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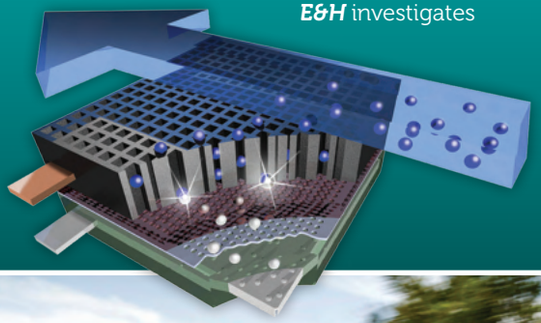
CELL-BY DATE

As battery R&D pioneers fast-track new designs, is time already up for lithium-ion technology? ***E&H*** investigates



January 2013

Spark of genius

With plenty of power, performance and range, the Tesla Model S can easily compete with Detroit's V8 muscle cars. And the Californian company's CTO, J. B. Straubel, tells ***E&H*** there's much more to come

January 2013

BENTLEY BOY

The largest producer of W12 engines is going down the plug-in hybrid route. Engineering head Rolf Frech reveals why

BOX CLEVER

Audi unveils a novel dual-mode hybrid study that's now entering prototype testing

RANGE FINDER

Behind the scenes at Fisker Automotive, with chief powertrain engineer Paul Boskovitch

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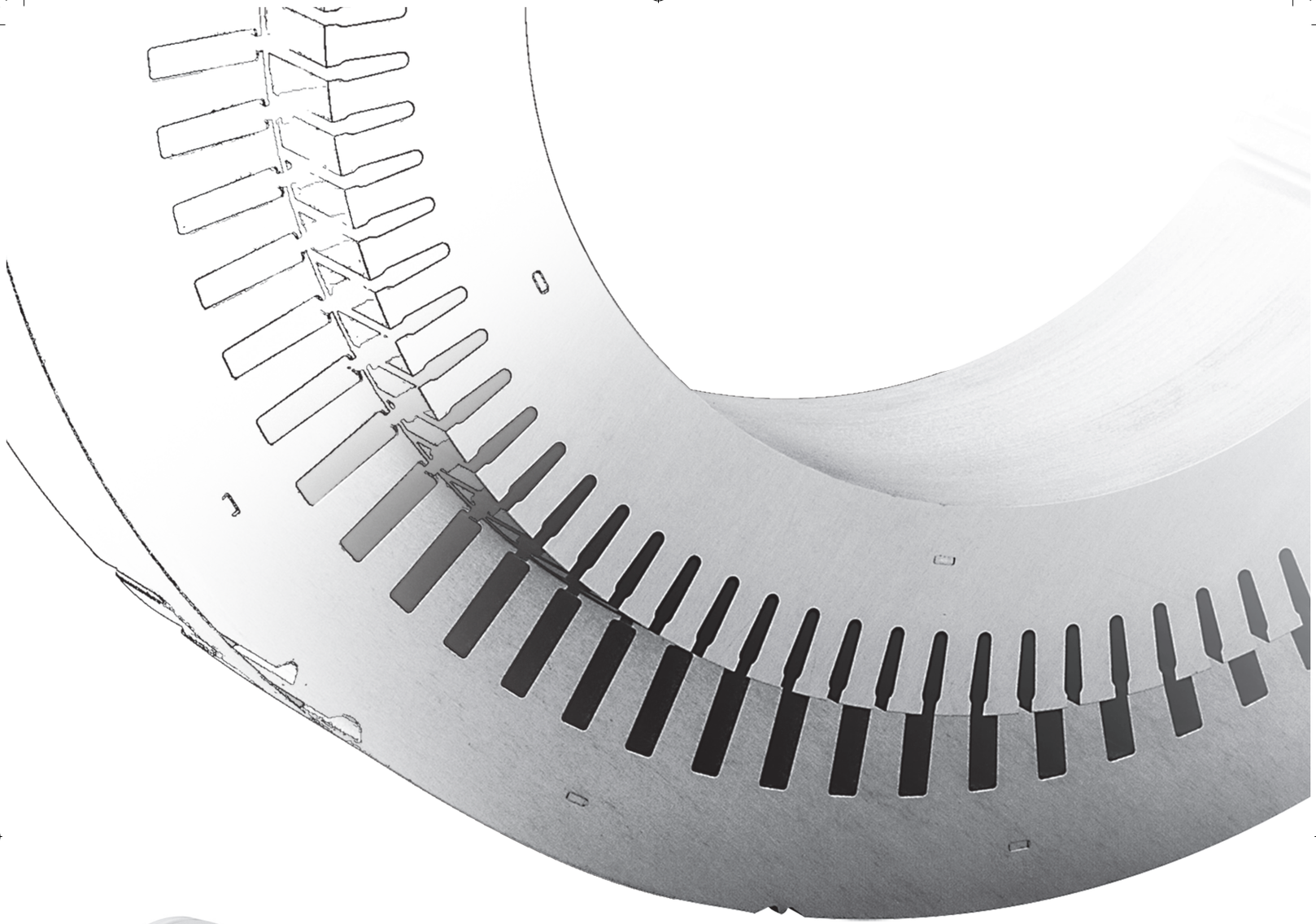

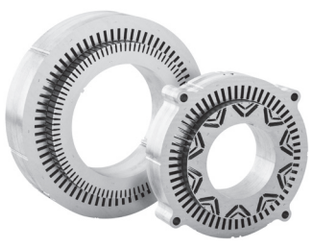

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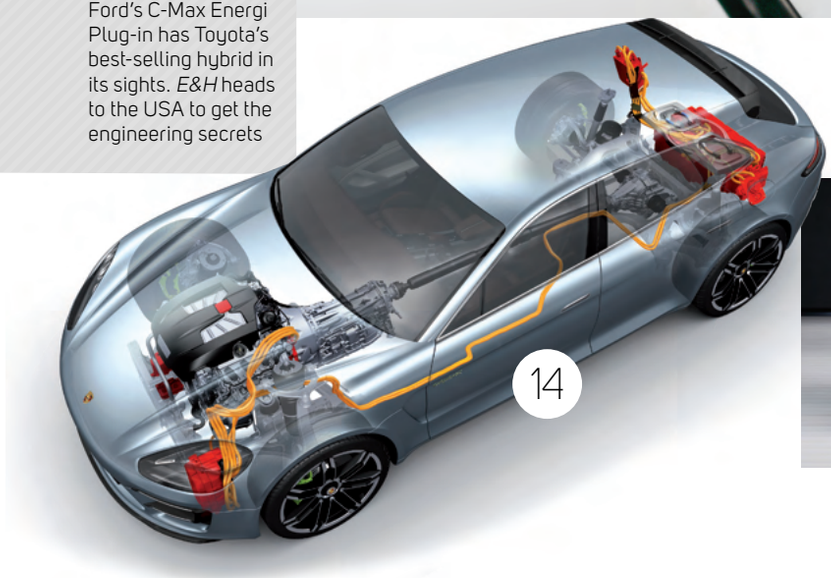
WHAT'S NEW?



Cost-effective and compact solution for auxiliary applications in xEV

Automotive Easy 1B/2B power modules

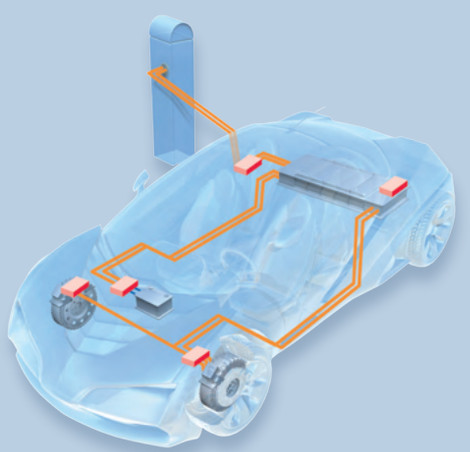
Easy 1B

Easy 2B

The new fully automotive-qualified Easy 1B and Easy 2B power modules provide a cost-effective, compact and flexible platform for applications with a power range of up to 6kW. The Automotive Easy modules are based on the popular industrial Easy power module family which has established quite a reputation for itself since its launch several years ago.

The availability of a high-voltage battery system in both Hybrid Electric Vehicles and Electric Vehicles provides the opportunity to increase the efficiency and reduce the cost of applications that are currently supplied by the low-voltage board net (14V) in IC engine vehicles. These systems include: air conditioning compressor, oil pump, cooling pump, power steering, heaters, auxiliary (HV to LV) DC/DC converter and charger.

All these different topologies can be addressed with customizable Easy-based modules. And it's flexible! You can choose your own layout, power components and package pin-out.



The Automotive Easy modules come with press-fit connections for quick and easy mounting and are fully automotive-qualified. Additional key benefits include reliable isolation, low stray inductance and NTC for temperature sensing.

Products based on the Automotive Easy modules are already in development for auxiliary drives, PTC heater and auxiliary DC/DC. Engineering samples are available on request.

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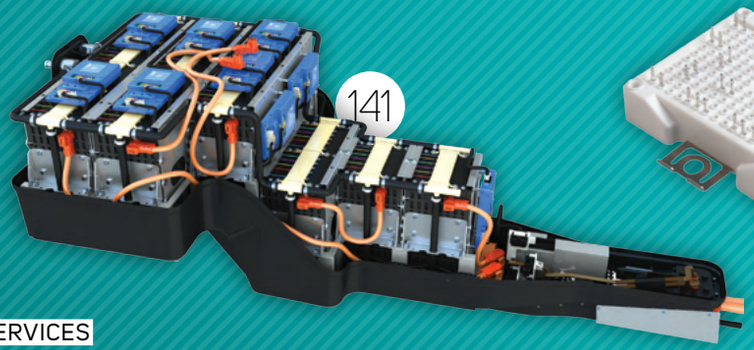

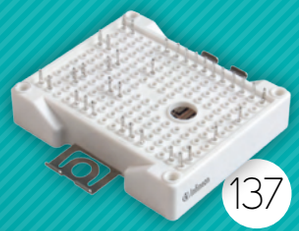

PRODUCTS & SERVICES

EDITOR'S NOTE

If you had a small – well, rather large – fortune, would you invest considerable sums of your wealth into starting up a car company? And not just any sort of conventional car company, I hasten to add, but one that specializes in a new breed of transportation: all-new vehicles from clean-sheet architectures (not aging platforms sourced from established OEMs) that are powered with what will be industry-leading EV drivetrains, essentially taking on the likes of GM, Ford, BMW, VW Group, Daimler, Toyota, Honda, Hyundai-Kia, Renault-Nissan (the list goes on and on), and their vast R&D budgets. Such a proposition doesn't sound too appealing, does it?

But that's exactly what two pioneering (and I know that word is used far too easily these days) start-up organizations in the USA have done. It hasn't been an easy journey by any means – it's been littered with technical challenges, engineering hurdles, politics and even accusations of foul play – but both Tesla and Fisker have seemingly done it. They have worked hard, believed in their respective engineering solutions, and broken into the automotive sphere. They've taken on the automotive giants and created a real impact, and it's safe to say that both start-ups are here to stay.

Why am I obsessing over Fisker and Tesla? Well, although we haven't had the opportunity to drive their pioneering (there's that word again) products (yet), Fisker's range-extender setup and Tesla's battery electric powertrain have gained acclaim worldwide, from lifestyle journalists through to the more technical-minded engineering press. And now *E&H* brings you exclusive, behind-the-scenes stories of both organizations. Starting with Fisker, our man in the USA, Jim McCraw, chews the fat with chief engineer Paul Boskovitch, who reveals that although the start-up's current vehicle range – consisting of only the Karma at the moment, but more exciting products will follow very soon – is pleasing to the eye, development (and design) at Fisker always starts with the powertrain, which in the Karma's case is the battery pack, twin traction motors, a 2-liter IC unit and a complex rear-drive axle system.

Then we booked Jim a flight to California to spend a day at Tesla and meet the car maker's CTO, J. B. Straubel, who talks us through not only what the future holds in terms of EV development, but also a technical tour of the Model S, a product conceived in Silicon Valley that's now the quickest sedan built in all the USA – and yes, just to confirm this stat, that's quicker than those V8 bruisers coming out of Detroit.

Our time with these two organizations reaffirmed my thoughts on just how important such start-ups are to the automotive industry, and especially the electric vehicle sector. The likes of Fisker and Tesla approach things in a different manner. They can bring products to market differently than the likes of the large conglomerate OEMs, and it's this diversification and engineering mix that I think is creating the most exciting powertrain development vibe for over a century. Long may this continue!

Dean Slavnich

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Jewel in the e-tron crown

A clever new hybrid system has been created by Audi powertrain engineers, and not only is the technology already being tested in prototype form, but it could even make production one day soon

WORDS: **DEAN SLAVNICH**

It's widely known that Audi is pursuing electric powertrain development with ambition and aggression across all technology concepts, to the point that by 2020 the ever-successful German car maker hopes to provide the market with an e-tron model in every vehicle segment.

So, far from simply continuing to further the likes of the R8 e-tron, A3 e-tron, the e-tron quattro study, and the A1 e-tron range-extender with a small AVL-developed IC engine (see *Audi's Electric Juggling Act*, overleaf), Audi's busy EV team has now found a new electric powertrain technology to investigate, internally named the dual-mode hybrid. The project is still in its infancy, but *E&H* has learned that Audi engineers are hopeful of what the system promises when combining an efficient IC engine, two electric motors and a single-speed transmission in one clever package.

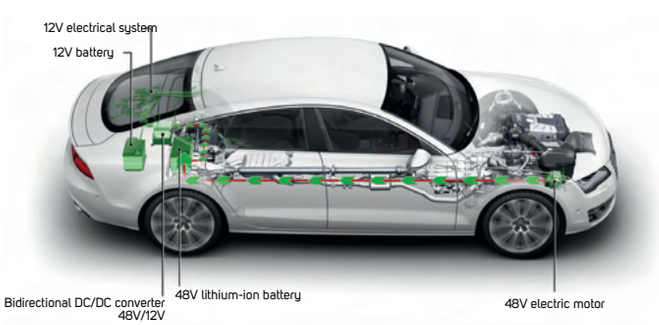
Audi's fierce competitor, BMW, has officially decided to go down the IC three-cylinder development route (see page 11 for the Concept Active Tourer plug-in hybrid), but Audi – despite its close cousin Volkswagen successfully marketing three-cylinder engines for many years – has so far chosen not to implement these tiny powertrains within its small-car range, favoring instead highly efficient four-cylinder designs. But that could all change. This dual-mode hybrid study, which is currently being tested in A1 prototypes in Germany, makes use of a specially created 1.5-liter three-cylinder TFSI that's heavily based on the car maker's popular 2-liter four-cylinder.

The dual-mode hybrid technology in the Crosslane (above) show car is undergoing testing and validation in Audi A1 e-tron prototypes (left)

CLEVER HYBRIDS

Audi is looking to take stop/start to a new level through the development of a groundbreaking technology. The system, which is currently in prototype testing phase, has been applied to an A7 Sportback diesel sedan and operates by switching off the IC engine during a car's journey in order to save on fuel and emissions, using instead momentum and battery power to keep the car moving.

The Intelligent Hybrid Electric Vehicle (iHEV) technology operates via a powerful 48V electric motor located in the belt drive of the vehicle. While the IC engine is switched off, energy to the vehicle is provided by a high-strength 48V lithium-ion battery. It's an interesting solution but early testing has been successful: in Germany on dynamically challenging country roads, the A7 prototype covered a 61km test route using iHEV 43% of the time, reducing fuel consumption by 10%.



For the dual-mode study, the three-cylinder has been designed to offer 130ps and 200Nm of torque. The IC unit is combined with an electric motor (called EM 1), which mainly functions as a starter and alternator. EM 1 develops 68ps and a maximum torque of 210Nm. Electric traction is provided by the second electric motor (EM 2) in the drivetrain, and this motor is good for 116ps and 250Nm of torque.

A crucial part of this entire package is the drastically streamlined single-speed transmission, which enables the IC engine, including the alternator, to be engaged or disengaged as required from the rest of the drivetrain by means of a claw clutch.

Such an arrangement means that the dual-mode system allows the car to be driven up to speeds of 55km/h exclusively by EM 2 in full electric mode, with the required energy for this 'urban speed range' mode (as Audi terms it) coming mainly from the traction battery. However, in addition to the city driving setting, a serial mode is available with this technology, which essentially sees the IC engine and EM 1 generate electrical energy that's used to support, relieve or substitute the battery should it need to be recharged.

The plug-in hybrid drive system of the Audi Crosslane comprises a combustion engine, two electric motors and a single-stage transmission

Full EV, hybrid and conventional IC

For speeds of up to 130km/h, the technology allows for full electric mode. However, from a speed of around 55km/h, the system allows the IC engine and EM 1 to be directly coupled to the drivetrain, therefore realizing a hybrid operation that offers the flexibility of combining the drive units to maximize either efficiency or performance. At around 130km/h, the IC engine fully takes over and drives the vehicle in a conventional way, but the setup is such that if required, EM 1 can support the three-cylinder

AUDI'S ELECTRIC JUGGLING ACT

R8 e-tron: A full electric vehicle supercar (limited production only) due at the end of this year.

A3 e-tron concept: An A3 production version featuring parallel plug-in hybrid technology will go into series production by 2014. Q7 and A4 plug-in hybrid drives will follow shortly sporting the same technology setup.

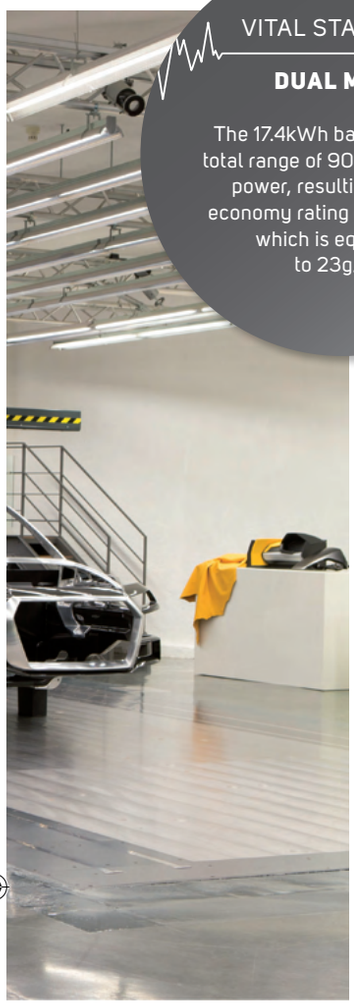
The e-tron quattro study: An alternative to the parallel plug-in system, which sees splitting power of the IC engine and the electric drive between the axles.

No production decision has yet been made on this technology, but testing is ongoing.

LMP1 prototype R18 e-tron quattro: A similar concept to the e-tron quattro study – and a winner of the Le Mans 24 Hours – this system sees a centrally mounted V6 TDI delivering 510ps to the rear wheels, while for a short time the front wheels are driven by electric power of around 101ps in output per wheel.

A1 e-tron: This is probably our favorite Audi e-tron to date here at *E&H*. Designed especially for urban areas is this range-extender vehicle, which sees an electric motor drive the front wheels with 75kW peak power for around 50km. A rotary engine, co-created by AVL, is placed at the rear and displaces 254cc, allowing for trips of up to

250km to be made. Fleet testing of this vehicle is ongoing in Germany and the program has so far covered more than 50,000km with positive feedback.



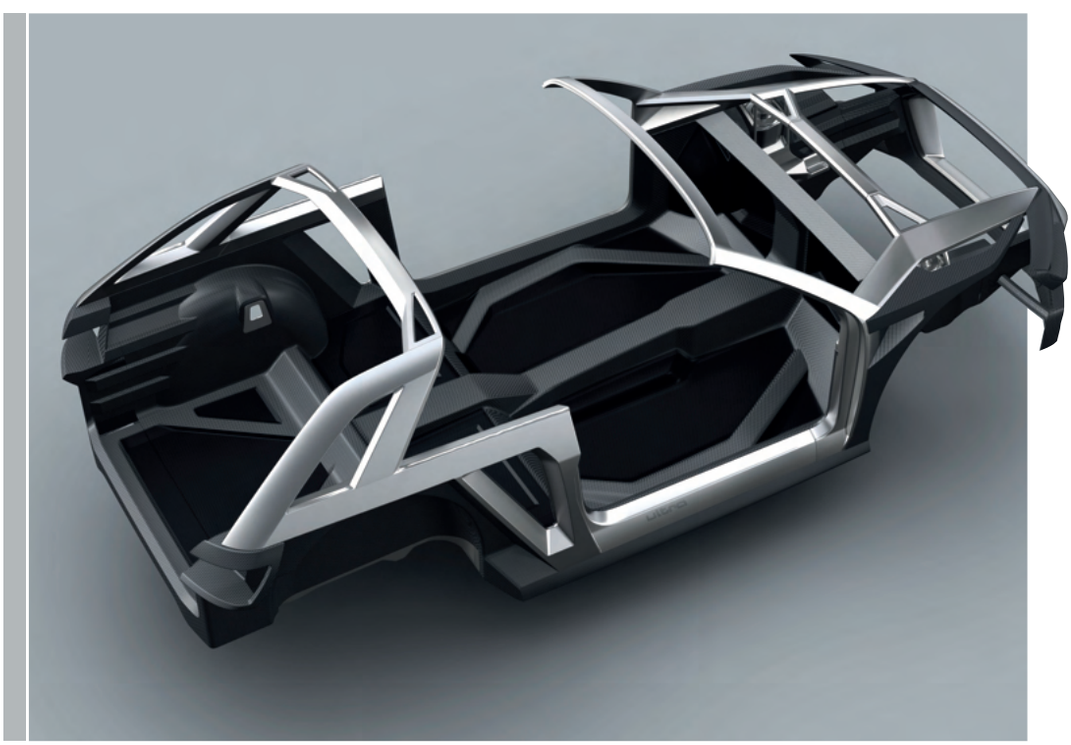
VITAL STATISTICS

DUAL MODE

The 17.4kWh battery offers a total range of 90km on electric power, resulting in a fuel economy rating of 235.2mpg, which is equivalent to 23g/km

Above: The three-cylinder IC unit in the A1 e-tron is placed at the front and combines with an electric motor, which mainly functions as a starter and alternator

Below: The multimaterial space frame consisting of three materials: aluminum, carbon fiber-reinforced polymer and glass fiber-reinforced polymer, all of which offset heavy EV components and systems



DID YOU KNOW...?

In 1997, Audi became the first European car maker to build a hybrid model in a limited production run – the Audi Duo, which was based on the A4 Avant. Its drive was powered by a 1.9-liter TDI developing 90ps and an electric motor developing 21kW, all of which was supplemented by a lead gel battery at the rear. The Duo's plug-in hybrid nature meant that the battery could be charged from an electrical outlet, and the electric motor recovered energy during braking. Today, Audi offers the market full hybrid vehicles featuring lithium-ion battery technology in the B, C and D segments.

to either reduce fuel consumption or briefly increase overall performance.

So what does all this electric powertrain innovation mean when the A1 prototypes hit the real world? Well, the numbers, according to Audi, are rather impressive: total system output is 177ps, which allows for a 0-100km/h sprint of nine seconds. The 17.4kWh battery, the majority of which is installed under the rear seats of the A1, offers a total range of 90km on electric power, resulting in a fuel economy rating of 235.2mpg, which is equivalent to 23g/km.

At the Paris Motor Show, Audi showed the shiny Crosslane Coupe concept car, which houses the same dual-mode hybrid technology in the A1 prototype vehicles undergoing testing. The only real difference – apart from the sleek design – was that the show car also featured an innovative multimaterial space frame consisting of three materials – aluminum, carbon fiber-reinforced polymer, and glass fiber-reinforced polymer, which kept the weight of the concept to 1,390kg including the battery pack. It's thought Audi is looking into this weight-saving material concoction for future EVs.

As for the dual-mode hybrid, for the time being any official word from Audi regarding the future of this technology will have to wait until prototype testing and final validation studies are complete. At conceptual form, however, dual-mode has a lot to offer, and seeing that Audi is putting into production a whole load of electric powertrain designs, it's not out of the realm of possibility that this system too can make it into showrooms.

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Plug the gap

BMW's dominance in IC engine design is well understood, and soon a raft of full EVs will also be coming out of Bavaria – but what about a plug-in hybrid offering?

CONCEPT ACTIVE TOURER:

Length: 4,353mm
Width: 1,834mm
Height: 1,560mm
Wheelbase: 2,670mm

With work fully underway on its sub i brand products (the i3 is due in 2013, and then the i8 a year later), BMW has now shown a new dimension to its Efficient Dynamics engineering portfolio – a practical plug-in hybrid that made its debut at the Paris Motor Show.

And while the design is sleek and eye-catching, more noteworthy is what's under the skin of the 4,353mm long Concept Active Tourer: a three-cylinder petrol engine that represents the very future of BMW IC designs, an advanced new synchronous electric motor and a compact lithium-ion battery pack.

The motor has been developed fully in-house by BMW engineers – staying true to the car maker's philosophy to retain electric powertrain expertise and knowledge within the group and not rely overly on external suppliers. As with many BMW vehicles to date, the IC unit does not drive the rear wheels, but instead powers the front wheels. The electric motor, which has been designed as a fully fledged power unit, acts on the rear-axle – if necessary powering the car on its own.

The motor and three-cylinder IC engine combine together to achieve a total system power output of 190ps and some 200Nm of instant torque. BMW says that such power will shift the Concept Active Tourer to 100km/h from standstill in eight seconds. Top speed is 200km/h. The vehicle also features a boost function that can be applied to use additional power provided by the electric motor when attempting dynamic maneuvers, such as overtaking.

The drivetrain has been designed so that power can be drawn from both axes of the vehicle and fed into the battery pack, which has also been designed in-house by engineers in Germany.

ON YOUR ELECTRIC BIKE!

Alongside its four-wheel EV developments of late, BMW is also pushing ahead with creating new solutions when it comes to two-wheel electric products – like the E-Scooter.

Electric scooters are not new, but to date they've almost exclusively been used for city commuting due to their limited performance and range. However, the E-Scooter promises to change all that, since the project has two main development requirements: dynamic performance figures that are on a par with those of a scooter with an IC engine; and a high driving range.

As such, the E-Scooter's high battery capacity provides a daily driving range of over 100km, but at the same time, the study has also realized 0-60km/h acceleration figures that are comparable with current scooters on the market powered by a 600cc engine.

The E-Scooter battery is charged at regular household power sockets, so no special charging station is required. When the battery is completely flat, the charging period is less than three hours.

Unlike existing maxi scooters with IC engines, the concept does not have a main frame. Instead, the aluminum battery casing – which also contains the electronic system required for battery cell monitoring – takes over the function of the frame. The steering head support is connected to it, as is the rear frame and the left-hand-mounted single swing arm with directly hinged, horizontally installed shock absorber.

Due to its high output, the BMW study has no hub motor with direct drive or planetary gearbox. Instead, the electric machine is mounted behind the battery casing. The secondary drive consists of a toothed belt from the electric machine to the belt pulley mounted coaxially on the swinging fork pivot with drive pinion. From here, power transmission occurs via a roller chain to the rear wheel. When the E-Scooter is decelerated in trailing throttle or when braking, the energy released is recuperated, increasing range by up to 20%.

With a fully charged battery, the concept offers a range of 30km on electricity alone, before the three-cylinder engine kicks into life to enable longer journeys. This means that the average fuel consumption of the plug-in hybrid is 113mpg, with CO_2 emissions of less than 60g/km. The electric motor also helps in this area by recuperating maximum energy at the rear axle during deceleration, while a high-voltage generator connected to the IC unit additionally charges the battery when needed.

Being part of the Efficient Dynamics technology umbrella meant that the Concept Active Tourer has shared subsystems and components with other experimental vehicles. However, its plug-in hybrid nature has meant that specifically developed for this project was an anticipatory operating program that promises to optimize the efficiency levels of the electric motor and the performance of the battery. This is done through a technology that draws real-time data provided by the navigation system, enabling an advanced calculation to be made for suitable driving routes. BMW estimates that this charging strategy could save up to 10% of energy, allowing the plug-in hybrid to drive more on electric power.

The plug-in hybrid system in the Concept Active Tourer combines a new synchronous electric motor, a compact lithium-ion battery pack and a three-cylinder IC engine that's undergoing testing

B38 development

Yet perhaps the biggest story with this latest EV project from BMW is the new three-cylinder TwinPower turbo gasoline engine, labeled B38, which has a nearly identical design to that of the 1.5-liter, three-cylinder turbodiesel, codenamed B37. While *E&H* is concerned mainly with electric powertrain creations, sustainable transportation is what the industry is striving toward, and some see small IC engines with three-cylinders as being the solution. One can't ignore the fact that premium brands such as BMW are now officially headed down the three-cylinder IC route – and these designs will provide a core power source for the company's upcoming PHEV and HEV products.

The B38 is based on BMW's award-winning six-cylinder design, with TwinPower turbo tech combining with high-precision injection through the use of latest-generation Valvetronic. Being a BMW engine, the three-cylinder offers smooth running, revving power, spontaneous response and a dynamic feel. While most of the above is catered for by the use of forced induction and fully variable valve control, the B38 also gets a solid balance shaft running through the crankcase, spinning opposite and at equal revs to the crankshaft above it in order to negate the vibration risk. Both three-cylinders will go on sale within the next two-years, but a final decision on the Concept Active Tourer has yet to be made.

