild-hybrid starter-generator, have announced the achievement of major milestones in the development path to high-volume automotive applications, including the successful delivery of the Gen-2 second-generation 14V prototypes intended for OEM technology evaluation engines that are mounted on dynamometers as well as in prototype vehicles.

Past developments of the SuperGen technology focussed on initial proof of concept and technology risk assessment. A number of prototype units were developed for OEM assessments between 2006 and 2008. They were relatively large, and operated with external 380V power electronics. Results and customer feedback were positive but OEM development partners quickly realized that matching typical alternator package size, fully integrating the power electronics within the unit and developing a cost-effective 14V system would be critical to future high volume applications. The latest SuperGen hardware meets these requirements in a compact, low-voltage unit which can easily be integrated into new and existing engine applications.

SuperGen can provide a standalone single-stage boosting system for 1- to 1.4-liter engines – even replacing two-stage turbocharging systems. For engines up to 3 liters in size, SuperGen would typically provide the high-pressure stage of a two-stage boosting system, with a turbocharger providing the low-pressure stage. A boost-pressure ratio of up to 2.5 is available with very fast transient response – less than 0.5 seconds from off-load to full boost, at all engine speeds from idle up to maximum power. This enables aggressive engine downsizing and down-speeding, with corresponding benefits in fuel economy. This can be achieved without incurring any driveability or performance penalties and requires no additional energy storage. Critically, SuperGen completely replaces the vehicle's 12V/14V alternator and provides mild hybrid functions – stop/start and up to 10kW of regenerative braking – without the need to introduce a 48V bus on the vehicle.



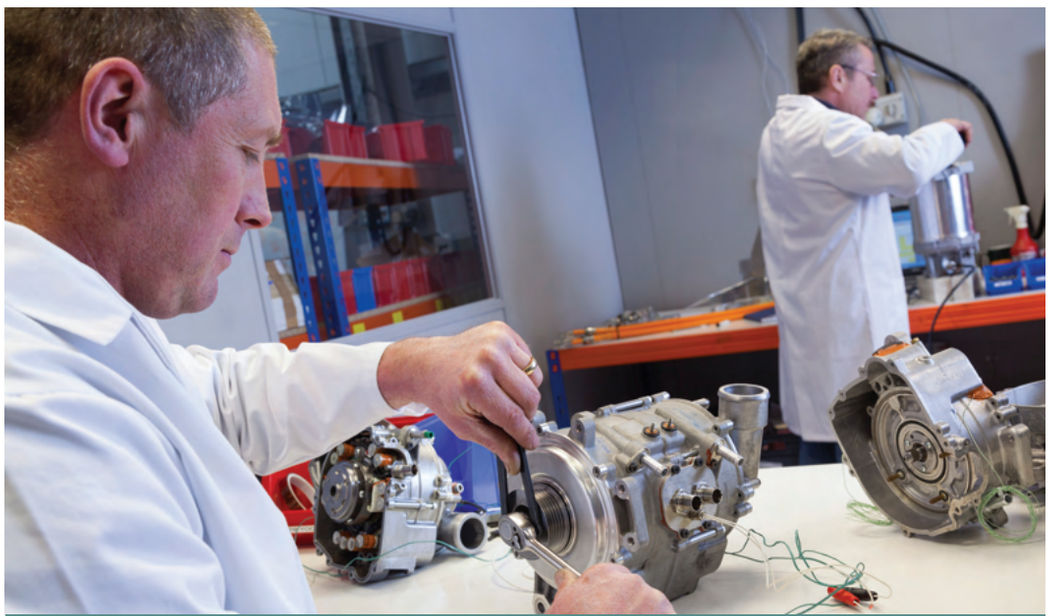
SuperGen comprises four integrated subsystems, including the E1 motor generator with integrated inverter; epicyclic traction-drive transmission; E2 motor-generator with integrated inverter; and centrifugal compressor.

The key to the SuperGen concept lies in the patented combination of an efficient power-combining differential epicyclic traction-drive transmission, with the fast response and power augmentation functionality of the electrically coupled carrier, which is used to vary the speed of the compressor independently of engine speed. The continuously variable speed control feature of the system eliminates the need for the SuperGen drive to be clutched.

Maximum compressor speed of up to 170,000rpm can be achieved with fully variable control at the command of the SuperGen's integrated motor controllers. In fact, the transmission operates as an electrically controlled CVT with full control of output shaft speed by modulation of the speed of the E2 coupled planet carrier. This e-CVT functionality further enables full off-loading of the SuperGen to occur without the need for a clutch.

The high drive ratio precludes the economic application of toothed gears and favors the application of traction-drive technology, in which torque transfer between the ground ring and roller components is enabled by the very high viscosity of the entrained traction fluid.

The newly developed Gen-2 transmission is rated at 15kW of compressor power and is efficient and quiet. It has demonstrated excellent durability with no rolling contact fatigue failures of the traction surfaces in nearly a year of development testing. The unit runs with its own (sealed for life) traction fluid, which provides torque transfer, lubrication and cooling. Several lubricant suppliers have been involved in supplying traction fluids for test – all meeting Integral Powertrain's performance goals.



The SuperGen technology has been under development at Integral Powertrain and its OEM partners since 2012. The end goal is for the project to realize series production within four years and for one million-plus units to be produced each year

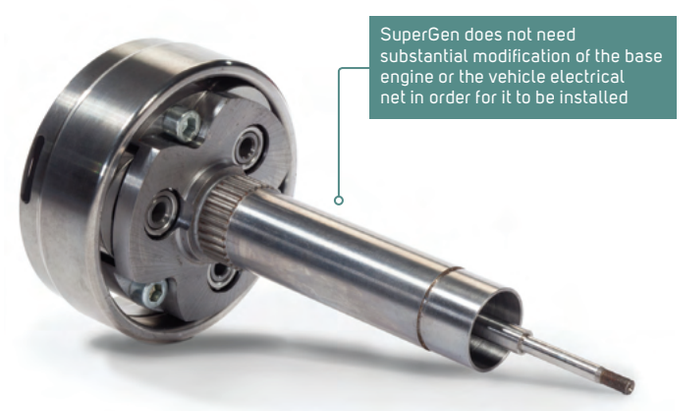
SuperGen uses two motor-generators. These are internal permanent magnet (IPM) electric machines, each designed to provide over 20Nm in engine starting mode and 4.5kW steady-state. In order to minimize cost and complexity, each machine's inverter is close-coupled to the stator and cooling jacket. The tight integration of the motors and their respective inverters and cooling greatly reduces energy losses due to conduction and ensures excellent efficiency across the complete operating range.

During a boost transient, such as a throttle tip-in, the E1 and E2 machines briefly draw power from the energy storage system during the transition to full boost. This typically takes less than 0.15 seconds and represents an energy demand of less than 1kJ. This avoids an interruption in driveline torque as the compressor accelerates – clutch jolt being a familiar problem with conventional superchargers. It also enables greater load control on the poly-vee drivebelt, eliminating belt slippage and squeal.

A built-in clutch system between the annulus and the planet carrier enables the E1 and E2 motor-generators to provide up to 150Nm of torque at the crankshaft. This means that the SuperGen can crank the engine for starting and provide very high levels of energy recovery during vehicle braking. The ability to employ both motors for a wide range of tasks represents a substantial advantage for SuperGen when compared with other electric superchargers or motor-generator systems currently on the market.

As a single-stage supercharger, SuperGen provides a superior match to next-generation downsized gasoline engines, and this is especially the case in applications where the device replaces both the alternator and any turbocharger unit. In these applications, the sub-0.5sec response characteristic, the excellent off-idle torque performance, and mild-hybrid stop/start and regenerative braking functions all enable fuel economy improvements of around 15% over typical single-stage gasoline DI-turbocharged engines.

SuperGen can also operate as the high-pressure stage of a two-stage boosting system, combining the hybridization advantages of SuperGen with the additional benefits of turbocharging. This Turbo-SuperGen (TSG) application is particularly suited to the next generation of gasoline and diesel engines with high-specific power output. The excellent transient response and high power capability of the compressor (many times higher than conventional e-booster technology) and the overall seamless match with the turbocharger, ensure a system that achieves convincing performance and response at all engine speeds without penalizing economy and refinement.



SuperGen does not need substantial modification of the base engine or the vehicle electrical net in order for it to be installed

Importantly for OEM product developers, SuperGen applications do not require substantial customization of the base engine or the vehicle electrical net. The SuperGen replaces the existing 14V alternator and, being similarly sized, fits into the same space. No supercharger installation or special belt drive, clutch or variable-speed drive is required, therefore saving space, mass and cost. All lubrication and system transmission cooling functions are integrated into the unit. The result is a much lower cost of implementation for the OEM, with lower design, development and validation requirements and a much easier pathway to high-volume widespread use.

Under development by Integral Powertrain since 2012, and in partnership with several global passenger-car OEMs, SuperGen is intended to be available for series production applications in the 2016-17 timeframe. Production of well over a million units per annum is currently projected, based on highly positive assessment feedback from Integral Powertrain's OEM development partners.

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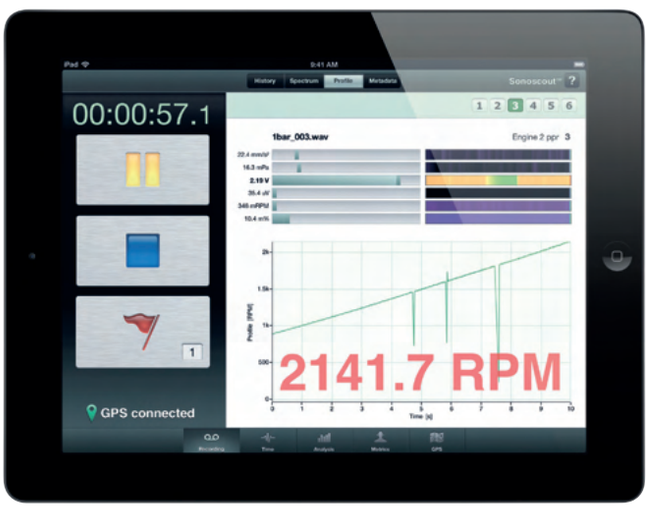
Multichannel recording on-the-go using an iPad for in-vehicle replay, comparison and analysis saves development time without compromising test accuracy

As NVH engineers know, many short tests are necessary to develop refined vehicle sound and minimize vibration. And time is always limited due to the availability of vehicles and test facilities, and the overall pressure on development schedules.

The highly portable Sonoscout system ensures that setting up each test is as quick as possible, and it maximizes confidence during measurements by providing full visibility of all test parameters. Then immediately after recording, it assists engineers with fast validation of data through analyses of the time history, and with on-screen comparisons of tests and vehicles. Ultimately, Sonoscout reduces the risk of having to repeat tests, enables more engineering on the go, and easily exports data to PULSE Reflex or other post-processing environments.

The Sonoscout system consists of binaural headphones that record sound at both ear positions, an iPad app, and a compact, wireless data-acquisition front end. Sound and vibration data from up to 12 channels is streamed via wi-fi from the front end to the iPad, where it is recorded and analyzed and from which the test is controlled. An SD card option enables standalone recording, after which data is streamed to the iPad.



In addition to the six measurement channels at the top, the display selected here shows a tacho profile with clear breaks in the signal that would invalidate the test program

The Sonoscout system's binaural headphones record sound at both ear positions while a touchscreen control enables smart recording from the driver's seat

During testing, CANbus information can be displayed alongside the incoming signals, giving throttle position, rpm and speed for easy development testing such as 30% throttle or run-ups/run-downs. Large buttons give simple control from the driver's seat, and events and time periods can be marked with a single tap.

Sonoscout is a fast grab-and-go tool, and the headphones and other transducers are the only cabling to connect to the front end. With its seven-hour battery and wi-fi functionality, it is quick to place anywhere. TEDS transducer recognition minimizes setup errors by automating information input, while the need for input ranging is eliminated with Brüel & Kjær's Dyn-X technology. This automatically switches between two parallel A/D convertors to avoid overloads, under-ranging and signal clipping, and gives an effective dynamic range of over 160dB.

Replay of sound is possible immediately after testing, while the user selects, clips and loops time histories on screen. The multitouch operation is highly intuitive; users simply swipe between screens and pinch to zoom in on displays.

During analysis, users choose up to four displays that can each show FFT, 1/3 octave analysis, order analysis, spectra or spectrograms, from different data sets. This ability to easily perform side-by-side comparisons is vital for much of the before/after testing during development, and including it in a mobile system enables more engineering on the go. Tests can also finish sooner, when the engineers know they have the results they need.

Transferring data to a computer is also simple, and performed by entering the iPad's IP address into the URL bar of the computer's browser, or by using iTunes and DiskAid. Once downloaded, event markers can then be displayed in Google Earth, overlaid on GPS data from the test.

A demonstration 'virtual front-end' mode in the iPad app enables potential users to try out the complete functionality of Sonoscout for free. Sonoscout can be downloaded from Apple's App Store.

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Rotor angle error correction

The effects of rotor angle errors and the correction methods for optimized control of permanent magnet machines are critical factors in electric powertrain development

Due to their outstanding power density, permanent magnet synchronous machines play a prominent role in highly integrated applications such as hybrid vehicle powertrains. Accurate knowledge of the rotor angle is necessary to achieve optimal utilization and reliable motor operation.

Potential errors in the measurement of the rotor angle can be split between time-varying (gaining error between resolver signals) and time-constant (misalignment of the rotor's zero position against the angle sensor). Time-varying errors cause a torque ripple that results in increasing noise, less comfort and lower efficiency. Time-constant errors result in lower torque accuracy, which critically affects functional aspects such as ESP, torque vectoring and lower efficiency.

The intensity of this issue can be illustrated in the rotating synchronous d/q frame of the PM. In extreme cases where the error of the electrical angle is 90°, an intended pure torque producing q-current is turned into a field-only producing d-current. Thus, no torque is produced at all.

Torque deviation for q-currents is proportional to cos(ε) and d-currents is proportional to sin(ε), where ε is the misalignment angle. Consequently, the torque deviation is extremely sensitive against the operating range of the PM. At high q-currents, torque deviation due to an angle error is small (such as an ε = 2° results in a 0.04% torque deviation). At high d-currents the deviation is larger (3.5%).

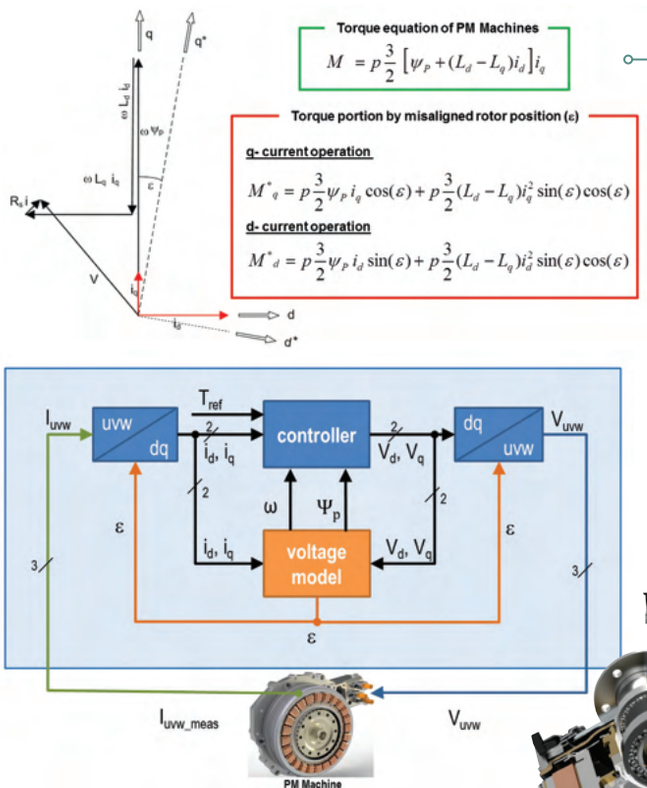
Due to the automotive industry's significant redundancy and safety requirements, the use of a rotor angular position sensor is practically mandatory. But what are the effects of errors introduced during serial production and errors due to the overall tolerance chain on the angle?

Mechanical tolerances of rotor manufacturing and assembly of the position sensor have an effect on the angle. The corresponding electrical angle deviation is equal to the mechanical deviation multiplied by the number of permanent magnet pole pairs. For example, a mechanical tolerance of 1° of an eight-pole machine results in an electrical angle error of 4° and ~7% torque deviation. Therefore, it is imperative to add an automated calibration of the angular offset at the end of line. Several calibration methods are available, including magnetic alignment of the rotor with DC current; evaluation of the voltage equation of the d/q system on the running motor; and analysis of the current response of injected test signals.

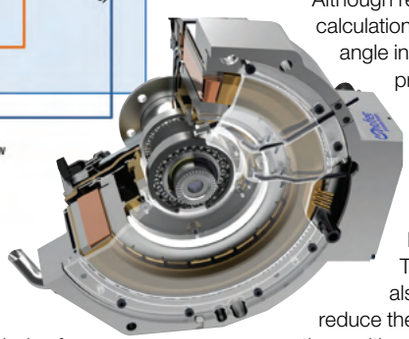
The issue is further complicated as the offset between the position signal and the rotor is affected by the tolerances of the sensor itself and the signal processing. Temperature drift, aging and signal delays may also cause a varying error. The influence of factors such as the propagation time or frequency dependence can be easily determined through simple formulae in the control software.

To fully compensate the effect of the remaining factors, an offset auto-tracking function is necessary during normal operation. This may be accomplished via several methods. One potential software approach is through an observer module, which calculates a control loop based on the known system parameters in parallel with the real control path and derives the correction angle from the differences. Another method is based on calculating the electric angle from the current and voltage values in accordance with the EMF method, or by integrating the phase voltage with a flux estimator model.

Although real-time calculation of the rotor angle increases the processor load, it substantially improves the control performance, especially at high speeds. This method also helps to reduce the cost of the entire position sensor system. Instead of a high-precision resolver, a more cost-efficient hall sensor configuration could be integrated for monitoring purposes only. For precise torque control the calculated angular value is used.



Left: The torque of PM machines
Center: PM machine voltage model
Below: PM machines are playing a greater role in EV development



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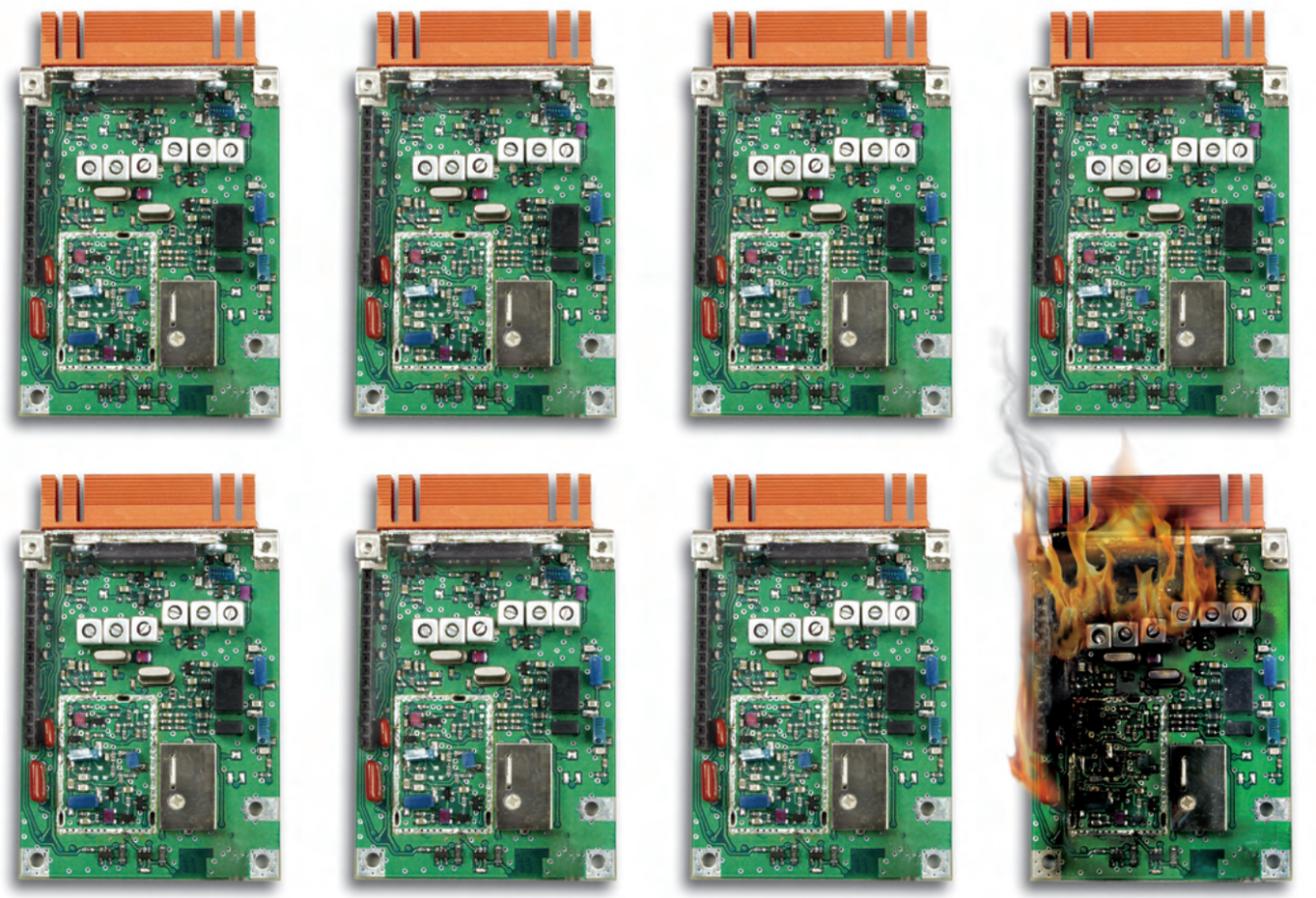

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THE BERGQUIST COMPANY
Laminates Division

Battery test system series

A two-channel test system has been developed to analyze the expanding operating specifications of batteries in EV, HEV, grid-storage and battery-safety applications

Developing safe and reliable high-quality batteries requires a powerful and adaptable test system. In response to this need, Arbin has developed the EVTS-X tester series. EVTS-X systems are capable of testing scenarios that range from -400V to 800V and up to 600A, making them the most versatile testing systems on the market. The powerful two-channel test systems feature a revolutionary new architecture that gives unmatched testing flexibility.

Building on Arbin's reliable EVTS series, the EVTS-X has been engineered to meet the expanding range of operating specifications. Every Arbin system features fully independent test channels capable of running complex, user-defined test schedules in multiple current ranges. Arbin's EVTS-X systems boast two high-precision channels that offer powerful regenerative testing for electric vehicle and grid storage applications.

For higher-current applications, test channels on the Arbin systems can be operated in parallel. Arbin was the first company to introduce channel paralleling, which is now a common feature of test systems throughout the industry. By paralleling channels, users can effectively double the current capacity of their test system, for a wider range of testing scenarios and the ability to handle overcharging or abnormal charging applications.

The enhanced power and flexibility of the EVTS-X systems come from the addition of two new testing configuration modes. EVTS-X systems now provide the ability to connect two channels in series to double the overall voltage range of the test station. The channel series mode provides users with the ability to test an expanded range of battery packs with a single piece of test equipment.

Furthermore, Arbin has once again broken new ground with the introduction of the innovative discharge booster mode. This configuration provides users with the ability to reverse the polarity of one channel in series with the second test channel, giving an extreme negative voltage testing range. This mode provides one test channel with a full negative-to-positive voltage range for over-discharge, reverse charge, and other specialized R&D testing.

EVTS-X systems boast two high-precision channels that offer powerful regenerative testing for electric vehicle and grid storage applications

Capable of up to 400V and 300A per channel, the EVTS-X is designed to be a complete testing solution for a wide range of R&D applications. From basic charge/discharge testing to complex drive-cycle simulations, the system provides unmatched testing versatility. Arbin has begun producing EVTS-X systems and is now shipping them to customers around the world. Industry leaders working in EV, HEV, grid-storage and battery-safety applications have come to rely on Arbin for complete battery-testing solutions. The EVTS-X system enhances Arbin's extensive product line, which includes many standard and custom-designed systems for testing single cells, modules and large-scale battery packs.