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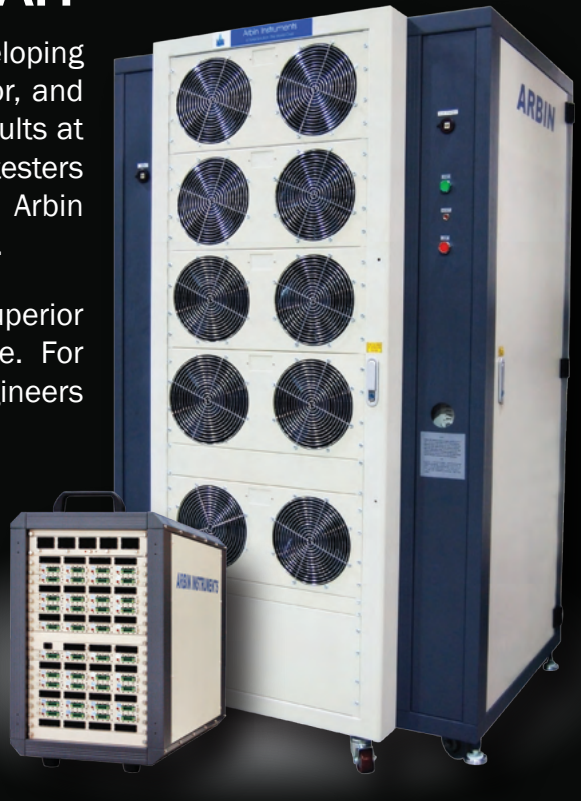

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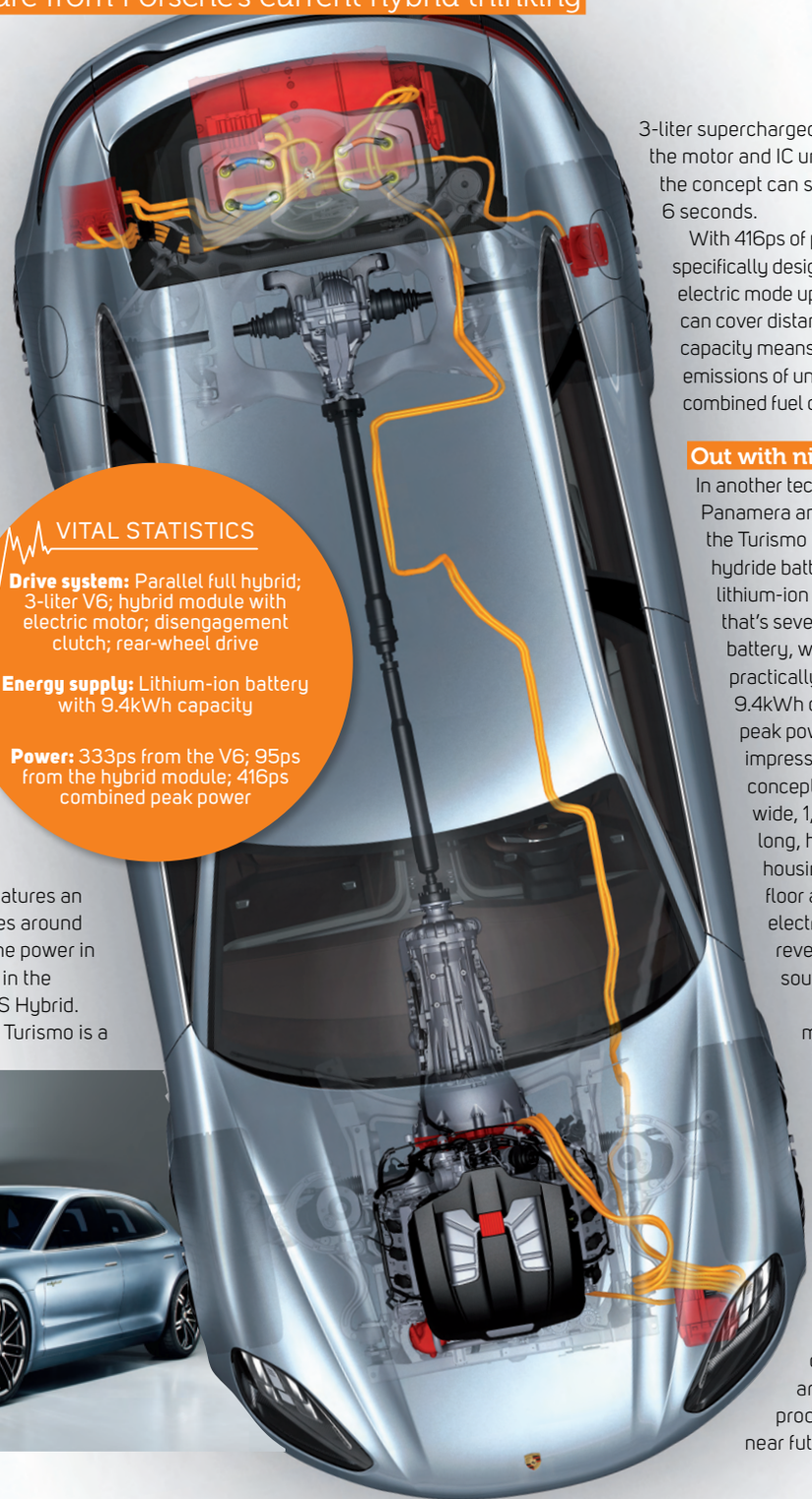
Change of heart

A concept it might be, but the Panamera Sport Turismo is a huge technological departure from Porsche's current hybrid thinking



Porsche – with a helping hand from its cousins in the VW Group – already offers the market performance-orientated hybrid products in the form of the now rather conventional (in an engineering sense) Panamera and Cayenne HEV derivatives. Then, next year, the stunning 918 Spyder, with its parallel full hybrid powertrain, will be launched at the very top end of the German car maker's line-up, tapping into the needs of customers who can afford a product that combines scintillating performance with environmentally friendly credentials. In between these hybrid offerings, though, could slot the stunning Panamera Sport Turismo – which purely remains a concept for now, but outlines Porsche's thinking when it comes to next-generation hybrid drive.

The Turismo's plug-in system features an all-new electric motor that produces around 95ps, which is twice as much as the power in Porsche's hybrid drive technology in the Panamera S Hybrid and Cayenne S Hybrid. Alongside the electric motor in the Turismo is a 3-liter supercharged V6 that offers 333ps, and the motor and IC unit work together to ensure the concept can sprint to 100km/h in less than 6 seconds.

With 416ps of peak power, the car has been specifically designed to be driven in pure electric mode up to a speed of 130km/h and can cover distances over 30km. Such pure EV capacity means the Turismo offers CO_2 emissions of under 82g/km of CO_2 and combined fuel consumption of around 80mpg.

VITAL STATISTICS

Drive system: Parallel full hybrid; 3-liter V6; hybrid module with electric motor; disengagement clutch; rear-wheel drive

Energy supply: Lithium-ion battery with 9.4kWh capacity

Power: 333ps from the V6; 95ps from the hybrid module; 416ps combined peak power

Out with nickel-hydride

In another technological departure from the Panamera and Cayenne hybrid drivetrains, the Turismo benefits not from a nickel-hydride battery, but a newly designed lithium-ion pack that offers performance that's several times better. The new battery, which Porsche says has practically the same dimensions, offers 9.4kWh of energy storage and high peak power – crucial to the concept's impressive pure electric range. The concept, which measures 1,990mm wide, 1,401mm high and 4,950mm long, has milled aluminum battery housing mounted under the boot floor and is made from electrochromatic glass, neatly revealing a view of the energy source to the outside world.

The Turismo's plug-in nature means the fluid-cooled lithium-ion battery is not charged while driving. However, Porsche says that the pack can be externally charged in just 2.5 hours.

This entire plug-in hybrid setup in the Turismo is termed as e-hybrid by Porsche's marketing team, and although there's no official word about either the drivetrain or the concept, both are likely to form some sort of production model in the very near future.

Unlike previous (and current) Porsche hybrids, the Turismo makes use of advanced lithium-ion battery technology

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Three of a kind

At the Paris Motor Show, Mercedes-Benz rolled out three eco-friendly vehicles with very different agendas but one common purpose: emissions reduction

WORDS: **DEAN SLAVNICH**


S MB 1099

Having brought you the very early development story of the SLS AMG Coupe Electric Drive back in late 2009, Mercedes-AMG is now ready to unleash the world's most powerful electric super sports car.

And if that's not enough – and in a real twist of irony for a company steeped in V8 performance – the SLS AMG Electric Drive is also the most powerful AMG high-performance vehicle of all time, thanks mainly to four electric motors producing 552kW and 1,000Nm of torque that drive the gullwing two-seater to 100km/h from standstill in just 3.9 seconds!

Playing a pivotal role in the engineering architecture of the SLS are four permanent-magnet synchronous electric motors, each weighing around 45kg, and achieving a maximum individual speed of 13,000rpm. The four motors individually drive the four wheels of the vehicle selectively via an axially-arranged transmission design, which allows for smooth torque distribution to individual wheels; the only other way to realize this setup would have been via wheel hub motors that have the disadvantage of generating unsprung masses.

As *E&H* predicted back in 2009, the electric SLS, which comes to market in June 2013, is a massive beneficiary of advanced technologies taken from M-B's activities in Formula 1. For example, the high-voltage battery is the result of an ongoing cooperation between the Mercedes-AMG mothership in Germany and Mercedes-AMG High Performance Powertrains in Brixworth, UK, a specialist in KERS hybrid concepts.

With advanced electric powertrain development – and transferring across state-of-the-art F1 technologies – Mercedes-AMG has created the most powerful gullwing vehicle ever, and it's all electric

Be electric

With a helping development hand from Tesla – in which Daimler has a stake in and subsequently has provided numerous components and subsystems for the Model S over recent months, Mercedes-Benz has unveiled its very own electric mass mobility solution: the Concept B-Class Electric Drive, a production version of which will be added to the growing M-B electric vehicle fleet within the next two years.

Mercedes says that the creation of Concept B-Class Electric Drive complements such local emissions-free vehicles as the B-Class F-Cell, Vito E-Cell and the Smart Fortwo electric drive.

Crucially, however, the intelligent powertrain arrangement that graces the B-Class concept will very likely be replicated for the production model. The concept takes full advantage of a 100kW electric motor that ensures emissions-free driving and provides 310Nm of instant torque. For the production EV version, though, expect both power ratings and the driving range to increase.

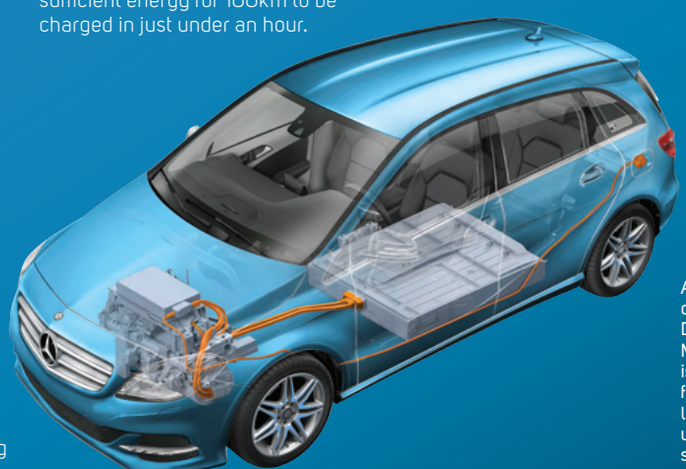
The concept boasts a very clever 'energy space' (as M-B terms it) design within the floor of the vehicle that houses a lithium-ion battery pack, allowing the EV to offer the same kind of space and practicality as a conventional B-Class model powered by an IC engine. This latter point is especially important to Dr Thomas Weber, Daimler's board member for R&D and head of Mercedes-Benz car development, who says: "In developing our electric vehicles, we accord top priority to customer benefits. Accordingly, the Concept B-Class Electric Drive demonstrates premium-standard electric mobility for all the family. This concept vehicle offers outstanding everyday practicality and great driving enjoyment."

The efficient lithium-ion battery, which M-B is not wanting to disclose too much about yet, has the capacity to drive the Concept B-Class Electric Drive for 200km. The vehicle can be recharged at any standard domestic 230V power outlet. In addition, there's a rapid charging function that's also integrated that enables sufficient energy for 100km to be charged in just under an hour.

VITAL STATISTICS

CONCEPT B-CLASS ELECTRIC DRIVE

Output: 100kW
Torque: 310Nm
Range: 200Km
0-100km/h acceleration: Under 10 seconds
Top speed: 150km/h



A production model heavily based on this Concept B-Class Electric Drive will be launched in 2014. For Mercedes-Benz, key to this project is for the EV to be practical and family-friendly, which is why the lithium-ion battery pack is housed underneath the cabin in a design solution that's termed energy space

VITAL STATISTICS

SLS AMG COUPE ELECTRIC DRIVE

Output: 552kW
Torque: 1,000Nm
0-100km/h acceleration: 3.9 seconds
Range: 250km
Battery energy content: 60kWh
Battery voltage: 400V

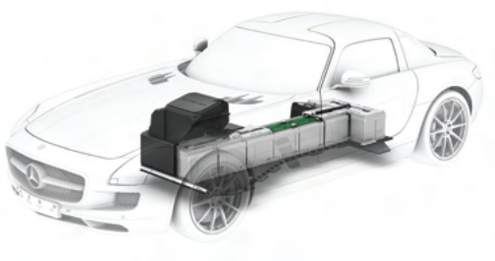
"Our vision of the most dynamic electric vehicle has become a reality"

It's a point that's not been missed by Ola Källenius, chairman of Mercedes-AMG: "The SLS AMG Coupe Electric Drive sets new standards for cars with electric drives. Our vision of the most dynamic electric vehicle has become a reality. With the help of our colleagues at Mercedes AMG High Performance Powertrains, we are bringing exciting advanced technology from the world of Formula 1 to the road."

Alongside the importance that the four electric motors have in this thrusting EV is the high-voltage battery, which is equally imperative. The liquid-cooled 548kg battery boasts an energy content of 60kWh, an electric load potential of 600kW and maximum voltage of 400V. The pack is located within a carbon-fiber monocoque that forms an integral part of the SLS. The monocoque housing is bolted to the aluminum space frame, which helps to offset the weight of the battery.

Twelve modules each comprising 72 lithium-ion cells make up the mainframe of the battery. This arrangement – with a total of 864 cells – has advantages, not only in terms of installation space, but also overall performance, says Källenius.

The liquid-cooled battery weighs 548kg and offers 60kWh of energy content



With so many electric components underneath the skin, an advanced cooling system was a must for the SLS. The result has been the creation of a high-performance ECU that converts the direct current from the high-voltage battery into the three-phasing alternating current that is required for the motors. Two low-temperature cooling circuits ensure that the four electric motors and power electronics are maintained at an even operating temperature. A new separate low-temperature circuit is responsible for cooling the high-voltage lithium-ion battery.

Natural high

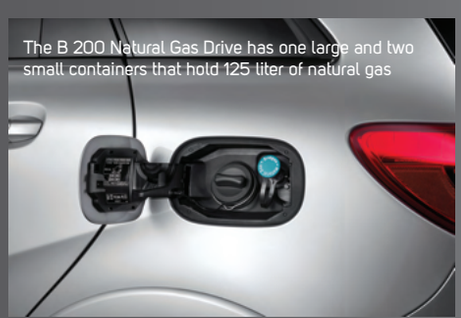
While electric powertrain engineering is what we mainly concern ourselves with here at *E&H*, there's no denying that alternative fuels such as biofuels and natural gas, which power today's IC engines, are also playing an important part in creating a more environmentally sustainable automotive industry.

A good example of cleaner IC engine technology comes in the form of the Mercedes B 200 Natural Gas Drive (NGD), which boasts 16% fewer CO_2 emissions, so significantly cleaner exhaust gases than petrol and diesel fuel, and offers around 50% lower fuel costs than comparable models.

That means that in natural gas mode, consumption of the 156ps B 200 NGD is just 4.2kg/100km, which corresponds to a CO_2 emissions rating of 115g/km. A top speed of 200km/h is possible, while a 0-100km/h sprint takes 9.1 seconds, all of which is comparable to the conventional IC-engined B-Class models currently on the market.

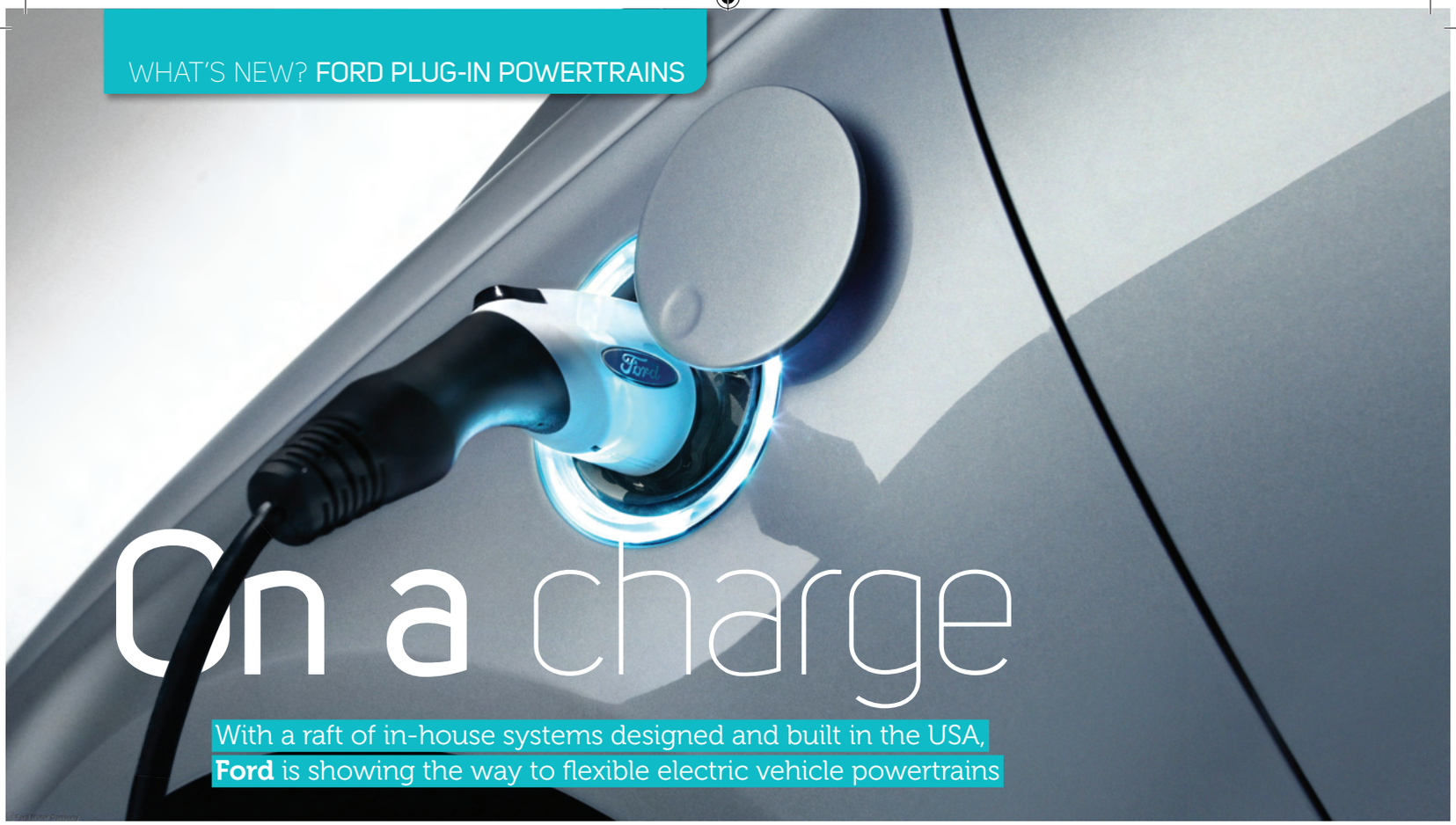
The B 200 NGD will be made available in most European markets by the end of the first quarter of 2013, and like its conceptual EV cousin, it takes full benefit of the 'energy space' modular body design located beneath the rear seats of the vehicle. For this model, however, the space does not house a powerful lithium-ion battery pack, but instead one large and two small containers that can hold up to 125 liters of natural gas.

In natural gas mode, B Class, which is launched in early 2013, is rated at 4.2kg/100km, which corresponds to a CO_2 emissions rating of 115g/km



The B 200 Natural Gas Drive has one large and two small containers that hold 125 liter of natural gas

The engineering within the B 200 NGD works according to the monovalent principle, which means the engine is basically operated using gas. However, for emergencies, there is a small 12-liter petrol tank onboard. Should the gas tank ever run dry, the powertrain switches over automatically to a petrol operation. Mercedes says that the range in the natural gas mode is around 500km. A manual or a 7G-DCT will be the two transmission choices from launch.



On a charge

With a raft of in-house systems designed and built in the USA, **Ford** is showing the way to flexible electric vehicle powertrains

It's a little known fact that Ford has been building gasoline-electric hybrid vehicles for more than 20 years, and currently boasts in the USA more different types of vehicles and propulsion systems than any other manufacturer.

Up until now, though, Ford has gone either the traditional hybrid route or the pure electric route, characterized by the Ford Escape hybrid SUV, the Ford Fusion hybrid sedan, the Lincoln MKX hybrid SUV and the Lincoln MKZ hybrid luxury sedan, starting first with nickel-metal hydride batteries in the first generation, then switching to more advanced lithium-ion batteries for its second- and third-generation products.

However, the time has come for the Blue Oval to introduce two all-new vehicles in this arena for 2013: the Ford C-Max Energi plug-in hybrid MPV and the Ford Fusion Energi plug-in hybrid sedan, both built on Ford's global C/D platform. Ford has high hopes for both vehicles, but especially the former, with the company keen to tell the world that it will outperform the Toyota Prius plug-in in every single category from power, through to range and charging time. High hopes indeed!

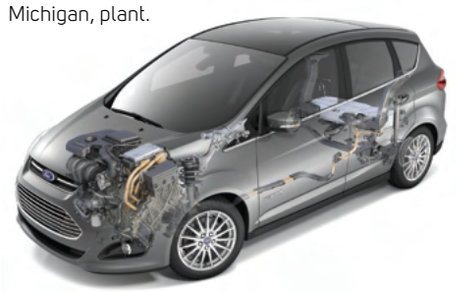
According to Kevin Laydon, Ford's exec director of electrified vehicles, the Ford plug-in hybrid combines a 2-liter Atkinson-cycle four-cylinder engine generating 141ps on its own; a new lightweight, air-cooled high-voltage 7.6kWh lithium-ion battery; an onboard charge module to convert household AC utility power to DC battery energy; a 118ps/88kW at 6,000rpm permanent-magnet AC synchronous electric drive motor; new control electronics; and a new CVT.

The battery has been specifically designed so that it can charge in as little as 2.5 hours using a Ford/Leviton 240V charging system, which is available as an option. The normal household 120V charger takes seven hours.

Commonality is the key

Laydon says that parts commonality between the hybrids, plug-ins and battery electrics, combined with the flexibility of production built into its assembly plants in Wayne, Michigan, and Hermosillo, Mexico, make it possible to keep costs down and vehicle prices competitively low. Ford engineer Gil Portalatin adds that this commonality can save up to 30%, making the car more affordable at consumer level.

Ford also takes great pride in the fact that the battery is built domestically at its Rawsonville, Michigan plant, and that the HF35 eCVT is built alongside conventional six-speed automatic transmission units in its Sterling Heights, Michigan, plant.



The new generation of Ford hybrid and plug-in hybrid vehicles share many components and subsystems, allowing the Blue Oval to save considerably on costs

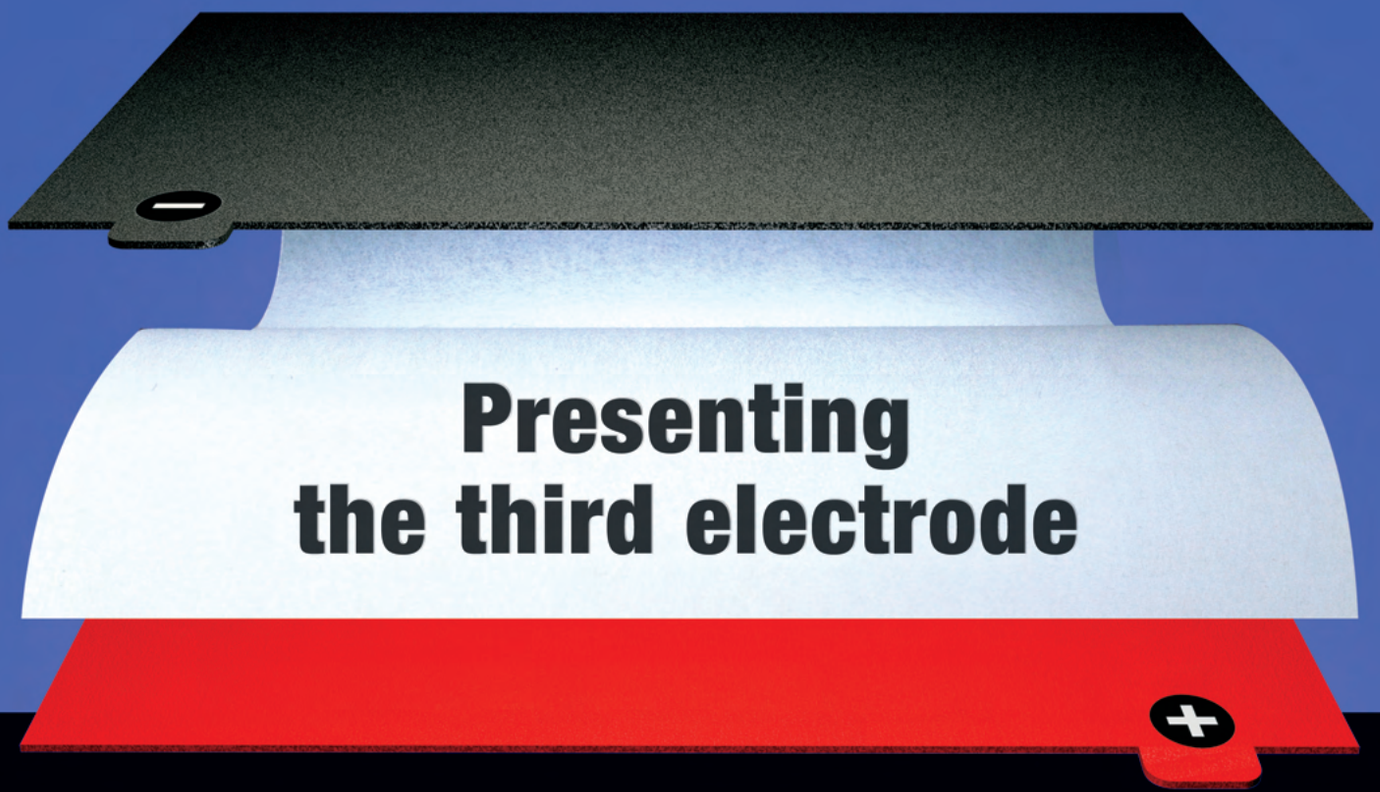
The onboard charging system provides these new breed of Ford vehicles with up to 21 miles of electric-only range in EPA combined city and highway driving cycles.

The C-Max Energi will be rated by the federal EPA at 108MPGe city, 92MPGe highway and 100MPGe combined. It has a three-mode switching system that can lock out the gasoline engine for electric-only driving, and driving in this mode can take the vehicle up to an unheard-of speed of 136km/h in electric-only. The other two modes are normal hybrid driving and a battery-saver mode that keeps the power pack fully charged for later use. A fourth mode, EV+, allows the vehicle to operate in electric-only mode for longer distances by learning driving routes.

Ford says that the combined range of a fully charged battery, the onboard charging system, regenerative braking and the gasoline engine, is 620 miles. Portalatin adds that the regenerative braking system can recover up to 95% of braking energy under ideal driving conditions.

Both vehicles will use an electric water pump for the engine, electric power steering, an electric heater for the vehicle electronics, electric air conditioning and heating, and an electric vacuum pump for the brake booster, with three onboard 12V sockets and one 110V accessory plug.

One of the more interesting aspects of the plug-in Fords is the MyFordMobile smartphone application, which enables owners to sync up with their vehicles; check the state of charge and time of full charge expected; and be warned if the charger is disconnected during charging.



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Production ready?

Following on from the stunning LF-LC sports coupe concept that debuted earlier this year, Lexus has recently presented the LF-CC. ***ETi*** explores a car whose looks match the technology underneath

Is this not just another Lexus hybrid concept all about design language?

No. We're hearing that the LF-CC will pave the way for the introduction of a new Lexus mid-sized coupe in the near future. And insiders say that the technology in this concept will definitely influence future models.

What kind of technology are we talking about?

A new 2.5-liter full hybrid powertrain with CO_2 emissions targeted below 100g/km. Lexus expects this powertrain – which will enter production probably toward the end of 2013 – to be the most efficient in its class, producing more than 2ps/g of CO_2.

So the LF-CC will enter production?

Well, a powertrain heavily based on this concept will. Details about the setup remain scarce. What's known is that this Lexus Hybrid Drive unit uses a new, smooth 2.5-liter four-cylinder DOHC petrol engine, mated to a compact, high-output electric motor. In addition to the engine and electric motor, the system also features a generator, high-performance battery, a power split device and a compact power control unit. The engine has been adapted specifically for use in the hybrid powertrain and benefits from a number of technical improvements, adopting the Atkinson cycle and D-4S direct injection technology to optimize both power and fuel efficiency.

And the battery?

As with the vast majority of Toyota/Lexus hybrids, it's a nickel-metal hydride solution. It's unlikely that the lithium-ion battery in the Prius Plug-in will be carried across for this project.

Does it looks as good in real life as it does on paper?

The LF-CC is stunning. For us, it was definitely one of the stars of the Paris Motor Show. It would be brilliant if this car could jump from the concept realm and into mass production.

The LF-CC previews Toyota's next-generation hybrid system which targets emissions below 100g/km of CO_2

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Liquid asset

More than a decade of intense R&D work means that hydrogen fuel cell vehicles are now commercially within reach

TECH SPEC:

IX35 FUEL CELL

Length: 4,410mm
Width: 1,820mm, **Height:** 1,655mm
Driving range: 588km
Vehicle efficiency: 0.96kgH2/100km
Top speed: 160km/h
0 to 100 km/h: 12.5 seconds
Fuel cell output power: 100kW
Energy storage system: Battery, 24kW, Fuel: Hydrogen (700 bar, 5.6kg)

The ix35 Fuel Cell (left and below) is the first hydrogen fuel cell vehicle to be made commercially available by Hyundai-Kia. Interestingly, the technology uses ambient air to supply oxygen to the stack

While work on battery electric vehicles continues at full speed by most car makers across the globe, you'd be forgiven for thinking that the automotive industry has forgotten the hydrogen fuel cell dream it marketed as the great green sustainable transportation hope of only a decade ago.

However, there are a few companies – namely Daimler, GM, Honda, Toyota and Hyundai-Kia – that continue to invest in the development of this technology, and it's the latter that's one of the first (along with Honda) to announce the launch of hydrogen fuel cell vehicles on the road by 2015.

In fact, by the time you read this, Hyundai will have already started small-scale series production of its innovative hydrogen ix35 Fuel Cell vehicle for public and private lease at its Ulsan manufacturing facility in Korea, with a target of building 1,000 vehicles by 2015. Beyond that timeframe, the South Korean OEM has set itself a mass production goal of 10,000 ix35 Fuel Cell models. It's an ambitious target for a technology that remains expensive, has little support in the way of infrastructure and generally represents something totally new to the consumer, but for Hyundai-Kia, it's an important program that's been given top priority by the company's R&D head, Woong Chul Yang. "The ix 35 Fuel Cell is the pinnacle of Hyundai's advance engineering and our most powerful commitment to be the industry leader in eco-friendly mobility," says Yang. "Zero-emissions cars are no longer a dream; our ix35 Fuel Cell vehicle is here today and ready for commercial use."

Ambient air

As with other fuel cell vehicle designs, the ix35 Fuel Cell (which sits at the top of Hyundai's Blue Drive sub-brand that also includes the Sonata Hybrid, i20 Blue Drive and the battery-powered i10) features a fuel cell stack that converts hydrogen to electricity, and this energy is then used to power the vehicle. However, unlike other fuel cell designs that use compressed air to supply oxygen to the stack, *E&H* has learned that the ix35 Fuel Cell makes use of ambient air instead. This arrangement serves to reduce parasitic losses in the oxygen supply, raising efficiency and reducing power consumption by as much as 50%, says Hyundai. Passengers inside the cabin feel an additional impact of this development because the elimination of an air compressor reduces noise and allows for a much quieter interior cabin.

Alongside the fuel cell stack in the ix35 Fuel Cell vehicle is the same LG-developed lithium-polymer battery that's found in the Sonata Hybrid. It's an interesting bit of kit that makes use of a polymer gel as the electrolyte, therefore resulting in a thinner and lighter casing, which translates to more room for designers to work with elsewhere in the vehicle, such as the cargo and interior. In total, the lithium-polymer battery is capable of delivering the same amounts of power as lithium-ion and nickel-metal hydride technologies, but in some Hyundai models this new battery development is 25% lighter, boasts 40% less volume and is 10% more efficient. It also discharges more slowly to maintain available power up to 1.7 times longer than conventional battery packs.

The stack and the battery work together to accelerate the Hyundai fuel cell to 100km/h from standstill in 12.5 seconds, before reaching a top speed of 160km/h. More important, though, is that the vehicle can travel for 588km without refueling – a key consumer offering over the current driving range of BEVs. At current market levels, Hyundai estimates it will cost around US$70 to fill the ix35 Fuel Cell with the 5.6kg of hydrogen it needs for a full tank in order to realize the impressive driving range.

Additional features of the ix35 Fuel Cell include a kinetic energy regeneration system that charges the battery and stop/start technology that shuts down the fuel cell stack and relies on battery power alone when idling.

The market launch of the ix35 Fuel Cell represents 14 years of continuous work for hundreds of engineers at Hyundai's fuel cell R&D center in Mabuk, Korea. During that time, the car maker has injected well over US$600 million into the project, which has seen prototype cars and test mules log more than two million miles of road tests in real-world conditions in Europe, Korea, and the USA.

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"The technologies on show at the Electric & Hybrid Pavilion are really, really good. There are so many new ideas and concepts to see"

Mukesh Muralidharan
senior software engineer, Robert Bosch

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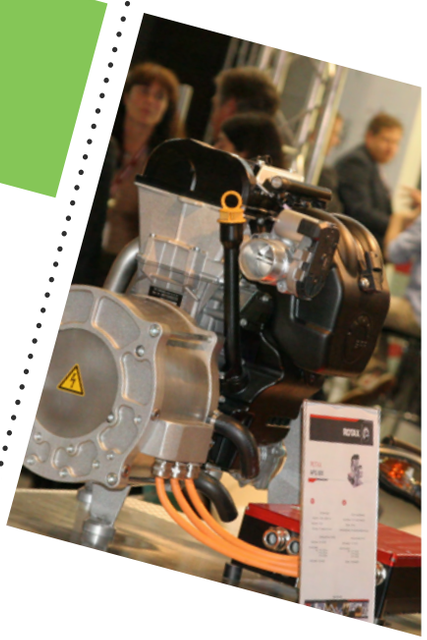

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"Our goal is to find out more about new materials, advanced technologies, new applications and source new suppliers"

Yahya Sahip
component engineer, base engines, Ford Otosan

Illustration courtesy of Magictorch

Cell-by date

As electric and hybrid vehicles slowly mature into more attractive alternatives to petrol- and diesel-powered automobiles, so do the batteries that help propel them

WORDS: JOHN CHALLEN

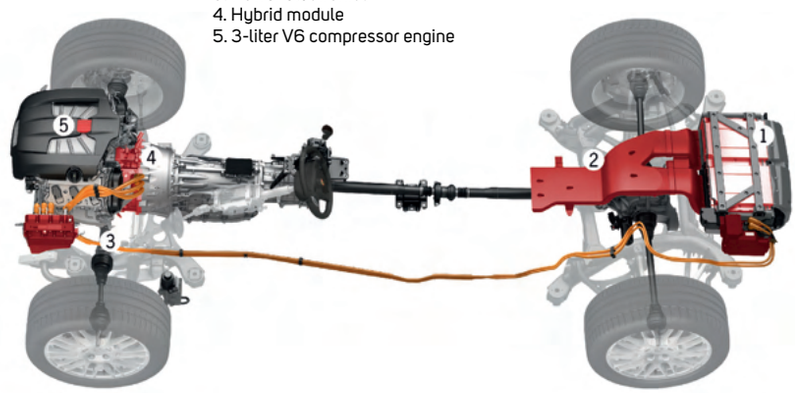
Battery technology for electric and hybrid automotive applications has come a long way in a relatively short space of time. Not too many years ago, few manufacturers had embraced lithium-ion, but it is now the industry standard, helping to power a growing – both in terms of actual units and size of vehicle – number of models. The green agenda has helped many people down the alternative powertrain route, but keeping them interested, by offering them more attractive and capable products, is key. As a result, battery developers and system integrators are busily searching for solutions to increase energy density and decrease pack size and cost.

Responsibility may predominantly lie with Tier 1 suppliers, but on the whole, car makers are very keen to have their say about what they want. Having introduced alternative hybrid propulsion systems to its Panamera and Cayenne models, Porsche now wants to adapt its all-new plug-in hybrid technology to other vehicles in the range. "We face the need to reduce the complexity and cost of batteries," says Otmar Bitsche, general manager electric mobility at Porsche. "Integrating the battery into existing body structures for electric vehicles, not to mention allowing battery systems to work with existing functional software vehicle architectures, is key. Like typical sports cars, we are aiming at high performance and highly efficient systems."

In the short term, Bitsche says that means that the generation and development of reusable components for batteries, with the potential of evolution – "adapting new cell technologies without a full re-development" – is very important and will take place at the Stuttgart-headquartered company, as well as the "optimization of existing concepts, such as the use of some additional cells to use the optimal voltage range of power electronics and electric motors".

Porsche is set to adopt lithium-ion battery technology (above) that is several times more powerful than the nickel-hydride solutions (below) that it employes in its current hybrid vehicle range

1. High-voltage nickel metal hydride battery
2. Air supply duct
3. Power electronics
4. Hybrid module
5. 3-liter V6 compressor engine



BATTERIES THAT PROMISE A 500-MILE RANGE

Back in 2009, IBM Research pioneered a sustainable mobility project – the Battery 500 Project – to develop lithium-air battery technology capable of powering a family-sized electric car for 500 miles on a single charge.

The latest development to the project is the addition of two new partners: Asahi Kasei and Central Glass, both of which bring decades of materials innovation from the automotive industry. The two organizations have been tasked with expanding the project's scope and exploring several new chemistries.

Asahi Kasei is one of Japan's leading chemical manufacturers and a pioneering global supplier of separator membrane for lithium-ion batteries. The company will use its experience in innovative membrane technology to create critical components for lithium-air batteries. Central Glass, a high-tech global electrolyte manufacturer for lithium-ion batteries, will use its chemical know-how to create a new class of electrolytes and high-performance additives specifically designed to improve lithium-air batteries.

"These new partners share our vision of electric cars being critical components of building a cleaner, better world, which is far less dependent on oil," says Dr Winfried Wilcke, IBM's principle investigator, who initiated the Battery 500 Project. "Their compatible experience, knowledge and commitment to bold innovation in electric vehicle battery technology can help us transfer this research from the lab onto the road."

Nissan, which has invested heavily in alternative propulsion to good effect, most notably with the Leaf family car, is wary of the cost implications these advanced components might bring. "An obvious challenge within the EV battery industry is to extend the range with a lower cost per unit, and as manufacturers, we are all trying different approaches to achieve this objective," says Kazuo Yajima, head of global battery business, Nissan.

"The battery performance of current vehicles meets or exceeds the distance requirements of more than 80% of Europeans, who drive less than 100km a day," he reasons. "But we are focused on developing smaller and higher-performance batteries, improving the energy and power density, and increasing application flexibility."

Science lessons

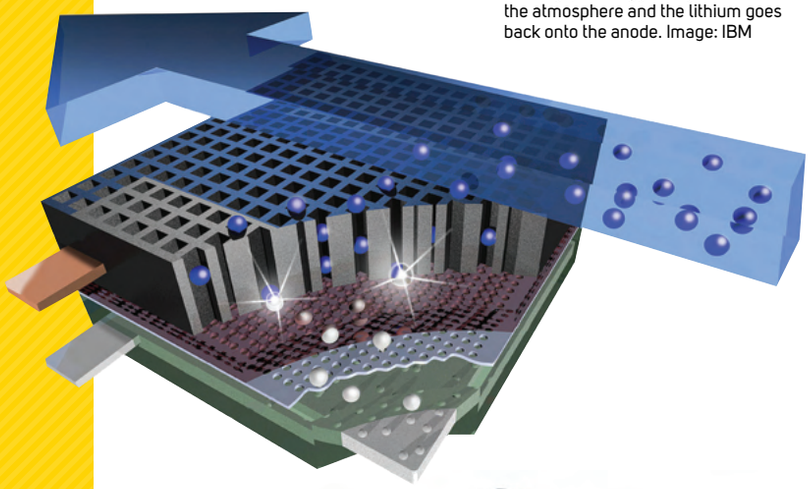
There is no denying that chemistry's role in future EV and HEV batteries is a major one, and even though Allen Patterson, senior electrochemist at battery maker Axeon, admits that to be the case, in general, the focus he says remains on lithium-ion, lithium chemistry and energy storage systems. But there are developments on the agenda for the near future: "There are a range of next-generation chemistries that are lithium-based and seen as the stepping stone towards increasing energy density," he reveals. "One of them is the silicon alloy system, where you can replace the graphite anode with a silicon compound, allowing you to store more energy in less space and volume." Patterson also claims that this novel approach, which answers so many industry needs, should be more cost-effective, too.

Most EVs today are limited to a range of 100 miles, and IBM believes that this is a key barrier to EV adoption unless a new battery technology can be developed that is affordable, lightweight, compact and has the capacity to power a typical family car several hundred miles or more on a single charge.

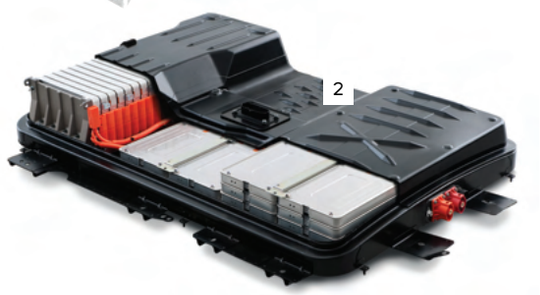
For a car running on today's lithium-ion batteries to match the range provided by a tank of gasoline, OEMs would need a very large battery that would weigh down the car and take up too much space, says IBM. As a result, the company is investigating lithium-air technology that offers higher energy density than lithium-ion batteries, due to lighter cathodes and the fact that their primary 'fuel' is the oxygen readily available in the atmosphere. To popularize EVs, an energy density 10 times greater than that of conventional lithium-ion batteries is needed, and these new partners to the project can help drive lithium-air technology toward that goal.

"New materials development is vitally important to ensuring the viability of lithium-air battery technology," says Tatsuya Mori, director, executive managing officer, Central Glass. "As a long-standing partner of IBM and leader in developing high-performance electrolytes for batteries, we're excited to share each other's chemical and scientific expertise in a field as exciting as electric vehicles."

Tetsuro Ohta, head of the advanced battery materials development center at Asahi Kasei, adds, "This alliance enables us to explore a new path to developing an improved rechargeable battery performance that cannot be met with conventional technologies."



IBM's innovative lithium air solution. During discharge, oxygen from the air reacts with lithium ions, forming lithium peroxide on a carbon matrix. Upon recharge, the oxygen is given back to the atmosphere and the lithium goes back onto the anode. Image: IBM



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1. Axeon continues to fast track the development of new battery designs for EVs. The supplier's technology has graced some standout tech demonstrators including prototypes from Jaguar Land Rover and Rolls-Royce

2. The battery pack in the Nissan Leaf differs from other designs in that it does not have an active thermal management system

"On the positive electrode (cathode) side, there are transition metal oxides, which generally tend to be compounds of cobalt, manganese and nickel in various compositions," he observes. "They form complicated inter-growth structures (two chemical compositions within the same particle), which can store more energy and generate more power." The Axeon engineer says they are seen as the next-generation cathodes that may also offer some cost reduction – mainly for electric vehicles where you don't need such high power.

According to Patterson, these inter-growth structures are seen as one of the more attractive options for generating higher energy density in EVs, but warns there is a long way to go. "Several companies are looking at them, such as LG Chem Power, BASF and Envia, but the silicon alloy system is less mature in its development because it has issues of cycle life. You need a product that will offer thousands of cycles, and at the moment it is in the range of hundreds."

Up until only the last quarter of 2012, many saw one of the big EV battery players as being US-based A123 Systems, which recently revealed the latest incarnation

"The battery performance of current vehicles meets or exceeds the distance requirements of more than 80% of Europeans, who drive less than 100km"

Kazuo Yajima, head of global battery business, Nissan

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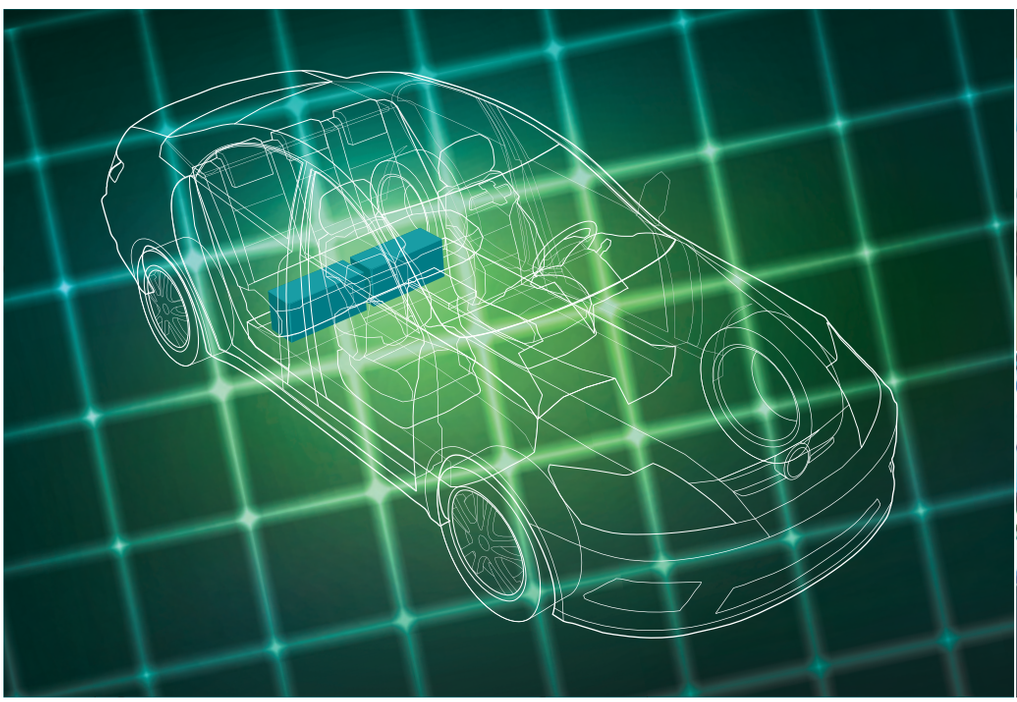

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As part of the High Energy Lithium-Ion Batteries project, BASF is conducting research into a new generation of lithium-ion batteries. The aim is to significantly increase the batteries' energy density to expand their use in EVs, as well as computers and cell phones. The image on the left from a BASF lab shows optimized electrolytes being removed from a steel cylinder by means of a dropper for transfer to the lithium-ion battery. This serves to check the quality of these materials and test new battery concepts

of its widely praised nanophosphate technology. However, with the company filing for Chapter 11 bankruptcy protection, and, at the time of going to press, its assets being sold to Johnson Controls (subject to finalization), the future of the company, as well as Nanophosphate EXT (extreme temperature) technology remains unclear.

"With Nanophosphate EXT, we were able to expand the operating range of the battery," confirms Jeff Kessen, director of the automotive solutions group at A123 Systems. "They can typically be tuned for low temperature power, but usually when you do that you lose some life at high temperature levels. Or, you tune the battery for high temperatures, but then you give up part of the low temperature power.

"With EXT, we get 20-30% more power at low temperatures than the current system, and we also get considerably better cycle rates at high temperatures."

The details of what exactly was changed with EXT have not been revealed, but Kessen admits to "fine-tuning the chemicals in the battery, as opposed to a "wholesale change". He continues, "We still use a carbon-based anode and the electrolyte is based on the same fundamentals as it was before. But in R&D it is possible to find big gains by making different active materials better together."

Material matters

Correct material choice is also subject to major decisions at the Chevrolet Volt's battery

BATTERIES WORTH THEIR SALT

Although lithium-ion technology continues to dominate the headlines in battery research and development, a new element has started to make its presence known as a potentially powerful alternative: sodium.

Sodium-ion technology possesses a number of benefits that lithium-based energy storage cannot capture, says Argonne chemist Christopher Johnson, who is leading an effort to improve the performance of ambient-temperature sodium-based batteries.

Perhaps most importantly, sodium is far more naturally abundant than lithium, which makes sodium lower in cost and less susceptible to extreme price fluctuations as the battery market rapidly expands.

"Our research into sodium-ion technology came about because one of the things we wanted to do was to cover all of our bases in the battery world," Johnson adds. "We knew going in that the energy density of sodium would be lower, but these other factors helped us decide that these systems could be worth pursuing."

Sodium ions are roughly three times as heavy as their lithium cousins, however, and their added weight makes it more difficult for them to shuttle back and forth between a battery's electrodes. As a consequence, scientists have to be more particular about choosing proper battery chemistries that work well with sodium on the atomic level.

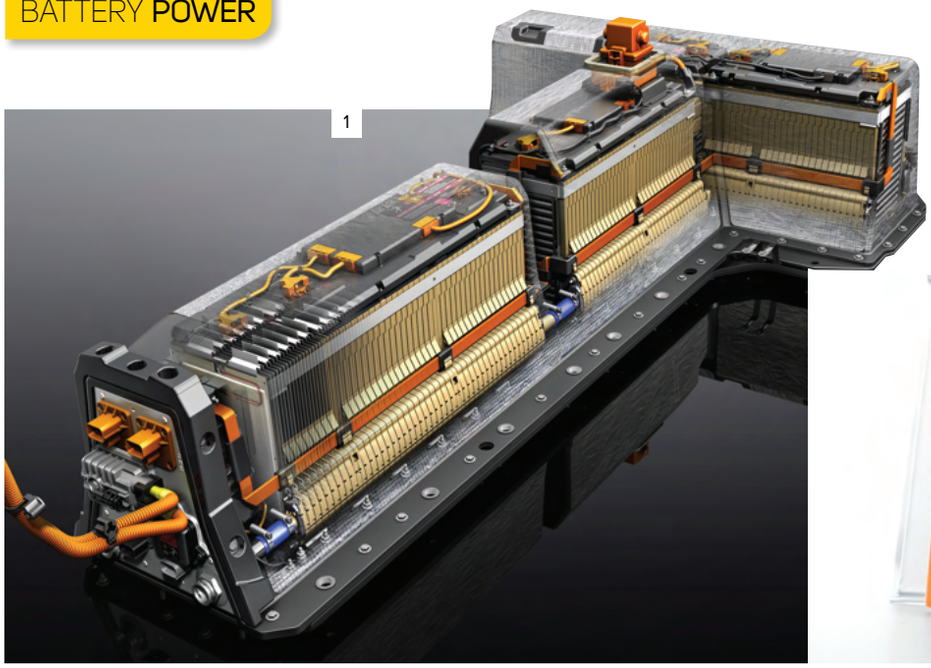
While some previous experiments have investigated the potential of high-temperature sodium-sulfur batteries, Johnson says that room-temperature sodium-ion batteries have only begun to be explored: "It's technologically more difficult and more expensive to go down the road of sodium-sulfur; we wanted to leverage the knowledge in lithium-ion batteries that we've collected over more than 15 years."

But because of their reduced energy density, it's thought that sodium-ion batteries will not work as effectively for the transportation industry, simply because it would take a far heavier battery to provide the same amount of energy to power a car. However, in areas such as stationary energy storage, weight is less of an issue, and sodium-ion batteries could find a wide range of applications.

"The big concerns for stationary energy storage are cost, performance and safety – and sodium-ion batteries would theoretically perform well on all of those measures," Johnson adds.

All batteries are composed of three distinct materials – a cathode, an anode and an electrolyte. Just as in lithium-ion batteries, each of these materials has to be tailored to accommodate the specific chemical reactions that will make the battery perform at its highest capacity. "You have to pick the right materials for each component to get the entire system to work the way it's designed," Johnson says.

The next stage of the research for Johnson and his team is to involve the exploration of aqueous, or water-based, sodium-ion batteries, which would have the advantage of being even safer and less expensive, he adds.



1. The T-shapped lithium-ion battery that forms part of GM's Voltec powertrain. In Volt/Ampera applications, the battery is housed in a central tunnel with liquid active thermal control

2. The current battery family range from US-based A123 Systems, which has filled for Chapter 11. Johnson Controls is rumored to be interested in buying the technology

supplier, LG Chem Power, but cost also remains the main issue here for the widespread adoption of EVs and HEVs. "Major R&D efforts have been undertaken to develop chemistries that will be capable of meeting these challenges," confirms Mohamed Alamgir, research director at LG Chem Power.

Alamgir is keeping many details close to his chest about the supplier's batteries, as well as the latest news on a partnership his company signed up to with GM to develop electric vehicles together. But he does reveal that the Michigan-based specialist already has multiple proprietary technologies such as separators offering added safety features, as well as a bespoke cell design for large-format batteries. "These technologies are now also being developed for other cell components such as cathode, anode and electrolytes," he confirms.

When it comes to major developments in the chemical make-up of next generation batteries, Alamgir retains caution at what consumers can expect to see in their vehicles in the years ahead. "While alternative anodes such as silicon alloys might find applications in large format batteries within the next five years that will increase energy density and lower cost, the concept of a lithium air battery is currently beset with multiple challenges that are not expected to be resolved in the next 10 years – if at all." LG Chem Power prefers, he confirms, to play it safe with the more mature technologies. "The focus here is to develop very high energy density, low-cost and thermally robust batteries that will not require any cooling system in addition to the expensive electronic control system."

"The chemistries around at the moment will remain for a good number of years. The very advanced alloy and cathode systems are at least five to 10 years away"

Allen Patterson, senior electrochemist at battery maker, Axeon

The next decade

Looking ahead to 2020, it all remains unclear as to what exactly to expect from batteries for EVs and HEVs. "EV battery technology is still in the development stage, and it is not easy to predict the future," admits Nissan's Yajima. "In general, one of the most likely areas for a breakthrough is in the materials. Longer term, it could be possible to rethink the electric vehicle, not as an extension of the existing internal combustion vehicle, but by focusing on an optimization of battery and vehicle."

Bitsche at Porsche believes there will be more internal changes with his company's plug-in HEV technology. "Plug-in batteries will remain a similar size, but have higher capacity due to the increasing energy density and higher power levels," he suggests. "However, Porsche-like performance is a challenge because of the Porsche requirement for high-power powertrains.

Patterson at Axeon admits that chemistries based on the silicon alloy systems that he highlighted – which historically were destined for the consumer electronics market – may take longer to reach fruition than many people expect, or even demand. "The chemistries around at the moment will remain for a good number of years," he adds. "The very advanced alloy and cathode systems are at least five to 10 years away.

"These new chemistries are going through validation at the moment and there are other chemistries that will follow on behind them, but we're talking around 2025 to 2030," reveals the Axeon man. "Potential solutions, such as lithium sulphur and lithium air, are being designed to make step changes in energy density in the region of three times what is offered in standard cells, or even five to 10 times in the case of lithium air."

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With a new generation of electric vehicles around the corner, lightweight design is undergoing a revolution. ***E&H*** examines the key strategies and processes for reaching the EV's optimal weight

WORDS: MAX MUELLER

Lightweight design has always been a key engineering concept, but the advent of bespoke electric vehicles such as BMW's i3 has further boosted its importance for increasing efficiency and consumer appeal. Exciting possibilities for lightening battery packs, electric motors and bodyshells are giving legitimacy to the question – will EVs ever become as light as conventionally IC-engined vehicles?

"In short, the answer is yes," says BMW's technology specialist, Manfred Poschenrieder, pointing to the company's groundbreaking i project. "In the i3, we will be able to compensate for the additional weight of the lithium-ion battery of about 250kg, mainly by the extensive use of carbon-fiber-reinforced polymers (CFRP) in the bodyshell. CFRP has an unsurpassed strength-to-weight ratio and is able to support its own weight up to a length of over 200km, around 10 times further than tempered shell, aluminum or magnesium. These properties make the material interesting for all components that are subject to high levels of strain, but we're also working on applications for other vehicle parts such as the rear seats. As an example, rear seat shells made from recycled CFRP offer a potential weight saving of 25% over glass fiber-reinforced materials."

1, 3 and 4: Despite the added weight of heavy battery, electric motor and charging components, the upcoming BMW i3 EV is expected to weigh only around 1,250kg due largely to the use of CFRP

At Ricardo, engineers accept the potential of carbon fiber, but are more cautious about the bigger picture. "I don't see a technology roadmap yet that would take us to an energy density of a battery and motor that would be equivalent to that of an IC engine and its fuel tank," says Dave Greenwood, Ricardo's product group head of hybrid and electric systems.

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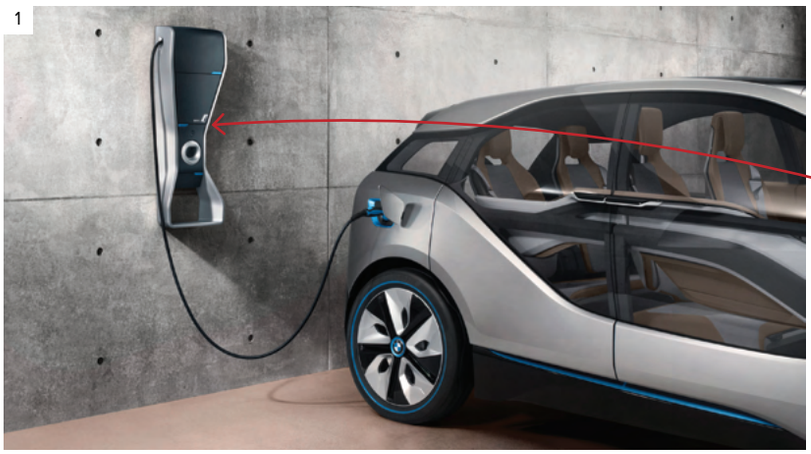


The extensive use of CFRP throughout the i8, as well as other lightweight materials inside the cabin, helped BMW achieve an optimal 50/50 weight distribution

3

4

Issues with carbon fiber

Despite the performance of carbon fiber, Greenwood sees two potential issues with its widespread use – recycling and total lifecycle emissions. "There is not much you can do with CF at the end of its life. It tends to be shredded or powdered and used as a bulk filler – a relatively low-value reuse of the material."

As for its production, CF tends to have high lifecycle emissions because of the amount of energy it takes to make the fibers and then turn them into a body. "BMW has built its CF plant next to a hydroelectric power station it has invested in," Greenwood outlines. "So, you can have two views on that. One is that they have created a power generation capability and are using it for their product so that their net emissions aren't significantly increased by moving to CF bodyshells.

"The other view is about societal cost," he continues. "If you feed that renewable energy into the grid, then there is an equivalent amount of the same average grid mix you would need to take out to manufacture the bodyshells – and if you take that view, the lifecycle impact of carbon fiber can be significant, outweighing the benefit of lightweighting. Some of the other manufacturers, such as Audi, are in favor of other materials for exactly that reason. Some manufacturers that power generation is one industry, and car manufacturing is another, and that you can get better lifecycle emissions by using materials such as aluminum."

> "Some manufacturers think that power generation is one industry and car manufacturing is another, and that you can get better lifecycle emissions by using materials such as aluminum"
>
> Dave Greenwood, product group head of hybrid and electric systems, Ricardo

Lightweight creations may form part of the DNA at Lotus Engineering, but even this specialist has to overcome weight/mass challenges when developing EVs. Evora 414E (above and below), for example, weighs 1,759kg

Phil Barker, chief engineer for hybrid and electric vehicles at Lotus, fully agrees: "One factor in the cost/weight compromise is production volumes," he says. "Niche volumes will probably be dominated by composite materials, but as production increases above 10,000 units per annum, formed metal will become more cost-effective – for weight reasons, this will probably be aluminum. There is an interesting place in the market for riveted and bonded aluminum, originally brought from aerospace design to the automotive market by Lotus. Since then, this type of structure has been adopted by Aston Martin and Jaguar Land Rover, resulting in lightweight but incredibly stiff structures."

Slim battery packs

The biggest potential for weight reduction, however, still lies in battery pack design. At Ricardo, developers look at four key areas: energy density, cell durability, high-power efficiency and structural integration. "In terms of the energy and power density of a cell, it's less about electrochemistry and more about surface texturing of the anodes and cathodes," explains Greenwood. "With nanotechnology, extremely high 'effective surface' to 'actual surface' ratios could be achieved."

As for battery durability, understanding degradation characteristics and longevity provides the key to saving weight. "A good example is the Prius," Greenwood continues. "The reason for the battery size reduction over successive generations was that Toyota was able to understand what real-world degradation looked like and reduce the safety margin."

Dr Mike Mekhiche, program director for hybrid drive solutions at BAE Systems, makes a similar point. "Batteries have to achieve a specific life-duration, resulting in 30% to 60% additional capacity and weight for a given set of vehicle duty cycles," he says.