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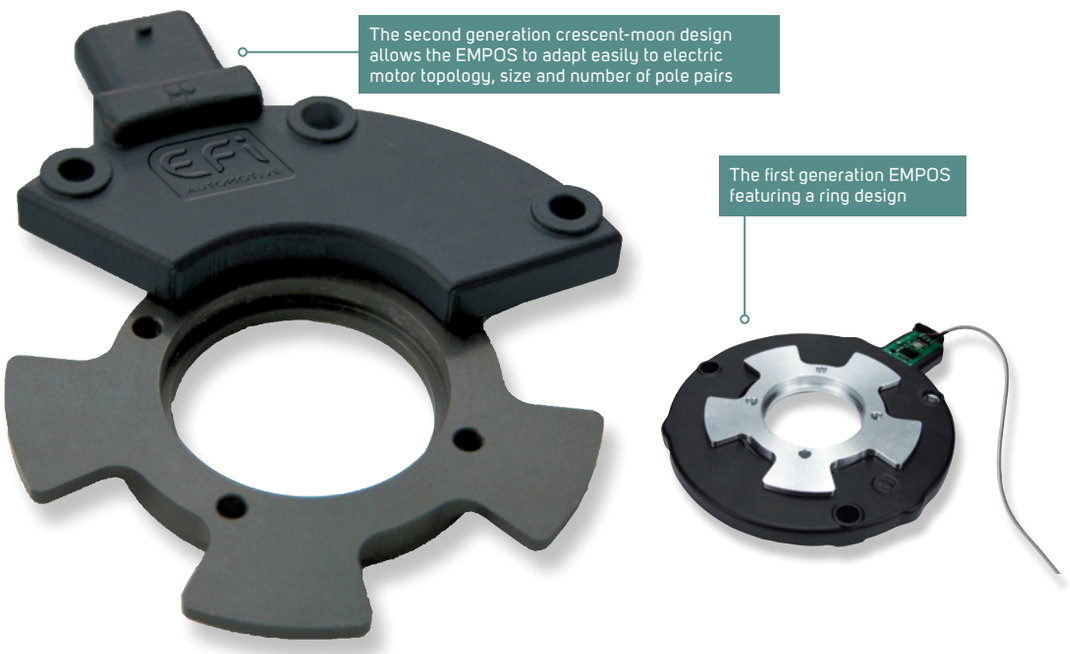
New rotor position sensor

A new version of an EMPOS eddy-current sensor offers easier integration, improved serviceability and lower cost than resolver-based solutions currently on the market

In today's budding EV market, permanent magnet synchronous motors (PMSMs) are the preferred choice of manufacturers for both hybrid and full electric drives. To ensure smooth operation at maximum efficiency, the motor's control system needs to know the angular position of the rotor. Most automotive applications use a resolver to deliver this information – the only robust solution presently available. However, resolver-based sensors have a number of drawbacks, including high sensitivity to external magnetic fields, very stringent positioning requirements and high cost for large diameters – and it is for these reasons that Electricfil Automotive based its electric motor position sensor (EMPOS) on eddy-current technology instead.



The EMPOS working principle is similar to that of a resolver, but the excitation frequency is much higher, typically a few MHz, making it possible to use printed circuit air coils instead of heavier wound coils on ferromagnetic sheet metals.

A primary winding and two secondary windings are printed on the same multilayer PCB, fixed to the stator. A trigger wheel made of aluminum or steel with N teeth is fixed to the rotor. When a high-frequency AC current is injected into the primary winding, a high-frequency magnetic field is generated, causing eddy currents to circulate in the teeth of the trigger wheel. These eddy currents then generate a magnetic field opposite the original field, thereby modifying the coupling between the primary and secondary windings. The sensor coils are designed to provide a coupling factor between primary and secondary windings that depends on the position of the trigger wheel. As such, the angular position of the rotor can therefore be calculated from the measured values of the two secondary voltages.

An application-specific integrated circuit (ASIC) generates the excitation signal and hosts the entire signal treatment chain, including both analog (amplification, demodulation, filtering, sampling) and digital (calculations, digital filtering) processing. The ASIC also provides diagnostic functions to avoid false position information in the event of any single failure.

The ASIC is soldered directly onto the sensor PCB to provide short signal paths for high-frequency analog signals. The position signal and a diagnostic signal are transmitted to the motor controller via either an analog or a digital serial interface. The digital interface ensures no loss of accuracy due to ADC accuracy, noise and EMI.

All required electronic components including the ASIC and passive SMD components are directly soldered on the sensor PCB, packaged in a sealed plastic housing with either a cable output or integrated connector. The total thickness of the packaged sensor can be less than 10mm. The trigger wheel teeth are about 2mm thick to provide the mechanical strength.

The first generation of EMPOS was designed with a 360° ring PCB and package. A second generation with a crescent-moon shape design has been developed for many applications to improve integration, serviceability and cost.

The ASIC has been designed to be compatible with three electrical interfaces. The digital interface offers the highest system performance-to-cost ratio, but two analog interfaces are available if required for compatibility with existing motor control units.

Integrated signal processing provides error compensation at high speeds for better motor control. In this way, EMPOS offers ±1° accuracy (electric), sufficient for EV and HEVs, at speeds up to 200,000rpm. It is insensitive to pollution, EMI, vibrations and positioning errors. It can measure the true absolute position at power-on and is available for through-shaft or end-of-shaft designs.

Electricfil Automotive has packed the circuit board and electronic components in a water- and oil-tight housing. The sensor is thin (<10mm) and lightweight, containing no ferromagnetic parts.

Prototypes are available from Electricfil for testing in customer facilities. Mass production is scheduled for early 2015.

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Motor modeling advances

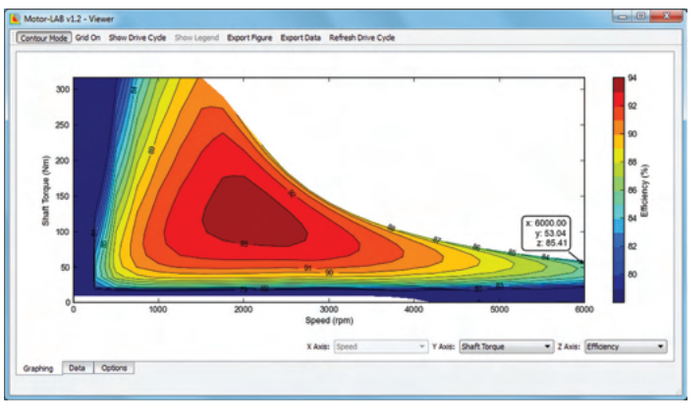
A research project has resulted in the launch of a combined electromagnetic and thermal modeling toolbox specifically designed for brushless AC motors in traction applications

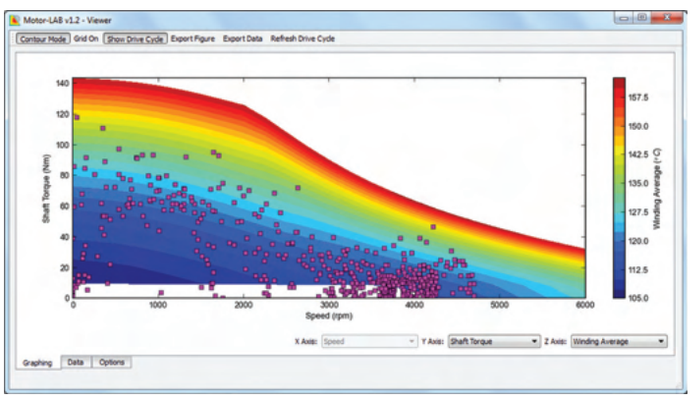
Motor Design has launched an all-new software tool. Designed as an add-on, Motor-LAB is the first of its kind; no other modeling tool offers equivalent functionality. The combined electromagnetic and thermal modeling toolbox couples with world-leading software brands such as Motor-CAD, SPEED, Flux and FEMM. It will also link to the new electromagnetic capabilities that will soon be available in Motor-CAD. The enhanced capability is now being piloted in preparation for its launch in 2014.

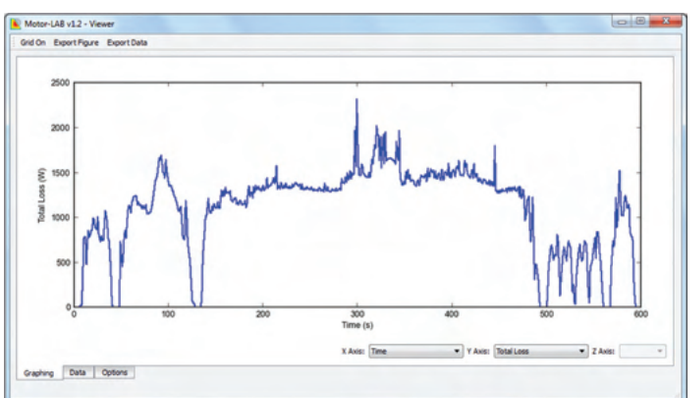
Motor-LAB is designed for brushless AC motors in traction applications. It was developed with a number of partners during a research project with the University of Bristol, and enables rapid and accurate modeling of any permanent magnet AC motor over the entire operational envelope. With Motor-LAB, engineers can create efficiency maps, plot torque and speed characteristics, study the continuous and peak thermally constrained operational envelope and analyze performance overdriving cycles. It is fast, easy to use and all the calculation methods have been experimentally validated.

The software includes various methods to account for DC and AC copper loss, magnet loss, iron loss and mechanical losses. Modeling techniques use FEA coupling to account for saturation effects and to accurately predict the variation of iron loss across the envelope. Integrated links to SPEED software enable automatic generation of these models with PC-FEA.

Motor-LAB has an intuitive user interface: data is produced in a simple format that can be easily exported to MATLAB, Microsoft Excel and other applications. A wide variety of graphs can be generated and a number of publication-quality output formats are supported. The software also includes a set of standard cycles and a vehicle model that can automatically generate driving cycles. Alternatively users can import their own driving-cycle data.







Top: Accurate efficiency maps can be generated rapidly to optimize the design of any permanent magnet AC motor across the whole operating envelope
Center: Driving cycle points can be instantly calculated and included on any plot
Bottom: From the start of 2014, electromagnetic performance data can be generated over any driving cycle using Motor-CAD's fast 2D FEA calculations

Motor-LAB was designed and developed by James Goss, a research engineer with Motor Design and the University of Bristol. He has been working on the project for the past three years.

"I have been privileged to work with a number of high-profile, experienced customers throughout the development process," says Goss. "This has helped us ensure that the tool is well suited to meeting the needs of the industry."

Currently Motor-LAB supports brushless AC permanent magnet motors, but Goss and the team are looking at extending the software to support other motor types.

Alongside Motor-LAB, motor designers will soon be able to assess their machine's electromagnetic performance using Motor-CAD's fast 2D FEA calculations. Developed with key partners, the integrated package is undergoing a pilot study with selected companies. Feedback suggests it could revolutionize the design and analysis of electric motors and generators when it is launched at the start of 2014.

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ONLINE READER ENQUIRY NO. 510

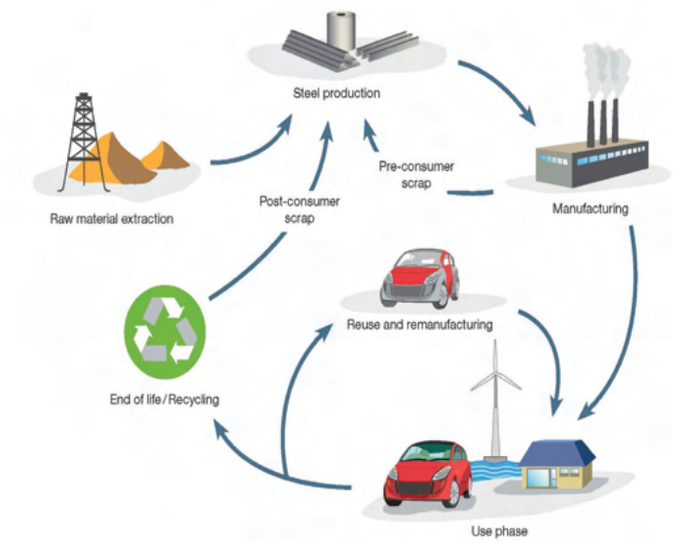
Lightweighting alternative

As OEMs look to reduce the mass of electric and hybrid vehicles with aluminum and steel alternatives, steel could be the unlikely sustainable solution in the lightweighting challenge

With the commercial imperative to maximize fuel economy and deliver the lowest possible CO_2/km figures in their future products, auto makers are increasingly focusing upon lightweighting alongside new powertrain technologies and electrification. But while the objective of reducing vehicle mass might instinctively be assumed to lead to the substitution of heavier materials with lighter alternatives, research by Tata Steel demonstrates that a more environmentally sustainable solution can be provided by using steel rather than aluminum or many composite alternatives.

Traditionally, steel is seen as a heavyweight material, but with the increasing use of advanced and ultra-high-strength steels in the automotive sector, designers are able to produce more structurally efficient body systems, significantly reducing the weight penalty over alternative materials. While any weight saving is desirable, this needs to be seen in the context of the wider environmental impacts: not just those while in use, but also those incurred during manufacture, end-of-life disposal and recycling. Analyzed in these terms, steel can be a compelling proposition.

Research led by Dr Nick Coleman at Tata Steel's environmental technology department in Rotherham, UK, investigated steel's role as a lightweighting material. "As a company, we fully appreciate the necessity of lightweighting, especially in electric and hybrid vehicles," he says. "But we strongly believe that any product should be considered in its entirety, and our research shows that steel can be a better option than many alternatives when considered in this way."



The lifecycle of steel (Source: World Steel)

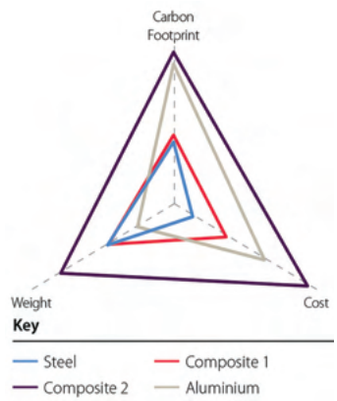
In this study, the Tata Steel team took the front-end module from a popular C-segment car, and compared a painted, galvanized steel solution to two alternative steel and plastic composite options. To gain a further reference point, they redesigned the steel solution using aluminum, with appropriate material selection to achieve the same function with minimum mass.

Coleman continues, "The full costing analysis showed that while it wasn't the lightest, the steel solution was significantly cheaper than the others, with the most expensive being the aluminum."

To measure the overall sustainability of a product requires an evaluation of its entire lifecycle. As stated earlier, this needs to take account of the emissions attributable to its manufacturing supply chain and end-of-life recycling processes as well as its service life. Emissions of all types of greenhouse gas are combined, subject to appropriate weightings, into a single metric of 'carbon dioxide equivalent' or CO_2e. This enables direct comparison of the emissions of products incorporating different materials, manufacturing processes, and even operating on different fuels.

Although the aluminum front-end module was found to be 19% lighter than its steel counterpart, the effect of this weight saving is comparatively modest during the life of the vehicle. Taking account of manufacturing and end-of-life recycling, the overall lifecycle carbon impact, for a vehicle driven 150,000km, was calculated as 44% higher. To put this into perspective, a customer would need to drive the vehicle for around 250,000km before the aluminum front-end module would achieve a break-even with steel in terms of its lifecycle carbon dioxide emissions. As this is well beyond the lifespan of most vehicles today, the analysis showed steel to be the more sustainable option, while the aluminum design, at 63% higher cost, was also commercially less attractive. Of the two alternative composite steel and plastic composite options, one was competitive on both mass and lifecycle impact but 29% more expensive, while the other cost and weighed significantly more and had a higher lifecycle carbon footprint.

An evaluation of mass, cost and lifecycle carbon footprint for different material solutions



There is no doubt that reducing weight is essential in creating the more fuel-efficient and affordable vehicles the industry needs, but what is becoming increasingly clear is that steel should not be forgotten in the lightweighting challenge.

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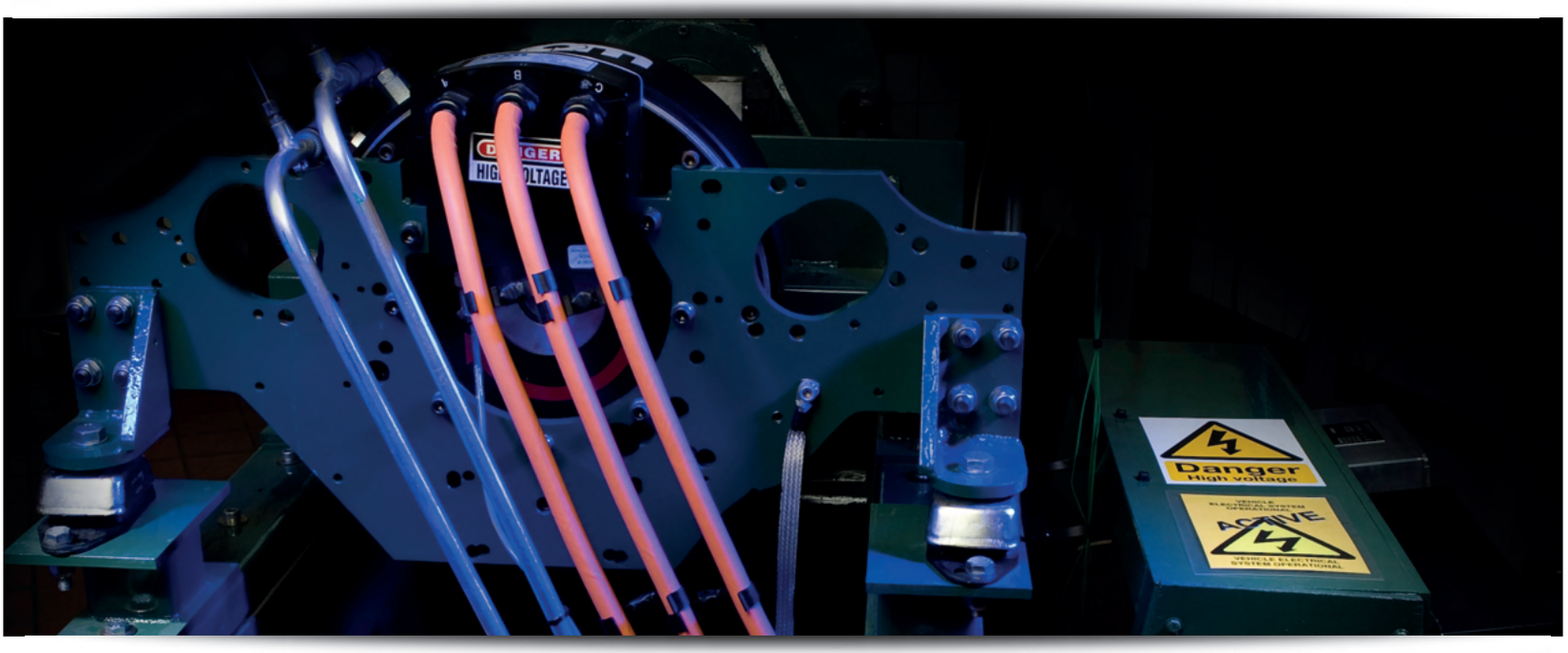
ENGINEERING

HYBRID AND ELECTRIC VEHICLES



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Inverter diversity matters

The selection of the correct inverter can have a much greater bearing on electrical powertrain performance and cost than was initially thought to be the case

In the search for ever-increasing levels of efficiency, traditional internal engines are experiencing high levels of innovation focused on downsizing and forced induction. While this does not appear to have a parallel with the ever-increasing levels of powertrain electrification, a focus on system performance – conceiving the battery, inverter and electric machine together – can have an equally dramatic effect on weight, size, performance and cost.

A traditional route to conceiving an electrified powertrain will tend to specify the system components in the order of electric machine, battery, and finally the inverter. In this sequence, the most complex unit – responsible for optimizing bidirectional energy flow between battery and electric machine, as well as integration with safety-critical vehicle operating systems – is given the lowest priority, possibly because of the belief that 'an inverter is an inverter'. However, inverter selection should be given greater consideration at the time of specifying the battery and motor, as the inverter will have an equally significant impact on whether or not the system's performance and cost targets are achieved.

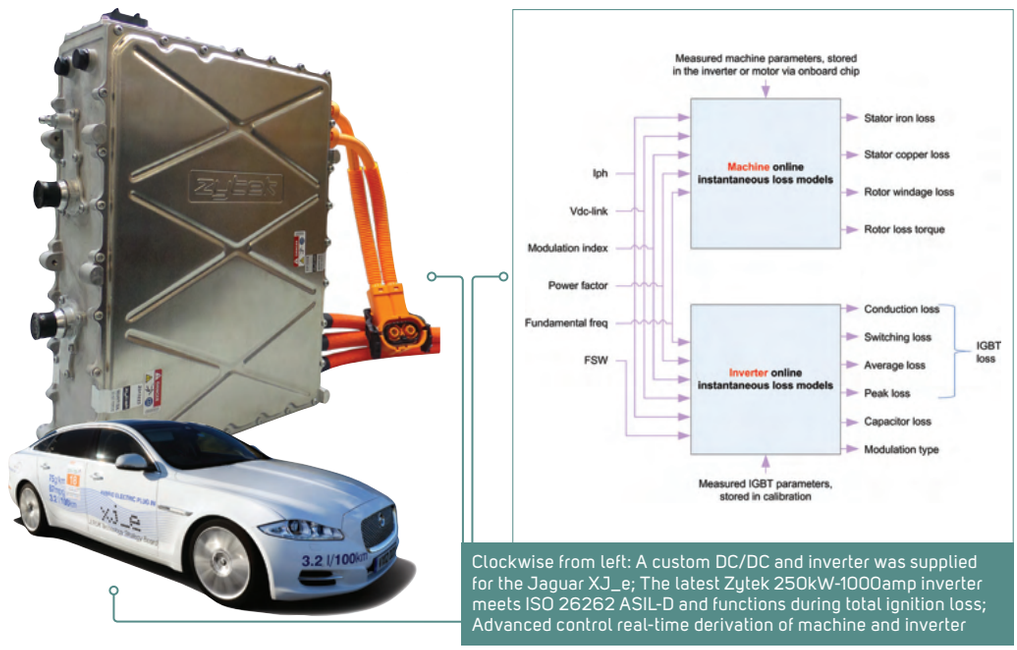
Zytek is experienced in the parallel development of electric machines, power electronics and batteries, all specifically engineered for use in the automotive market. As a consequence, the company is well placed to understand the key parameters required for consideration in the development of a successful HV traction system, with the inverter as the key enabler to unlock system potential.

Prior to the commencement of either an inverter selection, or the development of a bespoke product, basic primary parameters need to be understood: input voltage range; output voltage range (matched to the electric machine); output power and current; drive cycle (to ensure thermal performance); and working temperature range. Following this, secondary information will be required: maximum electrical frequency (used to select the optimum PWM frequency to control switching losses) and further battery characteristics (to optimize DC link capacitance to reduce DC ripple current losses). Even at this level, it's apparent that information presented on data sheets or sales flyers doesn't adequately convey the necessary information to compare inverters.

But having carefully selected or designed an inverter, only by using only very advanced, state-of-the-art machine control techniques can optimum performance be realized. Given a nameplate inverter electrical rating, it is a common misconception that all similarly rated inverters will drive electrical machines in the same manner. Zytek uses a proprietary AC controller, using space vector modulation with advanced discontinuous and over-commutation techniques, implemented on a system-by-system basis. At no point is any table look-up of torque versus machine current used, as this technique cannot be used for top-end, high-performance systems capable of extracting the maximum torque/amp. Live closed-loop models of both inverter and machine loss are run in the inverter, enabling operating efficiencies of >97% to be realized, along with high levels of delivered torque accuracy (typically <1% torque error when applied to salient machines, where torque is not proportional to any measurable physical variable).

Finally, from a safety aspect, vehicle level implementations require inverters to meet ISO 26262 ASIL-D, necessitating dualization of current sensing within the inverter using different sensing techniques, and the ability to continue to function even in the case of a complete loss of 12V ignition.

Having probably been daunted by all of the above, rest assured that inverters are completely capable of achieving all of the above and more, not only as a pure current switching device, but more of as the primary system enabler, and most importantly, as the primary choice when conceiving vehicle electrification requirements.



Clockwise from left: A custom DC/DC and inverter was supplied for the Jaguar XJ_e; The latest Zytek 250kW-1000amp inverter meets ISO 26262 ASIL-D and functions during total ignition loss; Advanced control real-time derivation of machine and inverter

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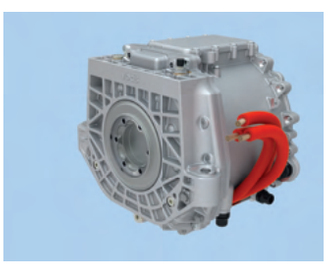

Top: ERS developed in partnership with Honda for the CRZ racing hybrid.

Above: Jaguar's XJ_e hybrid is powered by a custom Zytek inverter.

Test & Engineering Services

Zytek offers a range of vehicle and motor/inverter testing and engineering consultancy services.

In addition to a comprehensive array of facilities – including six specialist dynamometers capable of testing machines up to 360kW – Zytek also offers motor and inverter development services to the industry, including detailed design, prototype manufacture and test.