"Better economy of scale and resulting lower costs," he continues, "would enable batteries to be replaced more often and yet preserve an attractive return on investment. Instead of being sized to meet a six-year life, a two- or one-year-life battery may become acceptable because its replacement will not be a prohibitive financial burden and will automatically result in considerable weight reductions."

The third key area – the efficiency under high load conditions – hinges on cooling. "The more efficient the cell is at high power, the easier, simpler, cheaper and lighter the cooling mechanisms can become, meaning we can take further weight out of the battery pack," Ricardo's Greenwood explains.

The fourth focus point is the creative use of the battery pack to enhance structural integrity and crash safety. "There are many small, heavy cells in a battery that could move relative to each other," he continues. "If you ignore, for a moment, the associated electrochemical issues, this would make a neat mechanism for absorbing the energy from a crash. We're looking at combining the functions of battery cell support with structural rigidity and crash protection – if you can get the dual purpose, you get twice the use out of that bit of weight."

A Volvo XC60 EV – a Ricardo tech demonstrator. The company's head of hybrid and electric systems, Dave Greenwood, says biomimetics offer much potential for long-term EV development, especially in the area of weight optimization

Electric motor focus

Next to battery packs, electric motors seem to offer further lightweighting opportunities through the use of permanent magnet technology. "Rare-earth magnets such as neodymium iron boron with their high remnant flux density and ability to operate at higher temperatures allow for lighter motors with higher torque – between 30% and 60% less weight than equivalent induction motors, with an increase in efficiency of 5% or more," says BAE Systems' Mekhiche.

Additional improvements include magnetic steels with similar low losses and high flux density, and the introduction of advanced cooling systems that facilitate substantial weight and size reductions. By that same token, superconductor-based e-machines might one day achieve power and torque densities way above those of current magnetic and electric materials. "While such solutions exist

FOCUS ON HYBRIDRIVE

BAE Systems' HybriDrive offers a family of heavy-duty hybrid-electric products for the transportation industry. It consists of hybrid series, hybrid parallel and power management systems for bus, lorry, rail and maritime industries, and is currently in use in 3,800 buses worldwide, with the company claiming fuel savings of up to 40% in stop-and-go urban duty cycles.

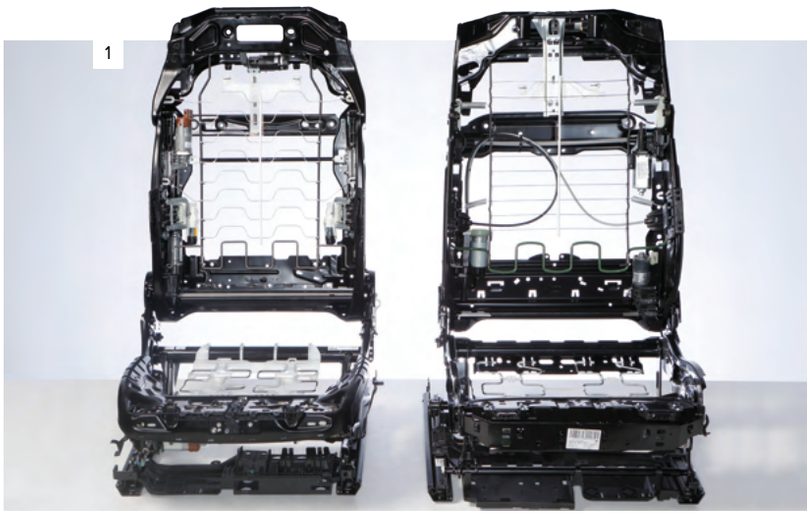
The HybriDrive parallel system is in its final development stages and specifically targets heavy-duty vocational trucks with duty cycles that include stop-and-go and higher average speeds. Unlike the series architecture, where the propulsion power is purely electric (with no connection between the engine and the wheels), the parallel system blends propulsion power from both the IC engine and the electric source.

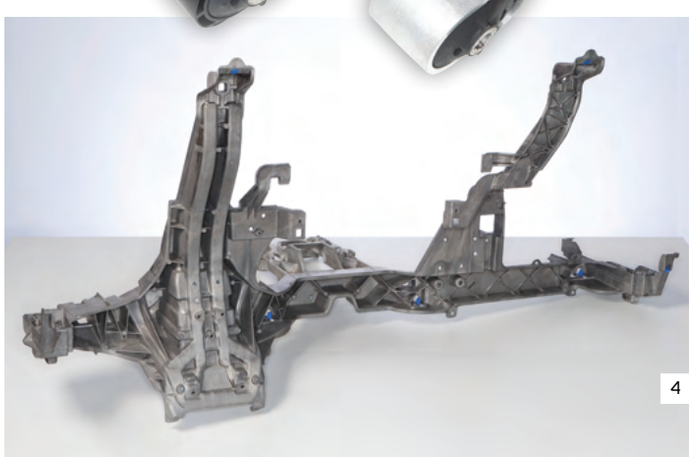
"Beyond the electrification of the powertrain, the series and parallel architectures also allow for further vehicle electrification where all the conventionally belt-driven vehicle accessories are electrified and made independent of the engine crankshaft," says BAE Systems' Mekhiche. "This brings additional fuel savings and smaller and lighter accessories that are driven based on vehicle demand instead of depending on the engine speed. In addition to allowing for the electrification of onboard loads, such as air-conditioning and air compressors, electric power can also be exported to external applications, such as in refuse compactors and cement mixers."

> "Rare-earth magnets allow for lighter motors with higher torque – between 30% and 60% less weight than equivalent induction motors, with an increase in efficiency of 5% or more"
>
> Dr Mike Mekhiche, program director for hybrid drive solutions, BAE Systems

in lab applications and small-scale demonstrators, the science is making tremendous progress and it's not unreasonable to expect these types of solutions to come to the market in the next two decades," he adds.

Bodyshells and interiors are also under scrutiny for adding excess weight to an EV. Choosing the right seat design can have a dramatic effect, especially in luxury electric vehicles. "Delivering luxury features intelligently without resorting to dozens of motors per seat is becoming very interesting," Greenwood adds. "Moreover, by using lightweight materials to reduce the physical thickness of the backrest, you can provide sufficient legroom for the rear passengers and shorten the vehicle several inches and take out further weight. Over time, we'd also like to see carbon fiber replaced with other kind of fibers that have a lower lifecycle impact."





1: Seats that are constructed from CFRP offer a total potential weight saving of 25% compared with glass fiber-reinforced materials

2: Sample infrared heating surface processes are enabling BMW to save weight in other areas of the vehicle, such as the doors

3: Another key weight optimization innovation from BMW is the lower tie bar and weight fixing to the engine oil sump

4: Car makers are increasingly looking at weight away from the powertrain, such as this BMW instrument panel carrier that's created from magnesium material

"BMW wants to exclude PVC from the interiors of its upcoming i-series. Other OEMs are not so strict"

Dr Alexander Jockisch, business director, Benecke-Kaliko

German interiors specialist Benecke-Kaliko provides an insight: "Lightweight materials will be based on polyolefins or become hybrid designs with different layers," states business director Dr Alexander Jockisch. "An example would be a conventional decorative top skin combined with a lightweight polyolefin foam layer such as Benecke-Kaliko's Yorn Light. The selection of a lightweight component doesn't necessarily mean a cost increase. Choosing surface materials also depends on the strategy of the OEM. BMW, for example, wants to exclude PVC from the interiors of its upcoming i-series. Other OEMs are not so strict."

But what about alternative thinking? Back to Greenwood: "Biomimetics is tremendously interesting. If you look at how natural qualities can improve mechanical structures and materials, there's nothing quite like evolution for having provided millions of years of iterative development. In particular, approaches such as additive layer manufacturing – effectively, 3D printing for mechanical components in volume – increases our ability to manufacture those complex organic shapes. This means interesting possibilities to further lighten vehicle structures."

The outlook for the future appears positive, as the industry focuses efforts on lightweight design of powertrains and vehicles as one of the five key strategic areas. "It's important to remember that IC engines matured over a period of over 100 years," Mekhiche concludes. "At the rate at which technology is improving, I have no doubt that within 10 to 20 years, EVs will surpass IC engine-based platforms in all performance aspects, while providing all the required environmental benefits."

From the publishers of Electric & Hybrid Vehicle Technology International magazine

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Hybrid class

Rolf Frech, member of the board for engineering at **Bentley Motors**, outlines the luxury car maker's electric – yes, electric – powertrain development plans, which will start with a plug-in hybrid SUV

WORDS: DEAN SLAVNICH

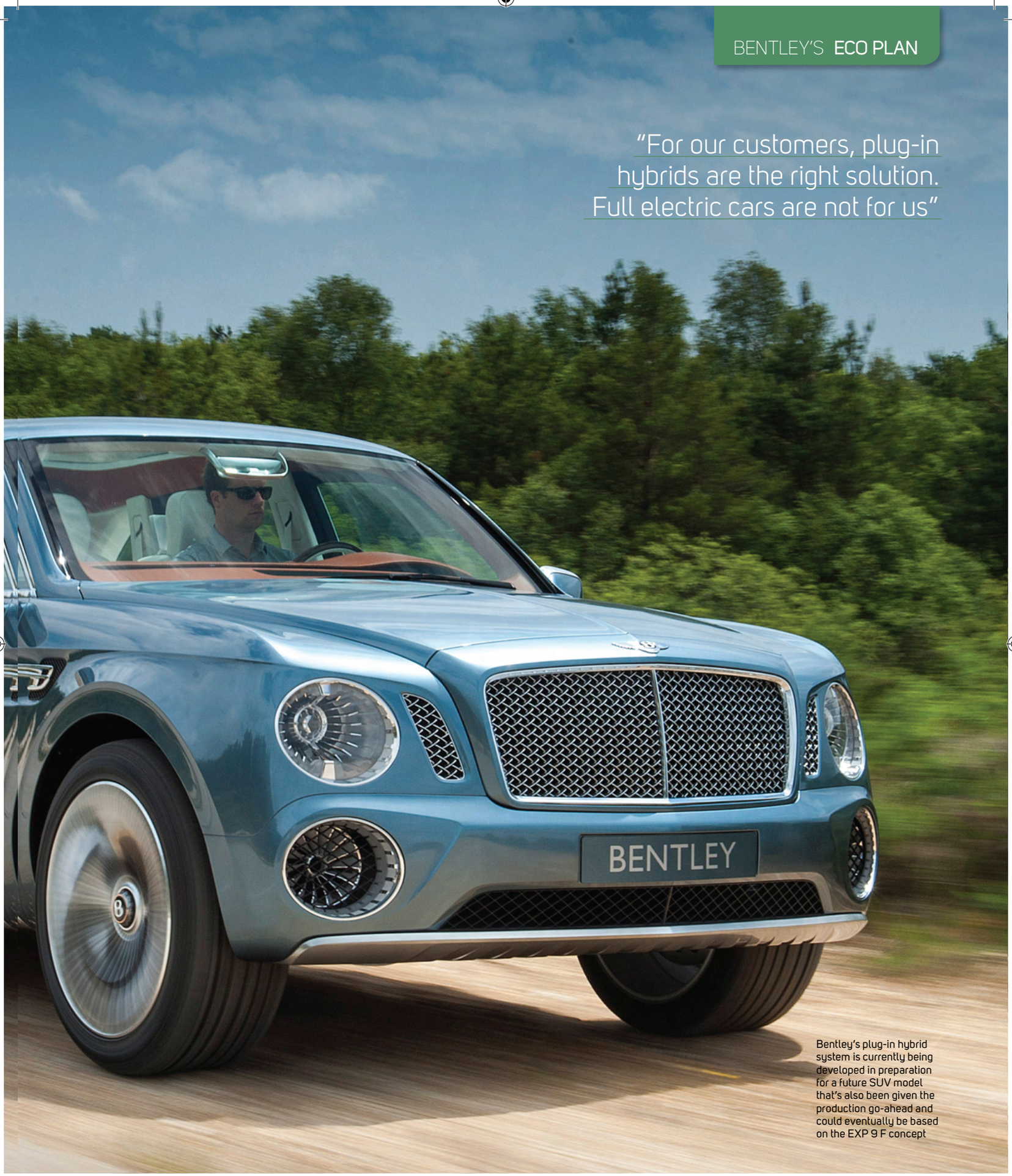
As director of engineering for Bentley, how concerned are you about emissions and fuel economy?

Of course, this is something that I think about a lot and, as a company, we have an environmental strategy. If you're talking to me with my engineering board member hat on, for me, it's not a black and white issue. It really isn't 'either or' for us. We strive to create the best efficiency, while offering performance. I see the possibility for Bentley – a real luxury car maker with cars that have great engines – to do a lot of things in terms of fuel consumption and emissions. For example, we are working hard on a plug-in hybrid and I believe that will be a really good solution for us.

For the plug-in hybrid technology, what sort of vehicle applications are you looking at?

We will start with the SUV, but we are looking at other possibilities. We have a great chance to get a lot of systems and parts from within the group – it's a massive advantage for us. Of course, there are already a lot of hybrids on the market, but we decided not to jump on this trend and bring out a conventional hybrid; instead, we wanted to wait a little and create a plug-in system.

"For our customers, plug-in hybrids are the right solution. Full electric cars are not for us"



Bentley's plug-in hybrid system is currently being developed in preparation for a future SUV model that's also been given the production go-ahead and could eventually be based on the EXP 9 F concept

So the plug-in powertrain won't be exclusive to the SUV?
No. It will be a strategy for Bentley. We have some ideas regarding the roadmap and how we take things forward, and there is a strategy in place for this technology.

How important is plug-in hybrid technology generally, not just for Bentley, but also for the automotive industry as a whole?
I think it represents the future for hybrids, I really do. But there are a lot of challenges to overcome in this area, mainly from the suppliers on the battery side of things.

Are full electric vehicles on the development agenda?
No, just a plug-in technology.

Why not a fully electric Bentley?
Simply because if you go for a full electric engine, your driving range is limited. I suppose you can drive it in large cities, but that's it, and even that depends on certain circumstances. I think all the strategies that have been discussed at industry level – such as battery swapping – will take a long time to get up and running, especially in terms of infrastructure. If you compare an EV to a plug-in, for example, you have the same [electric] situation, so you can drive for about 40km in the city, which is normally enough for that environment. However, the plug-in hybrid has an engine that will allow it to go for longer. For our customers, plug-in hybrids are the right solution. Full electric cars are not for us.

Frech, who is a fan of modern diesel engines, says there are numerous challenges to overcome in EV R&D, such as making batteries more powerful so they can drive vehicles for longer distances

Did you look at a range-extender setup before opting for a plug-in solution?
I see the range-extender as being something in between a classic full electric car and a plug-in. So this setup is focused on only recharging the battery; you can't drive with the plug-in and you can't get the power out of the combustion engine. At the same time, you also have to have everything that the combustion engine needs, so fuel on board, exhaust systems, and you must fulfill emissions regulations. Of course, you have the option to recharge the battery, but you're only really going halfway with this solution. So, if there has to be a combustion engine inside the car, its job shouldn't be to only recharge the battery, but to also drive the car.

"We will start with the SUV, but we are looking at other possibilities. We have a great chance to get a lot of systems and parts from within the group – it's a massive advantage for us"

You're an engineering man at heart. What do you make of modern, highly technical, low-emission diesel engines, such as the ones being pioneered by BMW and Audi? Is this type of IC engine technology a good fit for Bentley?
It all depends on the business case. Our greatest markets are the USA and China. In China, you don't have the possibility to sell a diesel car; in the USA, there's a growing opportunity with diesel. If that continues, then yes, we'll look at the business case. I agree with you that diesel is a great technology and in Europe diesel engines offer great possibilities even for Bentley models, especially with the high torque that's possible at low speeds. But it all comes down to the business case.

Will cars with IC engines – featuring no electrification – still be around in 20 years' time?
I am not sure whether all our range will be 100% plug-in by that time. I am sure that there will still be combustion engines, perhaps not in every car, but the technology will still be on the market.

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Future shock

With a new state-of-the-art facility to work in and more engineers than ever on the job, Ford plans to rapidly expand its hybrid and electric offerings

WORDS: JIM McCRAW

Ford has adopted flexible manufacturing that will ultimately enable costs to be slashed when rolling out EV, HEV and PHEV products

Ford is now in its third generation of hybrid automobiles with the 2013 Fusion sedan, making it is easily the USA's largest producer of hybrid vehicles. And despite that impressive lead, Detroit's second largest OEM is not showing any signs of slowing down its EV/HEV activities, with recent announcements outlining the company's clear intent to do a great deal more with hybrids, plug-in hybrids and pure electric vehicles, all in the very near future.

To start with, the Blue Oval has just finished converting one of its existing buildings into a shiny and new advanced electrification center. The former engineering base offers around 26,000m^2 of usable workspace and garages, and houses more than 1,000 engineers who focus full time on battery, powertrain electrification and general hybrid projects. This represents the largest co-located electric vehicle engineering team in the industry.

Ford's chief engineer for global hybrid and battery electric vehicles, Eric Kuehn, says the new center – and more importantly, the engineers who work in it – are vitally important to the car maker's future development projects. "Bringing the engineering capabilities and capacities in-house, having these dedicated people working collaboratively to generate the best of the best that we can, exercising their minds, and advancing the technology are first and foremost. Second is having the testing capability right here in the building, giving the engineers access to be able to work things through without wasting a lot of time."

In-house importance

With the center operating at full capacity, one of Ford's engineering goals is to bring nearly every aspect of its electrification programs in-house. Earlier in 2012, the company opened its own hybrid transmission manufacturing plant in a base located in Sterling Heights, Michigan, creating some 220 jobs in the process. More of this type of activity is likely to follow, and with these moves, Ford expects to cut the costs of its hybrid systems by up to 30% over the previous technology generation.

Kuehn says the company's battery-testing capabilities will double by 2013, and that testing enhancement will decrease development time by as much as 25%. The company will soon have 160 operating battery test channels, testing for power, performance, useful life and thermal behaviors across a wide range of temperatures and operating conditions.

1. Ford's new electrification center houses more than 1,000 engineers all focusing on battery and general hybrid projects

2. Despite already being the largest producer of HEVs in the USA, Ford is showing no signs of slowing down with a raft of new products on the way, such as the C-Max Hybrid

3. At the Rawsonville plant, a Ford technician assembles new battery packs for C-Max Hybrid and C-Max Energi Plug-In Hybrid models

4. Ford's chief engineer for battery electric vehicles, Kuehn, says battery testing capabilities will double at the car maker next year

1

2

"With battery electrics and plug-ins, the first discussion you have to have is, is there a customer base yet? And is there infrastructure there yet that is compatible with these systems?"

For local production of its lithium-ion batteries, Ford is currently partnered with Compact Power, a US subsidiary of Korean giant LG Chem, to assemble batteries for the Focus Electric in Holland, Michigan. The CPI subsidiary is headed by Prabhakar Patil, the engineer who led Ford's first hybrid project, the Escape SUV, back in 2004. The first-gen Escape was followed with the first Fusion Hybrid sedan in 2010, using a much improved, more efficient system. For 2013, Ford will offer a new version, the Fusion Energi, its first plug-in hybrid, which the company says could be the most fuel-efficient mid-size car in the world.

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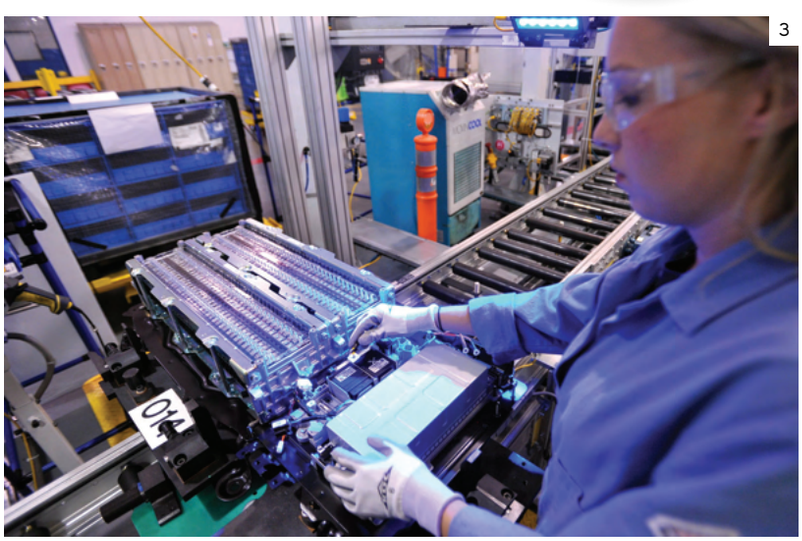

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The Blue Oval has its sights set on Toyota, generally seen as the global leader in hybrid creations. The Energi will be joined by a new Fusion Hybrid, which, according to Kuehn, should get 47mpg on the EPA highway test, some 5mpg better than its main competitor, the Toyota Camry Hybrid.

The same vehicle platform will be used for two additional product offerings, the C-Max Hybrid hatchback, which Ford says should achieve 47mpg city, 47mpg highway and 47mpg combined, some 3mpg better than the Prius V Hybrid, with a price US$1,300 lower than the Toyota. A plug-in hybrid version of the C-Max (see page 20) will also make its debut in 2013, offering 95mpg in electric mode and a range of 550 miles.

Then, for the all-electric vehicle sector, Ford will pit its upcoming Focus Electric against the Nissan Leaf. The Ford EV is rated by the EPA at more than 110mpg, with a charging time of four hours using the optional 240V charging station, which amounts to around half the charging time of the Leaf.

Solid foundations

"When you look at the overall development of the Focus Electric, the people, the processes and the development cycle are all built on the foundation of 20 years of working on this technology and in this space," says Kuehn with pride. "That enables us to leverage things that we've done along the way, and gives us what we needed to deliver for the Focus Electric."

He says Ford's 'Power Of Choice' program now offers the sedan or small SUV customer the choice of a hybrid, a plug-in hybrid, a battery electric, turbocharged gasoline engines and naturally aspirated gasoline engines because, "We're not suggesting that there's one silver bullet solution. All of them have their place, and all of them have a role in what has to be delivered in that product."

He continues, "Remember, with the Focus Electric, we have 23kWh of battery capacity, versus the hybrid electric, which is only about 1.4kWh. The Focus Electric has its own battery cooling system, while the hybrid only has to be air-cooled. Their functions, and their system managements, are different. So we have to test on a component level and a vehicle level in order to make sure that the components and the vehicles meet the performance criteria we have set. We have to pre-condition the batteries for whatever extremes of temperature we find. We torture our batteries, our systems and our vehicles to make sure we ferret out any issues long before the car reaches the customers."

But what about exporting some of these technologies? Kuehn says all of Ford's battery, motor and control systems testing is global in nature, so that, in most cases, the requirements of foreign markets can be met or systems can be modified for export.

"In the case of the hybrid electric vehicle, it's the most adaptable to the markets we would want to target. With the next level – battery electrics and plug-ins – the first discussion you have to have is, is there a customer base there yet? And is there infrastructure there yet that is compatible with these systems? There may be a consumer desire for a battery electric vehicle, but if the infrastructure doesn't exist for charging, charge rate, charge capacity or the electrical grid, it may not be something that can be supported.

"In Europe, there is already a number of cities that have CO_2-free zones, which may be a driver for more battery electric vehicles or plug-in hybrids that can drive in electric-only modes. Germany and the Scandinavian countries are taking aggressive steps toward emissions-free modes of transportation. We are keeping a close, watchful eye on those processes, supplying vehicles such as the Transit Connect Electric and Focus Electric to those fleets, and trying to see how those vehicles would fit in to the overall scheme of things in Europe."

FORD TO GO FURTHER

Ford's 2012 turbocharged three-cylinder 1-liter EcoBoost gasoline engine was not only the Blue Oval's first outright winner in the International Engine of the Year Awards – and the most convincing victor in the history of the fiercely fought competition – but it was also the under-hood star of the company's recent Go Further event in Amsterdam, where CEO Alan Mulally mapped the route to recovery from heavy losses for the OEM in Europe.

"We acknowledge the current reality and have developed a plan to deal with it," was his message to an audience of 2,500 dealers, staff, and media in the Dutch city's new Ziggo Dome concert hall. During the presentation – broadcast live around the world – he and his top team revealed no fewer than 15 new models to be rolled out over the coming four years. Celebrating the International Engine of the Year achievement, Mulally's senior executives broke news that brought a gasp from many present: EcoBoost will power some versions of the all-new Mondeo for Europe!

Mondeo 1-liter models will be the largest ever Ford vehicle to be fitted with such a small displacement engine. "Today's smartest technology offers customers more from less," Barb Samardzich, VP of product development, told the audience. "This is as true of engines as it is of computers and smartphones. By equipping the all-new Mondeo with our acclaimed 1-liter EcoBoost engine, we are delivering cutting-edge technology that delivers a very real and tangible customer benefit."

Ford's International Engine of the Year winner – already in Fiesta, Focus, B-Max and C-Max – is the most power-dense production engine the company has ever made. With a block small enough to sit on a piece of A4 paper, it produces 125ps and 170Nm of torque – or up to 200Nm in 'overboost' mode – and all delivered from just 1,450rpm.

1. Ford says the Fusion Energi, which is the car maker's first plug-in hybrid product, has the potential to be the world's most fuel-efficient mid-size car

2. The Van Dyke transmission plant. In 2012, Ford opened a new hybrid transmission manufacturing facility in Sterling Heights, Michigan

"We torture our batteries, our systems and our vehicles to make sure we ferret out any issues long before the car reaches the customers"

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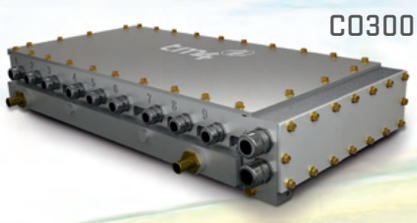

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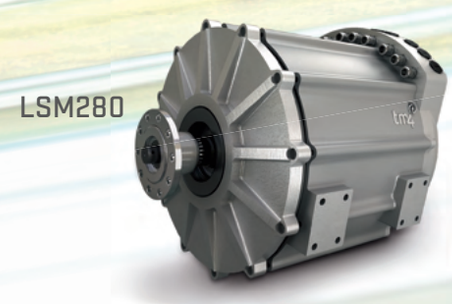

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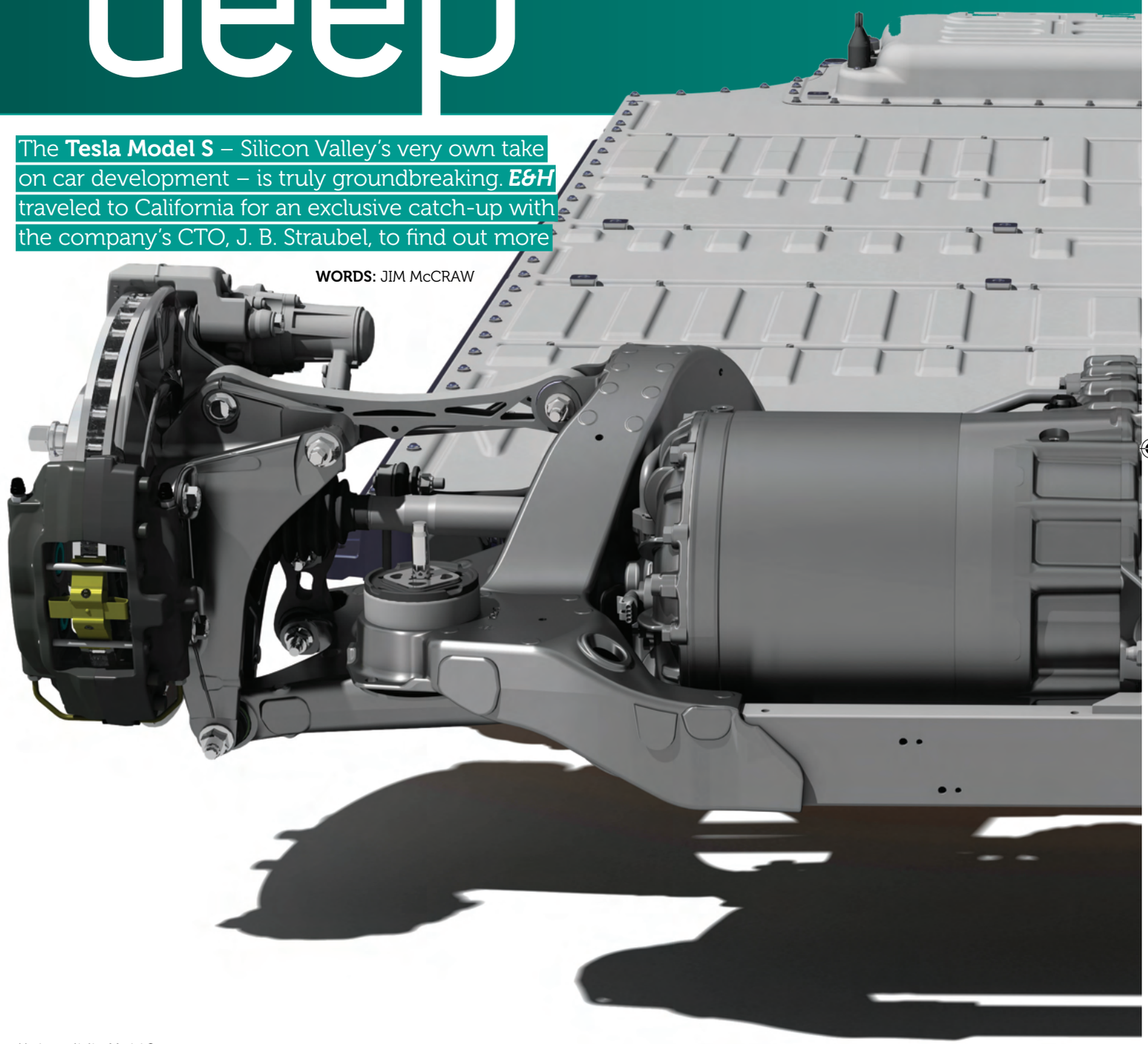
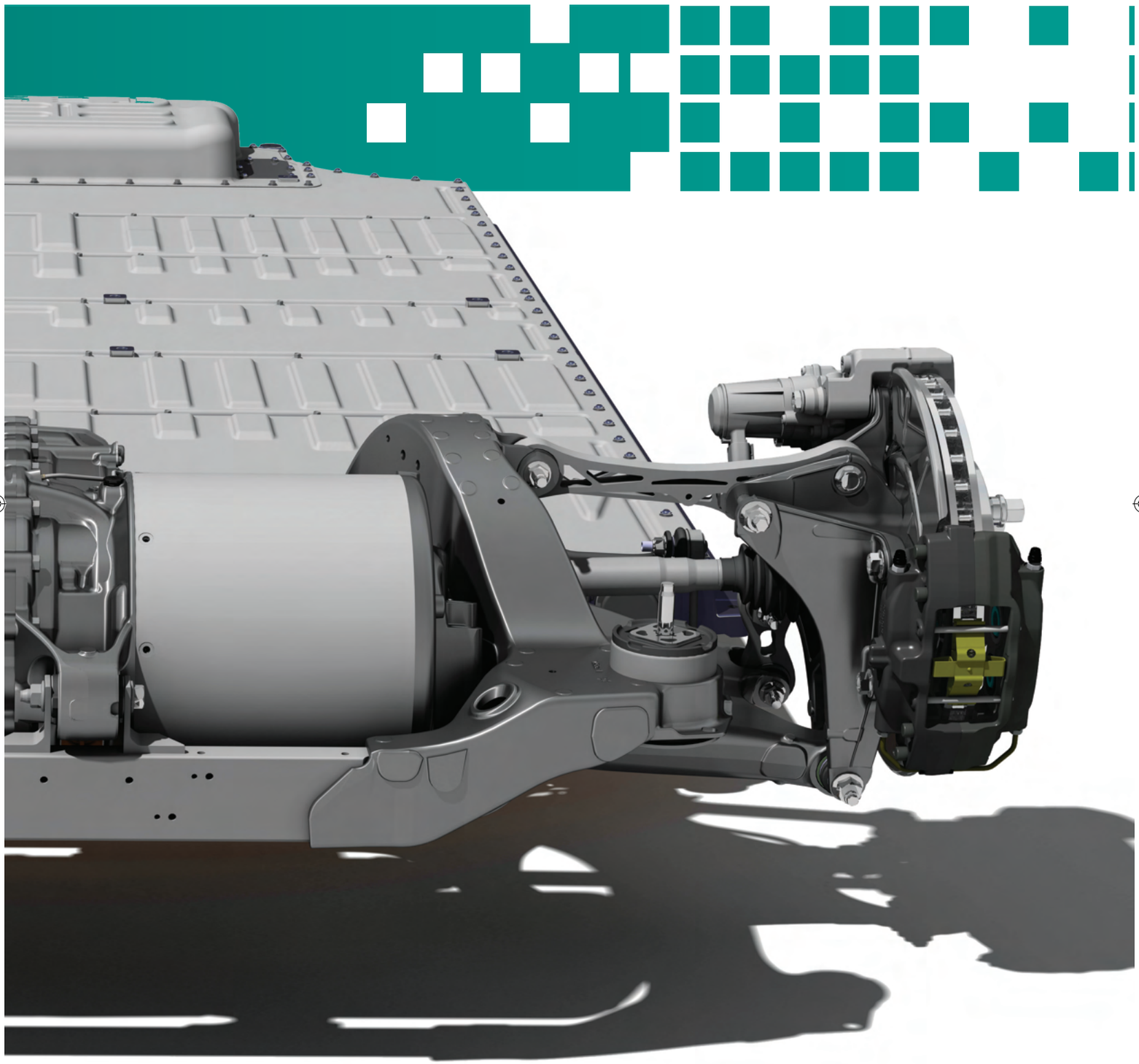
Skin deep

The **Tesla Model S** – Silicon Valley's very own take on car development – is truly groundbreaking. ***E&H*** traveled to California for an exclusive catch-up with the company's CTO, J. B. Straubel, to find out more

WORDS: JIM McCRAW



Underneath the Model S. Some say this is the greatest electric sedan to date



The Tesla Model S all-electric sedan is the quickest sedan ever built in the USA, taking just 3.9 seconds to race from standstill to 100km/h. Blink, and you'll miss it. But that's not all: with the potential to cover 265 miles, this truly remarkable vehicle also takes the crown for being the clear leader in the EPA-rated driving range. But here's the thing: all this comes from a product that tips the scales at a hefty 2,180kg. How is this possible? Well, simply put, it's because this is the first electric sedan conceived in Silicon Valley, by a cadre of geniuses.

The aluminum-bodied Model S, only the second car in the company's short history since the original Lotus-based electric roadster, is powered by a single rear-mounted 16,000rpm electric motor rated at up to 415ps at 5,000rpm and 600Nm of instant torque. The motor is spun by an enormous battery pack mounted underneath the entire central floor of the car, containing some 7,000 lithium-ion cells. And the key here is the battery pack, which naturally is very powerful, weighing in at nearly 455kg.

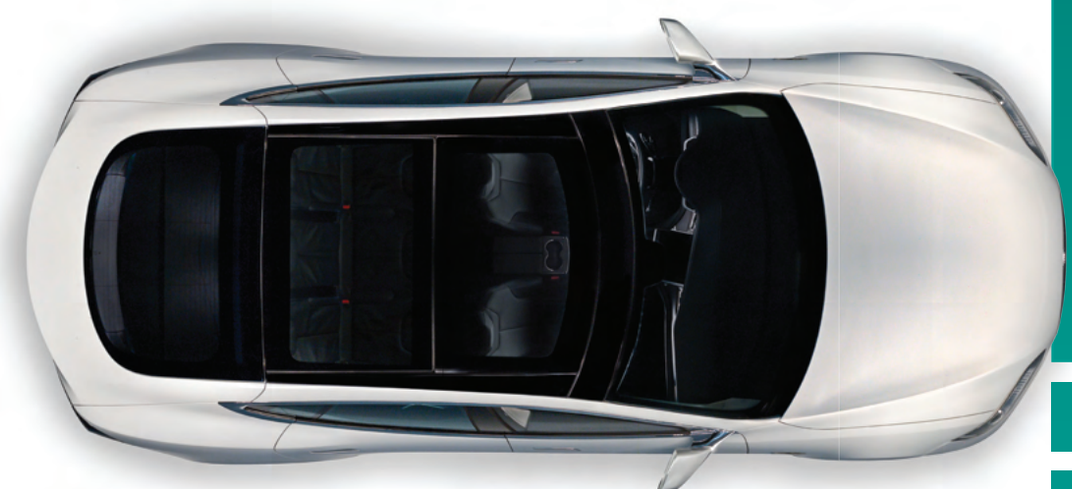
Straubel says that the Model S was designed as an electric vehicle from the ground up, meaning that the end product could meet high performance targets

"In many other EVs, the battery is a very distinct thing that bolts into an existing car; in the Model S, all the systems merge together"

Batteries in all shapes and sizes

But the innovation doesn't end there. The Model S is the first electric car to be offered with a range of battery sizes, outputs and charging cycles, to accommodate a range of buyers willing to buy in for as little as US$49,900 or as much as US$97,900, depending on which of the four models is chosen, and taking into account the selection of battery size and charging system.

J. B. Straubel, with a master's in energy systems engineering from Stanford University, is Tesla's chief technical officer and a co-founder of the company in 2003. He describes some of the concepts, the thinking, the planning and the execution of the company's first family electric car as revolutionary. "The chassis, suspension and powertrain are – and were – a very, very tight collaboration," he recalls.



With a 0-100km/h sprint time of just under four seconds, the Model S can easily compete with V8 competition developed in Detroit

TECH SPECS

Powertrain: A liquid-cooled arrangement that includes the battery, motor, drive inverter and gearbox

Battery type: 40kWh microprocessor controlled lithium-ion battery

Induction: Three-phase, four-pole AC induction motor with a copper rotor

Inverter: Drive inverter with variable frequency drive and regenerative braking system

Transmission: Single-speed fixed gear with a 9.73:1 reduction ratio

Length: 4,978mm

Height: 1,435mm

Width: 1,964mm

Kerb weight: 2,180kg

Weight distribution: 48/52

1. Tesla is the only car maker in the world at present to offer its customers free and unlimited battery charging at its network of supercharger stations

2. The Model S is available with a raft of equipment options and specs, much like what customers expect with new IC engined sedans

3. A single-speed gearbox is used, which minimizes interfaces in the Model S

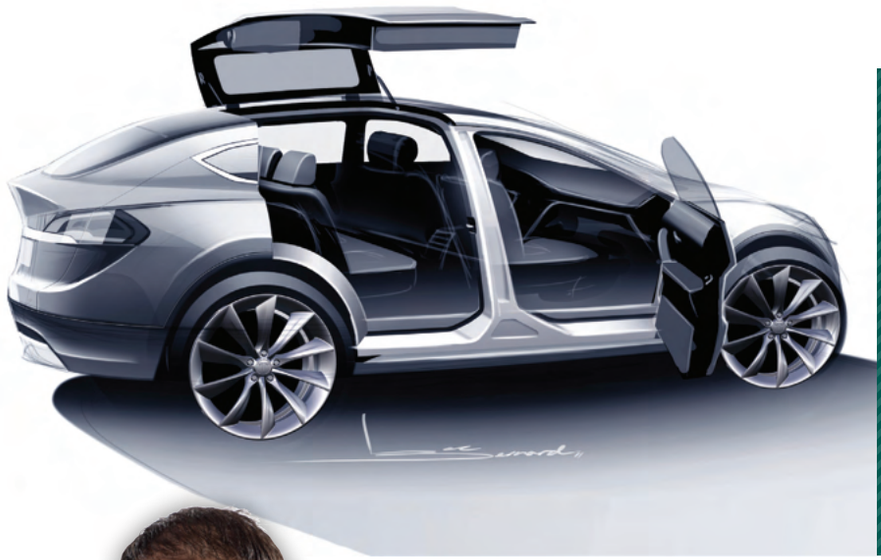
4. The electric sedan can take charge from 110V and 240V home charging systems or mobile charging connectors

"Air suspension was not the cheapest, but it has some really unique capabilities. It can be seamless between different versions of the car, especially the 60 and 85kWh versions, because they do have a mass difference. With a coil spring suspension, you would need different physical springs. With air suspension, it can be adjusted dynamically, and it gives us a chance to adjust ride height dynamically [four levels, in total], which feeds back into efficiency. When you're cruising on the freeway, you want the car to ride quite a bit lower to prevent air getting trapped underneath it."

The air suspension allows the suspension calibration to change vehicle height with speed, and offers automatic front-rear leveling depending on load. Although it is called active air suspension, it does not change continuously from corner to corner.

The Model S boasts world-class aerodynamic performance, with battery and motor cooling system louvers that close off the front end of the car when maximum cooling is not needed, and a class-leading drag coefficient of 0.24, which adds to the range.

One of the more unusual aspects at face value of the Model S is that it contains a substantial number of parts and systems, including the steering and other system components, made by Mercedes-Benz. However, this fact is less surprising when taking into account that Daimler is a shareholder in the company.



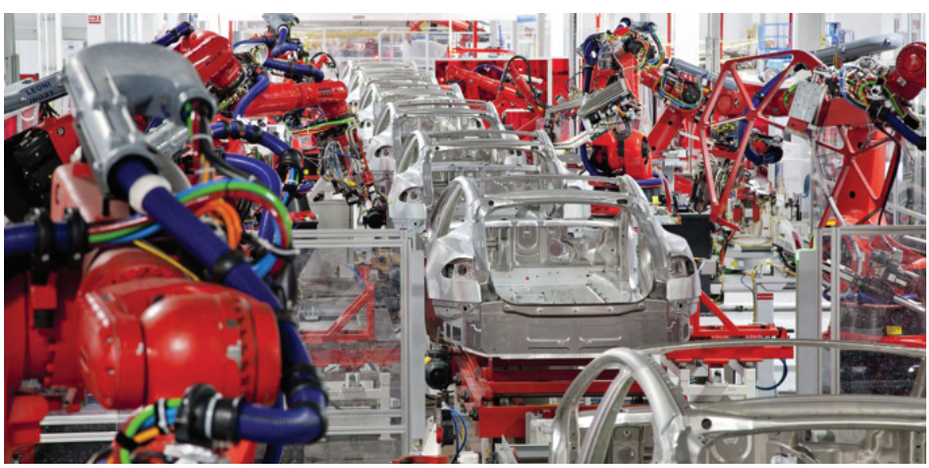
X MARKS THE SPOT

Due for market launch in 2014, the Model X is Tesla's take on a family vehicle with performance at its roots. The company insists that the Tesla Vehicle Platform enables Model X to perform in ways never expected from a car of this size, thanks mainly to a center of gravity lower than any other SUV. Model X will be offered with optional dual motor all-wheel drive. The second motor in this setup enables much more than simply all-weather, all-road capabilities: it increases torque by 50%. When fitted with the AWD technology, Tesla is promising Model X will outperform the fastest SUVs and many sportscars with a 0-100km/h sprint of just five seconds. Unveiled in February of this year, Model X will be offered with a 60 or 85kWh battery pack.

"We did evaluate two motors in the rear, but we ended up getting better power density, overall efficiency and range with a single large motor, because the larger motor has higher efficiency, especially at higher power"

Straubel continues, "Although we offer three different sizes of battery [40, 60 and 85kWh], the enclosure and all of the interfaces are the same. The way the car is designed, the battery is not a standalone component. The enclosure contains parts of the car and the chassis. I think it's the right optimization, even though it makes it a bit hard to calculate the boundaries. We designed the car from the ground up as an EV, and that let us blur some of those boundaries. In many other EVs, the battery is a very distinct thing that bolts into an existing car; in the Model S, all the systems merge together."

The huge battery, which is assembled in the Tesla factory from cells provided by Panasonic/Sanyo, contains, as mentioned, some 7,000 individual cells. It is positioned at the bottom center of the car, to keep it out of harm's way, and offers a flat-bottom design, a normal trunk and interior layout, and greatly improves the handling of the car because the center of gravity is very low.



Model S production commences at Tesla's factory in Fremont, California, where assembly of the large lithium-ion battery also takes place

Lessons from the Roadster

Straubel says that the choice of a single large motor over two smaller motors was easy, based on the company's experience with the original car, the Tesla Roadster.

"That was a long optimization in itself," continues the CTO. "The Roadster has a similar architecture, and we did evaluate two motors in the rear, but we ended up getting better power density, overall efficiency and range with a single large motor, because the larger motor has higher efficiency, especially at higher power. It certainly was more cost efficient than having two small motors, two inverters, two small gearboxes, more complexity and more connections." As a result, the Model S has several built-in drive modes controlled by software.

The proprietary rear drive unit of the Model S, a single-speed gearbox with a 9.73:1 reduction ratio, minimizes interfaces and connections. "Those were the things that gave us the biggest reliability challenges on the Roadster," recalls Straubel, "so we learned from that and tried to get rid of those."

The huge motor was designed by Tesla using MATLAB SimuLink and a dozen or so other simulation software packages, and is built at its factory in Fremont, California.

ALL-ROUND EV HERO

The story of Straubel's career started at a junkyard in Wisconsin where, at the age of 14, he discovered a discarded electric golf cart and decided to rebuild it, and it was here where began a lifelong fascination with energy work and electric vehicles.

As a co-founder of Tesla, Straubel has overseen the technical and engineering design of the vehicles, focusing on the battery, motor, power electronics and high-level software sub-systems. He also evaluates new technology, manages vehicle systems testing, and handles technical interfaces with key vendors.

Prior to Tesla, Straubel was the CTO and co-founder of the aerospace company Volacom, which designed a specialized high-altitude electric aircraft platform using a novel power plant. At Volacom, he invented and patented a new long-endurance hybrid electric propulsion concept that was later licensed to Boeing.

Before Volacom, he worked at Rosen Motors as a propulsion engineer developing a hybrid electric vehicle drivetrain based on a micro turbine and a high-speed flywheel. He was also part of the early team at Pentadyne, where he designed a first-gen 150kW power inverter, motor-generator controls and magnetic bearing systems.

Armed with a bachelor's in energy systems engineering and a master's in energy engineering from Stanford University, Straubel today lives in Menlo Park, California, where he continues to indulge his passion for electric transportation: he built an electric Porsche 944 that held a world EV racing record, a custom electric bicycle, and a pioneering hybrid trailer system. He is also an accomplished pilot.

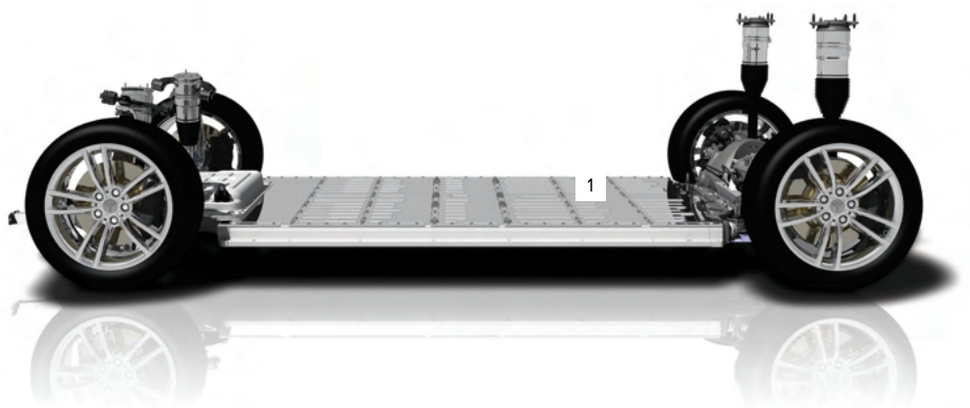
Although the car has a 100% aluminum body, and lightweight seats and interior trim, the finished product is undoubtedly heavy – coming in at nearly 2,200kg, which really is large upmarket SUV territory. Around one fifth of that total mass is down to the massive battery and another big chunk comes from the drive motor.

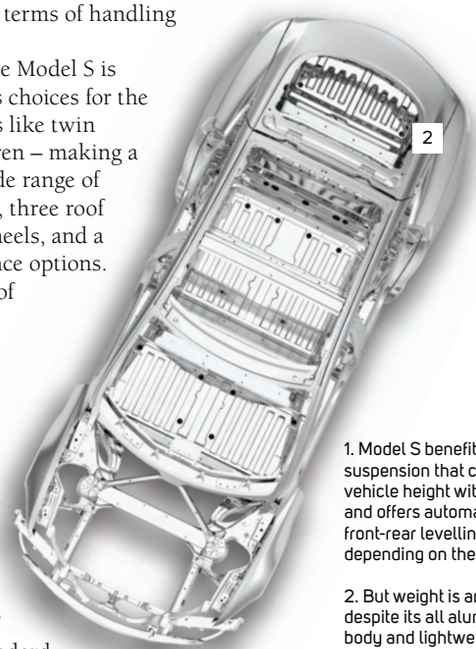
"We wish it were a little lighter than that," admits Straubel. "Like so many engineering projects, we worked with a target and fought and designed and tested and went through the whole development program, but, all too often, weight tends to creep in. I still think it's a pretty compelling car in terms of handling and performance."

Putting weight aside, the Model S is certainly compelling in its choices for the customer, offering options like twin rear-facing seats for children – making a total of seven seats – a wide range of colors and interior fabrics, three roof designs, 21in tires and wheels, and a tech package of convenience options. There's also a wide range of charging options.

EPA politics

The Model S can charge on 110V and 240V home charging systems or public charging stations, using an SAE J1772 adapter. Tesla offers a twin-charger option of two 20kW chargers in lieu of the standard 10kW charger for US$1,500, standard on the two top models, and a US$1,200 high-powered 20kW wall connector. Cars equipped with the 85kWh battery system can be charged, free and unlimited, at one of Tesla's own network of supercharger stations, promising only 30 minutes of charge time. No other electric car company in the world offers this feature.





1. Model S benefits from air suspension that changes vehicle height with speed and offers automatic front-rear levelling depending on the load

2. But weight is an issue: despite its all aluminum body and lightweight parts, Model S is 2,200kg heavy

When the Model S was finished and tested by the US EPA, it was rated at a range of 265 miles, but only after the test was changed from the initial two-cycle test to a new five-cycle test, which lowered the range substantially.

Straubel says the EPA has good intentions, but the car was designed to have a 300-mile two-cycle range. "We did a number of things along the way to course-correct from where we were, and at the end of the day the car came in with almost a 330-mile two-cycle range, but the 265-mile range on the five-cycle." He points out that, as with any ordinary gasoline or diesel passenger car, the driver will ultimately control the maximum range of the Model S, not the EPA.

"This is an intensely political issue and all the different groups lobby so furiously that it is really difficult to get something that is consistent and uniform. The actual test is a little bit less critical as long it's consistent across the industry and provides something that consumers can benchmark and understand."

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Reinventing the wheel

By simply turning an electric motor inside out, Protean has created a compact in-wheel electric propulsion system that is looking for a home in the right type of future vehicle

WORDS: JIM McCRAW

To prove its technology, Protean has built a fleet of proof-of-concept demonstrators, including the Brabus Mercedes-Benz E-Class four-motor EV

The elements of Protean Electric are worldwide, with corporate headquarters in Troy, Michigan; a research and development facility in Farnham, UK; a new production factory in Liyang, China; and some US$84 million in fresh capital from a small group of new American and Chinese investors. All this is important because this global, professional setup embodies the technology that the company's engineers have created and, unlike many other startups, there's a real feeling that Protean has genuinely come up with something worthwhile as the industry strives to achieve new transportation solutions.

The technology in question, which Protean is currently prepared to build for customers or to license for manufacture, is a compact in-wheel electric propulsion motor that offers light weight, compact size, very high power density and scaleability to match a variety of requirements. It can be used in pure battery-electric vehicles, gasoline electric vehicles, diesel electric vehicles and fuel-cell hybrid vehicles, and/or all-wheel-drive vehicles right up to light commercial applications in both size and weight.

In-wheel electric motors are not new, of course, but Protean's initial design is more than impressive. The motor is 419mm in diameter, 114mm wide, weighs in at 30kg and develops 110ps and 800Nm of peak torque at 400V DC. Crucially, the technology can be used in pairs in front-wheel-drive, rear-wheel-drive and all-wheel-drive applications.

The motor system's advantages over current electric propulsion motors are many, according to CEO Bob Purcell. He says his company's developments can deliver hybrid and electric vehicle technology faster with fewer new parts, less complexity and at a lower total cost than other leading electric drive systems. According to Purcell, the motors can be developed as a retrofit application for existing fleets, as well as for new vehicles. As built, it does not require external gearing, drive shafts or differentials. Each motor has a built-in inverter, control electronics and software, and does not need a separate motor power electronics module to be fitted to the vehicle.

The key for Purcell is that Protean's system avoids the costs of unique hybrid drive tooling, changes to chassis, bodies and transmissions, and can help create a hybrid vehicle with fewer modifications to base engine components. As such, it's far less disruptive in the assembly plant. Protean's drive system also has superior regenerative braking capabilities, which allow up to 85% of the available kinetic energy to be recovered during braking. This efficiency can increase range by up to 30% and contribute to the reduction of both battery size and cost.

Each motor in a typical system is cooled by normal ethylene glycol fluid that is channeled from the windings and electronics through central passages in each motor to an auxiliary radiator, pumping in the vehicle's cooling system. It is then cooled and returned in a continuous loop.

Remember the EV-1?

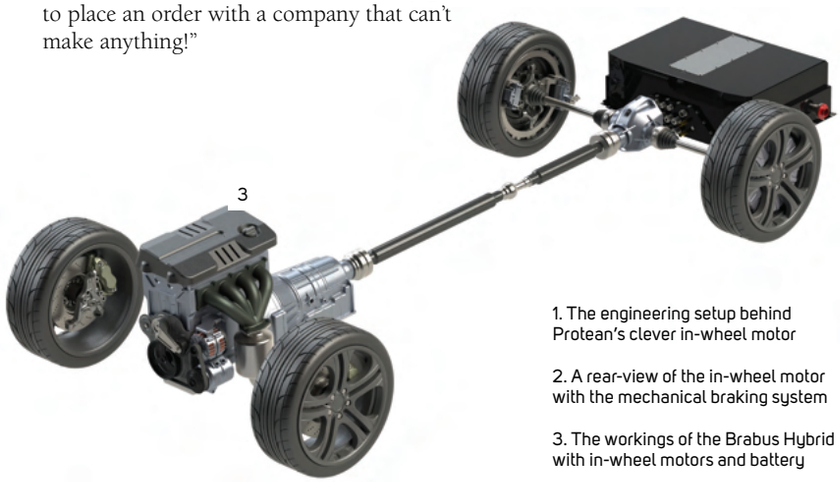
Purcell's enthusiasm about EV technology is one thing, but that support becomes all the more creditable when looking into the CEO's background: he's not only a veteran of 27 years at GM in advanced propulsion systems, he's also considered by many as the father of the GM EV-1 electric vehicle production program. From 1994 to 2002, Purcell ran the GM advanced technology vehicles program, producing the EV-1, the S-10 compact electric pickup truck, the Precept concept vehicle and assorted alternative-fuel and military vehicles.

The secret engineering ingredient with the Protean technology is that the patented drive motor has essentially been built inside-out. "With a conventional motor, you have a central rotating shaft with a stationary outer hub," explains Purcell. "Our motor is just the opposite. We have a stationary core with a rotating outer hub. It's that rotating outer hub that enables you to direct-mount the wheel. You don't have conventional transmissions, axles or gears. You bolt the wheel directly to the brake rotor. With previous geared designs, you had to add a lot of mass and a lot of complexity to make it work." Protean has been awarded 17 patents for its unique technology and design, and more than 60 additional patent applications have been filed internationally and with specific countries in North America, Europe and Asia.

Purcell says that the team of scientists and engineers at Protean's lab in Farnham discovered a way to put the motor on the outside in order to be able to direct-mount to the wheel and eliminate all the complexity. "I believe this to be the ultimate, the optimal in-wheel motor system," adds the CEO with real confidence, before pointing out that the braking system, co-developed with Alcon, is also inside-out. Other partners in the project include FEV, AB Mikroelectronik, ATS, Mahle, Sierra Instruments and Trelleborg, all of which have OEM connections and huge experience in this arena.

The former GM man, who started building Chevrolet V8 racing engines when he was six years old, says that Protean is prepared to license the manufacture of its in-wheel motors to OEM partners around the world, and is equally prepared to build its motors in small, custom quantities at the new plant in Liyang, China. "We have the three things we need to have a successful start-up company: cash, customers and capacity. You can't sign final agreements for customer orders unless you can prove to the customer than you can service their order. It doesn't do a customer any good to place an order with a company that can't make anything!"

"We have the three things we need to have a successful start-up company: cash, customers and capacity"



1. The engineering setup behind Protean's clever in-wheel motor

2. A rear-view of the in-wheel motor with the mechanical braking system

3. The workings of the Brabus Hybrid with in-wheel motors and battery

Purcell says that the first engineering objection to in-wheel motors – unsprung mass – was tested for Protean in a project with Lotus, and the Lotus testing program concluded that, at 30kg per corner, standard vehicle suspension systems could be used effectively without degradation of vehicle ride and handling. "We have a very high density permanent-magnet machine that is extremely mass-efficient in a very dense package, a package that weighs 68lb [30kg] and puts out over 100hp [101ps], so this is a very high-tech machine."

Protean has so far built a fleet of proof-of-concept vehicles using a four-motor, all-wheel-drive electric Volvo C30 coupe, a Brabus Mercedes-Benz E-Class rear-drive hybrid sedan, a Brabus Mercedes-Benz E-Class four-motor electric vehicle, a Vauxhall Vivaro front-drive PHEV hybrid and a Ford F-150 rear-drive pickup truck converted to four-motor electric propulsion with a 3,175kg gross weight, all without significant failures.

Discussing specifically the tiny Volvo C30 AWD project, Purcell says, "That first concept vehicle we built with Volvo was a sub-five-second car from 0-60mph [0-100km/h], but the handling characteristics of that car put it in a class with Formula cars, with individual torque control at each wheel. That was a car with conventional suspension built on the same platform as a Ford Focus." Purcell adds that, in production, the end application would be a short, narrow, lightweight car with all-wheel-drive, with up to 440bhp from a combined 123kg of motors, with no noise, no gasoline consumed and no emissions.

The CEO says it's findings such as these that are getting many in the industry excited about the technology Protean has to offer. And with so much on offer – and all of that proven – this may be an idea whose time has come at last.

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Designer range

WORDS: JIM McCRAW

When internationally renowned car designer Henrik Fisker decided to build an electric car of his own, it all started with the powertrain

Unquestionably one of the most ambitious, most complex extended-range electric car projects ever is the Fisker Karma luxury sedan. But after all of its ups and downs, government loans, factory startups and other impediments, the program continues to thrive.

To create a brand-new vehicle took an initial powertrain team of 243 engineers and managers, not including supplier personnel. EV veteran Paul Boskovitch is the engineer in charge of Fisker's powertrain activities. He says the entire car was designed around the powertrain, which includes the battery pack, twin traction motors, a 2-liter GM-sourced gasoline engine, a generator, inverter, control electronics and a complex rear-drive axle system with traction control.

Boskovitch and his team used computer simulations to arrive at the 225kg lithium-ion nanophosphate battery pack size and output, currently 180kW and 20kWh, sourced by A123 Systems. The chief engineer says that the entire battery design process was very precise, leaving margin for assembly tolerances but little other room for expansion or change until the next generation of vehicle, which is already underway. The battery pack was sized to meet the Environmental Protection Agency urban dynamometer driving schedule city cycle of 50.5 miles and the New European Driving Cycle (Type 1) of 51.5 miles.

Paul Boskovitch, powertrain chief at Fisker, says the next-generation range-extender powertrain will be smaller, lighter, more powerful but less costly

"The permanent-magnet motors were selected because they give us the best combination of power density, speed and overall efficiency levels"

To power the onboard generator, the team selected a known quantity, the GM Ecotec 2-liter turbocharged four-cylinder rated at 260ps, connected to a 175kW generator, mounted in the normal front engine location.

Magnet motors from China

The twin rear-mounted traction motors are interior permanent-magnet motors sourced to Fisker by Jing-Jin Electric Technologies in Beijing, China, designed to Fisker specs and generating nearly 202ps each and 1,300Nm of total torque at zero rpm.

"The permanent-magnet motors were selected because I know the company, I know the chief scientist there, and because they give us the best combination of power density, speed and overall efficiency levels," says Boskovitch. "We've made some improvements overall in efficiency and mass, so we will have one motor on the next design. On the Karma, we chose to use two motors

A standard design feature on the Karma – and one that is not used by any other electric, hybrid or extended-range vehicle on the market – is the solar power generation system incorporated into the roof

"The magnetic design is critical, in order to get the efficiency and to make sure you don't have any thermal issues"

The twin rear-mounted traction motors, designed to Fisker specs, generate nearly 202ps each and 1,300Nm of total torque

At the very heart of Fisker Automotive is high-tech powertrain designs – and that's an ethos that boss Henrik Fisker insists upon

because of the way they fit into the system and the ability of the inverters to support the power demands. The magnetic design is critical, in order to get the efficiency and to make sure you don't have any thermal issues."