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Sustainable e-mobility

Kinetics Drive Solutions has employed innovative and advanced electric drive and control technology as the key ingredient in a pioneering electric city bus project

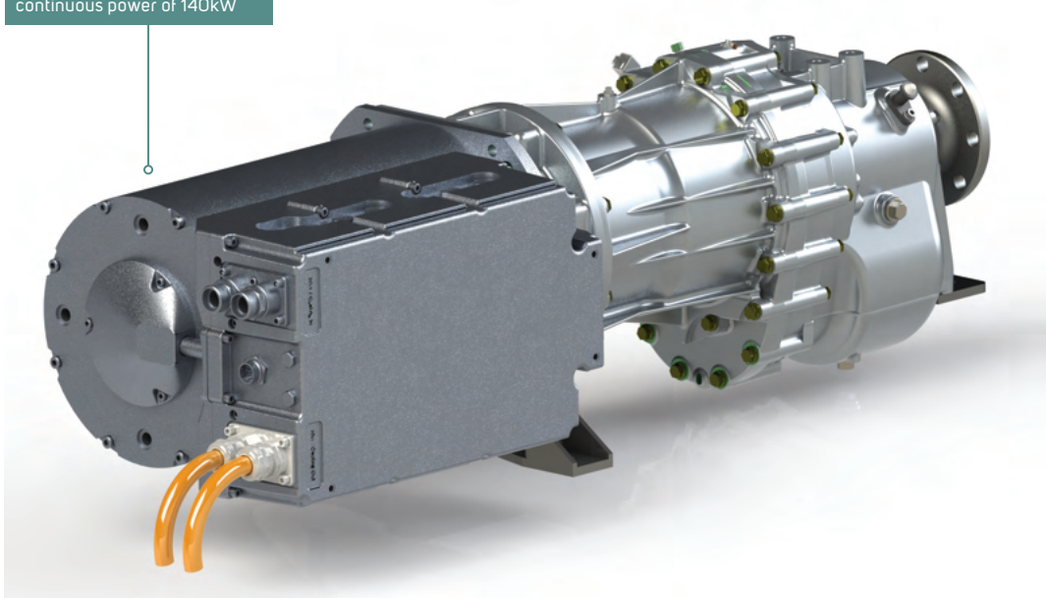
There are several prerequisites for a battery-electric vehicle to be economic. These include moderate dimensioning of the battery, minimized downtime for battery recharging or replacement, and the efficient use of the available electrical energy.

All three conditions are met in the case of city buses with battery swapping technology, which is part of the scope of a pioneering electric city bus project by Kinetics Drive Solutions (KDS).

Having fixed driving routes enables optimized design of the energy storage and drive system, and automated rapid battery replacement minimizes downtime and solves the range problem. An optimized drive from matched components minimizes energy losses and provides regenerative braking, where the kinetic energy is converted back into electrical energy and stored in the battery. In a city bus, whose driving profile is dominated by repeated acceleration and braking, regenerative braking plays a crucial role. This is where the superiority of electric over conventional propulsion is clear.

Economy in the use of electrical energy is the primary objective for the designers of an electric drive. The system must also be compact and rugged, yet remain affordable. An ideal solution is the combination of a permanent magnet synchronous motor (PSM) with integrated four-quadrant inverter and three-speed dual-clutch transmission (DCT).

The integrated powerMELA C140 is able to deliver a continuous power output of 140kW. The integrated inverter results in a compact design, critical even in a large vehicle such as a bus, and its high operating voltage of over 600V keeps the current relatively low. This allows the use of smaller diameter cables, saving material and installation costs. The machine has directly cooled windings, which helps provide a very high power density. A single motor drives the KDS DCT and the combined system successfully powers a 65-seat city bus. With advanced electronic control managing the drive package, the electric machine and DCT work together perfectly.



The integrated powerMELA/DCT powertrain delivers continuous power of 140kW

KDS has developed and built this special double-clutch gearbox for heavy electric vehicles. It is designed so that the powerMELA electric motor can be flanged directly. The total weight of the drive system, including motor, inverter and gearbox, is less than 300kg – a surprisingly low figure. Since the speed of the electric motor is regulated more effectively than any other type of motor, the intelligent KDS transmission can plan gear changes so that torque interruption during gearshifts is almost eliminated.

A city bus with powerMELA/double clutch transmission powertrain

The key to its success is not only the merger of two hardware and software technologies into a highly efficient drive system, but the nature of the integration into the vehicle and the infrastructure available to the operator.

KDS also designed an integrated fleet- and energy-management system based on Sensor-Technik telematics hardware, providing an extensive insight into the operation of the vehicle. Information reported to the fleet manager includes location, detailed information about the onboard energy storage and state of charge, and vehicle information such as speed, distance and operating mode.

As the world looks for new transport solutions, battery-powered electric buses are an innovative and environmentally friendly means of transportation.

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E-motor testing in China

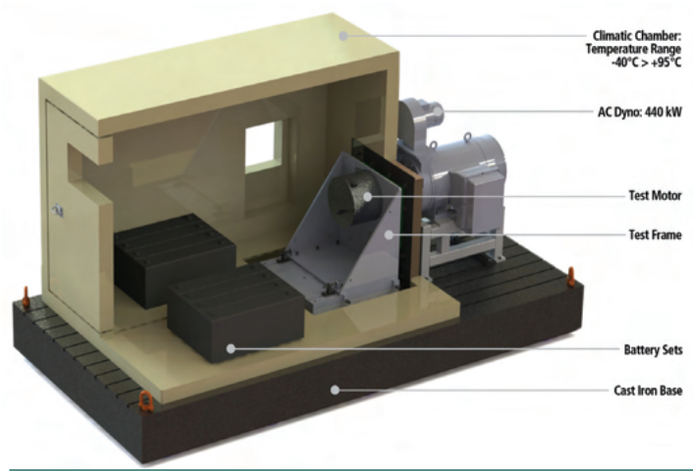
In light of the anti-pollution initiatives recently ratified by the new Chinese government, Foton is ideally placed to lead the way in electric motor and hybrid vehicle development

Based in Beijing, Foton has nearly 40,000 employees in nine Chinese provinces. In 2010, the company sold more than 680,000 vehicles, maintaining a leading position among global commercial vehicle manufacturers.

For Foton, high quality and flexibility were critical selection criteria for choosing a trusted partner to help build their new electric motor development facility in Beijing. After an exhaustive search, Sierra CP Engineering, based in the UK, and EST, its Beijing-based partner, were selected to develop the project based on 30 years of global experience. Their ability to demonstrate both high quality and flexibility in the approach they proposed to building one of the most advanced test facilities of its kind in China, convinced Foton that they were the ideal partners for this project.

When completed, the new facility will include test stands within climatic chambers that enable full dynamic and real-world testing to be carried out under a wide range of climatic conditions. The facility was designed to put the new Foton electric motor packages through their paces, as well as to simulate or test battery packs, battery management systems and motor control systems. These new capabilities make it possible for them to test any part or combination of parts associated with an electric motor or hybrid powertrain.

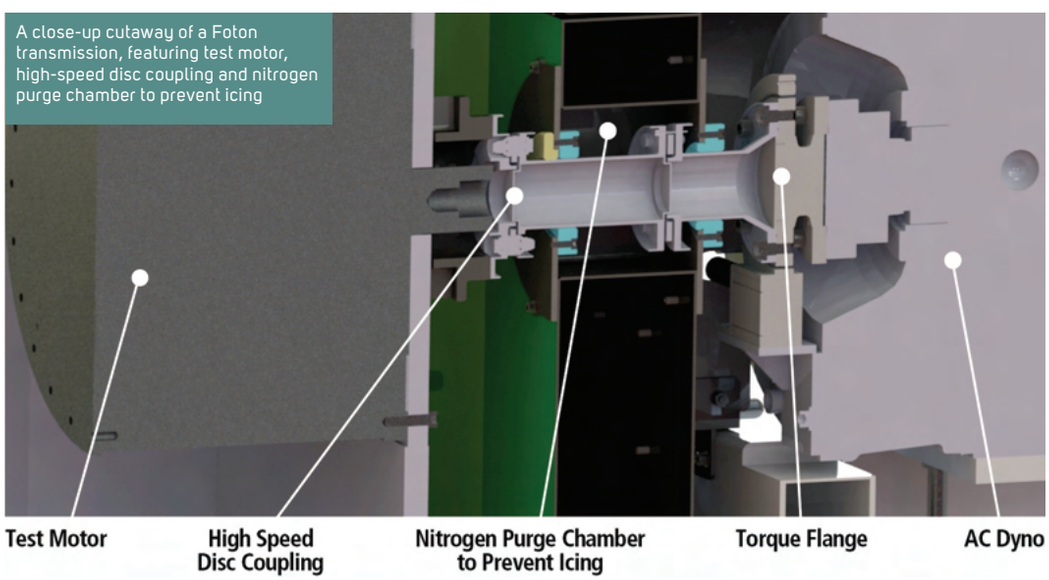
A combination of 165kW and 440kW transient AC dynamometers provide full road load and vehicle simulation. The climatic chambers surrounding the units under test accurately simulate the environmental conditions experienced around the world, ranging from -40°C to +50°C. The test stands are complemented by high-speed data acquisition and controlled by the highly intuitive Cadet V14 automation system. Cadet was designed and developed by Sierra CP to provide integrated control and data acquisition. It has the rare capability of ensuring backward compatibility with previous Cadet software and I/O platforms, thus ensuring clients experience cost-effective and highly flexible operational use for the long-term.



The high-tech Foton climatic chamber can accurately simulate environmental conditions experienced around the world, ranging from -40°C to +50°C

The larger 440kW system has been designed with the potential for future expansion. The addition of a second transient AC dynamometer and enhancements that include minimum operational test stand downtime enable Foton to provide cost-effective system development and enable full hybrid or conventional powertrain tests to be undertaken.

The award of this prestigious contract in China against strong competition is further evidence of Sierra CP's successful global expansion and its ability to offer a fresh approach that is cost-effective, innovative and, most importantly, flexible. This is proving to be a significant advantage for global customers such as Foton, who are looking for that test system edge against the competition in this highly prized area of automotive technology.



A close-up cutaway of a Foton transmission, featuring test motor, high-speed disc coupling and nitrogen purge chamber to prevent icing

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ONLINE READER ENQUIRY NO. 514

Comprehensive testing

One-stop-shop testing solutions for all types of energy-storage devices

Maccor Model 4300M connected to Princeton Applied Research PARSTAT 4000 Impedance Analyzer

A pioneer of the modern battery test industry, Maccor started operations in Oklahoma in 1986, as a company dedicated to the development of high performance battery test systems.

In just 27 years the company – with a nucleus of engineers experienced in emerging battery technologies and computer control systems – has experienced continued and rapid growth as the EV and HEV sectors have grown in importance and sales.

In the past, the only commercial products available to evaluate battery performance were designed and built specifically for lead-acid vehicle-battery applications. These were relatively high-power units, without any high degree of accuracy, had limited test programming capabilities, and collected data relatively slowly. In the mid-1980s, when there was a surge in new battery technologies, it became obvious that the available battery test systems were inadequate for market needs.

As such, Maccor developed a unique battery test system that provided extremely accurate results, collected test data at high speed, would test large numbers of batteries at the same time, and could perform virtually any test sequence required.

Maccor has since realized a greater than 80% share in the US market it operates in and has a major slice of the markets in Europe and the Asia Pacific. With nearly 1,500 systems in regular operation in over 45 countries, Maccor is a leader in the battery test industry. Recently, Maccor announced an exclusive agreement with the Scientific Instruments business unit of Ametek Advanced Measurement Technology. Scientific Instruments comprises the Princeton Applied Research and Solartron Analytical and Signal Recovery businesses of Ametek. Princeton Applied Research is a leading manufacturer of research instruments used in the field of electrochemistry, while Solartron Analytical is a leader in instruments and software used in electrical materials characterization and electrochemical systems.

Maccor and Scientific Instruments will offer integrated solutions that incorporate Maccor's automated test systems with Ametek's frequency response analyzers and other electrochemical analysis systems, multiplexing and interconnect cables, and integrated impedance analysis software. These integrated solutions are expected to result in higher productivity by switching automatically between Maccor's test equipment and Ametek's electrical impedance system; provide greater data integrity with more reliable and reproducible test results; and reduce idle time and in-test waiting from operators currently moving from one instrument to another. Discussing the new relationship, Ben Lease, vice president and business unit manager for Ametek Scientific Instruments, comments, "Our customers will be able to use their new and existing Princeton Applied Research and Solartron Analytical instruments in conjunction with Maccor's systems, gaining a greater understanding of their products, processes and materials."

Mark Hulse, vice president of sales and marketing for Maccor, says, "There is a growing need among end users to obtain specific electrochemical instrument results, such as electrochemical impedance spectroscopy and frequency response analysis, at various points during testing of energy storage devices. Without an integrated solution this can be a time- and labor-consuming process. Now, with Ametek, we can provide best-in-class solutions."

Maccor Model 4300M connected to Solartron Analytical 1260/87 Impedance Analyzer

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ONLINE READER ENQUIRY NO. 515

Electric traction systems

Following an agreement with a Chinese manufacturer of rotating electric systems, TM4 is now deploying its heavy-duty electric powertrain technologies worldwide

Spun off from Hydro-Québec in 1998, TM4 pioneered the electric propulsion system technology developed by Hydro-Québec's renowned research center. Today, it provides its customers with distinctive expertise in leveraging its permanent magnet, power electronics and control technology, to enhance the performance of electric and hybrid transport applications.

TM4 has developed its Sumo powertrain line specifically for the medium- and heavy-duty commercial vehicle markets. These motors are high torque/low speed and designed to interface with standard rear differentials without the need for an intermediate gearbox. The first of these systems was launched in May 2012 and, with its 3,400Nm of torque, targets heavy-duty vehicles.

In North America, one of TM4's key customers for this product is bus manufacturer Nova Bus, a Volvo Bus subsidiary. Both companies are part of a government-funded electric bus development and commercialization consortium. The Sumo systems have also been delivered to multiple companies in Europe, North America and China.

Patented wire coil forming machine used during the stator manufacturing process at TM4's Boucherville facility

Right: An electric bus equipped with a PEPS-supplied electric powertrain Below: The LSM280 high torque motor which is part of the TM4 Sumo powertrain line for medium- and heavy-duty commercial vehicles

Retaining its direct-drive approach for commercial vehicles, TM4 will also launch in 2013 smaller variants of its Sumo powertrains for medium-duty buses and commercial vehicles. There are many benefits when removing the transmission of an electric vehicle. While improving system reliability and reducing overall maintenance costs, it also increases the powertrain's efficiency considerably, allowing optimal use of the energy stored in the battery pack.

All of TM4's motors are combined with a new generation of high-voltage controllers delivering the industry's highest specific power and current densities. Part of the reason behind this achievement is TM4's Reflex gate driver technology. Combining hardware and software innovations, this innovation anticipates a voltage peak on the IGBT, and ensures that it never reaches the voltage limit. TM4 uses standard automotive grade IGBTs, but designs and manufactures its own gate drivers. While other companies using the same module limit the current to 450A, TM4 manages to limit the current to 650A (at 450V, 20 kHz, 65°C). TM4's unique new feature is an active mechanism that uses the stray inductance of the IGBT to control the current during the turn-off process, without slowing down the rate of voltage change. It is only active when necessary, and it has virtually no negative effect on efficiency and temperature.

In 2012, to accelerate the worldwide deployment of its products, TM4 entered into an agreement with Prestolite Electric Beijing for the creation of a sino/foreign equity joint venture company named Prestolite E-Propulsion Systems (Beijing) (PEPS). Leveraging TM4's licensed powertrain technologies and Prestolite Electric Beijing's extensive network and outstanding reputation in ASEAN markets, PEPS is developing, manufacturing, selling and supporting electric traction systems for trucks and buses, as well as commercial, off-road and marine vehicles. This joint venture supplies clients in China, Taiwan, Hong Kong and Macao, as well as Indonesia, the Philippines, Thailand, Singapore and the other ASEAN countries.

For more than a year, PEPS has been testing and evaluating the new powertrain technologies developed by TM4 with many OEM partners and customers. TM4's heavy-duty motors and controllers received the China National Accreditation Service certification in June 2012, a first step toward commercialization of these products by PEPS.

PEPS' production facility, located in Beijing, started production in June 2013 and will initially produce up to 4,000 heavy-duty powertrains annually.

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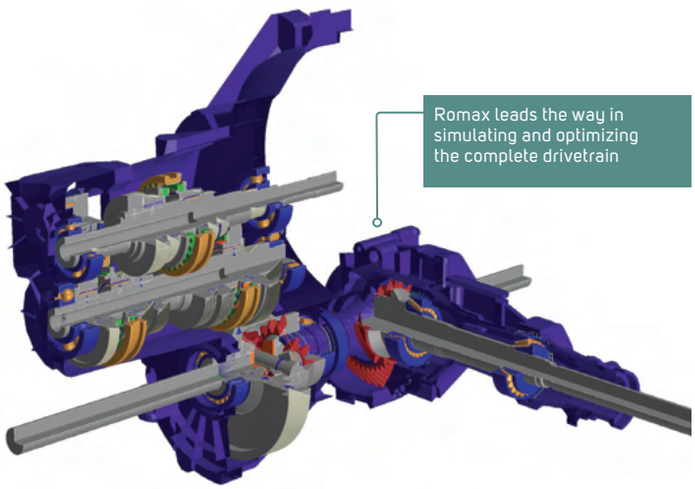
ONLINE READER ENQUIRY NO. 516

NVH and efficiency issues

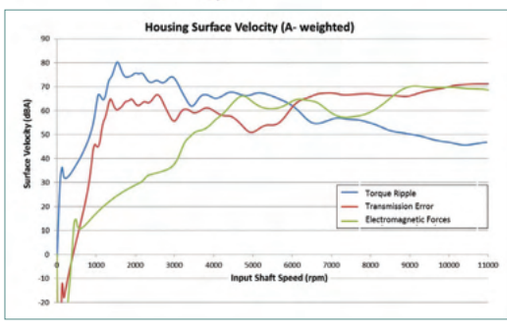
The absence of an IC engine, which normally masks various subsystem noises, is placing a new emphasis on electric and hybrid vehicle driveline refinement

Refinement has been the hidden challenge of electric and hybrid vehicle development, as potential customers notice – perhaps for the first time – the cacophony of noise emitted by the auxiliary systems of a modern car, from air-conditioning and wiper motors, to the driveline itself. People have grown used to almost inaudible transmissions, but the absence of IC engine noise, combined with new sources from the electric motor, means that electric powertrain noise can be a major consideration for potential customers.

For Romax, the optimization of transmission and driveline refinement is nothing new; the same principles of intensive simulation-led design used for the best conventional powertrains, particularly at the crucial early stages, remain key to achieving product design objectives. A common failing of many EV developers is to treat the electric motor and transmission as distinct elements. Transmission error from the gears, and torque ripple and electromagnetic forces from the motor, can generate structure-borne noise and vibration. As the resonant frequencies of the complete structure will be very different from its individual parts, the excitation of the components will yield a very different vibratory response if their performance is considered in isolation. Thus an electric motor and transmission individually rated as extremely quiet may be unacceptably noisy when combined with an EV powertrain.



Romax leads the way in simulating and optimizing the complete drivetrain



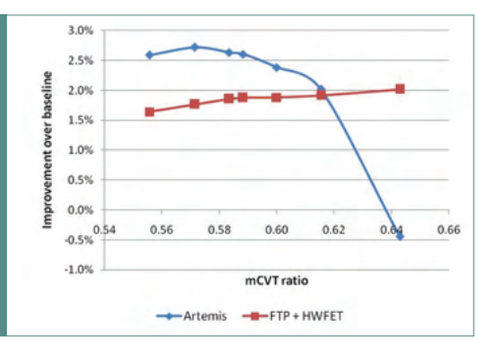
The chart outlines data relating to noise sources in the driveline, with all such sources needing to be to be considered simultaneously

Given the current interest in switched-reluctance as opposed to permanent magnet machines, in order to avoid the use of increasingly expensive and scarce rare earth elements, this can be particularly problematic. Without analysis encompassing the full powertrain, the true paths of vibratory transmission will not be properly characterized through simulation; consequently, any noise prediction will be potentially misleading. The RomaxDesigner product creates an all-encompassing simulation of the full EV or HEV powertrain architecture. This simulation of the entire powertrain operation – be it conventional, electric or hybrid – can help to ensure that the transmission is engineered to meet the standards expected of a highly refined, low-noise vehicle.

While NVH refinement poses a new challenge for EV design, efficiency remains critical. The EV price premium over conventional vehicles is strongly associated with battery cost, so any efficiency gain that reduces the energy storage requirement – or offers crucial extra range – is highly desirable.

When matching an electric machine to a transmission, it is possible to have up to 2,000 potential design combinations of layout, ratio and motor configuration. Conventional time-domain vehicle modeling approaches are generally restricted to an analysis of just a few configurations, typically focusing on just one drive-cycle such as the NEDC. To expedite the design process and achieve higher levels of effectiveness, Romax has developed a more streamlined approach that enables the company to rapidly assess not just the effectiveness of a design in terms of a given drive-cycle such as the NEDC, but also its robustness against different cycles and real-world driving styles, with little time impact. Further innovation means all design variants within the whole design space can be considered this way very early in the design stage.

By developing its simulation technology, Romax is helping to provide software and design methodologies to ensure that the next generation of HEVs and EVs is as efficient and refined as their customers will surely expect.



The graph shows data relating to the robustness of fuel economy, where it is necessary to consider such factors against aspects such as driving styles at concept stage

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ONLINE READER ENQUIRY NO. 517

New jump starter design

An advanced lightweight battery technology is impressing car makers around the world with its high-energy density, efficiency, durability and environmental friendliness

As a society, we are increasingly using more mobile devices such as cell phones, iPads and Android tablets; GPS devices; personal game consoles; and powered automotive accessories, including vehicle fridges or vacuums. While these technologies are playing an ever-important role in our lives, they are also frustrating users with their battery life, power depletion levels, and how long they take to charge.

In an effort to overcome these challenges, the first solution that companies – and industries – came up with was large, lead-acid batteries, which were renowned for their safety, reliability and low production price. The drawback to lead-acid battery technology, however, included a heavy weight of around 4.5kg, which was very inconvenient regardless of the end application, and a total lifetime expectancy of only 300-500 cycles, which translates to a maximum of two to three years. The marketplace was in real need of a better battery solution – and one that could cater to the changing demands of modern consumers.

In early 2011, Carku – a leading lithium-ion battery solution provider in China – started to design and manufacture lighter weight, portable, high-power automotive jump starters. The technical team focused on longer battery life and affordability after undertaking very detailed research and experimentation within the battery sector for an extended period of time. The team set out to create a multifunctional product that could get a stranded motorist back on the road, as well as providing the user with a mobile charging solution for rechargeable battery-powered devices.

Following extensive R&D, Shenzhen Carku today offers the market a product range that includes a special high-tech and very powerful LiPo battery system

Following two years of intense R&D, Carku showcased its new product range at the Automotive Aftermarket Industry and Tuning Trade Fair in Guangzhou, China, in February 2012. At the show, more than 200 people came to the Carku booth each day to inspect the innovative breakthrough technology that formed the company's new product range. Each subsequent industry expo that Carku has attended has attracted more and more industry professionals keen to investigate the company's innovative designs.

Key technology features of the Carku product range include the use of a special LiPo battery that incorporates a powerful, high capacity, improved conductivity electrolyte core. The product delivers a consistently enhanced flow of electrical current directly into the car's battery. By selecting the very best grades of metallic components, power arrives unobstructed. As a result, the mini jump starter offers maximum power to meet the demands of an automotive electrical system, while providing engineers and system designers with calibrated solutions that meet a wide variety of battery-dependent devices that often need to be recharged.

In addition to the powerful battery, there is an advanced electronic circuit featuring a three-cell lithium battery that is rated at 11.1V, boosting output all the way to 19V, with a possible step down to 5V in order to meet the requirements of the USB standard. As such, this setup delivers power through two cable adapters and 16 connectors to charge many different types of mobile devices for the first-generation Lipo-Jump system. The entire unit measures 16cm long, 7.5cm wide and 2.8cm high. It weighs only 400g and offers a lifetime expectancy of more than 1,000 cycles, which equates to five to six years. What's more, this package is available at a very competitive price.

Shenzhen Carku Technology is quickly becoming one of largest next-generation jump starter OEM and ODM solution providers and turnkey manufacturers in China, with a 30% growth in factory shipping quantities every month since 2012.

The company's patented Lipo-Jump technology is now in its fourth generation, and is impressing vehicle owners with its light weight, high energy density, efficiency, durability, environmental friendliness and convenience, with multiple functions including charging for most mobile devices.

After launching a raft of new jump starter products such as Rescue-Jump, Easy-Jump and the aforementioned Lipo-Jump, the company believes that the next generation of jump starters will now begin to make an impact across the globe.

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ONLINE READER ENQUIRY NO. 518

Battery solution provider

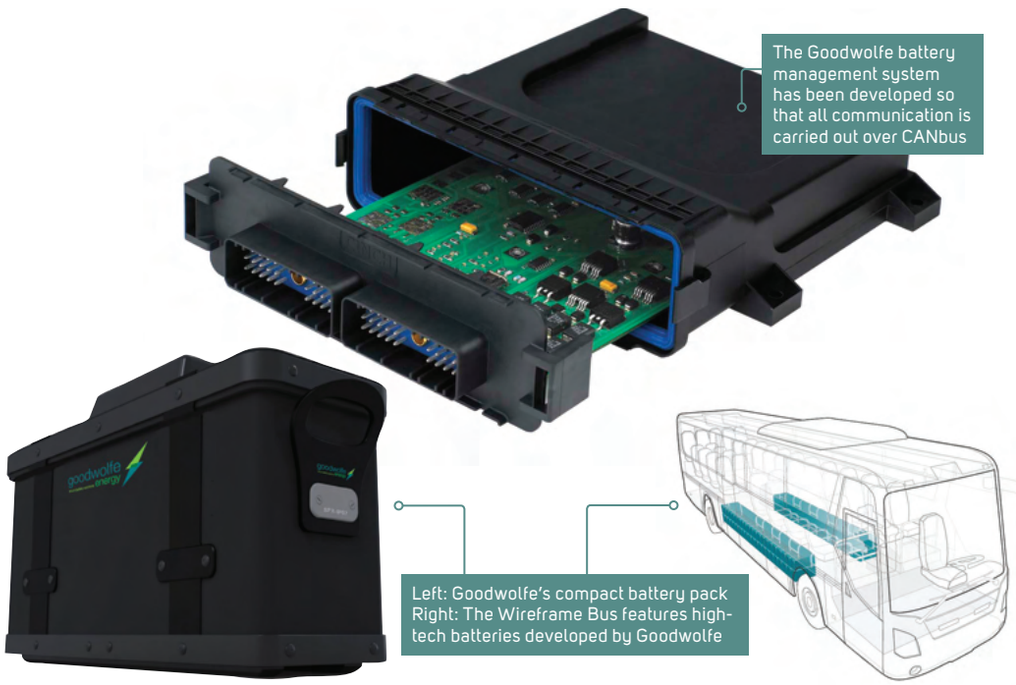
Following the successful integration of lithium battery systems into various hybrid and electric car projects, one company is now moving into the development of power solutions

With more than 20 years' experience within the automotive sector, and specifically in battery systems development, the team at Goodwolfe Energy has designed a modular product range that can be used in a variety of applications to create packs of any voltage and capacity. Having worked with companies such as Bosch, Microcab, Renault and Jaguar Land Rover, Goodwolfe has proved that its systems are more than capable of meeting the safety and performance criteria of some of Europe's leading automotive organizations.

In addition, over two million miles of vehicle testing has been undertaken to help fully develop Goodwolfe's battery modules and the advanced cell balancing protocols for HEV and PHEV applications. These advances have enabled the company to expand outside of the automotive market and take on new projects outside of the traditional electric or hybrid vehicle segments.

One of the projects currently underway is the development of an electric off-road leisure vehicle, which will be powered using standard battery modules in order to produce a 10.56kWh pack. Another example of how the company can configure its standard products to any application is the integration of a lithium pack into an electric bus, with the Goodwolfe team working closely with an international manufacturer to design a pure electric bus with a 240kWh power requirement. Both of these applications use packs made of prismatic cells that range from 40Ah to 1,000Ah, making them ideal for use in applications such as buses and larger vehicles.

Goodwolfe Energy also offers a design, development and delivery service for bespoke solutions that can fit almost any specification. The innovative packaging of the cells means that systems can be designed in a variety of shapes and sizes, ideal for those projects with unusual space requirements. This principle is helping Goodwolfe to work with a Japanese company in order to develop a system for a uniquely designed motorcycle.



The Goodwolfe battery management system has been developed so that all communication is carried out over CANbus

Left: Goodwolfe's compact battery pack
Right: The Wireframe Bus features high-tech batteries developed by Goodwolfe

Another project in development is a 9kWh battery pack for a hybrid supercar. This particular pack will be made up using cylindrical cells, which is ideal for a hybrid supercar given that the cells have a low self-discharge rate and a charge efficiency of more than 95%, highlighting how well they retain their energy.

It's accepted that a battery management system is essential to the performance of a lithium-ion battery system and in this area Goodwolfe Energy offers its customers a state-of-the-art solution that protects and monitors the battery to guarantee optimum functionality. The cell management modules use innovative algorithms to ensure that the user always has the full amount of energy available. All communication is carried out over CANbus, with the CANbus battery integration system (CANBIS) controlling and relaying the more detailed safety and diagnostic features to the user. The CANBIS updates every 20 milliseconds, providing up-to-date information on state of charge, state of health, live voltage, current measurements, power availability and regenerative braking parameters. The installation of the CANBIS system has been designed by Goodwolfe to save hundreds of man hours, especially as it uses a PC-based configuration tool that enables users to customize the system to their requirements. In addition to this, the company is also developing a new version of its battery management system based on the its experience in more than 80 projects in the past five years. This new technology is expected to be available in the fourth quarter of this year.

Although the company has expanded into the military and marine sectors, its roots remain in the automotive industry. As the electric and hybrid vehicle market grows, Goodwolfe Energy continues to look into the development of new products and welcomes the opportunity to work on different applications and projects.

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ONLINE READER ENQUIRY NO. 519

Cable connectivity

High-tech power and motor signal cable assemblies can be used to provide safe and durable connections in the motor compartment of electric vehicles

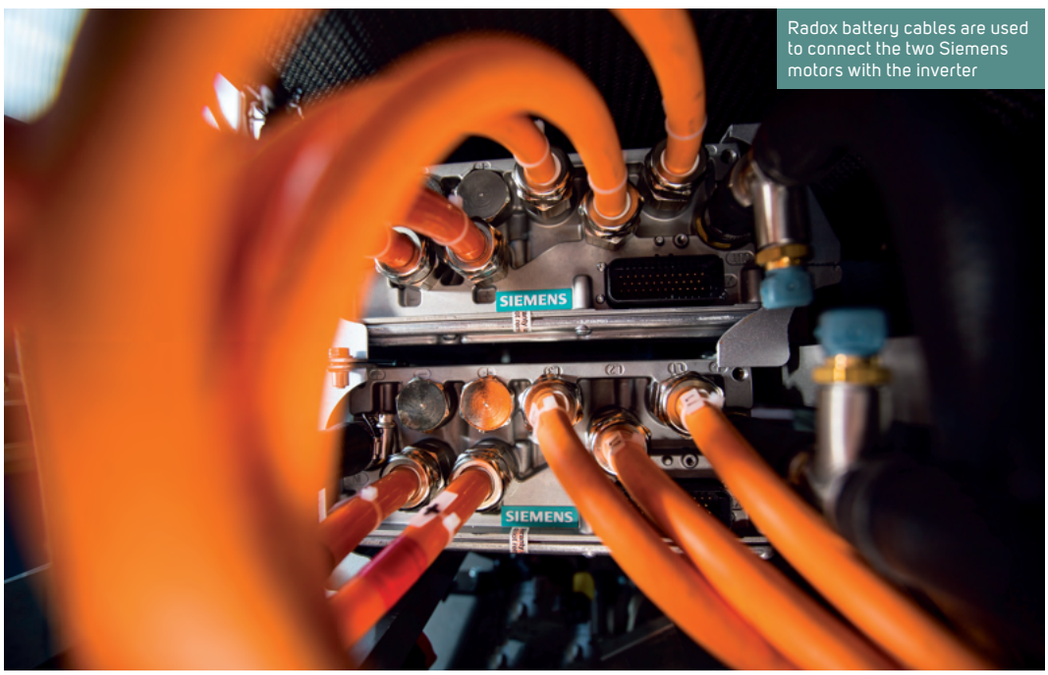
The first luxury electric sports car from Exagon Motors will be going into production from the beginning of 2014. These innovative vehicles boast two liquid-cooled electric motors from Siemens that include assemblies from Huber+Suhner.

Each year, between 150 and 300 Furtive-eGT sports cars from Exagon Motors will take to the roads. These exclusive vehicles feature two 203ps electric motors from Siemens. Capable of accelerating from 0-100km/h in just 3.5 seconds, they can achieve a top speed of 250km/h.

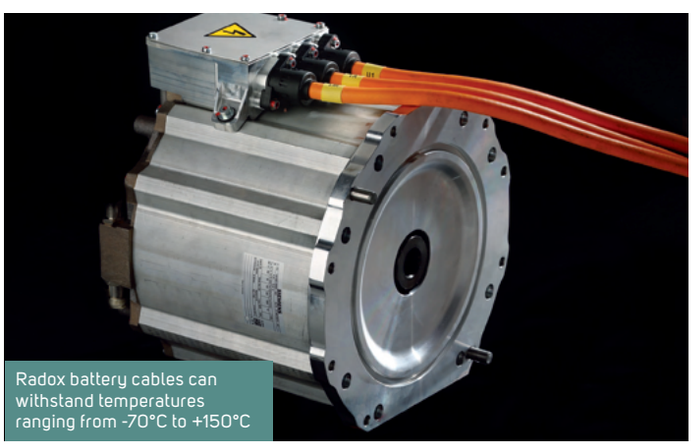
Siemens is using connectivity solutions from Huber+Suhner to connect each 148kW electric motor. For this project, the cable manufacturer is supplying power cables and motor signal cables. The latter comprise multicore, shielded Radox signal cables together with various connectors. These assemblies connect the electric motors with a range of control units for monitoring the motor operating temperatures and other functions.

Radox battery cables are also used to connect the two Siemens motors with the inverters. These inverters convert the energy generated by the 53kWh lithium-ion batteries into three-phase alternating current, which is then conveyed to the motor via three shielded Radox battery cables.

Radox cables are particularly well suited to the demanding conditions in the motor compartment. Thanks to their electron-beam, cross-linked insulation material, they are capable of withstanding temperatures ranging from -70°C to +150°C. They are also highly resistant to thermal pressure, abrasion and fluids including fuel, oil, battery acid, salt water and detergents – all of which makes them ideal for providing long-lasting, secure connections in the motor compartment.



Radox battery cables are used to connect the two Siemens motors with the inverter


Radox battery cables can withstand temperatures ranging from -70°C to +150°C

Huber+Suhner delivers more than just high-quality cable assemblies. Its team of application engineers, based in Weikersheim, Germany, is also on hand to lend its industry expertise to customer projects. In this particular project, the company will be required to propose solutions for as yet unclarified aspects, such as the best way to seal the low-voltage cable harness.

Huber+Suhner has been providing innovative and safe connectivity solutions ever since electric and hybrid vehicles first entered into production. “We offer long-standing experience of the automotive industry together with industry certification,” explains the company’s Rudi Löw. “This is coupled with our extensive knowledge of cable production and high-quality products.” These are all factors that have managed to impress Siemens.

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ONLINE READER ENQUIRY NO. 520

Freight port e-mobility

A specialist in wheeled non-road mobile machinery is launching a new electrically driven trailer vehicle system for the delivery and transportation of heavy and large goods

The Gaussin Manugistique ATT V3 automotive terminal trailer system (below) that uses the SKAI2 800V DC/250kVA high-voltage inverter system (left)

The principal economic viability of the electrification of commercial vehicles has already been analyzed and proven in many different applications through hybridized or fully electrified prototype vehicles. As production volumes of electrified commercial vehicles and mobile machinery are still moderate, the industry is looking for power electronics based on a modular off-the-shelf concept. Individual requirements can be covered by small adaptations of existing platforms. In this way, product quality and cost efficiency can be guaranteed, even though the individual project volumes are still small.

Traditional container handling vehicles are powered by rather large diesel engines. Gaussin Manugistique, together with its electric powertrain engineering team, has completely abandoned traditions and developed a full electric powertrain for the new range of its Gaussin ATT (automotive terminal trailer) vehicle platform.

The result is an all-in-one product, merging prime mover and trailer in one unique vehicle. At a maximum capacity of 60 tons, it is capable of speeds up to 25km/h, and up to 40km/h when empty. The vehicle trailer can be configured in different ways to suit the loading of 6, 12 and 13.5m standard containers.

The Gaussin ATT is a two-wheel-drive vehicle benefiting from an efficient distribution of mass with most loads (container, battery pack) right in the middle of the axles, which is the most efficient and optimized configuration. The front axle of the ATT vehicle is a driven and steerable system that is powered by two individual eight-pole PM synchronous motors integrated in the wheels for an efficient transmission of torque without wasting energy, resulting in a maximum torque of 580Nm and a maximum speed of 3,400rpm. This means a high level of performance, and the powertrain always provides an optimized level of torque and power adapted to any road situation.

The SKAI2 high-voltage 800V inverter system, together with Quasar motor control software, was the natural choice for this drive application due to its very high robustness with respect to environmental and load-cycle conditions. The ATT system battery voltage is 750V (maximum) and system efficiency is rated at 95%.

A typical load cycle of the Gaussin ATT is as follows: the vehicle waits for a container in a lane with other vehicles, then receives a 60-ton container and drives to the stocking area, unloads the container, and drives back empty to the starting point. One such cycle lasts 15 minutes. During this cycle the torque and speed requirements vary a great deal, therefore putting a lot of thermal stress on the inverter system. The SKAI2 has been proved to be best suited to meet the life expectancy of such a drive system under these tough conditions. It therefore enables efficient heavy-duty movement in frequent stop/start phases.

In addition to this, the environmental conditions at seaside ferry ports demand special precautions, and this is another reason to choose the SKAI2 inverter system. Built into an IP67 enclosure, the compact SKAI2 inverters withstand high vibration amplitudes up to $10G_{rms}$.

The Quasar motor control software and the SKAI2 inverter hardware platform are an established team and, due to their robust design, are perfectly suited for tough vehicle applications. The successful Gaussin ATT powertrain project is a good working example of the cooperation between Semikron as the inverter manufacturer, and DriveTek acting as the engineering service provider for the end customer.

The SKAI2 platform comprises highly integrated inverter electronics systems, and these traction inverters provide the ideal powertrain solution for many applications in the field of vehicle electrification.

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ONLINE READER ENQUIRY NO. 521

High-voltage test systems

PEC's new series of system-level test equipment meets demands for system- and pack-level testing at different stages of development and manufacturing

Large amounts of capital are being invested into developing durable, safe and cost-effective battery systems for applications in electromobility, renewable energy and smart grids as a supporting infrastructure. This has created a huge demand for system- and pack-level testing at different stages of development and manufacturing.

Battery manufacturers need end-of-line testing as part of their QA process; research divisions are focusing on improving weight and space utilization, as well as lifetime and thermal performance; independent testing facilities are working on new programs for standardization, certification and benchmarking; battery management system designers are looking at safety, state of charge and state of health models.

Numerous test and simulation solutions for these diverse requirements are often implemented by using customized power sink and sources, in combination with external data acquisition systems, which are controlled by either a software application or a C-program in a PC environment.

PEC is now introducing a new series of high-voltage test systems to complement its range of cell- and module-level testing. The systems will be supported by the same LifeTest software environment, guaranteeing a user-friendly configuration of drive cycles, auxiliary I/O, battery management system (BMS) communication, and thermal chamber interfaces.

The system's architecture is based on the same embedded controls as the rest of the PEC product line. This setup offers real-time, reliable and independent control of charge and discharge modes as well as communication with, and control of, all test peripherals. The end user can set up a hardware-in-the-loop test easily, including thermal chambers, interfaces to vehicle management, and analog and digital I/Os.

PEC's 1,000V, two-channel test system architecture is based on the same embedded controls as the rest of the PEC product line

The strong software background of the company has enabled PEC to develop a complete laboratory management system for battery test labs, called LifeTest, which controls all PEC test equipment and its peripherals. The LifeTest software centralizes all data generated by the cell-, module- and pack-level testers, climate and thermal chambers and even several third-party test equipment into one centralized database.

According to a PEC spokesman, "The high-voltage tester was the logical step in our development and growth. The increased demand for system- and pack-level testing, together with the fact that our customers are increasingly looking for a one-stop shop makes this a perfect timing for the release. A solution with different suppliers and interfaces only creates extra costs for the customer and no added value. Now we are able to offer our clients the complete testing capability including cell-, module- and pack-level electrical and environmental testing, all supported by our LifeTest management platform and controls."

PEC covers the majority of the application fields in testing EV, HEV, PHEV and bus packs by offering two standard product ranges – the 600V and 1,000V tester – available in a 160kW and 240kW configuration and one or two channels per cabinet.

All of the existing features that PEC's customers have for cell and module testing are still available on the new machines, including water-cooled electronics; real-time sampling and capacity calculation; automated climate chamber control; integration with external equipment and sensors via the auxiliary I/O system, and BMS integration through CANbus.

The high-voltage systems also feature an active energy feedback to the grid and DC energy balancing between the channels.

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ONLINE READER ENQUIRY NO. 522

Efficiency drive

Speedy start-up for micro-mild hybrid applications is helping car makers across the globe to meet stringent emissions legislation

Controlled Power Technologies (CPT) is an award-winning company that specializes in cost-effective CO_2 reduction measurements for OEMs. Its CEO, Nick Pascoe, says that the company's switched-reluctance machines can help facilitate a new generation of affordable low-voltage micro-mild hybrids.

There are many routes to hybridization, some costing much more than others. As a company, CPT has focused its efforts on low-voltage electrification, thereby avoiding a major redesign of the powertrain or vehicle electrical system. The results are key fuel consumption advantages and minimized costs. Gasoline and diesel engines can both benefit from this trend, thus taking the industry beyond simple stop/start systems.

CPT gained distinction in the industry when it sold its VTES electric supercharger business to Valeo for US$42m. This was the first application of its technology following more than a decade of research and development of switched-reluctance machines as the best solution for micro-mild hybrids. The company is now concentrating on bringing other applications of its core technology to mass-market readiness and its SpeedStart belt-integrated starter-generator is close to high-volume production.

The CPT SpeedStart starter-generator is validated for 1.2 million engine stop/starts – a testing development benchmark and new industry standard

CPT is also the first company to validate its starter-generator for unrestricted operation by completing more than two-and-a-half years of continuous testing to set a new benchmark of 1.2 million stop/starts, which is now considered a new industry standard that will be required for the first generation of micro-mild hybrid vehicles. No issues were identified with the technology throughout this period of remorseless testing.

CPT has tested its SpeedStart system as meticulously as possible to confirm its capacity for frequent stopping and restarting of an engine beyond the 300,000 stop/starts currently mandated by the industry – although contemporary vehicle OEM strategies generally ensure that this number, and the associated real-world fuel economy benefit, is rarely achieved. CPT's SpeedStart starter-generator system is particularly relevant in the USA, where car makers can now leapfrog European first-generation stop/start systems, by deploying a more robust technology with increased functionality and proven longevity.

CPT needed to demonstrate the low probability of failure during the lifespan of a vehicle and the ability to achieve the maximum number of restarts, because one of the most cost-effective techniques for low fuel consumption is simply stopping the engine whenever a vehicle is stationary. This becomes increasingly challenging as more ancillary devices are electrified – such as PAS, water pump, oil pump and even the air conditioning –requires an exceptional and virtually unnoticeable stop/start experience and, in particular, a driver change-of-mind capability in order to ensure that the operation is not intrusive to normal driving styles. This capability also enables opportunities for more sophisticated coast-down, engine-off recuperation strategies to be implemented.

At 12V, the fuel economy benefits of this powerful and highly efficient starter-generator system, combined with its high current energy generation over the full engine speed range, can be as much as 20% in urban environments. Driver benefits also include high torque and rapid response, leading to the desirable and almost imperceptible stop/start experience. And because of its modular design, it provides future-proofing for OEMs who wish to upgrade to 24V or 48V.

At 48V the machine becomes even more capable, offering stop/start cranking and higher efficiency generation with the added benefits of torque assist to the engine for acceleration. When required, fueling can be reduced during idle and cruise conditions by using the leanest engine calibration. Combined with electric assist for driveability, it can also provide high levels of regenerative braking and the opportunity for engine downsizing.

The SpeedStart technology undergoes forensic examination

CPT dynamometer testing of the 48V SpeedStart units

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ONLINE READER ENQUIRY NO. 523

Stranded energy solutions

The automotive industry is seeking a standardized method for the safe discharge of stranded energy in hybrid and electric vehicle applications

In the event of an automobile accident, a gasoline tank can be drained to prevent a potentially explosive situation. This scenario is not so simple for electric and hybrid vehicles. Stranded energy is the residual charge, or stored energy, left in an EV battery after an automobile accident that cannot be directly accessed. This charge poses great risk to secondary responders, including tow truck operators, dealerships and vehicle repair shops, because it can lead to a potential shock or fire hazard. First and secondary responders need a safe, standardized method for handling the potentially dangerous, live battery inside.

Currently, there are no industry standards addressing stranded energy. The US National Highway Traffic Safety Administration (NHTSA), National Fire Protection Association (NFPA) and SAE International are all working to address this gap. The SAE Battery Standards Fuel Gauge Committee is currently developing a new industry standard titled SAE J3009: Stranded Energy – Reporting and Extraction from Vehicle Electrochemical Storage Systems. In addition, the SAE Battery Field Discharge and Disconnect Committee is working to develop a standard method and interface for the field discharge of live batteries.

What is needed is one uniform solution for stranded energy for all electric and hybrid models. While there is no standardized method for discharging damaged or used batteries, two potential solutions exist for removing stranded energy – the suitcase tester and the automatic self-discharge system. The two solutions are very different, and there are positives and negatives to both offerings.

Intertek is working with the automotive industry, including NHTSA and SAE, to formulate new standards that address energy. The company is seen as a global leader in providing OEMs and Tier 1s with advanced energy-storage testing equipment

The NHTSA and SAE committees have joined together to develop the suitcase tester, a solution based on the use of one uniform discharge tool. First responders would carry this tool to remove the energy left in the EV battery before towing. While this has its advantages, harmonization and acceptance by all automobile makers in the development of a standardized battery high-voltage (HV) port, the ability to access the EV battery via a diagnostic of the HV port after an automobile accident, and the need for system training for all users, are a number of potential difficulties with this solution.

The automatic self-discharge system provides an internal solution to the problem of stranded energy. If an electric or hybrid vehicle accident were to occur, the HV system would instantly be disconnected and the battery would self-discharge. However, many wonder if this is in fact realistic as battery damage could possibly prevent some internal systems from functioning. Others suggest that it would be safer simply to leave the energy stranded. Additional cost is also a consideration. This type of system would also have to be extremely durable and built to survive multiple possible accidents, which can be costly.

Gaps in industry safety standards lead to unacceptable and unsafe conditions. Both of these solutions are a clear indication that the EV community is working to address stranded energy to help ensure the safety of first and secondary responders who aid those involved in the event of an accident.

Intertek, a leading provider of quality testing solutions worldwide, offers a full suite of services for EV and energy-storage testing.

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ONLINE READER ENQUIRY NO. 524

Metallic bipolar plates

The serial production of power-dense metallic bipolar plates could help pave the way for durable, cost-efficient and high-performance fuel cell engines

The need for zero-emissions solutions is rapidly increasing in the global automotive market. As multiple fuel technology paths expand, fuel cell vehicles (FCVs) could prove to be a viable option if large production runs can be achieved cost-effectively.

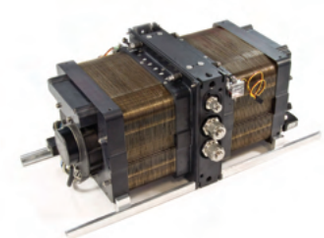
With many leading automotive manufacturers planning to release a fuel cell vehicle to the market by 2015, the need for cost-effective high-volume manufacturing grows stronger. To be ready to meet this demand, Dana Holding Corporation, a leader in fuel cell technologies, has become one of the first companies to launch serial production of metallic bipolar plates. This new development will help pave the way for mass production of cost-efficient, high-performance fuel cell engines.

"In each automotive fuel cell engine, there are between 300 and 400 metallic bipolar plates," explains Brian Cheadle, director of global business development for advanced technologies at Dana. "For the automotive industry, the ability to produce these with consistent quality and at fast cycle times for high volume will be a critical issue. As far as we are aware, no competitors have yet established such an integrated manufacturing process."

Fuel cell engines consist of a stack of repeating cells, each cell comprising a bipolar plate and a catalyst-coated membrane assembly consisting of anode and cathode electrodes. The bipolar plates are a critical functional component of the fuel cell stack, responsible for fuel and air distribution to each side of the two electrode surfaces, as well as stack cooling. To accomplish this, each bipolar plate must include external flow field channels for gas distribution and separate internal coolant passages. Each bipolar plate must also provide a robust sealing means, so that in the engine stack the engine fluids can be separately controlled. Finally, a conductive surface or coating is required to minimize electrical resistance losses.

Left: The serial production of metallic bipolar plates will help realize the mass production of fuel cell engines

Below left: Fuel cell engines consist of a stack of repeating cells containing up to hundreds of metallic bipolar plates for automotive applications



"Metallic bipolar plates are a preferred technology for automotive vehicle applications because they can achieve best-in-class power density," says Cheadle. "This enables car manufacturers to extract a lot of power for vehicle propulsion using a compact, lightweight engine that is more easily packaged in the vehicle."

Dana's ultra-thin metallic bipolar plate assemblies achieve superior engine performance, reliability and durability. Made from precision-stamped and laser-welded stainless-steel foil materials, Dana's bipolar plates incorporate the company's patented integrated sealing technology, consisting of a formed bead in the plate that is coated with a micro-layer of sealing material. This bead structure is designed to flex and seal under light compression loading, resulting in a very robust seal that is impermeable to hydrogen, offering OEM customers improved stack assembly reliability. Dana's plates also incorporate a proprietary conductive coating that enhances fuel cell performance at significantly lower cost levels than competing technologies.

By using this range of advanced process technologies specifically developed for metallic bipolar plates, Dana has now streamlined production to cost-effectively commercialize its metallic bipolar plates at its facility in Neu-Ulm, Germany. In the future, the company expects to expand production to additional regions in response to market demand.

Dana continually develops new products at its global technical centers, and the company's line-up of fuel cell products includes metallic bipolar plates; molded graphite composite bipolar plates; heat exchangers and thermal management systems; and hydrogen reformers.

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ONLINE READER ENQUIRY NO. 525

Correct voltage conversions

Hybrid and electric vehicles deal with new voltages in the areas of storage and generation, and should be converted to the right voltage for every specific electrical application

The challenge to improve the overall system efficiency of new hybrid and electric vehicles requires different working voltages in systems such as storage, generation and different main vehicle power networks. The energy generated in the electrical machine on voltage (AC), once rectified, is stored in the high-voltage battery (DC). The energy then flows to the various vehicle applications, which work at different and optimum voltages, to maximize efficiencies.