The rear differential module combines a single-speed transmission and 4.10:1 drive axle assembly. It was designed by Fisker Automotive and manufactured for Fisker by Tremec, a major five- and six-speed manual transmission supplier. Boskovitch says the traction-control implementation in the drive system is accomplished by clutches in the differential rather than by using the braking system to slow down spinning tires. The Karma uses an electrohydraulic regenerative brake-by-wire deceleration system based on Brembo 370mm six-piston front and 365mm four-piston rear brakes, ventilated front and solid at the rear.

With performance being a key target, it's not surprising to learn that ample power is one thing the Karma realizes with ease.

DID YOU KNOW:

BMW will soon start supplying Fisker with four-cylinder turbocharged IC engines

The Surf essentially is the Karma in station wagon mode

In battery power only, the sedan is rated at 7.9 seconds in 0-100km/h performance. In sport mode, with battery and engine/generator linked, the acceleration figure drops to 6.3 seconds, which is world class for a car weighing 2,400kg.

On the economy side of the ledger, Karma is rated at 50 miles range as an electric only, and 250 miles in extended range mode, giving a total driving range of 300 miles.

Solar power generation

A standard Karma item not used by any other electric, hybrid or extended-range vehicle on the market is the solar power generation system incorporated into the vehicle's roof – an additional engineering headache – but a feature that Henrik Fisker wanted to have as a product differentiator.

"You have to first identify the solar technology you're going to use," explains Boskovitch when asked about the technology. "Then you have to think about how it is going to be embedded as part of the overall structure. You've got to convert the power, so you have to have what we call a solar power boost converter. Like everything else, we validate it to 15 years of use or 150,000 miles, 99.5% field reliability at 50% confidence, independent of the rest of the vehicle.

A Karma being charged. The sedan has a 3.3kWh onboard charger with 120V and 240V capability

"We were very specific about that. Henrik really didn't want a car that would lag all the others. He specifically wanted it to be competitive in its class and also for it to be extremely efficient. Everything was precisely done. We did all of our simulations, and all of the components were based on requirements that floated the simulations that floated the specifications that went out, as it would be done in any normal auto company."

According to Boskovitch, the powertrain engineering team took the best part of four months to do the simulations and specifications, going from concept to showroom in 47 months. He adds that, to make the car do everything the powertrain is designed to do, and to add in all the luxury amenities, the Karma is equipped with no fewer than 32 controllers or computers.

What's more, Karma was designed on a combination of CATIA and MATLAB SimuLink with GT Power software for engine and exhaust system modeling.

Boskovitch is undaunted by the distances between corporate HQ in Anaheim, California; A123 in Massachusetts; JJET in China; and the car's Valmet assembly plant in Finland; and Fisker's top guy for powertrain matters promises that the next-generation Fisker powertrain for the more affordable Atlantic model, to be assembled in the USA in 2014, will be smaller, lighter, more power dense and less costly. The industry waits in anticipation.

> "Henrik really didn't want a car that would lag all the others. He specifically wanted it to be competitive in its class and also for it to be extremely efficient"

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PROFILE: BINYI BAI

Job title: Powertrain director
Company: Volvo Car China

What career did you dream of when you were growing up, and what was your first job?
Even as a child, my dream job was always related to automobile engineering. In fact, cars were my favorite type of toys from kindergarten age. My automotive interest has stayed with me throughout my professional career. So, it's no surprise that my first job, back in 1986, was in automotive engineering, where I started work for an engineering company on a research project focusing on the development of automated manual transmissions.

When did you first start playing around with powertrains?
Generally speaking, it was during my first year of automotive engineering studies at college. Although that doesn't sound very early on, it actually wasn't terribly late either – I was only 15 years old. At the time, I got the chance to look at and touch and inspect all types of vehicles, components, technologies and subsystems that were available in the automotive engineering department in Tsinghua University in Beijing, China.

What was your career path to the position you currently hold?
What with my desire from a young age to pursue a career in the automotive industry, it's no surprise that I have been an automotive guy since the beginning of my career. After finishing postgraduate studies in the USA, I started working as a chassis engineer in General Motors Milford Proving Ground. I then moved into the powertrain area as chief engineer of Delphi Powertrain Systems China before joining Volvo Car.

What are the best and worst elements of your job?
The best aspect of my job is being responsible for powertrains at Volvo Car China. This role gives me a tremendous amount of opportunities and potential to fulfill my engineering ambitions. The worst aspect of my job is that I don't get much time to do more hands-on engineering work, which is something I really enjoy.

What car do you currently drive?
My current car is a Volvo S80 long wheelbase.

> Easier may not necessarily be a good thing. More stringent legislation creates more challenges and drives the industry to continuous pursuit of technical advances

Emissions legislation aside, what's your dream engine spec?
My ideal engine setup would have a blend of high specific power output and flat torque curve. Such a combination would enable both the vehicle and powertrain to always operate in the most fuel-efficient region of the BSFC map.

What would be your ideal engine specification for today's eco-friendly world?
It would have to be an engine that has specific power of more than 150ps/liter, but that at the same time can ensure that the vehicle it is powering emits less than 90g/km CO_2. This combination would mean that such an engine would offer great performance and power output, while also meeting the most stringent emissions standards worldwide.

In your opinion, what is the best engine that's ever been produced?
Engine technology is evolving all the time – with new breakthrough designs constantly being worked on and developed. In my opinion, the best-ever engine is the very first one that was made, which started a whole new era for mankind.

Which OEMs do you have particular respect for in terms of engine development?
In general, European OEMs have been willing to investigate and implement more new engine technologies up front. Asian OEMs are extremely good at bringing new technologies to a mature state, perfecting them, and then producing top-quality engines. Finally, North American OEMs have been making good progress in developing small displacement, high fuel efficiency engines, particularly after the financial crisis. I respect all these qualities.

What could legislators do to make your working life easier?
Generally speaking, easier may not necessarily be a good thing. More stringent legislation creates more challenges and drives the industry to continuous pursuit of technical advances.

In your opinion, what will be powering a typical family sedan in the year 2030?
The typical powertrain for a family sedan in the year 2030 could be one or all of the following: electric motors (mainstream); fuel cells (smaller percentage); and a hybrid of electric motors and IC engines, with very high fuel efficiency and extremely low emissions.

ELECTRIC POWERTRAINS **ON TEST**

The range-extender and the plug-in

Opel/Vauxhall Ampera

E&H was among the first to sample GM's widely praised Voltec powertrain during the Opel/Vauxhall Ampera's international launch earlier this year, and was fortunate to be part of a very early drive in North America of the Chevrolet Volt last year, but most recently we were given the range-extender vehicle – in its European Ampera guise – for a week in order to assess the technology and live with what is essentially a new take on modern motoring.

So how did it fair? In short, Ampera promises the lot: a family car that's fuel efficient, eliminates range anxiety and is very eco-friendly. But just as important is that in terms of day-to-day usability, the five-door Ampera is practical, comfortable and can accommodate a family of four on long (or short) journeys.

There's no denying that it's the range-extender technology underneath the skin of the Ampera that's behind much of what's good about the vehicle. A 16kWh lithium-ion T-shaped battery combines with a 111kW electric drive unit (located alongside the IC engine) to deliver 80km of electric operation. When the 198kg battery reaches its minimum state of charge, power is inverted to the electric drive unit from an 86bhp, 1.4-liter engine that acts as a generator, enabling more than 500km of driving without refueling. The battery, which has been placed in the center tunnel of the vehicle and was developed with LG Chem, has 288 prismatic lithium-ion cells and provides 370Nm of instant torque.

Although a lot of work has gone into the battery, we did find that we were unable to achieve the 80km electric driving range, although that could have been largely to do with the cold weather at the time. Perhaps our biggest issue with the Ampera is price: at over US$50,000, we think consumers might feel it's a lot to pay for an Opel/Vauxhall, but fundamentally it's the state-of-the-art powertrain that they're buying, not the brand. Let's just hope they remember that.

Propulsion system: Electric drive system with two electric motors at the front; lithium-ion T-shaped battery in a central tunnel with liquid active thermal control; 1.4-liter Ecotec gasoline engine at the front

Toyota Prius Plug-in Hybrid

The world's best-selling hybrid model, the Toyota Prius, has transformed from a single model product to a family of full hybrids that includes the all-important Plug-in derivative.

In fact the importance of the Prius Plug-in can't be overstated, especially at a time when the likes of the Volt/Ampera are hitting the market. Like the standard Prius, the Plug-in derivative is powered by a refined and efficient full hybrid powertrain, but the big engineering difference here is the use of a new lithium-ion battery that can be fully charged in 90 minutes and enables the car to cover longer distances – 25km in total – and reach higher speeds – 82km/h – on electric power alone, all of which is a great improvement over what the standard Prius offers. This means the Prius Plug-in, rated at 49g/km, achieves a new low benchmark in its class for CO_2 emissions.

Along with the high-tech battery, which has been co-created with Panasonic EV Energy and can be charged in 90 minutes, the PHEV architecture also features a 1.8-liter VVT-i gasoline engine that extends the range of the car once the EV driving range has depleted. Battery power and IC engine combined will give a total driving range of around 1,240km, says Toyota. The Plug-in also benefits from an electric motor (that on its own powers the driven wheels when the car is in EV mode), a generator and a power-control unit. A power-split device uses a planetary gear set to combine and reallocate power from the engine, electric motor and generator.

Like the Ampera, the Prius Plug-in is practical and very family friendly. In many respects it offers an engaging ride in all modes, and this could partly be down to the fact that it weighs just 55kg more than the standard Prius.

But as with the Ampera, our single biggest issue here is price. The Prius Plug-in could cost up to US$52,000, which in turn will probably deter some fleet and private owners. It also represents a large cost increase over the standard Prius model.

So, taking all that into account, you probably want to know which we'd choose: the Ampera or the Prius Plug-in? It's a very close call, but for us the Ampera takes it simply because it offers a smoother operation and is a tad happier in EV mode.

Propulsion system: PMS motor (housed in a single transmission casing along with the generator and power-split device); lithium-ion battery back (rear); 1.8-liter VVTi gasoline engine at the front

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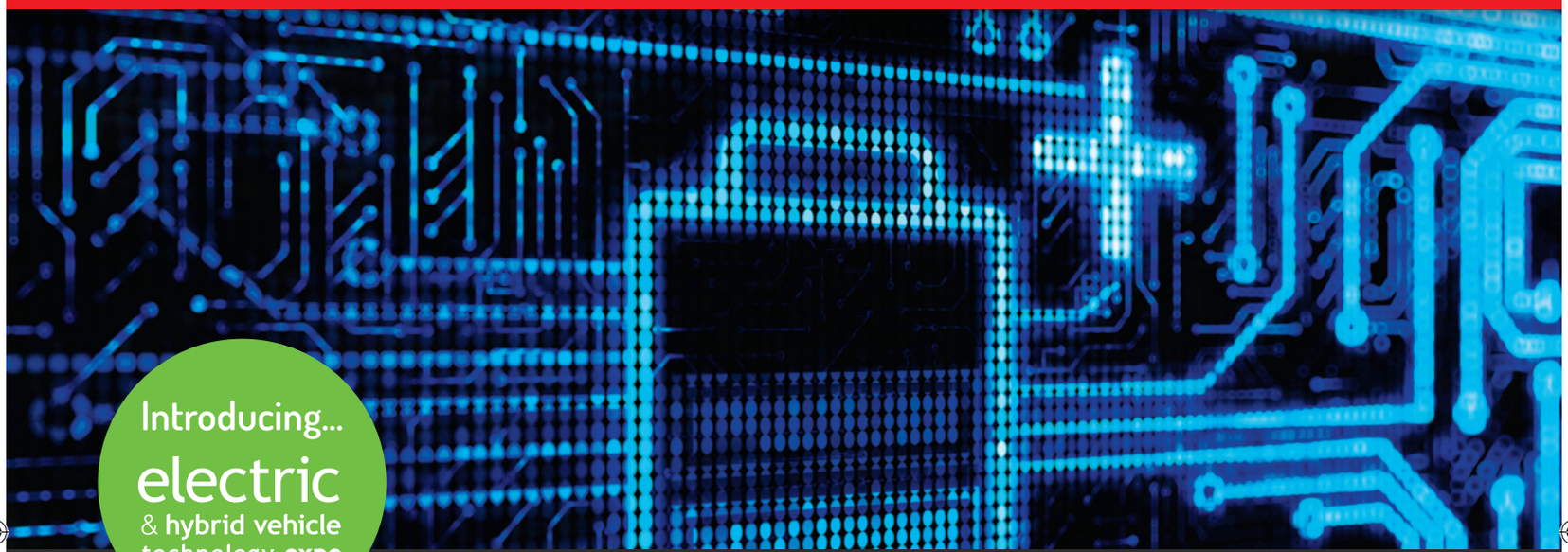

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EV NEWS

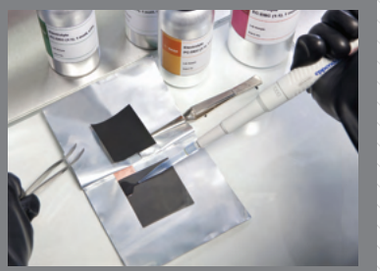
ASIAN OEMs SIGN FUEL CELL PACT

Honda, Toyota, Nissan and Hyundai have all signed an agreement with organizations from the Nordic countries to support the market introduction of FCEVs and hydrogen refueling infrastructure from between 2014 and 2017.

The deal is seen as an attempt to generate further dialog with public and private stakeholders in Norway, Sweden, Iceland and Denmark, with the ultimate aim being to accelerate the market introduction of FCEVs. It follows a similar deal signed in 2009 by car manufacturers in Europe, which identified 2015 as a point for FCEV market introduction in regions where hydrogen refueling is available.

In September of this year Honda's CEO, Takanobu Ito, made public the Japanese car maker's plans to develop an all-new FCEV for Japan, the USA and Europe, which will be launched in 2015 and promises to showcase technological advancements and major cost reductions.

ELECTROLYTE AGREEMENT CONFIRMED



BASF and Mitsubishi Chemical Corporation have announced the signing of a royalty-bearing licensing agreement that grants the German supplier usage rights for Vinylene Carbonate based on the Japanese organization's proprietary patents.

The tie-up is being seen as an important milestone as Vinylene Carbonate is a key ingredient in BASF's electrolyte formulations, which are used by cell manufacturers in the production of lithium-ion batteries.

The deal also provides BASF with the right to grant sub-licenses to cell manufacturers that use electrolyte formulations made by BASF or Mitsubishi Chemical.

Discussing the agreement, Ralf Meixner, senior VP of BASF's global battery materials business, said: "This license from Mitsubishi Chemical Corporation adds to our already strong battery materials technology and intellectual property portfolio, supporting our market activities and our long-term objective of becoming the leading provider of functional materials and components to serve cell and battery manufacturers worldwide."

DENSO REVEALS BATTERY BREAKTHROUGH

Denso has confirmed the development of a lithium-ion battery pack that further increases the fuel efficiency of vehicles with stop/start mild hybrid systems. The new technology enables the stop/start technology to use more regenerative power than conventional systems that use a single lead-acid battery.

The Japanese Tier 1's battery pack consists of a battery management unit and power supply control switch, as well as battery cells that are provided by a third-party source. The company says that the new lithium-ion battery pack stores regenerated power and then supplies the stored regenerated power to the electrical and electronic components, such as the car navigation and audio systems. This reduces the power generation required by the alternator, which results in an overall load reduction on the engine and improves the vehicle's fuel economy. Furthermore, the new battery pack is naturally air-cooled and therefore does not require a dedicated battery-cooling system.

TOYOTA EXPANDS EV AND HEV PRODUCTION IN CANADA

Toyota is to invest more than US$100 million to increase Lexus RX production at its Cambridge, Ontario, facility. The outlay will see Lexus RX capacity increase by 30,000 vehicles to 104,000 units, including 15,000 RX450h models, the hybrid electric version of the Lexus SUV. This latest round of investment will take Toyota's annual production capacity in Ontario to 500,000 units.

Plans to upgrade the Cambridge base represents the second major investment announcement for Toyota's Canadian manufacturing operation this year. In March the Japanese car maker announced a spending program of US$80 million for its Woodstock plant. As a result, Toyota is targeting early 2014 for expanded Lexus production in the country.

In August 2011 Toyota also announced plans to start assembling electric versions of its RAV4 sport utility vehicle in Woodstock under a partnership with California-based Tesla Motor – and this project represented the first electric vehicle built in Canada.

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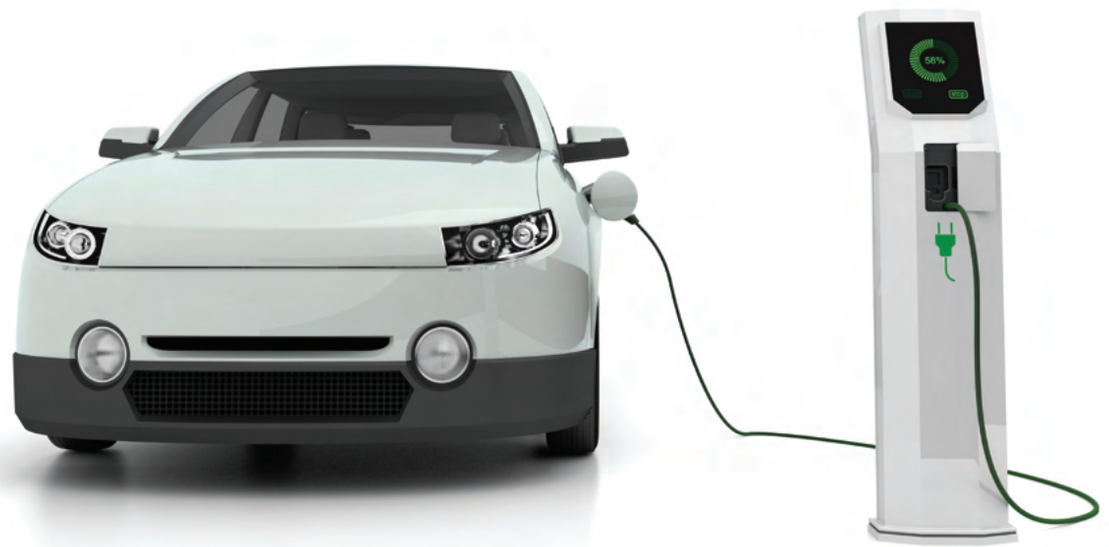

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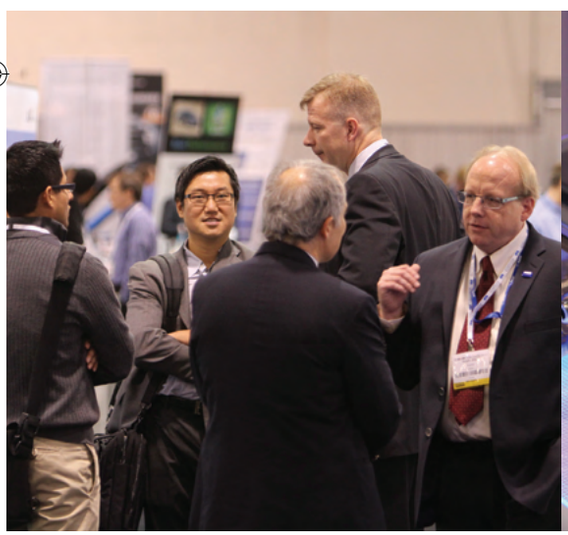

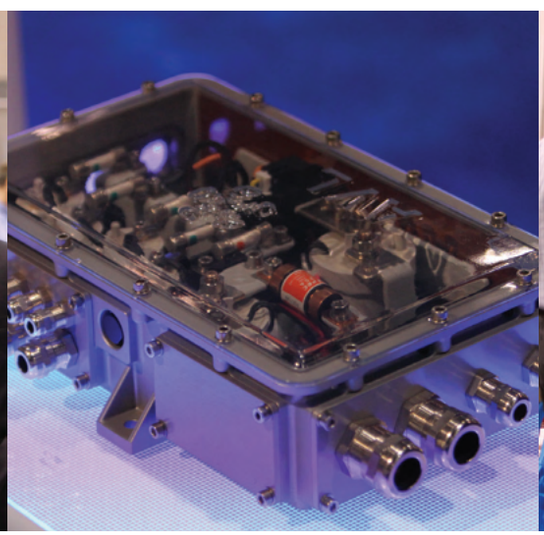

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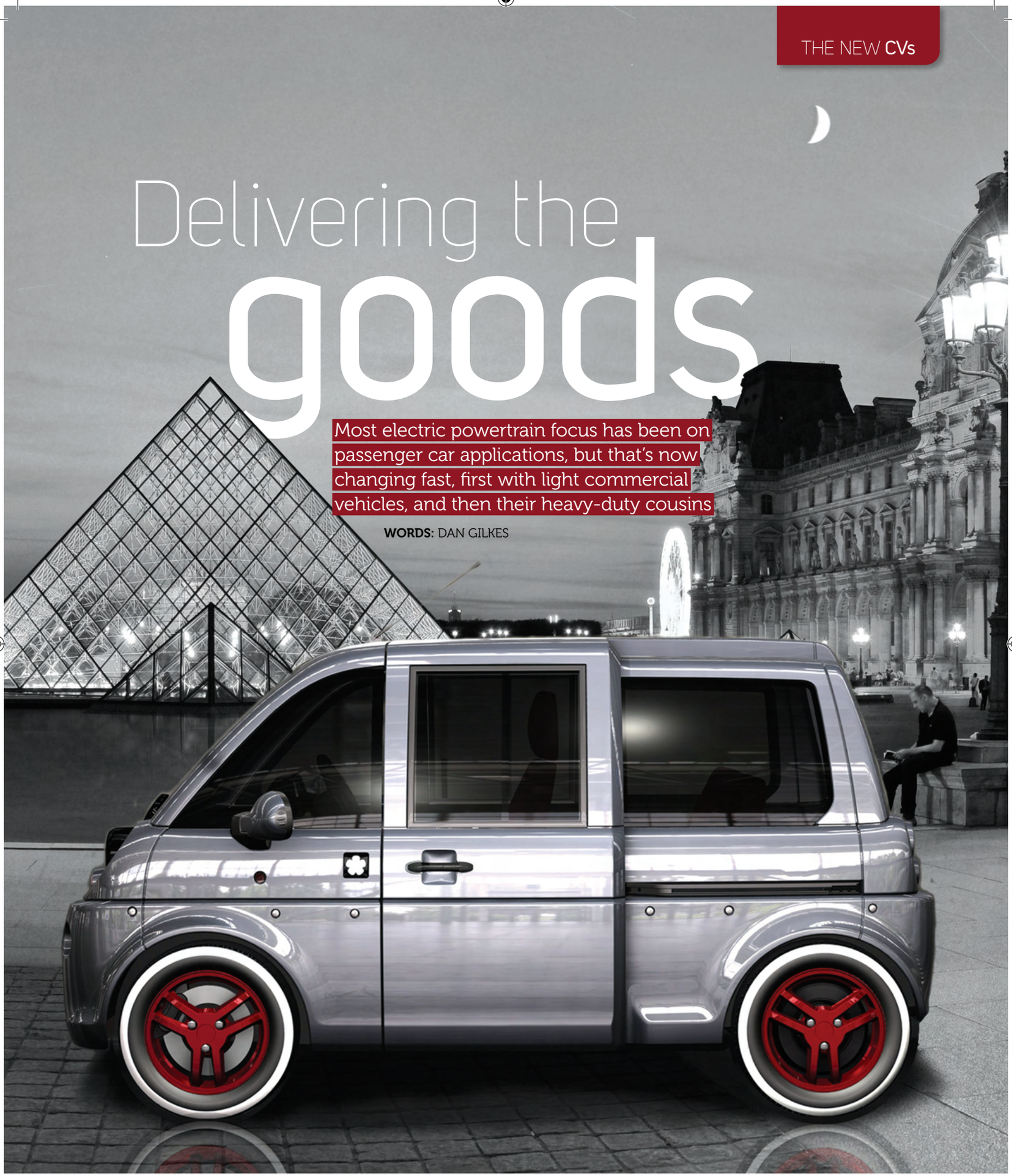
The much talked about Mia electric vehicle. Measuring just 2.87m in length and up to 815kg in weight, the Mia can accommodate three people and offer 260 liters of luggage space in the trunk. Customers can specify either an 8kWh battery or a 12kWh battery

Delivering the goods

Most electric powertrain focus has been on passenger car applications, but that's now changing fast, first with light commercial vehicles, and then their heavy-duty cousins

WORDS: DAN GILKES



While much of the global attention on electric and hybrid drive vehicles concerns passenger cars, light commercial vehicle manufacturers have also been pushing ahead with both full EV and hybrid models. As yet there are only a few that are commercially available, but that looks set to change with new arrivals from Nissan, Mercedes-Benz and Iveco, to name but three.

Although an urban delivery van might seem like the ideal candidate for electric or hybrid drive, due to the relatively low daily mileages, regular braking for regeneration, overnight depot parking for charging and a large body in which to house components, there are some problems with EV LCVs. The main one is weight, as many van users see the amount of payload they can carry as being a determining factor in a van purchase. In addition, batteries can be heavy and bulky, two things that are even less welcome in a van than in a passenger car. But that isn't holding back development, although manufacturers are going off in several directions.

Micro machine

There are a number of very compact electric vans on the market, many of which seem to come from French manufacturers. Two recent additions to this group are the Mia U Utility and the Goupil G3 and G5.

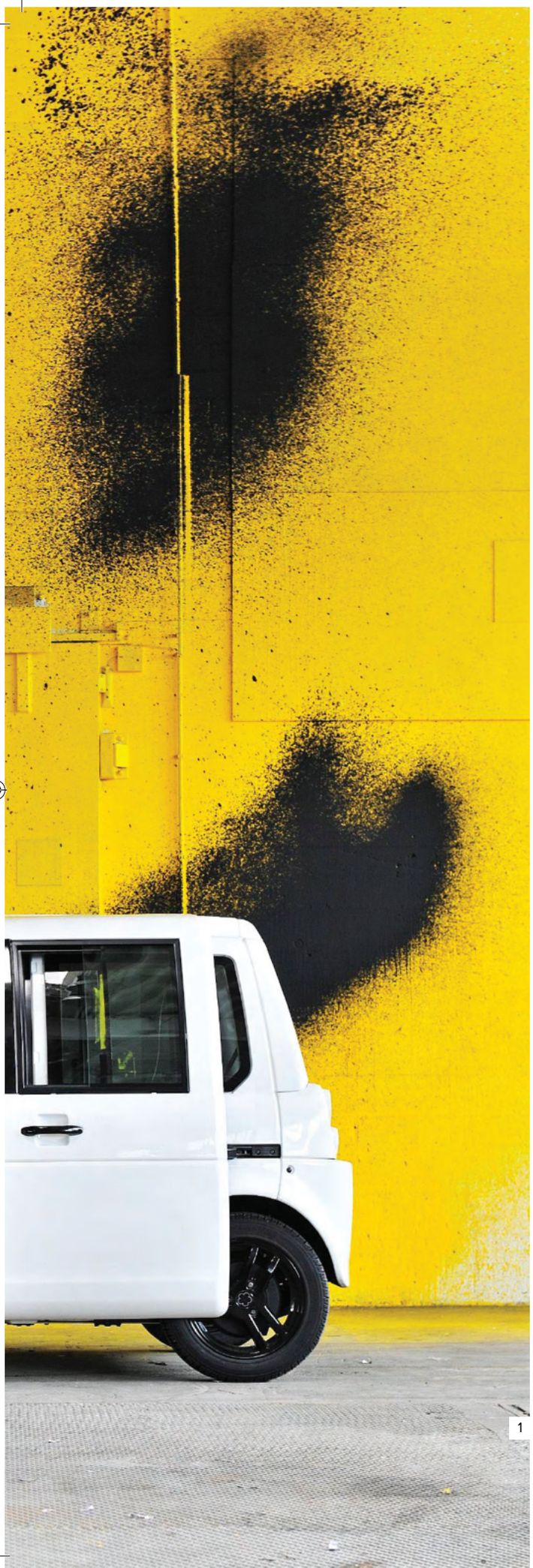
Though French-built, Mia is actually owned by German pharmaceutical company Kohl. The Mia range was introduced in Germany and France at the end of last year and is now being launched in the UK. Designed as an EV from the start, Mia is available as a three-seat or four-seat car, or as a single-seat utility van. The reason for these unusual seating numbers is that the driver sits centrally, with any passengers behind. At just 3.19m long, Mia uses sliding side doors and a lift-up glass rear hatch to provide access to what is actually a reasonably spacious interior.

Power comes from a 12kWh E4V lithium iron phosphate (LiFePO4) battery that delivers up to 125km of range. The vehicle can be plugged in to any domestic 220/240V electrical socket, achieving a full charge in five hours. However, with no memory effect, a 10-minute partial recharge will deliver up to 8km of range.

The batteries come with a five-year/70,000km warranty, and are currently priced at around US$7,500. The entire

Right: In addition to the original Mia model, the EV OEM also offers the Mia L, which is a long wheel base derivative and a Mia U, a light CV product

Below: Available in two wheelbases, the Goupil G3 electric vehicle can be supplied with a range of 14 tipper, dropside and cage bodies for utility applications



"We are currently looking for dealers. We have 11 in place and are looking for 20 by next year. We will also sell directly"

Paul Evans, managing director, Mia UK

Due for market launch in 2013, the Citroën Electric Berlingo (above) and its Peugeot stablemate, the Partner Electric, use two high-energy lithium-ion battery packs with a capacity of 22.5kWh, installed beneath the standard load floor either side of the rear axle

vehicle also carries a five-year/70,000km warranty and comes with roadside assistance for the same period.

As a commercial vehicle, the Mia U has a cargo volume of 1.5m^3 with one seat, or 1.2m^3 with two seats. The carrying capacity is 350kg, which is not bad for a van of this size. Prices start at around US$27,000 for the commercial vehicle.

"We are currently looking for dealers," says Mia's UK managing director, Paul Evans, of the company's current status. "We have 11 in place and are looking for 20 by next year. We will also sell directly to fleets."

The Goupil G3 is a slightly different proposition. Aimed more at local authorities and campus-style industrial operators, the vehicle uses forklift truck lead acid battery technology. Four battery pack options are available, offering 180Ah, 240Ah, 320Ah and 400Ah outputs. These deliver 60, 80, 100 and 120km ranges respectively.