This system evolution requires a variety of DC/DC converters to supply the right voltage for each specific work voltage for these new types of vehicles. Currently, Lear is working in the main DC/DC converter areas under discussion by the automotive community, including from high voltage to main network voltage (future 48V or current 12V and 24V); from 48V to the most common 12V and 24V; and from multiple voltage sources to main network voltage.

Depending on the type of vehicle, there could be a high voltage (300-425V DC) converted (Figure 1)

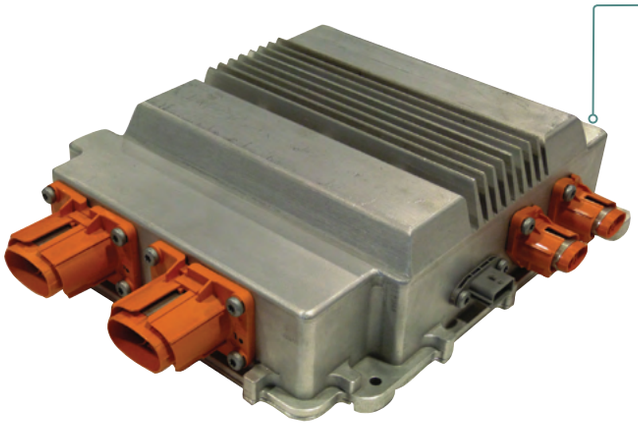

Figure 1: Lear's 400V-12V DC/DC converter meets the requirements of the main vehicle voltage network

to the main vehicle voltage network which, since the 1950s, has been set at 12V, and supplies all the traditional electrical and electronic vehicle devices.

In recent years, especially in Europe, 48V (Figure 2) has emerged as the third voltage in vehicles to support the improvement of energy generation, key functional performance and robustness (such as stop and start for micro hybrids). The introduction of new power functionality at higher voltages also adds more complexity, including increased safety concerns.

Also under discussion is the possibility that energy can be recovered from any energy source the vehicle encounters (thermal, vibration, solar, etc) to help complete vehicle energy balance. As such, Lear has created a multiple voltage input DC/DC converter, dubbed the Smart Energy Gateway (Figure 3), which is necessary to recover this energy and convert it to the main voltage network.

In response to these issues, Lear is able to propose standalone solutions or components that can be integrated with other power electronics devices to assure flexibility in meeting customer needs, depending on the technical and economic challenges of different OEMs.

Considering these challenges, there is no de facto standard yet, and the automotive community is looking for the best trade-off between technical performance (efficiency, power density, thermal management, etc) and cost. The efficiency of these power devices is needed due to the goal of reducing any wasted energy, which directly impacts on vehicle consumption and range of autonomy.

Greater device efficiency can be obtained through the right topology selection, along with other technical parameters such as switching frequency and key power switch technology. The thermal management of these devices also factors into this goal of efficiency – depending on the final power loss and whether the cooling system uses an air- or water-cooling technology, which itself has a big impact on the final mechanical concept and cost.

In line with the pursuit of these objectives, Lear can also deliver the best power density proposal, obtained through the right balance from the standpoints of power, size and weight, considering the high impact these factors have in complete vehicle assembly.

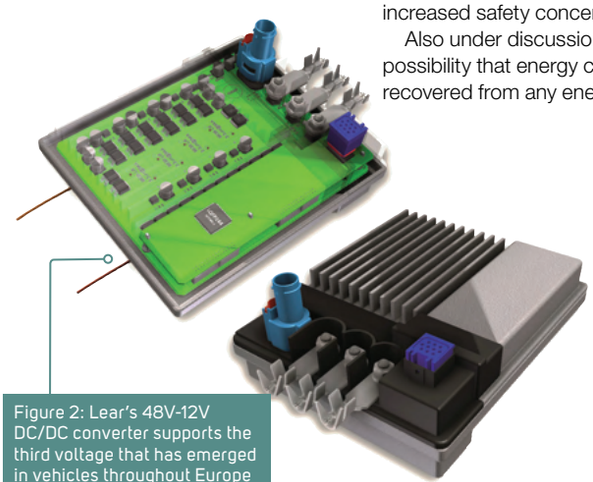

Figure 2: Lear's 48V-12V DC/DC converter supports the third voltage that has emerged in vehicles throughout Europe

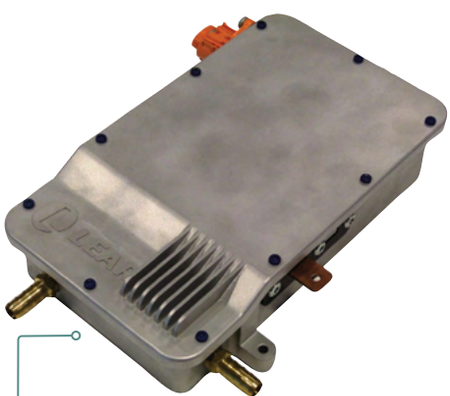

Figure 3: Lear's multiple voltage input DC/DC converter, the Smart Energy Gateway

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ONLINE READER ENQUIRY NO. 526

Electric race car advances

High-altitude hillclimb races are proving to be the perfect environment to showcase the latest capabilities of pioneering electric vehicle technology for road and track

Toyota Motorsport (TMG) – the Cologne-based company that originated in motorsport but now provides engineering services to a broad range of automotive clients – won the electric class at the 2012 Pikes Peak International Hill Climb in Colorado, successfully defending its title with its TMG EV P002 prototype, and setting a new record in the process.

Using knowledge gained from that triumph, TMG has upgraded the electric powertrain, which now delivers 400kW (543ps) of power and 1,200Nm of torque. Pikes Peak has represented a major challenge since the first event there in 1916. The hillclimb, which begins at an altitude of 2,800m and reaches the summit of 4,300m, is an ideal environment to showcase the strengths of electric powertrains, which maintain full power despite the thin atmosphere at high altitude.

Claudia Brasse, TMG's executive coordinator of strategic EV development, says, "The improvements we've made to the powertrain should confirm the TMG EV P002 as the standard-bearer for electric race cars. But as well as the electric powertrain, we're successfully innovating in the area of charging infrastructure. In the real world, you have to deal with varying levels of infrastructure and uncertainty regarding the power grid. The potential for offboard battery-to-battery charging technology is great. We have a flexible solution that can be adapted for different types of race and passenger car."

The TMG EV P002 set a new electric record on the Pikes Peak International Hill Climb in Colorado in August 2012

TMG is again using its offboard battery-to-battery charging technology, including a Schneider Electric EVlink DC charger, to charge from the mountainside, where there is no reliable connection to the power grid.

Mounted in the rear of a Toyota Hiace, it includes a 42kWh lithium-ion battery, which can be charged directly from the AC power grid and, after an overnight charge, can quickly deliver high levels of power to a battery-based electric car without any additional installation or infrastructure.

With varying current and voltage output, the TMG DC Quick Charger becomes an independent source of power for rapid recharging in any location. Such a solution is a clear example of the diverse EV development that TMG's record-breaking program with its EV race car is intended to draw attention to. In partnership with providers of best-in-class battery solutions, TMG has created comprehensive and customizable solutions for road cars, trucks and motorsport.

Motor and inverter technology is developing continuously, presenting a risk that in-house development could be overtaken by commercially available solutions, so TMG has created a development program based on off-the-shelf motors and inverters and dedicated high-performance solutions with collaboration partners. The performance of these components is also dependent on the respective management systems, so TMG has focused on developing unique expertise in this area.

By developing its own hardware and software, TMG is pioneering new techniques and optimizing existing processes to deliver better performance, reliability and safety. Challenging techniques such as torque vectoring and torque control have been enhanced by a dedicated team of researchers.

TMG's extensive testing lab allows for testing of EV components to complete the development cycle, with the benefits seen on the world's roads, tracks and, in the case of the TMG EV P002 race car, even mountainsides.

TMG has a dedicated EV department at its technical center in Cologne, Germany

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ONLINE READER ENQUIRY NO. 527

Flywheel hybrid progress

Torotrak's investment in flywheel hybrid innovator Flybrid Automotive has ensured a strong production future for this emerging technology

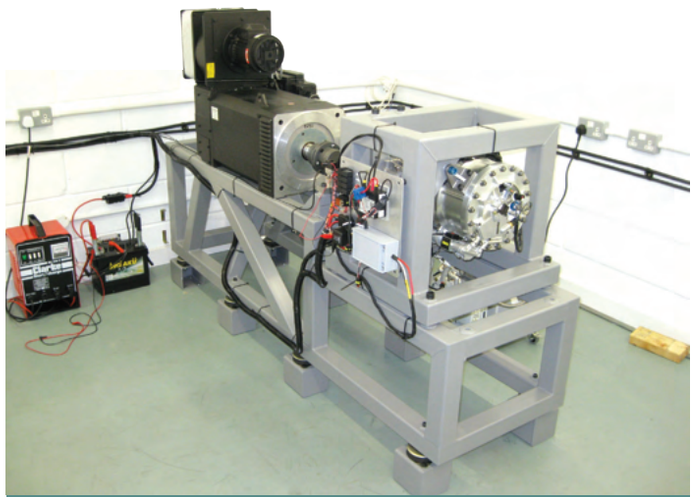
Torotrak announced on March 18 that it had invested around £3 million (US$4.5 million) to acquire a 20% stake in Flybrid Automotive, together with an option to acquire the remaining 80% by December 20, 2013. Flybrid's core product is a high-speed flywheel-based kinetic-energy recovery system (KERS), and the company can offer customers a full service including design, manufacture, assembly, development and support of the device. This can be applied to obtain both performance and fuel economy benefits for commercial vehicle and passenger car applications, and motor racing.

Several months after the announcement, the effect of the investment is being felt at Flybrid. The company can now direct its own funding toward key development items and move the product to market independent of outside influence. For low-volume applications such as buses this is particularly important, as the client is often unable to cover large up-front costs but is happy to pay a premium on each production unit.

A threefold expansion in rig test facilities is underway to complete the necessary preproduction testing of the product for key low-volume markets. This investment is supported by UK government funding through the Advanced Manufacturing Supply Chain Initiative, which has allocated over £800,000 (US$1.2 million) to Flybrid. This additional funding has enabled Flybrid to leverage its own investment and bring two products to market at the same time.

Flybrid Automotive will invest in flywheel manufacturing in the UK

Volvo has recently completed testing of this flywheel hybrid prototype and reported a fuel economy benefit of 25% over a car with similar performance



Full load test rig. A threefold expansion of the test facilities is planned at Silverstone

The test rig capability will include additional full-power test rigs capable of testing complete systems, together with the specialist ability to test subsystems and key components over accelerated durability cycles. All the rigs are being designed and built in-house at Flybrid to meet the exact required specification, which will include high-speed data collection and 24-hour 'lights-out' running capability. The rigs will be installed at the company's Silverstone headquarters, and create new jobs.

Flybrid has also joined the Proving Factory consortium, which plans to manufacture a number of low-carbon technologies in quantities of up to 20,000 units per year. The Proving Factory, backed by the Advanced Manufacturing Supply Chain Initiative and Tata Steel, will spend over £20 million (US$30 million) developing component manufacturing and system assembly factories in the UK. This manufacturing capability will supply bus and off-highway systems in low volume but can also be used for lower-volume premium car applications as a precursor to full Tier 1 engagement.

Interest in flywheel hybrid technology increased in May following publicity from Volvo regarding its own flywheel hybrid demonstrator vehicle. Reporting a fuel economy benefit of 25% over a car with similar performance, the car maker has publicly talked about bringing a flywheel hybrid product to market in 2017.

Jon Hilton, managing director of Flybrid Automotive, said: "With this investment now in place we are in a position to push at full speed toward production with the first preproduction systems expected to leave the factory in 2014 and the first full-production systems in 2015. The time is perfect to expand the business both in manufacturing and in licensing, and we look forward to bringing our product to market in collaboration with Torotrak."

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ONLINE READER ENQUIRY NO. 528

EV simulation tools

The design of electrical machines for use in EVs and HEVs is dependent on cost fluctuations of materials due to market pressures and overcoming multiphysics problems

Electric machines that use interior permanent magnets rely on rare earth metals that can vary drastically in price over a relatively short period of time. This unpredictability forces design engineers to look at alternative machine designs such as three-phase induction motors, which, unfortunately, can also become susceptible to fluctuation in the price of copper.

As such, engineers who design electric machines need simulation tools that can quickly, yet very accurately, be employed to drive product development. The method of choice by engineers who design electric machines is the finite element method (FEM). Historically, the FEM has been used as a final check – the last step of the design process before releasing the design to manufacturing. Successful companies have discovered that this is no longer acceptable and have moved simulation to early in the design cycle. The main reason for this is that technology has improved to the point where it is considerably faster, while not compromising accuracy. With the advent of high-performance computing and advances in the FEM, solution times have become so fast that problems solved with the FEM can now be used with optimization algorithms that enable design engineers to attain higher machine efficiencies with less material and lower costs.

The entire solution domain in which an electrical machine operates is most commonly characterized by its efficiency map (Figure 1). In order to predict the efficiency map through simulation, a relatively large number of datapoints need to be calculated. The extraction of these datapoints has been automated through the use of customized toolkits available in the Ansys Maxwell program. The user simply enters a few input parameters and then clicks on 'Calculate Efficiency Map', and the software automatically calculates all the necessary design points and generates the efficiency map.

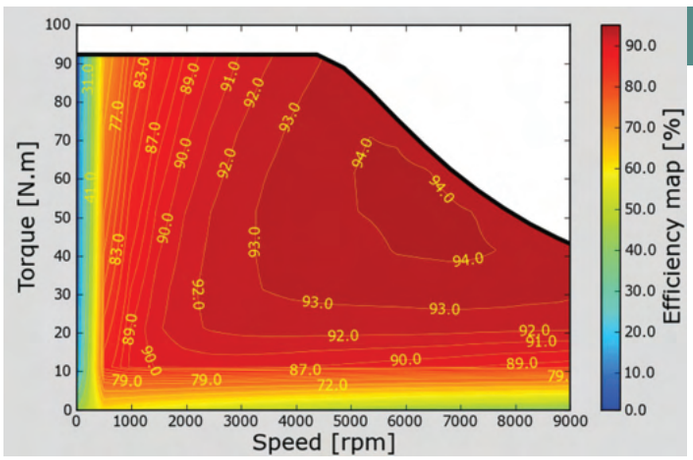

Figure 1: An efficiency map of an embedded permanent magnet motor

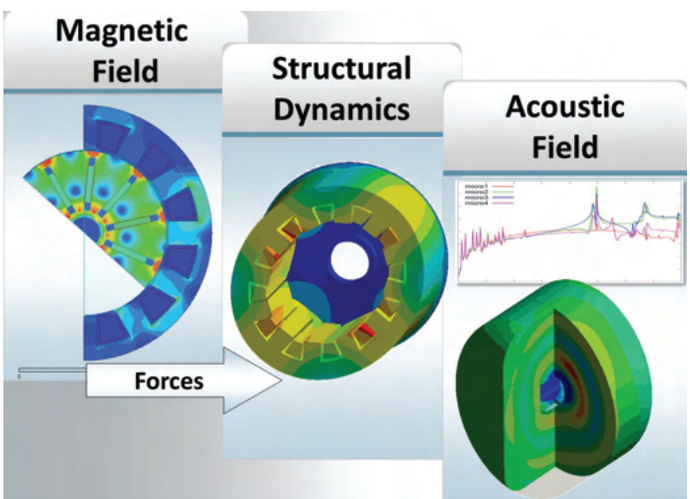

Figure 2: A multiphysics simulation of an embedded permanent magnet motor

Determining how a particular design will perform is a necessary step in the design process, but more importantly, it is critical for the design engineer to know how to improve the design. Can the same efficiency map be obtained with a motor design that uses less material and is easier to manufacture, in order to reduce costs? Using simulation early in the design phase, the engineering team can perform any type of optimization desired.

Once the design engineer is able to determine the optimum topology, the need to determine the effects of losses and distributed forces on the thermal, as well as noise and vibration of the electric machine, is critical. Electric machine design is a multiphysics problem at its core. For example, electrical energy is applied to the machine via power electronic devices (i.e. inverters), which introduce temporal harmonics to the system. This electrical energy is converted to magnetic energy, which in turn sets the rotor in motion, introducing spatial harmonics. This conversion is not 100% efficient and the losses that are incurred are realized as an increase in temperature in the electrical machine that needs to be reduced. Finally, the magnetic forces that cause the rotor to turn are the source of the stresses and strains across the machine that introduce noise and vibration. All physical properties – electrical, magnetic, thermal, stress, acoustic – need to be addressed by the design team.

Ansys has developed a simulation environment that enables seamless integration of these various physics problems to be achieved concurrently. By employing Ansys Workbench technology, a design engineering team can access the best-in-class single physics solvers, and integrate the solutions of these solvers (Figure 2).

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ONLINE READER ENQUIRY NO. 529

Whole vehicle integration

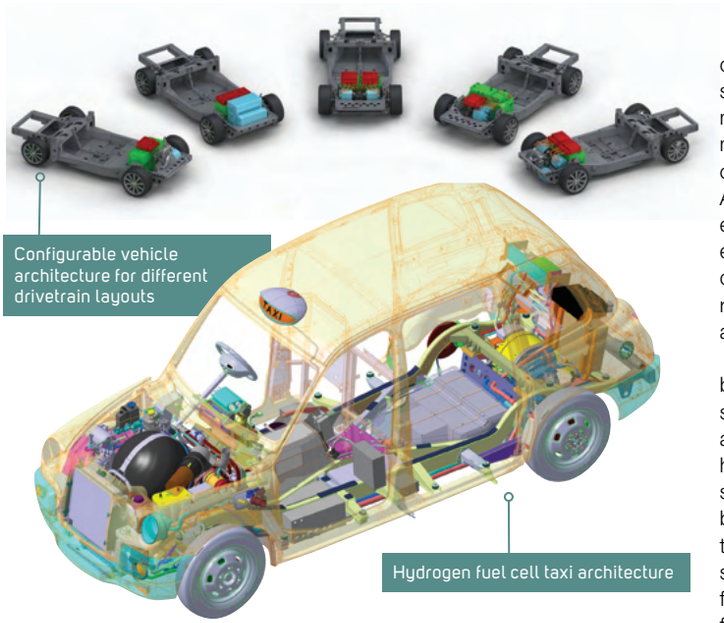
The time has come to design entire vehicles rather than develop components in isolation. It's a new and interesting approach that could optimize the entire engineering process

It is important to understand EV and HEV integration, especially regarding how hybridization affects other vehicle systems as well as ensuring that all the systems work together to improve safety and energy use. In 1975 Tony Rudd, technical director for Lotus Cars, commented, "The most elegantly effective and traditionally Lotus solution is the one with the least number of parts effectively deployed."

New systems will have different mounting points, different weights and other such factors to take into consideration. The battery pack, for example, can weigh hundreds of kilos and will need structural mounting to protect and restrain the battery. As such, mechanical durability should consider vibration and shock loadings throughout the lifetime of the vehicle.

It's easy to tell when an engine is over-revving but not when dealing with electric motors. The vehicle's ancillary systems tend to be intrusive as they're not masked by engine noise. There are also concerns for pedestrian safety with quieter vehicles.

Cell choice defines the first steps in the mechanical design of the pack. The mounting of the cells and electrical connections must allow safe assembly of the high-voltage battery. A BMS is required to ensure cells operate within defined parameters. Additionally, battery performance, safety and lifetime are all affected by temperature.



Lotus has developed software that explores the dynamic behavior of a vehicle when there are large changes, such as the addition of a 250kg battery pack. Wheel motors are an interesting development and Lotus has conducted a study that investigates how a vehicle behaves with increased unsprung mass.

There are also many cooling and heating requirements to consider. Though production solutions exist, an integrated approach provides a more holistic thermal management system.

Regenerative braking can recuperate energy to recharge the battery. If a high level of regenerative braking is desired, driveability is compromised. To solve this problem it's necessary to blend regenerative and friction braking. Lotus has used brake-blending techniques to enhance energy recuperation.

Conventional PAS uses engine-driven hydraulic pumps, whereas modern electric systems are now commonly referred to as ePAS. There are also eHPAS systems, where the hydraulic pump is driven by an electric motor. For some conversions, the most cost-effective route is potentially an eHPAS system, but production programs may need integrated ePAS.

Waste heat from the engine provides conventional heating but for HEV and EV applications, alternatives are needed. Lotus Engineering specifies a high-voltage water heater to provide heating.

The AC compressor is usually driven by the IC engine. Production solutions exist where a high-voltage motor drives the compressor, which means e-compressors are suitable only for EV and HEVs. Standard AC lubricating oil conducts electricity, making it unsuitable for e-compressors. In practice, dedicated AC filling equipment is required on the assembly line for EV and HEV applications.

Certain information that needs to be shown to the driver is mandatory, such as vehicle speed, odometer and warning lights. Graphic displays have evolved into sophisticated systems that provide interfaces between the driver and vehicle, and this technology replaces traditional switchgear systems. Additional functionality now includes energy flow graphics, DVD players, satnav, telephone and internet connectivity.

Control strategies can be varied, depending on the hybrid configuration, drive cycles, usage profiles and other similar data. These control codes are typically pre-determined but recent developments enable control strategies to be altered while the vehicle is being driven. External influences can modify strategies, optimizing for fuel consumption and energy use. Weather conditions, traffic flow and driving behavior could all be used and the availability of cloud-based data is one of the enablers to achieve this.

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ONLINE READER ENQUIRY NO. 530

Hall effect current sensing

A new line of fully integrated, galvanically isolated, Hall effect current sensor ICs has been created that provide highly accurate and low-noise-output voltage signals

Energy efficiency in HEVs and EVs is improved by converting belt-driven and hydraulic actuators to electrically driven actuators. This conversion enables engineers to power-down systems that operate continuously while traditional internal combustion engines are running, such as the fan-belt-driven cooling fan and power-steering pumps. Advanced current-sensor ICs provide the bandwidth, response time, measurement resolution and accuracy required to optimize motor and actuator systems, as outlined in Figure 1.

Hall effect current sensor ICs, such as those provided by Allegro MicroSystems, are small in size compared with sense resistor and operational amplifier solutions, as shown in Figure 2. These Hall effect solutions incorporate low-resistance conductors that minimize power loss and facilitate high-accuracy measurements that are required by HEVs. The Hall ICs also offer galvanic isolation for high- and low-side current sensing, along with factory programming at Allegro that results in uniform IC sensitivity and low offset voltages.

Charge current monitoring for smart battery systems requires monitoring of two battery terminals and typically includes two diagnostic signals, a single-wire data line for battery health, and a single-wire thermistor output for battery temperature monitoring. Integrated Hall effect sensor ICs simplify battery monitoring designs by relying on magnetic coupling, thereby eliminating the undesired dependence between the conductor resistance and current measurement accuracy that is unavoidable when using sense resistor-based current measurement solutions. Hall effect sensor ICs also provide extremely low conductor resistance (as low as 100μΩ), greatly reducing power dissipation and eliminating the excessive heat generated by sense resistors and operational amplifiers. Hall ICs improve the charging control of the battery system because there is practically no voltage developed across the conductor loop terminals, which helps maintain the integrity of the thermistor diagnostic signal and extends battery life.

Allegro MicroSystems has developed a line of fully integrated, galvanically isolated, Hall-effect current sensor ICs that provide highly accurate, low-noise-output voltage signals proportional to an applied AC or DC current. Allegro's proprietary integrated Hall effect devices employ advanced IC and packaging techniques for sensing current from 5A to 200A. Furthermore, Allegro current sensor ICs allow design engineers to use Hall effect based current sensor ICs in new EV and HEV applications where increased energy efficiency or new operating features are required. Wherever current sensing is needed, an integrated Hall effect IC can provide a solution.

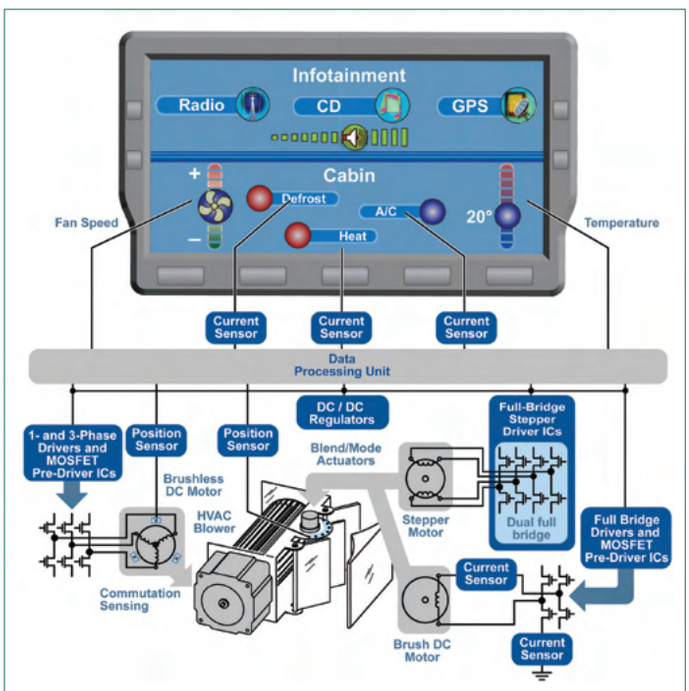

Figure 1: A detailed illustration of Hall sensing in power efficient electric actuators

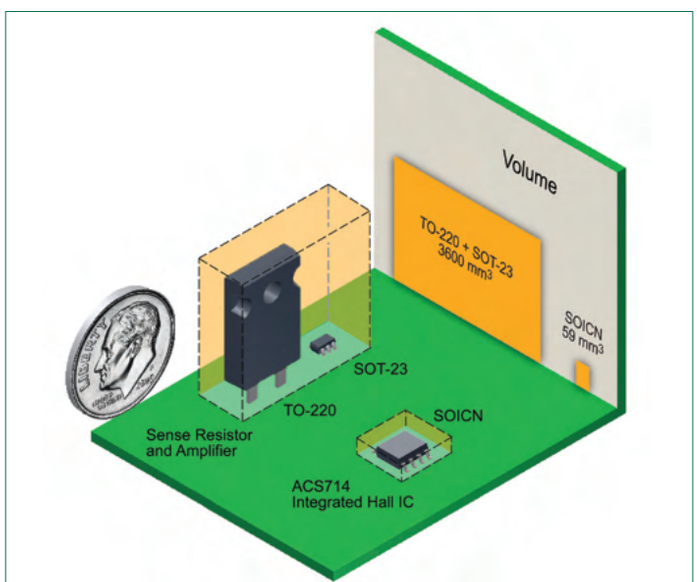

Figure 2: A comparison of the PCB volume requirements of the smaller Hall current sensor IC versus the sense resistor and operational amplifier solution

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ONLINE READER ENQUIRY NO. 531

Hybrid electric motor tester

The EPT-126 is a high-volume motor tester able to test various stop/start motor configurations, including integrated starter generators and belted starter generators

The EPT-126 is a high-volume motor tester that tests various stop/start motor configurations

A production tester for stop/start motor systems is the latest development resulting from D&V's 15-year history of advanced testing products. This equipment is fine-tuned and tailored especially for running fast test sequences within the end-of-line environment.

The EPT-126 is a high-volume motor tester that tests various stop/start motor configurations, including integrated starter generators and belted starter generators.

D&V Electronics testers enable new and current customers to capture real-time data and test their motors using methods that are not found in even the most advanced laboratory test systems. The internal tester components and controller from the PC are linked via a network connection for high-speed data transfer. This architecture provides expandability and high electrical noise immunity because of the excellent electrical insulation.

The heart of the system is the TwinCAT 3 engine from Beckhoff Automation. The real-time software package provides control over the hardware via industrial Ethernet protocol (EtherCat). This interface offers an array of advantages, including real-time performance – external events and I/O data can be processed as fast as 25-50µs; high speed – up to 100 distributed servo axes can be updated in just 100µs; and direct access to analog or digital I/O – there is no lower level bus or protocol.

D&V Electronics tester software provides an interface and functional background of the test system with positional control of the dynamometer motor, control of test devices, and viewing of test results with a digital oscilloscope in real time. The software is a Windows-based application with a simple user interface for top-level control functions. Lower-level scripting will also provide a more intricate method for programming, coding, and scripting of test procedures and specific functions. This will provide the functionality to control parameters precisely with timing and specific inputs.

There are multiple standout features that make this production tester an extremely reliable and unique product. For example, a soft-start retractable spline system has been developed, which assists in protecting against customer product damage. There is a product clamping assembly and a corresponding automated door system for safety. Operator safety is a paramount consideration when designing production-testing systems. Safety and takt time considerations also require a high level of programming in developing the interlocking and closure systems for the EPT-126 production tester. All of these efforts combine to secure the device under test safely behind guarding systems while running the full series of production evaluation tests, including proprietary D&V Electronics developed end-of-line tests.

D&V Electronics also provides sound and vibration evaluation testing for production test systems. The sound and vibration measuring option comes with a proprietary D&V signal-processing module that allows variable sampling frequencies and also outputs data suitable for numerous methods of characteristic wave analyses. This solution runs concurrently with the product evaluation of the tester.

D&V Electronics is leading the industry in end-of-line testing equipment for electric motors, belt starter generators and integrated starter generators, with production test systems in operation in Europe, North America and Asia.

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ONLINE READER ENQUIRY NO. 532

CV subsystem components

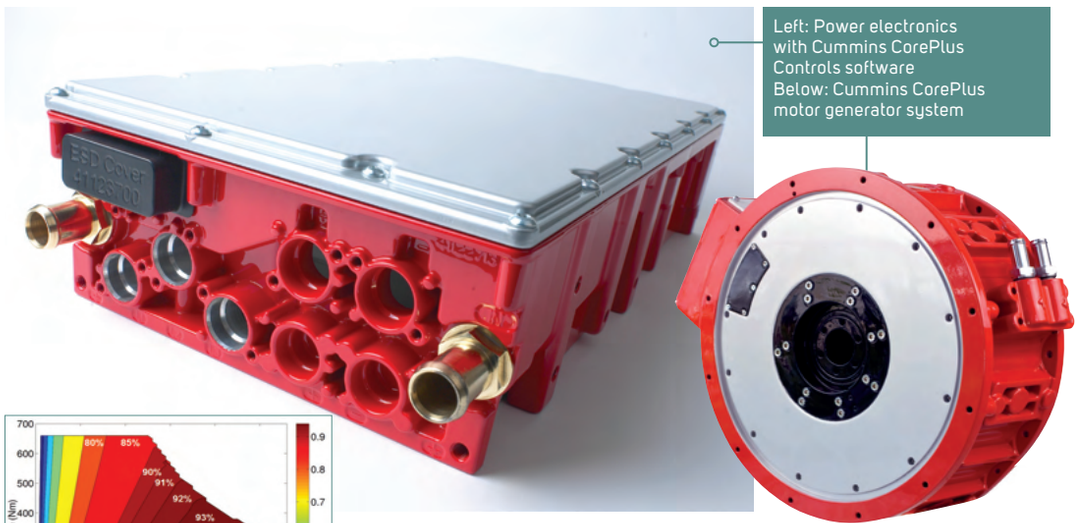
Commercial vehicle operators' concerns about greener trucks and buses could be allayed with the development of integrated hybrid subsystem components

Putting a hybrid drive in a commercial vehicle is hardly 'breaking news'. Europe's truck and bus makers have been developing diesel/electric chassis for years, so today they're no longer CV show talking points, but fully available production-line models, tried and tested by some of the biggest logistics, municipal and passenger transport fleets in Europe.

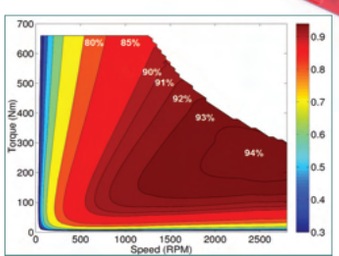
On paper, hybrids come with impressive credentials, especially in terms of cutting CO_2 and saving fuel, with OEMs regularly quoting reductions of up to 25% for both. By being able to use supplementary electrical power during a hybrid vehicle's launch phase, truck and bus manufacturers have the potential to remove one of the most fuel-thirsty stages in a vehicle's everyday operation.

Likewise, given the stop-start nature of inner-city delivery and refuse-collection trucks, as well as city-bus operations, using a regenerative braking system on a hybrid vehicle means there is plenty of opportunity to regularly top up its battery pack, further extending the use of the hybrid drive. Burning less fuel naturally means fewer harmful emissions too, especially in environmentally sensitive inner-city areas, where air quality is an increasingly major issue. Hybrid technology also provides large transport organizations with the perfect tool to demonstrate a clear 'green' strategy.

Yet despite all those obvious 'pros', many fleet buyers remain wary of hybrid trucks and buses thanks to 'cons' that include the additional weight of battery packs, vehicle servicing and reliability issues, technology durability uncertainties, and their additional cost.



Left: Power electronics with Cummins CorePlus Controls software
Below: Cummins CorePlus motor generator system



The Cummins CorePlus Hybrid Subsystem Components efficiency map

Cummins Generator Technologies' CorePlus motor generator, together with the firm's own controls software in the power electronics, will tackle those concerns head-on, both for OEMs and potential hybrid truck and bus buyers. Its compact design (168mm long) means the generator can be easily fitted between the engine and gearbox, with minimum disruption to existing drivetrain layouts.

Suitable for either parallel or series-hybrid drivetrains, its hollow rotor design fits any driveshaft configuration. And as its rotor casting has to handle the torque produced by the electric motor only (rather than the diesel engine), the overall weight is just 103kg.

By adding its own CorePlus power electronics inverter and controls software to the motor generator, Cummins Generator Technologies has been able to optimize performance and efficiency. The operating efficiency of the CorePlus generator, which has a maximum power of 90kW and a peak torque of 660Nm, is quoted as "greater than 95%". The latter is a particularly noteworthy point, explains Robert Lee, executive director, power generation strategy for Cummins Generator Technologies: "Efficiency is the single most important factor affecting a hybrid system's overall economic case, primarily through vehicle fuel savings.

"The higher the efficiency of the motor generator, the more energy is captured; so the hybrid drive can run for longer, thereby improving vehicles' fuel savings and reducing emissions even further."

By fully integrating the hybrid system with the rest of its hardware and software, Cummins has ensured new levels of safety as the motor generator and power electronics have full protection.

To help OEMs develop future hybrid systems, Cummins can also use custom simulation tools. For a given hybrid vehicle duty cycle, these can determine the best power, torque and performance requirements to deliver the best fuel and emissions savings. Furthermore, highly efficient low-cost solutions from the company's manufacturing site in China offer shorter payback on investment and rely less on government subsidies to promote adoption.

Lee concludes, "Working together, the CorePlus hybrid subsystem components offer a tightly integrated solution that improves performance, efficiency and system protection. We have the people and systems in place to work with OEMs to deliver the latest in engine electrification, anywhere in the world."

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ONLINE READER ENQUIRY NO. 533

Power electronics advances

The elimination of wire bonding technology has had an impact on the advances in performance power packaging for hybrid and electric vehicle semiconductors

Semiconductor companies often place huge importance on the improvements made on successive generations of silicon. This is all well and good, but in the world of power electronics, it must not be forgotten that high currents have to be routed to and from the semiconductor, and large amounts of heat extracted.

One of the fundamental methods for making an electrical connection to the semiconductor is wire bonding – several small links of wire attached to the surface of the silicon making the connection to the rest of the system. As Figure 1 indicates, this technology is highly established but has limitations in terms of reliability, cost and power density at high current levels.

A new solution in development for hybrid and electric vehicles using large amounts of insulated-gate bipolar transistors (IGBTs) and diodes in the main inverter is to eliminate the wire bonding by soldering directly to the silicon. CooliR²Die, as illustrated on the right-hand side of Figure 1, is one alternative. A fully tested, robust direct bonded copper carrier holds a 300A, 680V, 175°C-capable IGBT and diode complete with a pre-soldered surface that enables direct integration into a mechatronic assembly fitting to the customer's specific system.

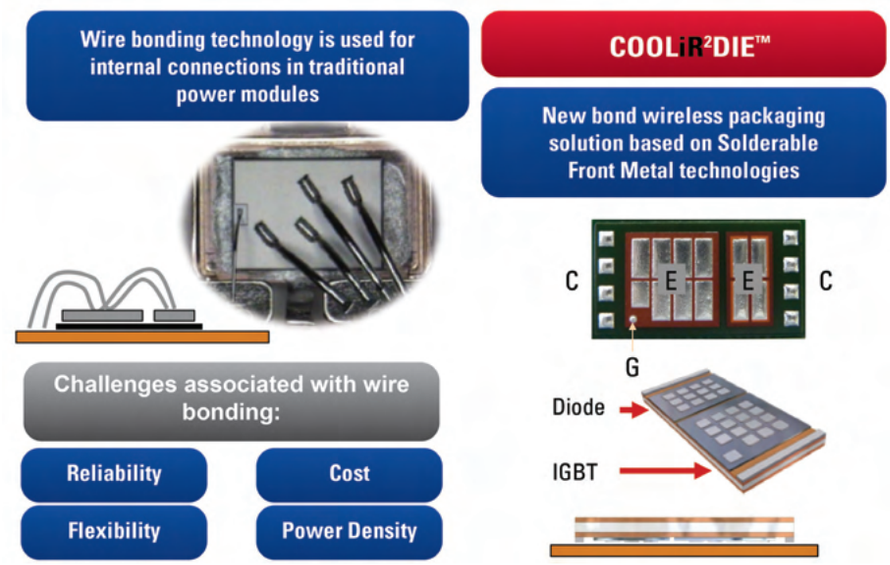

Figure 1: A comparison of traditional interconnect and new bond wireless technologies for EVs and HEVs

By eliminating the wire bonds, several advantages present themselves. Firstly, the cumbersome manufacturing step of wire bonding can be removed and replaced with a solder reflow process, improving yields and reducing manufacturing costs. The high inductances associated with the narrow wire bonds are also greatly reduced. Using the CooliR²Die technology, a 480A half-bridge module has been constructed with a loop inductance of less than 12nH (Figure 2). This enables smoother, faster switching, with reduced losses and fewer EMC challenges. At the same time this half-bridge configuration has a package resistance of less than 0.5mΩ; a 50% reduction on traditional wire bonded modules. A reduction of 0.5mΩ might not seem much, but with a phase current of 400A, such a reduction in package resistance results in a power saving of 80W per phase.

Furthermore, by eliminating the wire bonds on top of the package, both the top and bottom surfaces of the device can be used for cooling (Figure 1), improving current handling capability by up to 70%, and thus providing greater power density and efficiency.

As with any new technology, the consumer experience will either help or hinder adoption. In the automotive market, performance and reliability are essential. Although the torque provided by the electric motors gives a delightful 'wow' factor to the performance of HEVs, this must be accompanied by reliable operation. CooliR²Die was shown to achieve close to 1,000,000 active power cycles with a ΔTj = 85°C; roughly a ten-fold improvement in reliability over traditional wire-bonded modules.

Module	Rating	No. Phases	Weight (g)	A/cm³	Package Inductance (nH)	Package Resistance (mΩ)
Traditional Wire Bonded	650V /400A	3	485	8.8	30	1.0
				2X	0.4X	0.5X
COOLiR²Bridge™	680V /480A	1	225*	18.2	12	<0.5

*Weight for three single phase modules

Figure 2: A detailed performance comparison table of traditional wire bonded and CooliR²Die bond wireless half-bridge modules for main inverter applications

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ONLINE READER ENQUIRY NO. 534

Bidirectional charging

The advent of high-power bidirectional charging systems that restore batteries faster than Level 1 chargers could increase the adoption rate of EVs and PHEVs in the future

DRS has extensive experience in developing durable and high-tech bidirectional charging systems

EVs and PHEVs are the future of the automotive industry. In the coming decade, the transition to these vehicles in the commercial automobile industry will play a key role in reducing society's dependence on depleting oil levels, as well as improving the health of citizens and the environment, and creating a clean energy economy. Furthermore, these new vehicles will offer better performance with lower fuel and maintenance costs.

The main limitation to the accelerating adoption of these new vehicles has been their purchase cost, primarily due to the cost of lithium-ion battery systems. Although battery technologies are predicted to reduce costs and improve the performance and lifetimes of EVs, another less publicized technology will also play a critical role in the adoption rate of commercial EVs and PHEVs over the next few years – high-power bidirectional charging systems.

Tokyo Electric Power Company (TEPCO) conducted the first large-scale study on consumer behavior with EVs in the 1990s. A key finding of this study indicates that consumers and delivery fleet owners would use EVs for many more operational miles if charging cycle time could be reduced, along with the cost of the vehicle. EV and PHEV owners will typically install low power, <2kW (Level 1) chargers at their homes and will charge their vehicles at night during periods of low electricity demand. These relatively low power chargers require 8-22 hours to charge an EV and are limited by the residential 120 single-phase electrical infrastructure. This is adequate for typical consumer vehicle operation and is desirable by electrical utilities to create demand during relatively low night-time usage hours. Level 1 chargers can be installed as public networks in urban environments, but their slow charge times make them attractive only where the vehicle will be parked for many continuous hours.

High power, Level 2 (or higher) AC and DC chargers are advanced power conversion systems that use commercial grade power (240V/480V) and range from 2kW to >100kW. This class of device can charge vehicles faster than the time required for a Level 1 charger. The availability of high power chargers in the urban environment will accelerate both the number of EVs sold and the number of miles driven per vehicle.

A key feature lacking in most EV chargers is bidirectional power flow. It is desirable to enable bidirectional high-power charging systems to improve electric grid stability (frequency and power) and provide value-added, vehicle-to-grid (V2G) functions, which can help pay for EV and infrastructure costs.

Depending on the regulations in the local utility market, there is already an open market mechanism for V2G ancillary services in regulation and reserve reduction. This can provide incremental revenue to the EV charger/vehicle owner, who can provide these ancillary services at a lower cost than conventional fossil fuel. The primary challenges here are not technical, but regulatory, and in providing necessary real-time communication and control signals to the EV charger/vehicle owner.

An increasing number of defense industry technology providers with expertise in vehicle-based power systems have entered the EV/PHEV market with positive results. In particular, defense companies such as DRS are providing vehicle-based power systems to the commercial/industrial market. Historically, commercial vehicle-based chargers and converters have been a weak point of performance and durability on the EV/PHEVs. DRS has responded to that need with a rugged bidirectional charger that offers V2G capability at Level 2 charge rates and exportable power. The addition of exportable power for commercial and industrial EV/PHEV applications is a growing capability that provides additional utility to users. This option enables vehicles to provide high-quality AC output from the platform, and expands the flexibility of the power stored on board the vehicle.

DRS, a long-time supplier of mission-critical, highly durable vehicle power systems for the US Department of Defense, has successfully provided these products to the commercial market. The DRS patent-pending topology enables a low-cost bidirectional DC charger/inverter that matches traditional and high-voltage EV bus architectures. The DRS bidirectional charger/inverter is dramatically smaller, lighter and cheaper than conventional chargers. The DRS compact (single phase AC input) 15kW EV charger/inverter is lightweight and power dense, enabling easy integration into vehicle platforms.

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ONLINE READER ENQUIRY NO. 535

EV fuel cell components

As more heavy-duty commercial vehicles are fueled by renewable energies such as hydrogen, the need for a variety of components that can safely power these applications increases

There is no doubt that the development and use of renewable energies will steadily increase over the next few years and, together with its decentralization, eventually replace fossil-fueled power plants. Because of this green evolution in power generation, everything running on electricity will automatically become more environmentally friendly. Naturally this also applies to electric cars, whereas combustion engines will always require fossil fuels.

But what about hydrogen-powered vehicles? For certain applications, hydrogen is seen as the fuel of the future because it has a higher power density than modern batteries and refueling is just as fast as with fossil fuels. Although the well-to-wheel efficiency of these fuel cell vehicles is well behind that of battery electric cars, renewable energies will become a game changer once again, in favor of hydrogen production. This will be possible simply by using the surplus energy harvested by sun, tidal, water and wind power plants.

So, where hydrogen is the primary energy source of electric vehicles, which application makes the most sense? Certainly, heavy-duty vehicles, as found in the public transport and commercial vehicle sector, benefit the most from high power density and short refueling times.

The BDC546 DC/DC converter is primarily used in high-performance systems, such as fuel cell buses

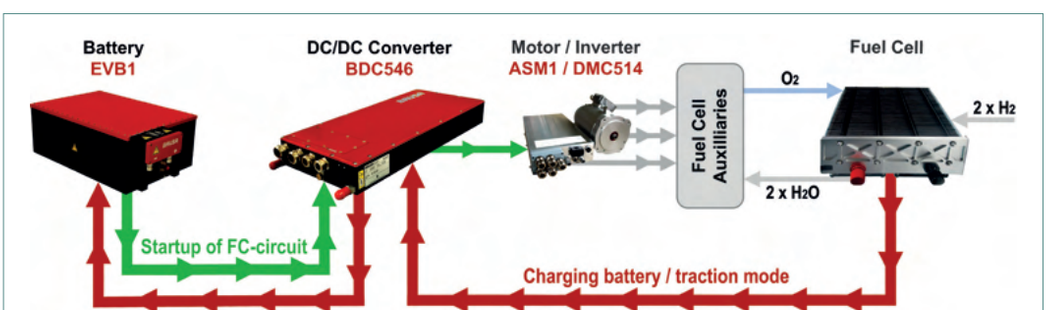
The zero-emissions Mercedes-Benz Citaro FuelCELL-Hybrid city bus is being used by public transport operator PostBus Switzerland (Source: Swiss Post)

Swiss company Brusa Elektronik – well known for its onboard battery chargers – has recently launched a new line of 750V drivetrain components to meet these heavy-duty requirements and complement its existing line-up of fuel cell auxiliary components. Being a developer and producer of motors and power electronics for electric vehicles for almost 30 years, Brusa claims to have an understanding of the complete vehicle like no other company in the field. This is certainly the case for fuel cell-powered vehicles and is apparent when taking a closer look at the product line-up; the portfolio ranges from controllers for fuel cell compressors, to DC-DC converters and power distribution systems.

Most impressive is the BDC546, which is a bidirectional 120kW DC-DC converter designed to act as a link between fuel cell, HV battery and drivetrain. Due to the wide voltage range, the BDC546 is primarily used in high-performance systems, such as fuel cell-powered buses. This compact DC-DC converter is realized with Brusa's proprietary SoftSwing technology. With this resonant switching topology, there are virtually no switching losses generated. This soft commutation technology leads to an outstanding electromagnetic compatibility, according to Brusa. The patented Liquid Pin system optimizes temperature behavior and cooling performance. Because of its versatility, the BDC546 can also be used in test bench applications or in combination with stationary transformers to realize a powerful DC fast charger.

Wherever possible, Brusa incorporates effective safety principles in its components, such as galvanic isolation and reinforced insulation, to ensure maximum electrical safety for the user and to protect the customer's investment.

Brusa Elektronik will present its solutions for fuel cell and battery electric vehicles at this year's eCarTec in Munich, from October 15-17, and at EVS27 in Barcelona, from November 17-20.



An example of high-tech and advanced Brusa Elektronik components and subsystems that are used in a fuel cell arrangement

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ONLINE READER ENQUIRY NO. 536

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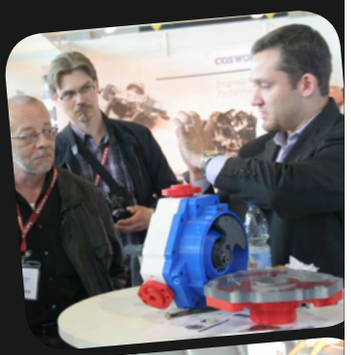

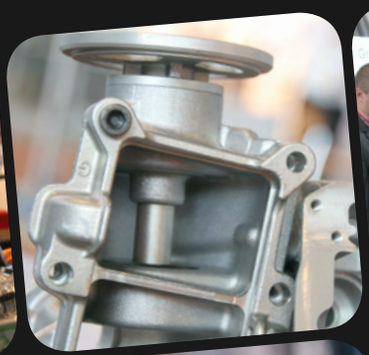

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Hybrid vehicle DC/DC and DC/AC converters

Arens' POWERPAC for medium- and heavy-duty hybrid vehicles provides true sine wave power for demanding truck, bus, agricultural and construction equipment environments. Available in air- and liquid-cooled versions, the POWERPAC's compact size improves power density and surge capacity, and has a continuous temperature range of -40°C to +65°C. A rugged die-cast enclosure is sealed to IP67/6K9K with a sealed fan, CAN communication, intelligent thermal protection and self-diagnostic capabilities.

The 4kW DC/DC converter delivers clean 12/24V DC power for traditional vehicle systems including lights, wipers, radios and other ancillary devices. The DC/DC converter delivers constant power from the hybrid battery, unlike alternators that require the engine to remain idling to supply power.

The 6kW DC/AC inverter converts high DC voltage to 120, 240 or 208 three-phase AC voltage, powering operator tools or recharging hand-tool batteries. The inverter is especially useful on medium-duty work trucks where the operator needs ancillary power tools to complete their job. Instead of mounting an auxiliary generator and carrying additional fuel, the DC/AC inverter delivers substantial power for hand tools and remote lights.

Arens
W: www.arens.com

ONLINE READER ENQUIRY NO. 537

Canada's clean electricity can power electric vehicles in Canada and the USA

The advent of EVs provides a unique opportunity to Canada in both reducing emissions from transportation and tapping into its vast reserves of clean and renewable electricity from hydro sources. According to a recent study by the Canadian Hydropower Association (CHA), the 360TWh/year of electricity currently produced by hydropower represents 60% of Canada's total electricity generation. The remainder comes from nuclear and combustible fuels. On a global basis, hydropower accounts for only 16% of electricity produced while 67% is represented by combustible fuels. Current Canadian plans call for adding another 25,000MW (124TWh) of hydropower and the CHA has identified the potential for a further 138,000MW of hydropower from sites across Canada.

A Canadian market penetration of 50% of light-duty vehicles by EVs would only consume 36.5TWh/year of power or about 10% of current annual hydropower production in Canada. Given the gradual growth in EVs, and the likelihood of more hydro sites being developed, Canada is well positioned to power its EVs with clean electricity. Canada regularly exports electricity to the USA and can dramatically increase its export of clean electricity. What's more, studies show that Canada's hydropower resources are enough to accommodate a 50% vehicle conversion into EVs on both sides of the border.