Available in two wheelbases, the G3 can be supplied with a range of 14 tipper, dropside and cage bodies for utility applications. Maximum payload is 700kg and the base tipper starts at around US$24,000. Batteries come with a four-year/1,500-cycle warranty, and cost US$3,195 for a battery, or US$127 for an individual cell.

The latest addition to the Goupil line-up is the G5 hybrid vehicle. Designed primarily to run on electric power, where the G5 delivers 60-100km of range and a top speed of 40km/h, the hybrid system uses a 500cc two-cylinder petrol engine, producing 15kW.

Both the electric and petrol motors drive through a CVT transmission, with the petrol engine taking over drive above 25km/h. Maximum speed in petrol mode

is 70km/h and the G5 promises up to 400km of range, including 100km of electric drive.

The G5 uses similar lead acid traction batteries to the smaller G3, although with 180Ah, 240Ah and 320Ah ratings. The front brakes are conventional hydraulic discs, and rear braking is an electric brake with energy recovery, contributing to battery recharging.

Conventional matters

The recent Hanover IAA truck show saw the introduction of three compact electric vans, from Nissan, Citroën and Peugeot, all of which should be commercially available by the end of 2013. Nissan's e-NV200 uses the NV200 van as its base, and the driveline technology from the OEM's Leaf electric car.

That means the same laminated lithium-ion batteries and proven 80kW AC electric motor, generating 280Nm of torque. Nissan has managed to package the 48 battery modules beneath the load floor, meaning the van can maintain its 4.2m^3 carrying capacity.

Range and performance will be comparable to the Leaf, so operators will be able to recharge to 80% capacity in just 30 minutes through a quick charge facility.

Nissan also plans to put the electric capacity in the batteries to additional use. The power will be available to the van user, to power tools, and to electrical equipment, making the compact van suitable as a mobile workshop or food preparation station for outdoor events.

This additional use of battery technology doesn't stop there. In Hanover, Nissan showed a concept Cabstar e-Refrigerator truck. Rather than use the batteries to power the vehicle itself, the battery pack and electric compressor are employed to drive the truck's chiller and refrigerator compartments, reducing CO_2 and noise emissions from the truck's diesel engine.

The Cabstar e-Refrigerator truck uses its battery pack and electric compressor to power the truck's chiller and refrigerator compartments

PSA partners Peugeot and Citroën will both introduce electric vans in 2013 – the Electric Berlingo for Citroën and the Partner Electric for Peugeot. Identical in all but name and badge, the vans use two high-energy lithium-ion battery packs with a capacity of 22.5kWh, installed beneath the standard load floor either side of the rear axle.

The permanent magnet synchronous drive motor, developed in cooperation with Mitsubishi Motors Corporation, delivers a maximum power of 49kW with a torque output of 200Nm. This is transmitted to the front wheels through a speed reducer. The range available is 170km, well ahead of some competitors.

The vans come with a standard ESP system, coupled with hill-start assist. In addition, they have dual energy recovery systems, recovering energy during deceleration and during active braking.

Drivers are equipped with an eco driving instrument panel, clearly showing energy consumption and recovery. This also shows the energy consumed by the van's electric heating system, which comes equipped with an eco mode to limit consumption.

The vans have two charging modes: a normal six- to nine-hour charge on a 16A supply, or a fast charge (125A) delivering 80% of full charge in 30 minutes. Both vans can be ordered in short- or long-body configuration, offering up to 4.1m^3 of load capacity. Maximum payload remains at 675kg, the same as the diesel-powered models.

The e-NV200 (below), which made its debut at the Hanover IAA truck show, uses the same driveline technology (right) from the Leaf electric car

Make mine a large one

As mentioned, the big problem with an electric commercial vehicle is weight, and the bigger the van, the worse that problem becomes. Taken to its extremes, an electric articulated truck would use so much of its carrying capacity to provide drive that it would barely have any load carrying capacity at all.

That isn't preventing development, however, and Mercedes-Benz is looking to

extend its E-Cell range up from the existing Vito E-Cell to a new Sprinter E-Cell model. Building on the technology used in the Vito E-Cell, which is now available on a leasing agreement from Mercedes-Benz, the larger Sprinter E-Cell uses two lithium-ion batteries.

Each battery has 93 cells and a combined capacity of 35.2kWh. The van uses a permanent magnet synchronous motor to deliver a constant output of 70kW, with a short-term peak output of 100kW. The motor produces 220Nm of torque, rising to 270Nm for short-term acceleration.

Mercedes says that when connected to a 400V power source, the vehicle's charger, which supplies 22kW at 32A, can charge the batteries in just two hours. This should greatly extend the possible operation of a Sprinter E-Cell, as there is no need for overnight charging.

A top speed of 80km/h has been limited in favor of extended range, which the OEM puts at 135km according to the NEDC tests. This puts the van well above the range required by most urban operators, for whom daily journeys are usually within 100km, according to Mercedes.

The batteries, which have been proved on the Smart electric car, are located in robust containers between the axles and below the body, so there is no loss of load volume. This also makes the Sprinter E-Cell suitable for manufacture as a chassis cab, allowing a range of bodies to be fitted to the frame.

With a gross weight of 3.5 metric tons, Mercedes says the Sprinter E-Cell has a payload of up to 1,200kg, depending on the body.

Fellow Daimler Trucks division Fuso Truck and Bus is to begin production of the Canter Eco Hybrid compact truck in Europe, at its plant in Portugal. The parallel hybrid uses a conventional 3-liter diesel engine to deliver 110kW of power and 370Nm of torque. The truck is also equipped with a permanently excited synchronous motor with an output of 40kW and 200Nm.

The motor draws its power from air-cooled lithium-ion batteries housed between the axles. The batteries have a capacity of 7.5Ah, yet weigh just 63kg. They come with a five-year guarantee that can be extended to cover a 10-year operating life. The truck also carries a liquid-cooled inverter and a DC-DC voltage converter within the battery housing.

FUTURE VISION

Looking a little further ahead, Fiat's truck and bus division, Iveco, which already offers a full EV version of the Daily van, has provided its vision of a possible way forward for LCV technology. The Iveco Dual Energy concept is a light-duty chassis offering a flexible approach, capable of switching to the most appropriate source of energy depending on the vehicle's operation.

The concept relies on two types of traction: one exclusively electric, to satisfy zero-emissions zones in cities; the other a thermoelectric hybrid, suitable for longer journeys and inter-urban travel.

The chassis configuration allows for a range of options, from standard dual energy hybrid, to full electric traction. It even offers the option of a transverse engine with front drive alongside a rear-mounted electric drive to the rear axle, in effect producing a four-wheel drive chassis.

The electric engine-generator paired with an inverter has been developed in collaboration with Bosch, while the multimode transmission comes from fellow Fiat company FPT Industrial. Lithium-ion traction batteries are from Johnson Control, with the electric steering system delivered by ZF Lenksysteme, the electric brake system is by Brembo, two-level air-conditioning comes from Denso, the heat exchanger is from CRF, and the D-air enveloping airbag safety system is from Dainese.

There are no plans to put the Iveco Dual Energy into production, but the project certainly shows a possible evolution of current large van and light truck development.

1

2

1. Mercedes-Benz and Daimler Trucks show off their blossoming eco-friendly CV range. From left to right: Antos, Fuso Canter Eco Hybrid, Sprinter and Vito E-Cell.

2: Building on the company's E-Cell technology, the Sprinter E-Cell makes use of two lithium-ion batteries, with each battery featuring 93 cells and a combined capacity of 35.2kWh

Power is transmitted through the Canter Eco Hybrid's Duonic dual-clutch transmission, which is based on a mechanical six-gear manual gearbox with two hydraulic wet clutches and an electronic control system. The Duonic system combines the convenience of an automatic transmission, which pre-engages the next gear for minimal power flow loss, with the efficiency of a mechanical transmission.

When pulling away, the Canter Eco Hybrid uses electric power alone, cutting emissions and noise. Once a speed of 10km/h is reached, the diesel engine cuts in, with the electric motor supporting the diesel engine at higher speeds. A stop/start system switches the diesel engine off when stationary, although it continues to run in neutral when under electric power to provide power to ancillary systems and power take-offs.

The hybrid system reduces the carrying capacity of the 7.5 metric ton truck by just 150kg, yet is said to reduce fuel consumption by up to 23%, with a comparable reduction in CO_2.

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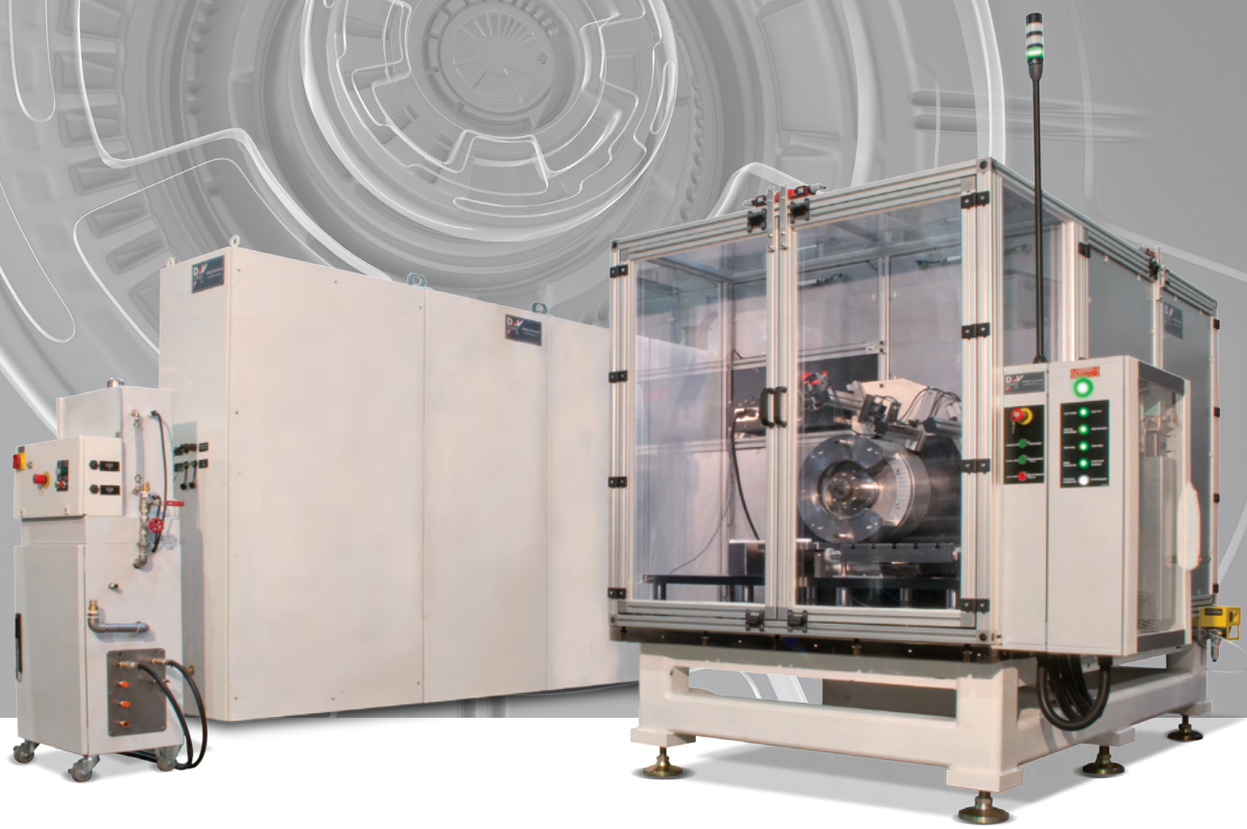

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The electric general

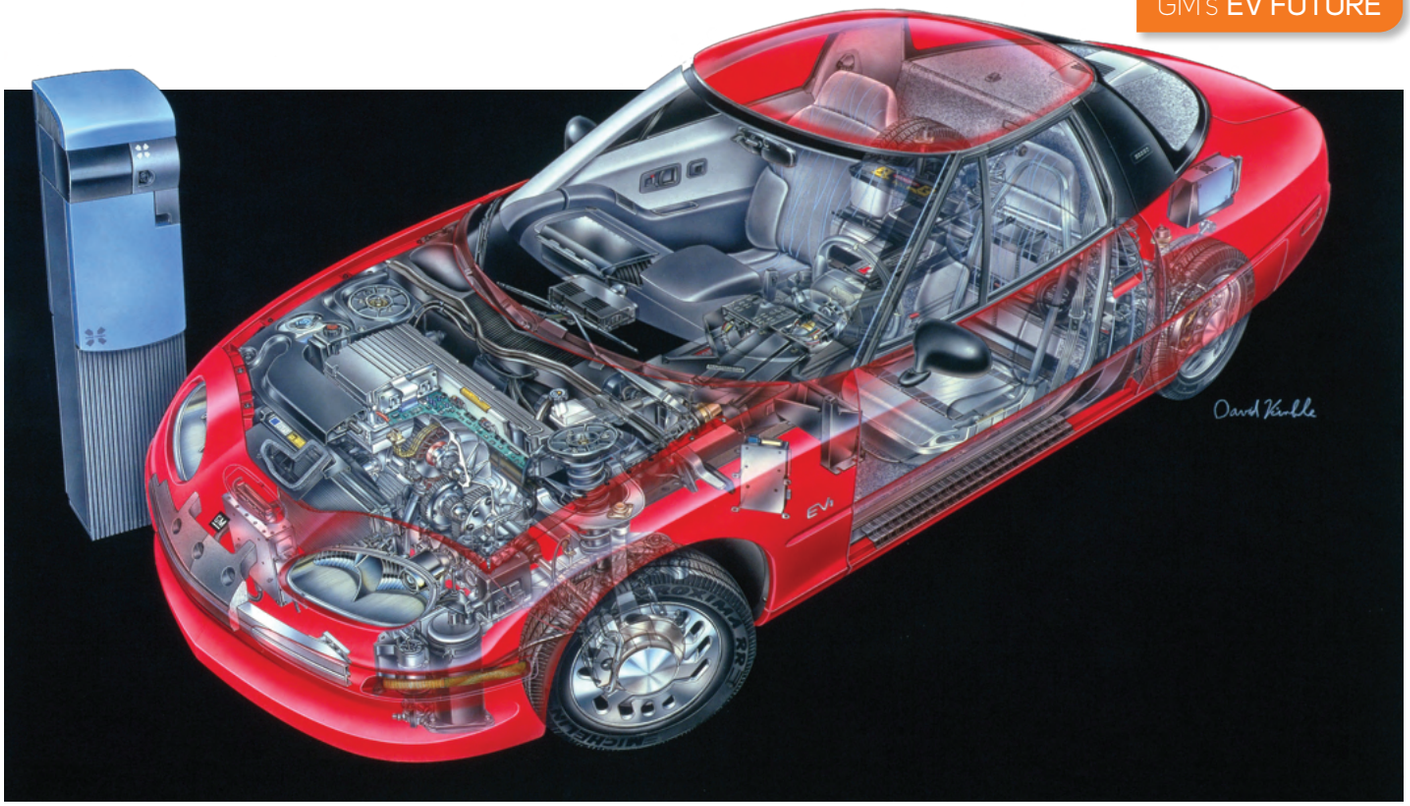
General Motors is at the crossroads of technology, engineering and sales with its first generation of extended-range electric sedans

WORDS: JIM MCCRAW

Meet Larry Nitz. He plays a very important role in the automotive world's efforts to create full electric vehicles, hybrids, range-extenders and other such eco-friendly propulsion technologies. Why is Nitz so important, you ask? Well, as engineering director for electric and hybrid powertrain development at Detroit's largest car maker, he sits on one of the hottest seats in all of General Motors, helping to not only steer the US giant, but also to influence the general direction of the global automotive industry.

So let's cut to the chase. With the creation of mild hybrid SUVs and pickup trucks behind him, and the recent introduction of a large-scale, volume-production eAssist electric launch system destined to power hundreds of thousands of GM midsize cars – and not forgetting the groundbreaking Chevrolet Volt and Opel Ampera extended-range electric vehicles – Nitz sees a big, bright future for further powertrain electrification at GM.

"We see continued innovation and improvement in batteries in the future, with continued evolutional improvement in the lithium-ion technology that we have in the Volt and the Spark EV, and the eAssist system in the Malibu, LaCrosse and Regal. They are all lithium-ion batteries, but each one of them is a little different, tuned to where they can best perform."



The 36-year GM Powertrain veteran says the eAssist systems, essentially relatively small power batteries installed in the trunk areas of three of the company's hottest-selling American midsize sedans, are designed to deliver a big jolt of specific power in a compact 0.6kWh package. "It's a buffer," he explains. "It's a buffer to enable the powertrain to operate more efficiently. We turn it off when it's not efficient, and we don't intend to store a lot of energy in it. We keep costs down that way, and the battery can deliver between 15 and 20kW of power. Importantly, it does everything it needs to do in the form of a small power battery. It's technically very different from an energy battery for a battery-electric car, for example, where it's sized for energy and its power ratio is actually very low, but the battery is so big that it can deliver all the power that's needed."

Nitz says that the varying requirements for the Volt/Ampera system naturally create a very challenging engineering job because forming "a power battery that's also an energy battery, and a powerful battery that can deliver full vehicle performance on the battery alone without being overly sized for a long EV range, is not easy".

Many believe GM's ill-fated EV-1 project played a central role in the demise of BEVs in the 1990s. Nitz, who worked on the project, says lessons have been learnt. Fewer than 1,200 units were built in the end, with the technology underneath being a three-phase AC induction electric motor with IGBT power inverter. Gen 1 used lead-acid batteries, while Gen 2 featured a nickel metal hydride affair

He continues, "It's right in the middle; it's specifically engineering a solution to enable the customer to do his/her commuting gasoline-free, and yet we have the gasoline generator so that you can drive across the USA if you choose to."

Lessons from EV-1

With 15 years of continuous duty in the alternative-vehicle arena at GM – meaning that Nitz has personally worked on all different types and styles of eco-friendly propulsion, including the ill-fated EV-1 electric – the engineering director now looks out into the 2.0 electric vehicle future without trepidation.

"We have a long-term vision for all three types of vehicles, extended-range like the Volt and Ampera, electrically assisted gasoline engines and pure electric like the Spark EV. What we have learned – what we know – is that it isn't just volume production that's going to bring the costs down, it's actual technology improvements. And technology improvements come packaged in generations. So we have a long-term vision of how we will evolve, change, improve and modify our components and vehicles over multiple generations. I can't talk about the specifics other than to say that we know what we are doing as it relates to the customer-facing attributes of the Volt, what customers love about it, what they want more of, and what they want less of. It's no surprise that they want lower prices, and always more capability. Our job is to continue to work all that out."


GM designed and engineered 99% of the 155 components in the Volt battery

of this journey, at this time, to be able to use our computer-aided engineering tools to help us not only discover, but also validate how these batteries will perform, and how they will be useful to us in creating compelling vehicles such as the Chevrolet Volt. Is there a superbattery technology coming in the future? Well, there are families of improved lithium batteries coming, certainly. It is amazing to think of the possibilities of what lithium can do."

Nitz says that lithium, independent of international political intrigues, is pretty widely available in friendly countries such as Argentina, Australia, Brazil, Chile, China and some locations in Europe, so that's not a worry as some have suggested. He also says that the known reserves amount to 12 million metric tons, with more than half of that located in Chile. The important thing to note is that only about 2kg is needed for each Volt, and logic dictates that this current level will decrease as the technology matures.

For the near term, however, the current level of lithium-ion battery technology will remain where it is. "You would have thought that, over all these years, we would have uncovered every possible combination of materials that can make batteries, but the fact of the matter is that we haven't. We have just scratched the surface in many cases, and learned how to manage what the possibilities are. There are families of lithium, anodes, cathodes, separators and electrolytes that can be put together to make a multitude of different batteries with very different characteristics, and we are thrilled to be part

Electric motor realm

GM has been researching and building electric motors for decades – long before the EV-1 project – and this is an important point for Nitz, who says that the company has quietly built a significant capability in designing, developing, validating, processing and producing high-tech electric traction motors.

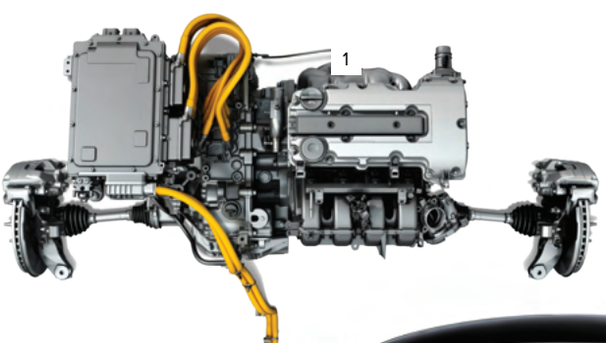
"The coming battery electric vehicle, for example, will use a GM-produced electric motor and a GM-produced electric drive system, built in Whitemarsh, Maryland. That's something I'm really proud of," he says.

1: The 1.4-liter I4 range extender powertrain

2: Some see the range-extender Volt as being the successor to the EV-1

3: The Volt Voltec drive unit with 4ET50 transmission

4: A full recharge on the Volt using a 120V unit takes around 10.5 hours. A 240V charging unit reduces the time to around 4.25 hours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"You would have thought that we would have uncovered every possible combination of materials that can make batteries, but the fact is that we haven't"


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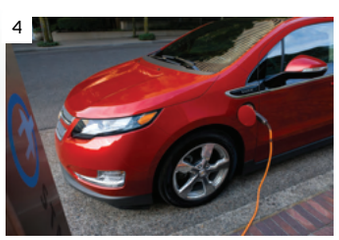
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The eAssist system has already been launched on key midsize sedans, such as the Chevrolet Malibu

Nitz says that the engineering team performs "thousands and thousands" of simulations every day on electric motors in order to realize optimal designs. "We've designed these motors in-house ourselves, and every feature of these motors is a GM design. Sometimes we buy motors for our designs, and sometimes we'll build motors ourselves. It depends on the project. It is a capability that we are talking about more, and we are very proud of that capability."

Top of the development agenda now for Nitz's team is getting more power density, more torque and greater efficiency out of the size, space and materials, and overall cost of the electric motor.

The electronics, and the controls that go with them, are the third leg of the engineering stool that Nitz is keen to discuss. He says there are a couple of things helping GM with power control, allowing the car maker's products to pull away from rivals: "Certainly, the semiconductor industry continues to move forward. The power switches that we use are getting more efficient, faster and smaller, with better thermal management.

"When we talk about switching 100kW or 300 or more amperes of current, you have to remember that's a lot of current," says Nitz. "Doing that in an effectively sized package is very important. Power inverters are getting more capable, more efficient and smaller. It's not Moore's Law. There are some disruptive technologies that are not ready yet, but we continue to study these concepts. These are the very technologies that cause you to rethink how you would design a part."

As an example, he cites the silicon carbide technology currently used in LED lighting, leading to a smaller package and much higher operating temperatures. "We see improvements in silicon and in silicon carbide as a potential game-changer, and we're watching that very carefully. Certainly, the microprocessors that run our controls continue to get faster and more capable. Our systems are torque and direction by wire, so we subscribe to very high safety standards, and some of the newer, more capable processors help us to deliver a very safe and capable system at a lower cost. So we're excited about these new opportunities in the semiconductor industry as they are developed for automotive applications."

Nitz also sees incremental improvements in vehicle systems such as cooling, heating, air conditioning and fully blended by-wire regenerative brake systems. He points with pride to the fact that GM's OnStar system can now provide customers with remote vehicle starting and remote cabin conditioning via grid and smartphone applications with the right level of connectivity. "It's solutions like these and many more that will take us into the future," he adds.

"The coming Spark BEV will use a GM-produced electric motor and electric drive system, built in Whitemarsh, Maryland. That's something I'm really proud of"

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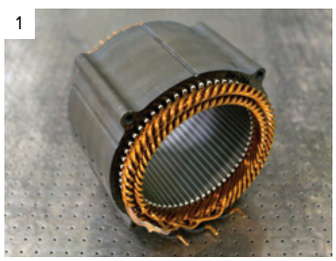

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3: Despite benefiting from state-of-the-art EV powertrain technologies, the Spark EV will hit showrooms in the USA in 2013 priced at just $25,000 with tax incentives

1: GM's new 85kW electric motor that features in the Chevrolet Spark EV

2: Spark EV boasts 540Nm of torque and can charge up to 80% in 20 minutes

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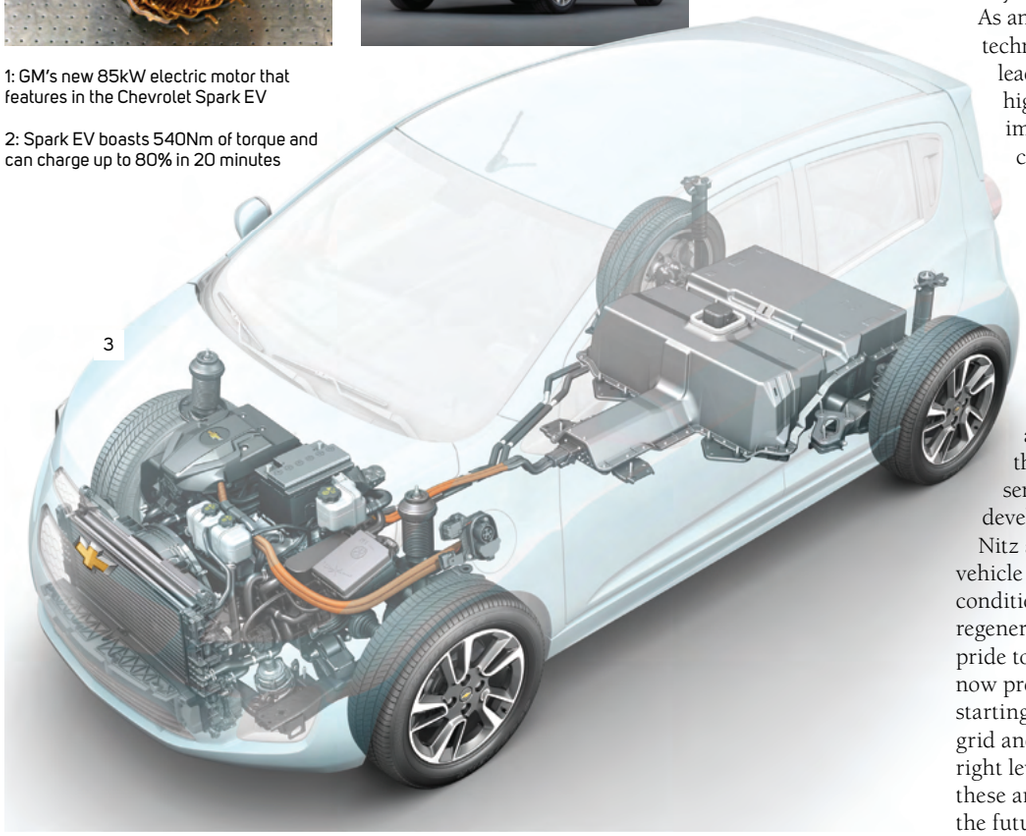

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One code **fits all**

As performance expectations of hybrid vehicles increase, designers are adopting more complex simulation methods in order to fully optimize electric and hybrid vehicles

WORDS: **KARL VADASZFFY**

UK-based CD-adapco is one of the world's largest independent suppliers of CFD-centric code. The company, which has more than 30 years' experience in thermal-fluid simulations, has its heritage steeped in aerodynamic thermal and combustion simulation.

Already well established in the mainstream automotive design process, CD-adapco, which in 2012 celebrated turnover of US$160 million, is keen to demonstrate to the electric and hybrid segments of the automotive industry the great enhancements that have been made over the past three years to guarantee its code's crossover appeal.

Steve Hartridge, who became director of electric and hybrid vehicles in 2009, explains the thinking: "Traditionally, we modeled flow and thermal behavior of systems – for example, how does your underhood perform when you're going along at 50km/h, how hot is the exhaust, and where's the heat going? What we've done is add the ability to model hybrid-specific phenomena within the same process. As an example, you can now model flow, thermal and electrochemistry, enabling you to model battery cells, modules and packs, or flow, thermal and electromagnetics, all aimed at detailed electric machine design, within our flagship STAR-CCM+ code."

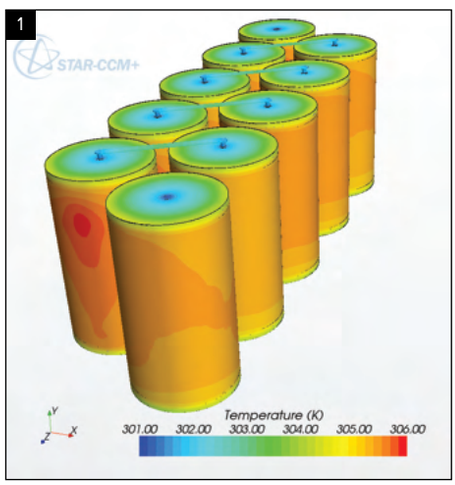
Battery pack simulation

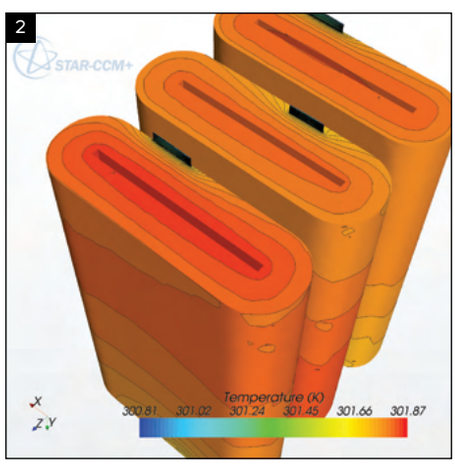
The inclusion of electrochemistry models enables the user to simulate the coupled effects of thermal environment and electrical load on a battery pack. By simulating these coupled phenomena within a single solution, a more accurate answer is achieved. The user also benefits by using only a single, modern interface, which makes the entire process more productive in what is already a very competitive environment. Enabling complex battery packs to be simulated, both electrochemically and thermally through complex drive cycles, is CD-adapco's aim.