The CHA believes that developing further hydropower generating sites is both doable and desirable. It can contribute major reductions in emissions from electricity generation and transportation and lessen society's dependence on fossil fuels for transportation in both countries.

Electric Mobility Canada
W: www.emc-mec.ca

ONLINE READER ENQUIRY NO. 538

Charging ahead

More than 90% of all charging procedures will in future be completed at home or at work. Therefore, the creation of a full coverage e-charging station network – like that for petrol – is no longer the key issue. Of greater importance is the intelligent control of electricity sourcing during battery recharging. KEBA's KeContact enables the extremely comprehensive, finely tuned control of the charging process and thus efficient load management.

A variety of charging strategies can be established using KeContact, which allow a PEV to be charged in one hour or overnight. Should several PEVs or an entire vehicle fleet be connected to the wallboxes, it is possible to determine for each one how fast, at what time, and which vehicle should be charged, even in the case of vehicles that can only be charged on the basis of ISO 61851 Mode 3.

For cars that are charged according to ISO 15118, the control unit can provide an even more differentiated charging strategy through its linkage of the data of the vehicle, the owner or fleet management and the data of the power supplier, which is aimed at securing the most efficient and inexpensive charging procedure.

In order to avoid overloads, which, as a rule, constitute the most expensive electricity, KeContact limits the charge performance or shifts the charging point to a lower cost window. In coordination with the energy provider, the system automatically reduces performance peaks and smooths electricity intake, which, above all, saves costs.

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ONLINE READER ENQUIRY NO. 539

Tesla Motors boosts production capabilities with electrical design software from Mentor Graphics

Mentor Graphics has announced that electric car manufacturer Tesla Motors has standardized the Mentor Graphics Capital toolset for 12V electrical systems design.

After evaluating alternative solutions, Tesla concluded that the Capital toolset matched the two-key selection criteria: strong electrical system configuration control, and a well-established base within leading automotive wire harness suppliers. As production volumes grew, it became important to ensure robust, vehicle-specific data exchange with Tesla's wire harness suppliers.

The Capital toolset is a powerful electrical systems software environment spanning vehicle architecture, systems design and integration, service documentation creation, and wire harness manufacturing tools. Configuration management is a core strength of the Capital toolset, helping to ensure that delivered harnesses exactly match the feature set of each vehicle.

"Model S has very advanced electrical systems with tremendous configuration complexity," said Paul Lomangino, director of engineering applications, Tesla Motors. "It has been vital, during our ramp-up to full production, that the logistical integration and effective sharing of data with our suppliers was seamless. Capital software was able to overcome the challenges of configuration management and data exchange with our key suppliers."

Mentor Graphics
W: www.mentor.com

ONLINE READER ENQUIRY NO. 540

Guaranteed accurate hybrid/electric battery monitor

Linear Technology presents the new LTC6804 high-voltage battery monitor for HEVs and EVs, and other high voltage, stacked-battery systems. An LTC6804 can measure up to 12 series connected battery cells at voltages up to 4.2V with 16bit resolution and better than 0.04% accuracy.

This high precision is maintained over time, temperature and operating conditions by a sub-surface Zener voltage reference similar to references used in precision instrumentation. When stacked in series, the LTC6804 enables the measurement of every battery cell voltage in large high-voltage systems, within 800µs. Six operating modes are available to optimize update rate, resolution and the low pass response of the built-in third-order noise filter. In the fastest mode, all cells can be measured within 240µs.

Multiple LTC6804s can be interconnected over long distances and operated simultaneously, using Linear's proprietary two-wire isoSPI interface. Integrated into every LTC6804, the isoSPI interface provides high RF noise immunity up to 1Mbps and up to 100m of cable, using only a twisted pair.

The LTC6804 was designed to minimize power consumption, especially during long-term storage.

Linear Technology
W: www.linear.com

ONLINE READER ENQUIRY NO. 541

Serial production for high-performance lithium battery systems

AKASOL has been developing battery systems for EVs for more than 20 years. Since joining the Schulz Group in 2008, with a focus on high-performance battery development, the German company has become a supplier to many commercial and light vehicle OEMs, as well as marine and off-road powertrain suppliers.

Most of the clients who integrate AKASOL lithium-ion battery systems into their hybrid or full electric applications are convinced by the standardized, liquid-cooled lithium-ion based AKASYSTEM, which is available off-the-shelf in a wide range between 4kWh and 250kWh, with a high variety of voltage and power. AKASOL has also achieved a very high functional safety standard with ASIL and SIL certifications based on the battery system. This is one of the reasons why none of the battery systems, built in many different applications, has failed yet.

AKASOL
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ONLINE READER ENQUIRY NO. 542

Green speak

The sixth edition of the Macao International Environmental Co-operation Forum & Exhibition (MIECF) was held from March 21-23, 2013. This year's theme was 'Sustainable Cities – The Way Towards a Green Future', which continues MIECF's aim of being a platform to discuss sustainable city development and solutions for a low-carbon future.

The success of this year's MIECF was in part attributed to the more than 400 exhibiting companies from 24 countries and regions, and over 10,000 visitors. The green forum this year attracted 67 speakers and moderators from 13 countries and regions. Concurrent events such as the Green Business Matching, Green Public Day, and Technical Visits also drew the attention of many notable professionals in the environmental field.

Initiated and led by the government of the Macao Special Administrative Region (Macao SAR) and co-organized by the provincial governments in the Pearl River Delta (PRD)

and Hong Kong, MIECF is strategically positioned to nurture business, technology and information exchange and cooperation between the Pan-PRD Region in south China and the international markets. If you missed out on MIECF 2013, make sure to mark your calendars for next year's edition, which will be held on March 27-29, 2014.

MIECF
W. www.macaomiecf.com

ONLINE READER ENQUIRY NO. 543

OXIS strides forward in developing safer batteries

For the past 12 months, OXIS has been concentrating a large amount of research into improving the cycle life of lithium sulfur cells. In doing so, the company has adopted commercially available materials from well-established companies from across the world. Moreover, OXIS believes that by collaborating with leading specialized material manufacturers and exploring new technology with them, it can unlock the full potential of the chemistry.

OXIS is collaborating with world-class chemical companies to develop new polymer binders, carbon materials, electrode substrates and lithium salts, to get the best-possible performance improvement and drive toward a new generation of high-energy rechargeable batteries.

Unparalleled safety and ultra-light in weight are two key achievements to date.

GP Batteries of Singapore has signed an agreement with OXIS that will speed up the introduction of this remarkable technology in every imaginable energy sector. The expertise of both companies

will have a significant impact in powering EVs safely and over much longer distances than with the current Li-ion battery technology.

A company that has already chosen OXIS technology is Induct of France. Both its driverless, eight-passenger robotized shuttle, Navia, and its revolutionary, low-cost urban electric car, Modulgo, will eventually be powered by the OXIS batteries.

OXIS Energy
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W. www.oxisenergy.com

ONLINE READER ENQUIRY NO. 544

RO-LINX distribution systems

The increased electrification of cars is driving the need for reliable higher power distribution solutions in both powertrain and battery storage and interconnection. As long-term reliability in harsh environmental conditions, vibration and crash resistance are increasingly essential, Rogers Corporation's busbars have been successfully supplied into the industry for a few years now.

Many applications in an HEV require state-of-the-art power distribution solutions for challenging power electronics. A laminated busbar construction typically fits the motor drive and the converter applications when high current capabilities, compactness and 3D design are required. In energy storage applications, laminated busbars are used to interconnect the battery cells to provide compactness and flexibility.

RO-LINX PowerCircuit busbars and RO-LINX Hybrid are two

products in the RO-LINX family, custom designed to meet the mechanical and electrical needs, as well as integrated functionalities for the next generation of HEV market applications for both motor drive and battery applications.

Rogers' Power Distribution Systems Division is in a leading position to deliver solutions for power distribution and safe connectivity in the new era of HEVs.

Rogers Corporation
W. www.rogerscorp.com/pds

ONLINE READER ENQUIRY NO. 545

Sevcon motor controllers for Renault and Brammo

Renault has selected Sevcon to supply the all-important electric motor controllers for its groundbreaking new electric vehicle range – the Twizy ZE.

A Sevcon Gen4 Size 4 motor controller is used in the standard road vehicle and a Gen4 Size 2 unit is used in the smaller engine model. In both cases, the Sevcon Gen4 microprocessor-based controllers regulate the power delivery from the battery to the electric motor, to control the speed of the vehicle along with other engine and vehicle functions.

In addition to the Renault announcement, Brammo, a global leader in the electric motorcycle industry, is another manufacturer that has chosen Sevcon to supply motor controllers for its electric motorcycles.

The 160km/h Empulse features Brammo's unique integrated electric transmission (IET), which consists of a specially designed electric motor, clutch and six-speed manual gearbox. The IET gets its digital brainpower from Sevcon's Gen4 motor controllers, which enable

the motor, clutch and transmission to work together to replicate the acceleration, driving dynamics and overall performance of a motorcycle powered by an IC engine.

Sevcon
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W. www.sevcon.com

ONLINE READER ENQUIRY NO. 546

Power solutions for e-mobility

The most important requirement for setting up a modern EV charging infrastructure is a reliable and universal connection system for charging stations and vehicles. Phoenix Contact, a world leader in device connection technology and industrial automation solutions, offers the PLUSCON power line. This extensive portfolio of products and technologies enables the flexible, modular and efficient implementation of various concepts for charging infrastructure.

The PLUSCON charging connector system includes products for all the major interface standards, including SAE J1772 for North America, IEC 62196 for Europe, and GB for China.

No matter which standard is required, the PLUSCON power connector has a unique handle design. The handle is balanced with the cable to provide a lighter-weight feel compared with other designs. As a result of detailed attention to the design, the connector provides a reliable, durable EV charging interface.

For solutions inside the charging station, there is an extensive range of device connectors, cable assemblies and automation products, including the new integrated EV charge controller.

Over the past 90 years, Phoenix Contact has been at the forefront of industrial product innovation, offering solutions to meet the demands of interconnected power infrastructure for today and into the future.

Phoenix Contact
W. www.phoenixcontact.com/ev

ONLINE READER ENQUIRY NO. 547

Innovative power supplies

MTM Power has developed a special product line of onboard DC/DC converters with 400W and 600W output power for the dynamically developing EV market.

The PCMDS400/600-FT converter series covers an input voltage range of approximately 45-450V. To achieve the highest possible efficiency, it is recommended that users adjust the input voltage range precisely to the respective energy storage. An output voltage between 12V and 15V can be set with digital precision and is galvanically isolated from the input circuit by an isolation voltage of 2.5kV. The converters are continuously no-load and short-circuit protected. They can be switched into standby mode, in which the primary and secondary power consumption is negligibly low. This avoids discharge of the connected primary and secondary batteries in case the vehicle is stationary for longer periods. The

PCMDS400/600-FT series models also have robust die-cast aluminum cases. They are cooled via the base plate, for which the converter must be mounted on an appropriate heat-dissipating surface in the vehicle. The thermoselective vacuum encapsulation guarantees homogeneous heat dissipation within the modules, as well as an excellent resistance against environmental influences.

MTM Power
W. www.mtm-power.com

ONLINE READER ENQUIRY NO. 548

Platform control unit for electric powertrains

Specially developed for monitoring and controlling electric powertrains, the latest platform control unit from TTTech Automotive, called the electric Powertrain Monitoring Unit (ePMU), enables flexible integration together with power inverters and DC/DC converters for different power ratings and also allows for the integration of customer-developed software functions for different safety levels (up to ASIL D).

The hardware and software of the ePMU was developed in compliance with the functional safety standard ISO 26262 ASIL D. The powerful controller kernel of the ePMU was specifically designed for safety-related automotive applications. The ePMU provides interfaces to various actuators and sensors, but at the same time it is the central system interface to the communication network of electric and hybrid vehicles. Embedded in the overall vehicle safety concept, the ePMU prevents the drivetrain from behaving uncontrollably in various fault scenarios of the power inverter, such as unintended vehicle acceleration.

The core task of the ePMU is the accurate monitoring of the drive torque by means of constant comparison of the requested torque (set by the driver) with the actual torque at the driven wheels. A particular challenge is the safe detection of the rotation direction in the speed range close to vehicle standstill (0-2km/h).

Furthermore, the ePMU makes it possible to use OEM-, Tier 1- and Tier 2-specific software applications and basic software components that conform to the AUTOSAR standard or use existing (legacy) software.

TTTech Automotive
E. office@tttech.com
W. www.tttech.com/ePMU

ONLINE READER ENQUIRY NO. 549

Electric traction machines

Fischer Engineering Solutions is part of the Fischer Precise Group, one of the world's leading suppliers of precision spindles for machine tools. As a result of decades of experience with spindles and synergies for fast, precise and high-performance rotation, it is now possible to present a unique high-speed traction motor for electromobility.

With vast experience in bearing, motor and system technology in the high-speed range, Fischer Engineering has succeeded in developing a powerful, compact propulsion system for the automotive sector with peak power of 120kW at 18,000rpm and weighing only 22kg.

The synchronous reluctance motor achieves excellent efficiency across wide speed and torque ranges, with a simultaneously low mass moment of inertia. With the use and combination of various top technologies, a power density of 5.4kW/kg can be realized.

Furthermore, the customer-specific traction motors are built and tested in the company's own

precision production facility. This propulsion system has successfully proven its benchmark data on the test bench in a racing cycle simulation. The Fischer traction module FTM-120/18 is a propulsion module with a sophisticated design that satisfies the greatest demands in the electromobility sports and racing sector with minimal dimensions measuring Ø25 x 180mm.

Fischer Engineering Solutions
W. www.fischerengineering.ch

ONLINE READER ENQUIRY NO. 550

New compound for large cross-sections

In the scope of consistently expanding its product portfolio, an additional insulation material with excellent mechanical and electrical properties has been developed for use in Leoni's Hivocar cables.

Cables with large cross-sections (>35mm²) play an extremely important role in the area of alternative drives. Substantial power levels are transferred in a typical high-voltage cable harness for electric cars and hybrid vehicles. In order to enable this, the cables used must be appropriately dimensioned.

Past experience has shown that the required installation space for the routing of cables tends to be given little consideration. The final integration of cables frequently does not take place until the end of a development phase.

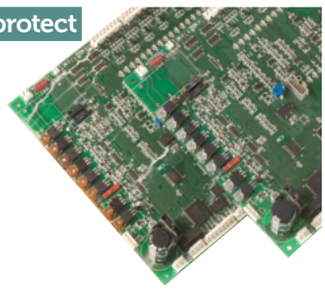
This is even more critical with the conversion of a car to hybrid drive, because the required space for the routing of the high-voltage cables was not originally planned for. Therefore the cables often have to be installed in confined cable channels, and the result of this is a requirement for lower bending radii and flexible cables.

In addition to an optimized geometry of the strands, the choice of insulation and sheath material has a key influence on the flexibility of the finished cable. Therefore, highly flexible silicones are already being used for T5/T6 (180°C/200°C) and irradiation cross-linked polyethylenes are being used in the T4 area (150°C).

With the development of Leoni's new flame-retardant compounds based on TPE-S for T3 (125°C), an additional material is now available for flexible cables that also meets the high demands of the high-voltage standard LV 216-2. For single-core shielded cables with cross-sections greater than 6mm², the material has already undergone extensive testing and is currently in use in the first cables.

Leoni
W. www.leoni.com
ONLINE READER ENQUIRY NO. 551

Parylene conformal coatings protect innovative technologies



What do most automotive electronic systems have in common? They must survive harsh automotive environments, high temperatures, corrosive fluids and vapors, and prolonged UV exposure. Electronic systems used in powertrain and fuel systems, in addition to emissions, lighting and fluid monitoring systems, continue to be designed in miniaturized, multilayer packages. In order for these systems to enjoy a long performance life, they must be protected.

Inert and pinhole-free, parylene conformal coatings are applied via a vapor deposition process in which the polymer film essentially grows a molecule at a time. As such, parylene coatings are lightweight, incredibly thin, and penetrate even the smallest of crevices, resulting in complete encapsulation. While parylene coatings have been used for more than 40 years due to their excellent chemical, moisture and dielectric barrier protection, engineers continue to find new applications that can benefit from the ultra-thin, pinhole-free protection the coating offers.

Parylene HT offers unmatched protection in high temperature environments (up to 350°C long term, 450°C short term), making it an ideal conformal coating to protect components such as MEMS, sensors, LEDs and circuit assemblies used in leading-edge automotive technologies. Parylene HT also provides excellent dielectric protection and superior UV stability. In conjunction with parylene coatings, SCS AdPro Plus and AdPro Poly are new adhesion technologies that improve adhesion of parylene to historically difficult substrates, including difficult metals, glass, plastics and polyimides.

Specialty Coating Systems
W. www.scscoatings.com
ONLINE READER ENQUIRY NO. 553

Shunt-based management system for Li-ion batteries

Isabellenhütte is a leader in the development of precise shunt-based measurement technologies. The new IB4 battery management system is designed for four-cell lithium ion batteries with individual cell voltages of up to 5V, and was developed in cooperation with the company's Braunschweig-based development partner I+ME Actia. It features 300A current measurement, 1,000A pulse, and highly precise resolution of 10mA, as well as a low measurement error range of just 0.4% of the measured value. The unit's power consumption is very low – 2.5mA when the master switch is on and 1.5mA when it is switched off. Numerous interfaces for communication, measurement value recording and control, allow the IB4 to be deployed flexibly. For example, two push-switch inputs provide the opportunity to query the state of charge at the touch of a button. There are various analog inputs, including those for the measurement of cell temperature, battery mode planning, total voltage, and hardware monitoring of cell voltages.

There are also control outputs for a bistable relay, five LED charge indicator displayed, as well as two optional low-side switching outputs for special applications such as heat monitoring. The IB4 from Isabellenhütte has an isolation voltage of 200V. The current sensor is a 100µΩ shunt.

Isabellenhütte
W. www.isabellenhuette.de
ONLINE READER ENQUIRY NO. 552

Safe and reliable lithium battery technology

Sinopoly Battery engages in production, sales, research and development of safe and reliable lithium-ion power batteries. With a main product range of 10Ah to 1,000Ah, Sinopoly batteries are capable of meeting the power supply and energy-storage needs of all customers.

It is commonly known that energy density is vital to achieving a reasonable driving range; and it is one of the most important factors in choosing batteries for HEVs and EVs. The high-energy-density Sinopoly batteries enable vehicles to have longer run-time and more reliable performance. Another factor EV manufacturers are concerned with is safety. The batteries have passed various safety tests, such as fire-endurance and high-temperature tests. They have also received certifications such as CE and UN38.3.

Sinopoly's lithium-ion battery cells and packs are applicable in various types of EVs, including pure electric cars, electric buses and electric motorcycles. Sinopoly has jointly developed a 12m electric coach, which can travel 270km on a single charge, with FAW Bus and Coach. The bus started operating in Jilin, China, in November 2011, after a satisfactory two-month trial run. The formulation of anode and cathode materials inside the battery delivers high power, excellent lifecycles, extreme temperature tolerance and a short recharge time.

With applications in many different fields, the battery cells and packs are sold to different customers across the whole world. Furthermore, Sinopoly Battery continues to be the safe, reliable way to maximize the performance of EVs.

Sinopoly Battery
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W. www.sinopolybattery.com

ONLINE READER ENQUIRY NO. 554

Axeon-powered electric Land Rover Defender research vehicles

Axeon, now part of the Johnson Matthey group, has supplied battery systems for an all-electric Land Rover Defender model unveiled at the Geneva Motor Show. The electric Defender has been developed for research purposes and is the first fully capable all-electric, all-terrain vehicle.

Having collaborated with Land Rover South Africa in 2011 on an all-electric Defender for use as a safari vehicle in game parks, Axeon has provided Land Rover with battery packs for a further seven development vehicles. These will enter field trials with selected partners later this year.

The bespoke 27kWh battery system replaces the standard 2.2-liter diesel engine in the Land

Rover Defender 110 models, thus eliminating tailpipe emissions. The 410kg battery is located in the engine bay area, enabling the all-electric Defender vehicles to retain their ground clearance and wading depth.

The battery system incorporates Axeon's proprietary BMS, which monitors the battery state as well as measuring and controlling key operational parameters, thus ensuring safety – particularly important for electric vehicles that may be subject to more challenging environments.

Johnson Matthey, a global specialty chemicals company, is continuing to invest in Axeon technology to make better batteries, improve battery technology, reduce cost and increase performance.

Axeon
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ONLINE READER ENQUIRY NO. 555

Electromobility solutions conference

Transportation as the world currently knows it may soon change forever, with hydrocarbon-based transport being touted as the way forward as fuel prices continue to rise and climate change fears continue to grow. Electromobility is the logical and sustainable solution to the challenges that the industry faces.

To succeed, deeper cooperation between all the players involved in the development of electromobility is required, as is the creation of a legitimate alternative that can convince customers. Also, the fundamental shift in the electricity grid that the mass adoption of electric vehicles implies needs to be ready.

Addressing such issues, EVS27 will gather academic, government and industry leaders from all over the world for four days in Barcelona, Spain, from November 17-20, 2013, at the Gran Via Venue, to transform mobility and its urban modality. Sharing experiences and knowledge in an environment where people also gain first-hand insight into the latest innovations will provide industry professionals with the necessary tools needed to overcome the challenges the market currently faces.

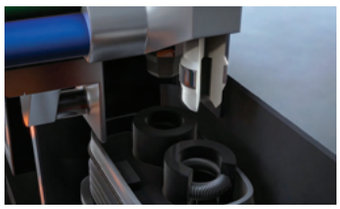
EVS27 – Electric Vehicle Symposium
W. www.evs27.org

ONLINE READER ENQUIRY NO. 556

Bal Seal canted-coil springs maintain critical connections in hybrids

In hybrid vehicles, the Bal Seal canted-coil spring makes and maintains critical connections to and from the lithium-ion battery array and other vehicle power systems. The springs' individual coils provide multipoint contact, thus ensuring consistent transmission of electricity to the motor during low-speed operation and reliable recharging of the array from regenerative braking systems. Depending on their placement, the springs can also shield the connector against the harmful effects of electromagnetic interference.

In the vehicle's external charging system, canted-coil springs help conduct electricity from a wall or base unit to the battery array. Capable of handling high current flow in tight spaces with minimal heat rise, these springs automatically compensate for misalignment and surface irregularities that may otherwise compromise charging efficiency. In alternative designs, springs can



be incorporated to ensure proper charger connection, as well.

With more than five decades of experience, a vast application knowledge base and certification to ISO/TS 16949, Bal Seal specializes in helping manufacturers develop breakthroughs that set industry standards, push the technology envelope and provide that all-important competitive edge.

Bal Seal Engineering
W. www.balseal.com

ONLINE READER ENQUIRY NO. 557

Lithium-ion battery solutions

REAP has been working in the field of BMS with large lithium-ion cells for more than 10 years.

The company's worldwide customer base consists of cell manufacturers, vehicle manufacturers and R&D institutions. Through REAP's strong combination of academic background, practical experience, battery and systems know-how, and its innovative approach to design, manufacturing and management, the company is in the perfect position to provide a complete solution for any lithium-ion battery project.

REAP is based on an excellent knowledge and understanding of lithium-ion batteries and continued product development. In 2013, the company launched its latest BMS products, including BMS21, which manages up to 21 battery cells.

Several battery management systems can be connected in series to manage high-voltage systems. In comparison with its predecessor (BMS14), BMS21 has simplified connections, a range of new functionality, plus other key improvements, including very low power consumption and datalogging.

A new battery control unit has also been developed, featuring onboard isolation testing and onboard pre-charge, thus minimizing the need for bulky and expensive external components.

REAP offers custom battery solutions and complete project services using its own versatile and parameterizable BMS products and excellent support from its engineers with extensive practical experience of system integration and trouble-shooting.

REAPsystems
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ONLINE READER ENQUIRY NO. 558

Choosing the right technology to profit from charging plug-in hybrid and full electric vehicles

Today, nearly all car manufacturers around the globe are developing electric and hybrid vehicles to satisfy the increasing demand for cleaner and more sustainable cars.

As such, plug-in hybrid and full electric vehicles need to be 'refueled' or charged. These new, eco-friendly vehicles need fast-charging locations just like petrol cars, so that it is possible to extend their total driving range as quickly as possible. A fast-charge takes around 20 minutes, which means a busy charging location might have 30 to 40 electric vehicles charging en route to distant destinations.

Electric vehicles and plug-in hybrids can be fast-charged just about anywhere, meaning businesses can offer drivers products and services while they wait for their EV to charge – an important aspect to keep in mind when thinking about EV charging and the creation of a fast charge infrastructure.

Another opportunity that's important to note is driver destination. People typically spend between one and two hours shopping, eating, enjoying a show, keeping fit or having a meeting, during which time their plug-in hybrid or electric vehicle can be fully charged.

This equates to up to 20 cars per day – but the correct cost-effective charger is needed for this to work effectively. For example, this isn't the case for the slow-charging infrastructure, where only one to two electric vehicles can be charged per day.

Most importantly, charging standards for electric vehicles and their related services are only now becoming established, so choosing the right type of charger in the right location with the right up-time, combined with an insight in user statistics, will give a return on investment. Get it right and it is possible to be in profit in a couple of years' time.

ABB
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ONLINE READER ENQUIRY NO. 559

Environmentally friendly AWD solution for electric and hybrid vehicles

BorgWarner's electronically driven all-wheel drive (eAWD) system for electric and hybrid vehicles provides all-wheel drive traction and stability without adding the weight and driveline losses that reduce fuel economy and increase emissions.

The electric all-wheel drive combines AWD and hybridization into one compact robust package for hybrid and electric vehicles. Core units of the system are two electric motors, one of which provides propulsion torque to the rear wheels through a planetary gear arrangement on each side.

To improve lateral dynamics, a much smaller (1/10) second electric torque vectoring motor adjusts the differential torque left to right between the rear wheels on a balance shaft that is not rotating when there is no differential speed between right and left wheel. Therefore, vectored torque can be applied independent of vehicle speed, delivering increased stability with remarkable vehicle dynamics.

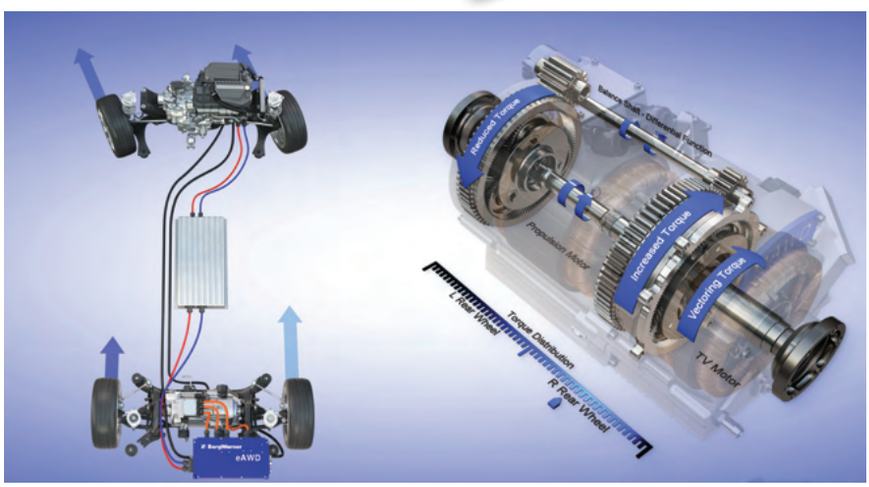
To further improve both stability and vehicle dynamics, the system offers an optional built-in torque vectoring function. Compared with conventional mechanical all-wheel-drive systems, the always-active eAWD system can reduce fuel consumption by up to 25%.

The torque vectoring concept can be applied in a mechanical driveline, where the propulsion motor is replaced with a conventional driveline. By upgrading the propulsion motor, the system can also be used in plug-in hybrid vehicles or battery-powered vehicles.

The eAWD system uses, by default, an oil-cooling concept integrated with the lubrication system that can be complemented with air- or water-cooled heat exchangers for use as high-power versions.

BorgWarner
W. torqtransfer.borgwarner.com

ONLINE READER ENQUIRY NO. 560



Ultracapacitors improve stop/start

As more consumers embrace electric and hybrid vehicles, manufacturers are bringing more energy-efficient and environmentally friendly designs to market. The stop/start technology in micro-hybrid vehicles is critical to their power and performance, and manufacturers are working to increase vehicle efficiency by improving characteristics of the battery system. Lithium-ion batteries are a popular option because they have a high energy density, but they do have a downside.

Choosing the right combination of energy storage and power delivery solutions – for instance, manufacturers are combining ultracapacitors with batteries – means automotive systems can capture and store regenerative braking energy more effectively.

Ultracapacitors perform reliably through a million or more charge-and-discharge cycles, leading to less maintenance, lower costs and fewer discarded parts in landfills. Ultracapacitors also perform reliably at temperatures from -40°C to 65°C, and possess the low internal resistance and high power density that manufacturers need to ensure micro-hybrids deliver power instantaneously. Idle-stop and recuperative systems shut down electric vehicles at red lights or installed traffic, and then use ultracapacitors to provide a short burst of energy to restart the motor. Ultracapacitors also play a significant role in regenerative braking systems and in powering acceleration, power steering, electrical systems, starter systems and boardnet stabilization.

By absorbing these power peaks, Maxwell Technologies' ultracapacitors offer a green, maintenance-free way to enhance battery life, increase vehicle reliability, reduce weight and deliver micro-hybrids that meet consumer demands.

Maxwell Technologies
E. sstrohmayer@maxwell.com
W. www.maxwell.com

ONLINE READER ENQUIRY NO. 562

ATC New Technologies teams with Bitrode for industry EV challenge

Since launching ATC New Technologies two years ago, Dirk Spiers has been single-handedly changing the way the industry thinks about battery lifecycle management.

Now, Spiers wants to change the way it drives.

This summer, ATC NT and suppliers Bitrode and Sovema Corporations will kick off a joint EV Industry Challenge – a campaign to encourage those who supply or work in the EV industry to drive electric vehicles.

The idea was hatched six months ago when Spiers complained to Laura Schacht, Bitrode's global marketing director, that so few colleagues in the industry are driving EVs.

"Why aren't you driving one?" Spiers asked her. "Well, why aren't you?" she shot back.

Both parties purchased Volts and, delighted with their EV experience, decided it was time to encourage colleagues to do the same.

"We have an entire ecosystem of suppliers who have opinions about cars they want to make money out of, but they won't buy them," says Spiers. "These are great cars, a rock-solid technology that needs our support to succeed. You need to eat your own dog food. Would the boss of Apple buy a Windows PC? I have never seen a vegetarian butcher."

Plans for the EV challenge include an interactive website that will serve as a platform by which participating companies can network with pro-electric vehicle organizations such as Plug In America, EDTA and participating OEMs, to promote the adoption of EVs throughout the very industry that makes them.

"This is really a challenge of conscience," says Spiers. "The revolution starts with us. If we want this to take off, we have to start with ourselves."

Bitrode
E. lschacht@bitrode.com
W. www.bitrode.com

ONLINE READER ENQUIRY NO. 561

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Regenerative type direct current power supply

The pCUBE unit is the ideal regenerative type direct current power supply to test the charging and discharging cycles of lithium-ion batteries. A maximum of 24 pCUBE units can be interconnected in serial and/or parallel mode as required by the user. With this feature, battery modules and battery packs can also be tested. The unit is programmed to achieve a quick response during current variations and responds with high precision.

With the use of high-speed digital control technology and a high-frequency insulation method, size and weight reduces by one-third in comparison with other products of similar capacity. This regenerative power supply combines two functions – power supply and electronic load – which helps to reduce running costs.

In order to respond to the testing of charging and discharging cycles of lithium-ion batteries for vehicle use, the unit is programmed to detect and react to current variations in very quick time. In addition to this, the unit also operates with high precision (0.1%V and 0.2%A).

Myway Plus Corporation
W. www.myway.co.jp

ONLINE READER ENQUIRY NO. 563

Extending lithium-ion battery life in series hybrid systems

Obrist Powertrain, an Austrian technology company with offices in the USA, is focused entirely on hybrid powertrain and battery technology. Its declared target is to radically improve the affordability of plug-in hybrid vehicles.

The company's new plug-in chargeable lithium-ion battery pack is ready for mass-production and offers an industry benchmark with its cost of US$388 per kWh and its extended lifetime. This ambitious cost target was achieved with the use of standard 18650 cells and by accelerating the assembly process. Due to a novel mounting and cell-fixation system, practically no cables are required to connect the cells.

Research has shown that cooling on the single cell level is of critical importance to achieving an extended battery life in demanding series hybrid applications. Accordingly, the patented system contains a number of innovative control and design features to ensure the highest safety and reliability standards are achieved.

A vehicle-integrated thermal management with interfaces for cooling and heating keeps the temperature within the lithium-ion comfort zone of 20-25°C. The liquid cooling of the battery allows for tight control and homogenous distribution of the cell temperature (max ΔT = 2-3K). Perfect monitoring is implemented through a central master controller and distributed control units.

Obrist Powertrain
W. www.obrist-powertrain.com

ONLINE READER ENQUIRY NO. 565

High efficiency 50kW drive system for e-mobility applications

Kolektor has unveiled its new high-efficiency 50kW drive system targeting e-mobility applications. Drive consists of a high-performance KM-400/50 motor-generator and KMC-400/230 electronic controller, which can run in motor or generator mode. Units can be offered as a kit, or as separate parts.

The KM-400/50 motor is based on robust radial flux brushless technology with continuous output power of 50kW at 7,000rpm, where it exhibits over 96% efficiency. Designed as a liquid cooled motor, it places special attention on the aggressive cooling of media such as salt water. When taking into consideration e-mobility applications, special attention is given to the construction of a vibration-tolerant solution. The unit is also equipped with integrated temperature and position sensors.

The KMC-400/230 electronic controller supports the electric requirements of the motor-generator. It can operate in range of 50-420VDC, while delivering a motor current of up to 250A per phase. The controller is delivered in an IP67 rated enclosure.

Kolektor
W. www.kolektor.com

ONLINE READER ENQUIRY NO. 564

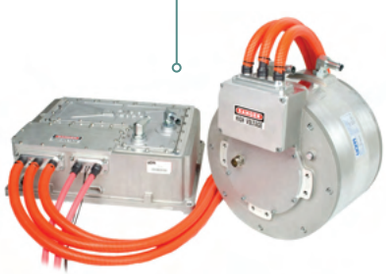
UQM PowerPhase technology

UQM Technologies brings over 35 years of experience to vehicle electrification, developing and manufacturing power-dense, high-efficiency electric motors, generators and power electronic controllers, primarily for transportation applications.

UQM Technologies' proprietary PowerPhase technology has been specifically developed to deliver high levels of torque efficiently at variable rotational speeds, transitioning from high torque to a relatively constant power curve as the rotational speed increases. Systems include an electric motor and controller combined to work together to further enhance efficiency, and UQM offers them with a range in peak output from 50kW to 220kW. UQM PowerPhase systems have high operating efficiencies and high power density, achieving smaller external dimensions and lower weight than competing products.

These PowerPhase systems can be used in full electric, hybrid and range-extended powertrain applications. The company's state-of-the-art facility can build 40,000 systems per year and is ISO 9001 certified. UQM has full development and testing labs in the same facility.

UQM PowerPhase products have been used to power a diverse variety of vehicle types. These include all-electric passenger vehicles and commercial vehicles.



UQM Technologies
W. www.uqm.com

ONLINE READER ENQUIRY NO. 566

Software for component and system temperature control

Control of component and system temperatures remains one of the most significant challenges in the design of electric machines because excessive thermal loading limits the maximum performance of an electronic device and significantly increases the energy footprint of the system. Deploying simulation in the early stages of the design process avoids expensive redesigns as the machine nears production and ensures optimal designs are chosen.

Star-CMM+ in combination with Speed is an integrated toolset for virtual prototyping of electric machines and delivers the power of integrated fluid dynamics and heat transfer simulation technology.

Speed has been in the business of electric machine designs for a quarter of a century and has been successfully used in the design of thousands of products. Based on a deep underlying theory of the electric machine, it calculates almost all aspects of design in an efficient way. Speed is also capable of contributing geometry and heat loads to STAR-CCM+, allowing for a full flow and thermal analysis of the electrical device.

STAR-CCM+ has a solver for magnetic vector potential, which operates in stationary and transient mode and couples to electrical potential solver for electromagnetic problems. This capability, when coupled with the existing models – namely fluid flow, heat transfer and structural mechanics – enables the electromechanical, thermal and structural analyses to be carried out from the same model. This enables simulation engineers to accurately visualize the performance of electric machines at the edge of their operating envelopes.

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ONLINE READER ENQUIRY NO. 567

High dynamic battery simulation

The high dynamic test bench energy system from Heinzinger Electronic's energy recovery system (ERS) series was one of the most interesting technical solutions for visitors interested in electric powertrain testing at Automotive Testing Expo 2013.

With more than 50 years' experience in power supply development, design and manufacturing, Heinzinger Electronic has created a battery simulator that differs from most others on the market. One of the key features of the system includes its outstanding high dynamic behavior.

Other systems often require 50Hz transformers on the input for galvanic isolation between load and grid. Due to this construction, dynamic performance is limited. However, Heinzinger Electronic's ERS uses switch-mode technology with high-frequency isolating transformers for galvanic isolation. Together with the phase shift design, the fastest regulation for source and sink operation is possible.

Accommodating the actual needs of the test bench, units are available off-the-shelf in voltage classes of 600V or 1,000V and with system power of 120kW and 160kW. By using multichannel outputs, it's possible to keep the energy in the output loop. Each channel is capable of doing 240kW – much more than the origin system power.

Heinzinger Electronic has designed a 2013 special edition ERS, which is available from stock and includes many of the features for battery testing or battery simulation applications, as well as for DC converter test stands.

Heinzinger Electronic
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ONLINE READER ENQUIRY NO. 568

Dalroad achieves TE connectivity authorized distributorship status

Components specialist Dalroad has been awarded Authorised Distributor status by global leader TE Connectivity (TE) for its hybrid and electric mobility solutions product line.

Built specifically for hybrid and electric vehicles to provide years of efficient operation, the shielded electrical components and systems are designed with low mass for improved power-to-weight ratios and engineered to endure extreme temperature variations, continuous vibration and long service intervals.

Now available off-the-shelf or as specials direct from Dalroad, the TE Connectivity range includes low-medium- and high-voltage terminals and connectors, contactors, relays, sensors and smart chargers.

Dalroad managing director, David Chinn-Shaw, says, "We are naturally delighted to have been made an Authorized Distributor for TE's Hybrid & Electric Mobility Solutions. As an added-value component supplier, Dalroad has, over the years, built a reputation for quality solutions, service and technical support, and this appointment by a world-class manufacturer underpins our continued commitment to providing our customers in the automotive industry with the very best products available."

In addition to the automotive industry, Dalroad also provides electromechanical, automation and control components to the industrial, automation and electronics sectors.

Dalroad
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ONLINE READER ENQUIRY NO. 569

Battery management in vehicle electrification

The GRX-5000 EV Battery Module Diagnostic Station is a platform first created for Nissan's Leaf program. It can perform both battery module balancing and diagnostics, enabling OEMs to implement a more cost-effective battery pack service strategy.

An alternative strategy, supported by the GRX-5000, is to design and build the battery pack with removable modules so that service can be performed below the pack level. Here, a pack with an issue could be removed from the vehicle and disassembled to the required module level. To confirm that the vehicle pack will function correctly with the replacement module, the GRX-5000 performs a balancing function to ensure it matches the correct state of charge/state of health for the given pack.

The GRX-5100 diagnostic station has been designed to perform full pack service, including balancing, full discharge and diagnostics, or as a jump-start unit for either NiMH or lithium-based hybrid vehicles. It can perform a full pack discharge, so that damaged packs can be discharged to a safe level prior to vehicle storage, and can perform safety checks, diagnostics and discharge, whether a pack is in or out of the vehicle.

The HYB-1000 Hybrid Battery System Analyzer is a diagnostic tool for hybrid battery packs that enables the user to perform a driving test while connected to the vehicle onboard diagnostics system. Sensor measurements from the vehicle during acceleration and braking are used to analyze the battery pack under stress and report its state of health. The HYB-1000 can also read and reset battery-related trouble codes.

Midtronics
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ONLINE READER ENQUIRY NO. 570

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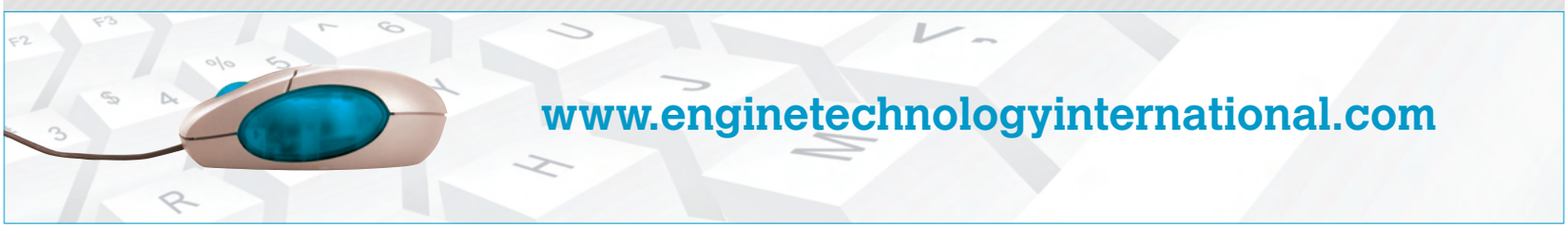

LAST WORD

Despite all the recent fuel cell joint venture development announcements, there has been a lack of new hydrogen vehicles coming to market, with the last significant offering being Honda's FCX Clarity launched five years ago

GREG OFFER

Dr Gregory Offer is a research fellow at Imperial College London, based in the Department of Earth Science and Engineering. His pioneering research focuses on such sustainable transportation aspects as fuel cell, battery and supercapacitor technologies

Anyone with some experience working with fuel cells and hydrogen should be familiar with the highs and lows of the hype cycle – from the excitement of the 1990s, when fuel cells were just 10 years away from saving the world, to the lows of 2009 when the Obama administration tried to slash US Department of Energy funding for the technology in favor of electric and hybrid vehicles. Much can be said about these hype cycles, but one thing is certain: they can be hugely damaging for research into new technologies, where innovation requires sustained support over many decades. But that's not how politics works, and the underlying challenge for those operating in R&D arenas has been to sustain such research programs during the good times and the bad.

There is a lesson from history here for the EV world: there is always a crash after a boom, so be prepared, and considering some of the promises that have been made on behalf of EVs, I predict a correction will come.

In contrast, the derision of fuel cells and hydrogen has bottomed out and we seem to be experiencing a resurgence of interest. One of the most promising signs is the consolidation between some major players, such as the Ford and Daimler alliance with Ballard and the spin-off Automotive Fuel Cell Cooperation venture, which has been extended to share information with Nissan. Additionally, BMW recently announced plans to license Toyota fuel cell technology to build a prototype in 2015. With fuel cell vehicle launches scheduled by all the major players for 2015/16, it seems they have decided the best way to deliver on the promises made a decade ago is to work together in the present.

> "Hopefully, within three years, the industry can blow away the hydrogen and fuel cell skeptics"

Parallel to the supplier/OEM tech challenge to fuel cells is the development of a refueling infrastructure – and here, too, the major players have been working tirelessly. By agreeing to synchronize their launches in clusters around the world (Japan/Korea, California, Germany/UK), the intention is to avoid a chicken and egg problem in the first few years of market launch when there will only be tens of thousands of fuel cell vehicles by achieving a local density of customers that will persuade investors and governments to build the infrastructure. To be the first solo mover in this case seems to be a disadvantage, but there does genuinely seem to be an alliance of vehicle manufacturers and refueling providers coming together globally with a credible plan to make success a reality.

However, that all said, we haven't seen any new fuel cell vehicle launches in recent years. Probably the best-publicized vehicle is the Honda FCX Clarity, although it is now five years old and there are only 200 available in California. So are we going to see a host of new fuel cell vehicles being launched over the next year or two? I hope so, and I eagerly anticipate some strong contenders from Toyota, GM, Nissan, Daimler and Hyundai-Kia, to name a few. Hopefully, within three years, the industry can blow away the hydrogen and fuel cell skeptics, and once and for all get rid of the annoying cliché "they always have been and always will be 10 years away".

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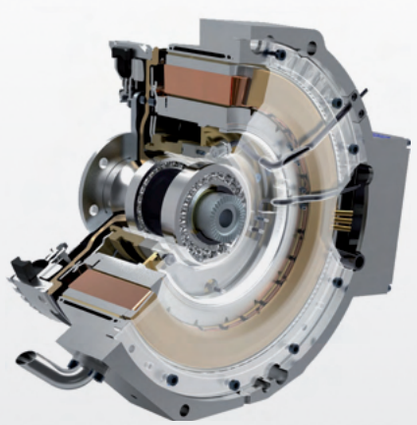

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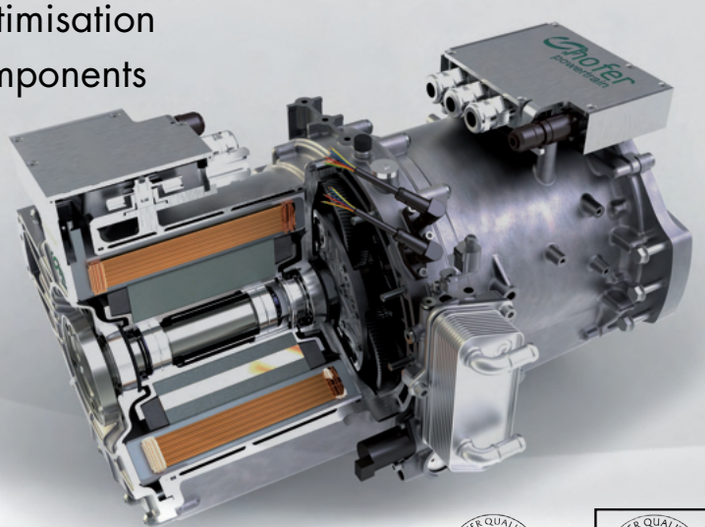

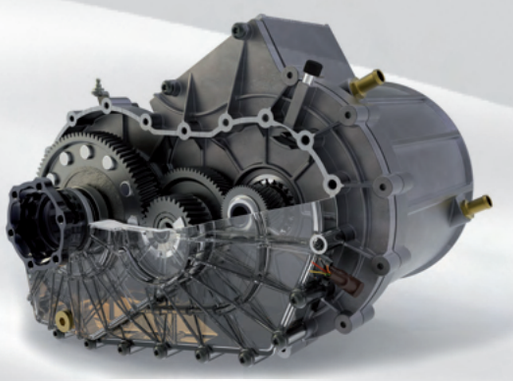

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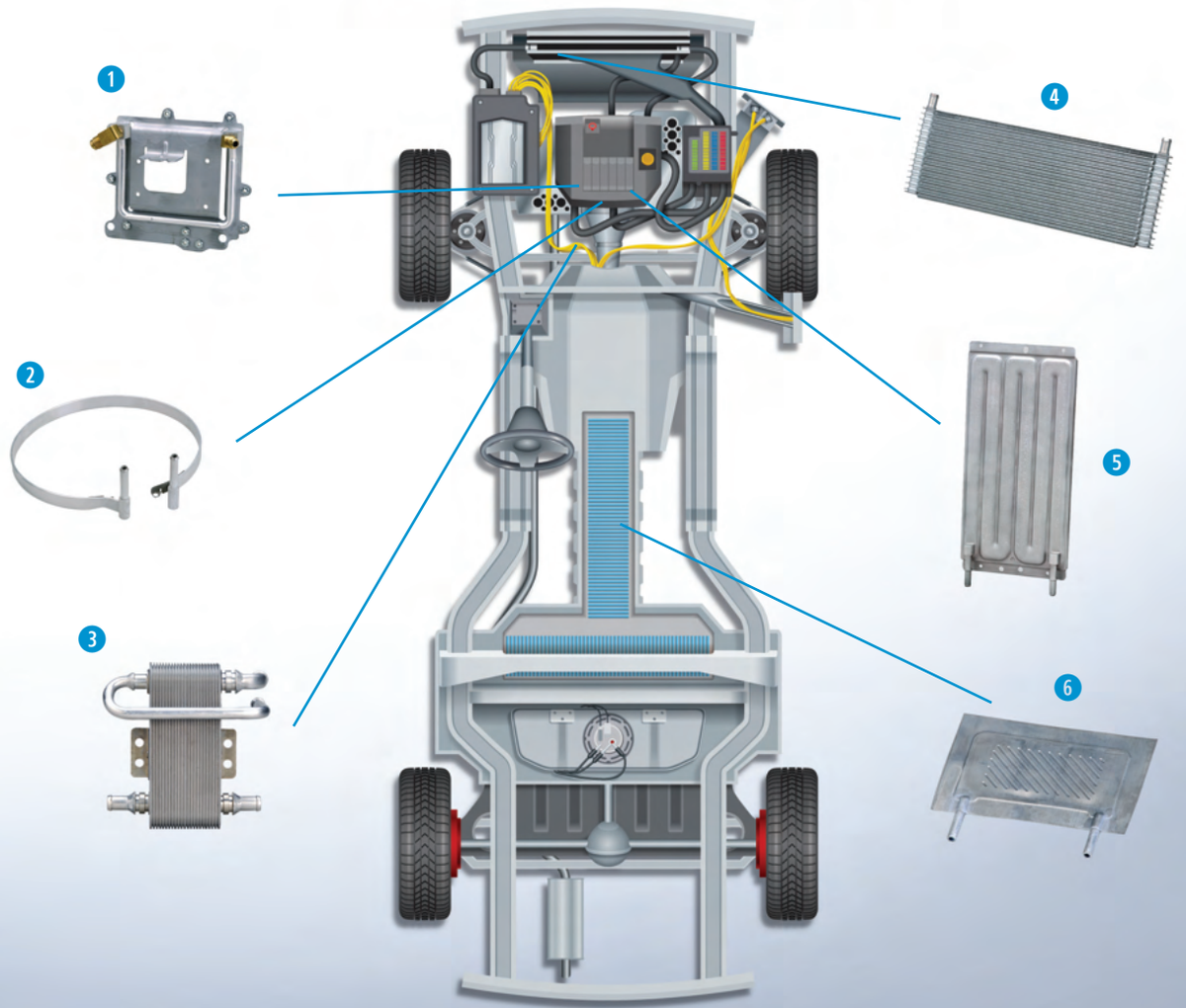

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