The key is that the technology has to work immediately and seamlessly, but because the code quickly produces high-quality results, ease-of-use is at its very core. To enable this,

"What we've done is add the ability to model hybrid-specific phenomena within the same process"

Steve Hartridge, director, electric and hybrid vehicles, CD-adapco





1. An in-depth spiral test cell commences on a new electric vehicle battery solution

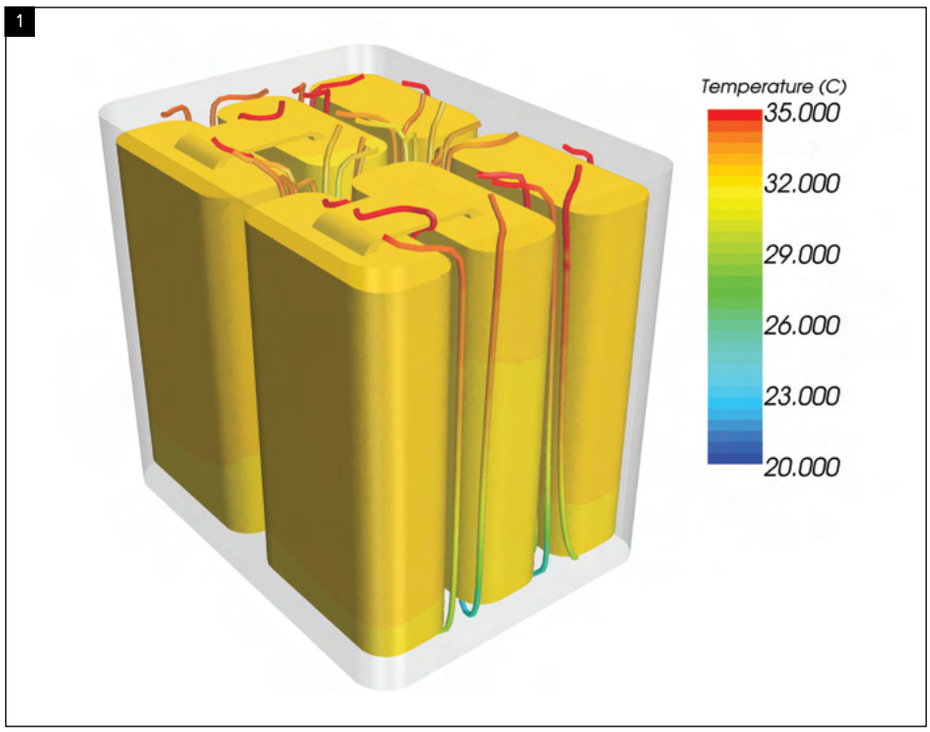
2. Temperature analysis takes place, providing the R&D team with critical data regarding the reliability of the technology

CD-adapco has an application-specific tool called Battery Design Studio. This tool enables the detailed simulation of single battery cells, using sophisticated electrochemistry models and geometric design details, and this information can be passed on in an encrypted form from cell supplier to end user. "By enabling cell suppliers to contribute to the analysis process, we remove redundancy, thereby adding efficiency," comments the 38-year-old Brit.

The electrochemistry extension in STAR-CCM+ requires minimum user effort because it fits easily within the existing engineering process, which can be automated; therefore, minimal user interactions are required to perform iterative design studies. As a result, engineers can spend more time analyzing data rather than preparing for simulations.

A question of interconnection

Another aspect that will benefit electric and hybrid vehicle developers is the interconnection between STAR-CCM+ and CD-adapco's electric machine code, called Speed, which was acquired in 2011 from Scotland's University of Glasgow. The reliability in an electric machine is determined by how well it is controlled thermally, with the typical failure mode being a breakdown in the insulation within the copper wires contained in the machine. "But the driving factor behind the temperature rise," says Hartridge, "is the load the machine's under. The dominance of either so-called copper losses or iron losses in the machine can vary depending on the load case, but the subsequent temperature needs to be controlled by the motor's cooling system."

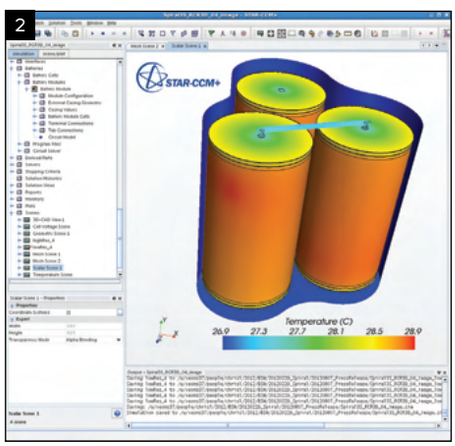


Once a user has defined an electric machine within the Speed environment, the data can be studied using analytic approaches and embedded 2D finite element solvers. Several operating points can be investigated, and the thermal loads for the copper and iron losses, plus any other losses, are then seamlessly mapped onto a 3D model in STAR-CCM+. From here, the component temperatures can be predicted in a complex model that also includes the surrounding cooling system, whether liquid- or air-cooled. Indeed, if the development project requires more exotic cooling systems, such as the spray cooling of end windings, these factors can also be included by the engineering team within the Speed package.

Both Battery Design Studio and Speed act as application-specific gateways into STAR-CCM+ and are computationally lightweight, enabling a battery cell or electric machine to be studied in isolation. Hartridge adds, "Although in the final analysis we know it's critical to include the thermal aspects, you can actually consider an electric machine, using analytical methods that have been developed for over 20 years, and enable someone to get within 95% of the design requirements quickly. Similarly, with a battery cell, someone can swiftly analyze its suitability for a given application. Both these tools run on regular computing resources, typically a laptop."

After this, the gateway into the complex 3D STAR-CCM+ tool can be used, including the flow and thermal aspects, which enables the engineer to obtain flow, thermal and electromagnetics analysis. "But there are no redundancies within the design chain," continues Hartridge. "You don't have to start again – you can just import a file, and on screen a representation will appear of the motor with all the understanding of its windings and how well it performs thermally and electromagnetically. Essentially, you could have an electric machine designer using the code, who then passes his model to a thermal analyst, someone well versed in our code, to consider it in a more complex model." The same approach can also be applied to a battery pack design.

Hartridge argues that, in terms of battery technology, the ability to run a calculation transient is essential: "If you have a constant load applied to a battery, you can't think of it in a steady-state sense, which is computationally more efficient." Instead, he maintains that a transient analysis is better suited to capturing the changing state of charge and associated effects within the cell. "Running long transient analysis can be a new challenge for traditional users, but our code is structured to help in this regard."



1. Temperature module and pulse analysis takes place

2. Batteries are evaluated in a virtual environment

Feeling the heat

The final piece of the electric and hybrid powertrain puzzle is the link between the electric machine and battery – the power electronics. The ever-increasing pressure to downsize and minimize such components and subsystems means that thermal mass is removed from a system. However, the system is still producing the same heat levels. Hartridge says, "The smaller and lighter the package, the less thermal inertia you have. So the more you downsize, the more thermal issues you have, as a general rule. Indeed, the limiting factor of the integrated gate bipolar transistor, often the heart of the power electronics package, is the maximum junction temperature on this chip."

It's easy to see how having an optimal thermal solution improves the function of the power electronics package. This leads engineers and R&D departments to look to evermore sophisticated solutions using liquid cooling, and here the ability of STAR-CCM+ to capture detailed geometry is a great advantage. Including this in the robust, automated workflow gives users the power to explore the design space and focus on engineering, reducing the number of prototypes to be tested.

With these recently developed capabilities aimed at the electric and hybrid vehicle market, CD-adapco believes it has a unique solution for engineers engaged in this work, extending the application of its flagship product, STAR-CCM+.

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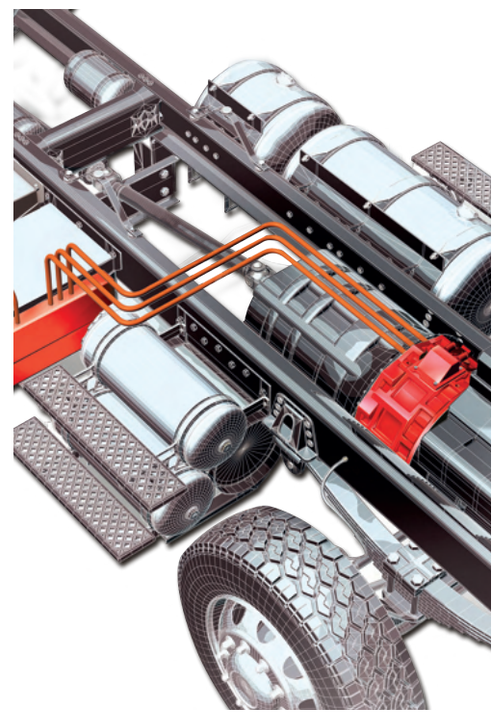

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Cell power

WORDS: **PHILIP BORGE**

Manz has grown from being a small automation specialist into a leading high-tech company that's now helping to optimize battery technology. But what does the future hold? The managing director of the battery segment, Albrecht Werner, shares his thoughts

With headquarters in Reutlingen but production facilities around the world, Manz has positioned itself to help lead the way in EV battery development

How did you become a leader in battery development?

Being in business for 25 years, the world has changed a lot, as envisioned by our founder and CEO Dieter Manz at the time of our humble beginnings in 1987. Remember, 1987 was the year after Chernobyl. Dieter Manz had grown even more skeptical about nuclear energy and he decided to venture out on his own to turn this skepticism into a respectable business. So Manz Automation was founded and in the early 1990s we introduced the first automation systems for the solar industry.

With time, Manz has grown to have the capability to process machines for crystalline and thin-film solar panels as well as display products, especially those in the touch-panel business. Today, with the Manz CIGSfab, we even supply a fully integrated production thin-film solar line. This is the reason why we skipped the 'automation' part in our name. Our products are based on expertise in six core technological fields: automation, laser processes, vacuum coating, printing, metrology and wet chemical processes.

Most of these technologies are needed in battery manufacturing as well. So for us, developing tools for the battery industry was a logical step back in 2009. We are a high-tech engineering company, we are well established in the solar energy market, and the battery area complements this, either in electric mobility or in stationary storage applications for homes and industry. Battery-making equipment is one of our fastest-growing business divisions.

Is the automotive battery business the biggest sector for Manz?

Not right now, but it's the fastest-growing one. We believe the biggest factors in the breakthrough of electric mobility are the capacity and the price of the batteries. And you need to address both of these elements in the production chain: the first one by improving the technology; the second one by bringing down production costs with mass-manufacturing technology.

What exactly is Manz's expertise in this area?

As a company, we work closely with battery cell and pack manufacturers, automobile manufacturers and stationary storage providers. Some of today's batteries powering electric vehicles are made on Manz's equipment.

We already have a good basis of standardized equipment that realizes many benefits for our customers, but despite these high standards, we also continue to develop processes and equipment based on customer requirements and demands.

"In 2020 we will hopefully rely on established industry standards, such as cell formats. There will be a huge potential for streamlining production lines here, and as an engineering company, we are at the forefront of this"

Albrecht Werner, managing director of the battery segment, Manz

MANZ: 25 YEARS OF INNOVATION

1987: Manz Automatisierungstechnik is founded
1990: Development of the first automation system for processing crystalline solar cells in a pilot-manufacturing project is undertaken
1994: Manz delivers the first automation solution for the FPD industry in Asia
2000: Manz delivers the first automation system for fully automated crystalline solar cell manufacturing lines. Soon after, Manz engineers also pioneer the first fully automated quality testing and sorting system for crystalline solar cells
2005: The company enters the thin-film market with equipment for the mechanical scribing of solar modules
2009: Manz forms R&D partnerships for the manufacture of lithium-ion batteries
2011: Manz delivers a world first in thin-film production size modules with efficiency of 14%
2012: Manz acquires CIGS and forms Manz CIGS Technology. The company also opens a new state-of-the-art facility in China with a vast production facility

The challenges are to meet and to beat the requirements of the battery manufacturers. The most important criteria are safety of the battery, cycle stability, production costs and lifecycle. These criteria can be achieved only with efficient and innovative solutions.

1 and 2: Manz boasts laser-cutting equipment that is far superior to the conventional cutting processes with punch cutters that are widely used in the industry

What sets Manz's technology apart from that of its competitors?

Manz provides nearly the entire production process from cell to pack, with the exception of the electrode coating. We believe the best solution for an OEM is to have one partner who can handle the complete process. Our customers can get everything from one source and we therefore provide better integration, communication and trouble-free interfaces. By working closely with battery and car makers, we can better fine-tune our process equipment for them.

Our long-time target is to become the technological leader in the battery business. To achieve this, our products and designs must always be up to date. For example, our laser-cutting equipment is superior to conventional cutting processes with punch cutters. Right now, our main customers use our equipment in automotive applications such as full EVs, PHEVs and HEVs.

When it comes to battery development, how important is a lightweight design?

A critical factor for all mobile applications is weight, so we always strive to reduce weight and size. We achieve this by better usage of raw materials and better processes. We have our own lightweight business unit that is involved with fiber-reinforced composite developments. In my opinion, fiber-reinforced composites are important in the successful establishment of e-mobility.

How will the EV battery of 2020 differ from that of today?

Firstly, costs will be a lot lower. I mentioned already the promises and benefits that mass production will bring. So, economies of scale will kick in, materials costs will go down and materials waste will be also much lower once more efficient production lines are established. And taking into consideration our very roots – automation – a lot will be achieved by exactly this.

Secondly, in 2020 we will hopefully rely on established industry standards, such as cell formats. There will be a huge potential for streamlining production lines here, and, as an engineering company, we are at the forefront of this.

The latest expansion for Manz came in Suzhou, China, with a new facility. How important is this new base?

The facility in Suzhou has about 16,000m² of factory space and another 4,000m² in the office building. It represents an investment of €10 million [US$12.8 million]. It is a big deal for us. The engineers and production specialists based at Suzhou can draw on the company's more than 20 years of experience in wet-chemical processes. With the opportunity to increase the staff from 400 in our previous facility there, to more than 700 in the first stage of our new facility, Manz is strengthening its commitment to Asian customers. The facility in Suzhou will also house a technology and training center. We are therefore able to validate and optimize manufacturing processes directly with our customers in China.

What markets will realize future growth for Manz?

Manz follows its markets very closely, be it in terms of technology development or geography. We need to be close to our customers since our equipment is supported by a holistic approach to service. We need to fully understand their needs. Therefore we install and test our machinery on the spot in order to deliver the efficiency gains that we promise.

As a global supplier of equipment for the production of solar panels, displays and Li-ion batteries, it is important that we have a presence in Asia; it's an important market for the entire industry. We need to be there, and yes, developing markets hold great promise for us due to their specific future needs for infrastructure and communications investments. However, since Manz is a public company, I cannot comment on numbers for the next two years.

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Best of British

E&H fires up the Ampera range-extender test car and takes a tour of the UK, speaking to some leading innovators to find out the very latest developments

WORDS: **SAUL WORDSWORTH**

With roots that date back to 1881, Morgan is a British company steeped in engineering tradition. Today, the car maker is evolving by ramping up its activities in the EV sector following the creation of the Plus E

"The UK is very sophisticated in the EV/HEV arena – and education and academia supports this"

Steve Hartridge, director of electric and hybrid vehicles, CD-adapco

The USA and China may be the undisputed leaders in electric vehicle technology development, but Europe is not far behind – and within Europe many see the UK as a key player in the further development of environmentally friendly powertrain technology.

"The UK is very sophisticated in the EV/HEV arena – and education and academia supports this," states Steve Hartridge, director of electric and hybrid vehicles for CD-adapco, a leading provider of simulation software to the industry. "There are plenty of examples where academia has come up with clever ideas that influence EV technology. Other countries are doing that with various levels of industrial might – but the UK's innovation culture helps."

It would seem there are many facets to the burgeoning EV sector in the UK, from government involvement and homegrown innovation, to OEM activity and the fact that Oxford has the highest density of EV charging points in Europe. In an effort to understand all these factors, *E&H* has traveled to the corners of the country to find out just how active EV development is in the UK.

"The project is a true collaboration aimed at delivering as much driving pleasure as possible in a zero-emissions vehicle"

Steve Morris, operations director, Morgan

For more than a century, Morgan has been making sports cars (and now EVs) in the spa town of Malvern

The Lotus Evora 414E concept, which showcases new developments in plug-in, range-extended electric propulsion, and new electronic technologies

Collaborations aplenty

"Collaboration between the government, industry and academic institutions in the UK continues to create opportunities, increase innovation and further develop the supply chain in the automotive industry," explains Jerry Hardcastle, global chief engineer at Nissan, the creator of the pioneering full-electric Leaf EV, which is to be built in Sunderland following US$300 million of EU funding, a further US$150 million grant from the Regional Growth Fund, and a blossoming relationship with Sheffield University. Other seats of learning known for their impressive work in the EV field include Oxford, Warwick, Loughborough and, in particular, Cranfield.

"We have worked with Morgan on its LIFEcar and Plus E projects," says Dr James Marco, Department of Automotive Engineering at Cranfield University (see *The OEMs*, page 109). "Our latest collaboration is called Future Vehicles, a research project funded by the Engineering and Physical Sciences Research Council under the UK Low Carbon Vehicles Integrated Delivery Programme, and involves five other British universities."

Alongside academia, government initiatives continue to push EV development forward. In September there was an announcement regarding the creation of a UK Energy Storage R&D Centre dedicated to the furthering of electric and hybrid vehicle battery research. The project, which focuses on a UK battery market estimated to be worth nearly US$400 million by 2020, is funded by government (US$14 million) and industry (US$6 million) investments. The center will be based at the University of Warwick and is the latest move to secure future growth opportunities for the UK's EV sector, building on the government's pledge of nearly US$640 million over the next four years to support electric cars and other ultra-low-carbon vehicles.

"The establishment of this center will help to increase the global competitiveness of the UK's emerging low-carbon vehicle industry," states David Bott, director of innovation programs at the Technology Strategy Board (TSB), a crucial cog in this UK wheel of innovation and development. The simple aim of the government-backed body is to accelerate economic growth by stimulating and supporting business-led innovation, in particular through funding and connecting partners. To date, the board has funded over 130 EV projects of a collaborative nature.

Tim O'Brien is innovation platform leader for low-carbon vehicles at TSB and says that the UK is well placed to advance these sustainable transportation technologies: "One of our goals is to pool basic research done at university level, pull it through into applied research, which is normally done by industry, and then put mechanisms in place to try to assist that technology into a commercial offering. With R&D you have to make all the investment up front before you get any payback. That is where we come in."

One of the TSB's more interesting projects to date has been its US$7.2 million backing of the T.27, which is claimed to be the world's most efficient electric car. This is a collaboration between Gordon Murray Design – the people behind the McLaren F1 – and Zytek, a leader in electric powertrains. The result is a vehicle that purports to use 29% less energy than any other electric vehicle. And *E&H* can reveal that Gordon Murray Design is in discussion with three possible manufacturers for the T.27.

SUPER SUPPLIERS

The UK currently boasts a plethora of organizations at the cutting edge of various aspects of EV technology. Yet few have greater international pull than Bladon Jets, a world leader in the field of micro gas-turbine-powered range extenders.

"Our range extender is, in effect, a gas-turbine-powered electricity generator," explains Philip Lelliot, director at Bladon Jets. "The generated electricity is used to recharge the car's batteries and provide extra power to supplement the battery output should it be required. The main purpose is to extend the range of the vehicle beyond that of pure electric mode."

The company's involvements with Jaguar on the C-X75 concept supercar, and with Pininfarina on the Cambiano electric range extended vehicle, are proof of its worldwide scope.

In a different engineering sphere, another global leader is Zytek, which offers advanced powertrain solutions, and has worked with Chrysler and General Motors, and has a long-term relationship with Daimler developing and building electric powertrains for the Smart Fortwo ED. Most recently it was a partner on the Plus E Morgan sports car.

"Our intention is to demonstrate driveability, performance and refinement that comfortably meets the expectations of Morgan's most discerning customers, with an easily implementable technical solution designed to world-class standards," says Zytek's director, Steve Tremble.

Moving on to London we find Qualcomm, another global leader, but this time in wireless technologies. The company is pioneering the development of its wireless electric vehicle charging system to help drive global EV adoption. The technology is founded on years of investment allied to ongoing exchanges with the University of Auckland, a pioneer in wireless power transfer. The result is a simple and effortless way to charge an electric vehicle by induction.

"Qualcomm Halo technology is based on the principle of resonant magnetic induction," says Dr Anthony Thomson, vice president of business development and strategy. "Our technology is unique in that we use wireless charging pads that have a non-circular design."

Another fine example of a global engineering leader within these shores is Axeon, based in Dundee, Scotland, and one of Europe's leading suppliers of lithium-ion battery systems. The company claims to have developed a new power pack that can give electric vehicles a 35% improvement in range over existing technologies, without adding weight to the battery.

"Great Britain is well placed in terms of developing technologies needed for electric vehicle advancement," sums up Lelliot of Bladon Jets when asked about what suppliers are up to. "This is not only in the area of batteries, but also drive motors, power electronics, and electric vehicle validation."

Left: Developed by Qualcomm, wireless electric vehicle charging uses inductive wireless energy transfer to eliminate the plug-in cord used by most of today's EVs and PHEVs

Below: The front end of a Bladon Jet engine. The high-tech R&D company, with an engineering base in Coventry, says small, light and clean-burning jet engines will provide a new generation of green and efficient power units

"Great Britain is well placed in terms of developing technologies for EV advancement"

Philip Lelliot, director, Bladon Jets

Bladon Jet's pioneering technology is being used in the Jaguar C-X75 supercar

Nissan's award-winning Sunderland plant will soon start rolling out all-electric Leaf models destined for most European markets. Nissan believes that the cost of producing the car locally could reduce its sticker price by one-third

Above: Ecotricity is targeting installation of EV charge points across the network of British motorway service stations

Right: The Morgan Plus E is powered by a derivative of Zytek's 70kW electric drive, providing 300Nm of torque

The OEMs

In global terms the UK is a backwater of EV manufacture, but there exist pockets of OEM activity of which any country would be proud. Premier among these is the plant in Sunderland that from March 2013 will be manufacturing the Nissan Leaf. Eventually 50,000 of these vehicles will roll off the production lines and into the European market annually. Nissan believes that the cost of producing the car locally could reduce its showroom price by one-third. Its current price of nearly US$40,000 includes the government's US$8,000 plug-in-car grant.

Nissan has also signed a memorandum of understanding with Gateshead College to establish the Northeast as what Etienne Henry, head of Nissan's zero emission business unit, calls "the epicenter of electric vehicle expertise in Europe". The manufacture of the Nissan Leaf in Sunderland looks like going some way to cementing Britain's place in the EV market for years to come.

Although this is a standout OEM project, there are other notable examples. Not least is the work being done by Lotus Engineering, an established leader in the creation of electric vehicles. The Lotus Evora 414E has been developed in conjunction with the TSB and in partnership with Nissan, Jaguar and Land Rover. This plug-in supercar, powered by two electric engines and with a range-extending gasoline engine, has been specifically designed to showcase what the UK car industry can do in the realm of ultra-low-carbon vehicles.

Cut from a similar cloth is Morgan Motor Company, which has been designing sports cars since 1910. Although a niche manufacturer, the company is a well-recognized international player with dealerships throughout the world. It also sees electrification as a vital part of its future strategy, which is why it developed the Morgan Plus E, an electric sports car devised as a concept to test market reaction. The power is delivered by a new derivative of Zytek's 70kW, 95ps electric engine.

"The project is a true collaboration aimed at delivering as much driving pleasure as possible in a zero-emissions vehicle," says Steve Morris, Morgan's operations director. By the middle of next year Morgan will have three prototype vehicles. If there is sufficient demand, it could enter production.

TEST THE LIMITS

To say that the UK leads the way in electric vehicle testing would be stretching a point, but in Millbrook it may well have one of the finest and most mature EV proving grounds in the world. The bespoke site in the Hertfordshire countryside boasts 700 acres of land and 70km of track.

Neil Fulton, Millbrook's group head of powertrain engineering, reveals more: "We are not a disused airfield. This is not a dig at our competitors, but the truth is we believe you need a combination of flat areas and hills to develop vehicles, particularly EVs. By building on our calibration programs for conventional vehicles, we have developed advanced EV testing procedures that meet the strictest government incentives."

Millbrook is an independent test facility and is careful to separate itself from the intellectual property it comes into contact with. Where OEMs or product manufacturers might test their own products, Millbrook's independent staff are steeped in experience, having tested dozens of different EVs for crash testing, durability, range and fuel economy.

"Our facilities expose us to very different markets, from buses to small trucks, and can provide highly reliable test services. Some OEMs in Europe haven't done any of their own crash tests. We have crash-tested over 40 EVs. Our experience is something money can't buy."

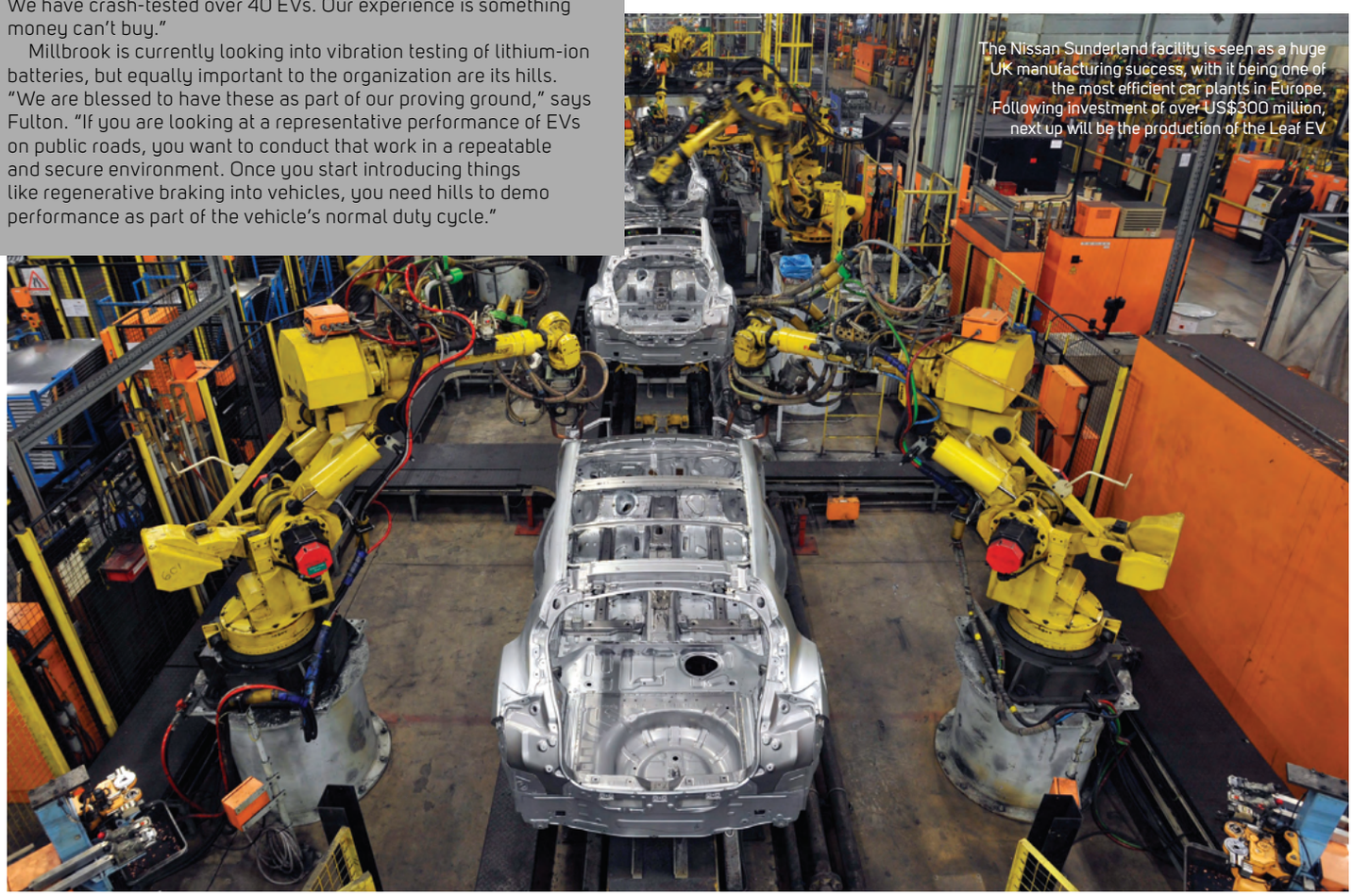
Millbrook is currently looking into vibration testing of lithium-ion batteries, but equally important to the organization are its hills. "We are blessed to have these as part of our proving ground," says Fulton. "If you are looking at a representative performance of EVs on public roads, you want to conduct that work in a repeatable and secure environment. Once you start introducing things like regenerative braking into vehicles, you need hills to demo performance as part of the vehicle's normal duty cycle."

Infrastructure investment

There are currently around 3,000 charging points across the UK, with Oxford boasting more outlets than gasoline stations, but the limited range of electric vehicles remains a problem. Enter Ecotricity, which plans to address this by installing charge points across the network of British motorway service stations, thereby giving EVs a fighting chance on the open road.

"The superchargers we are installing can recharge a car in the time it takes to have a cup of tea," says Ecotricity's founder, Dale Vince. The company is working closely with Nissan to install a plug-in point at every service station across the country. As Chargemaster CEO, David Martell, also points out: "People won't buy electric cars unless they see charging points around the place."

> "The superchargers can recharge a car in the time it takes to have a cup of tea"
>
> Dale Vince, founder, Ecotricity



The Nissan Sunderland facility is seen as a huge UK manufacturing success, with it being one of the most efficient car plants in Europe. Following investment of over US$300 million, next up will be the production of the Leaf EV

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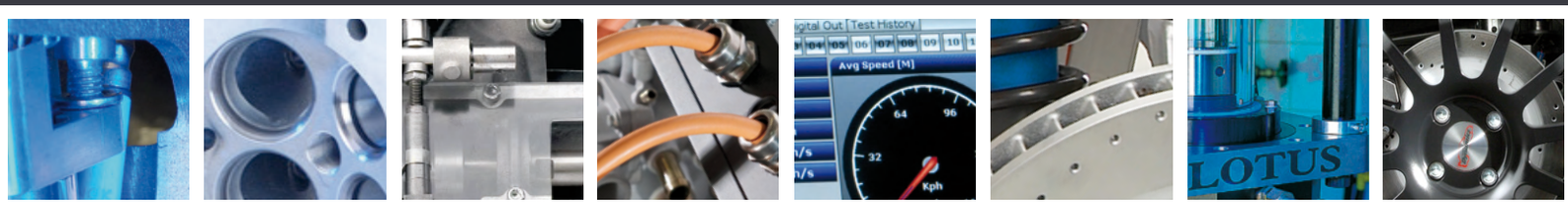

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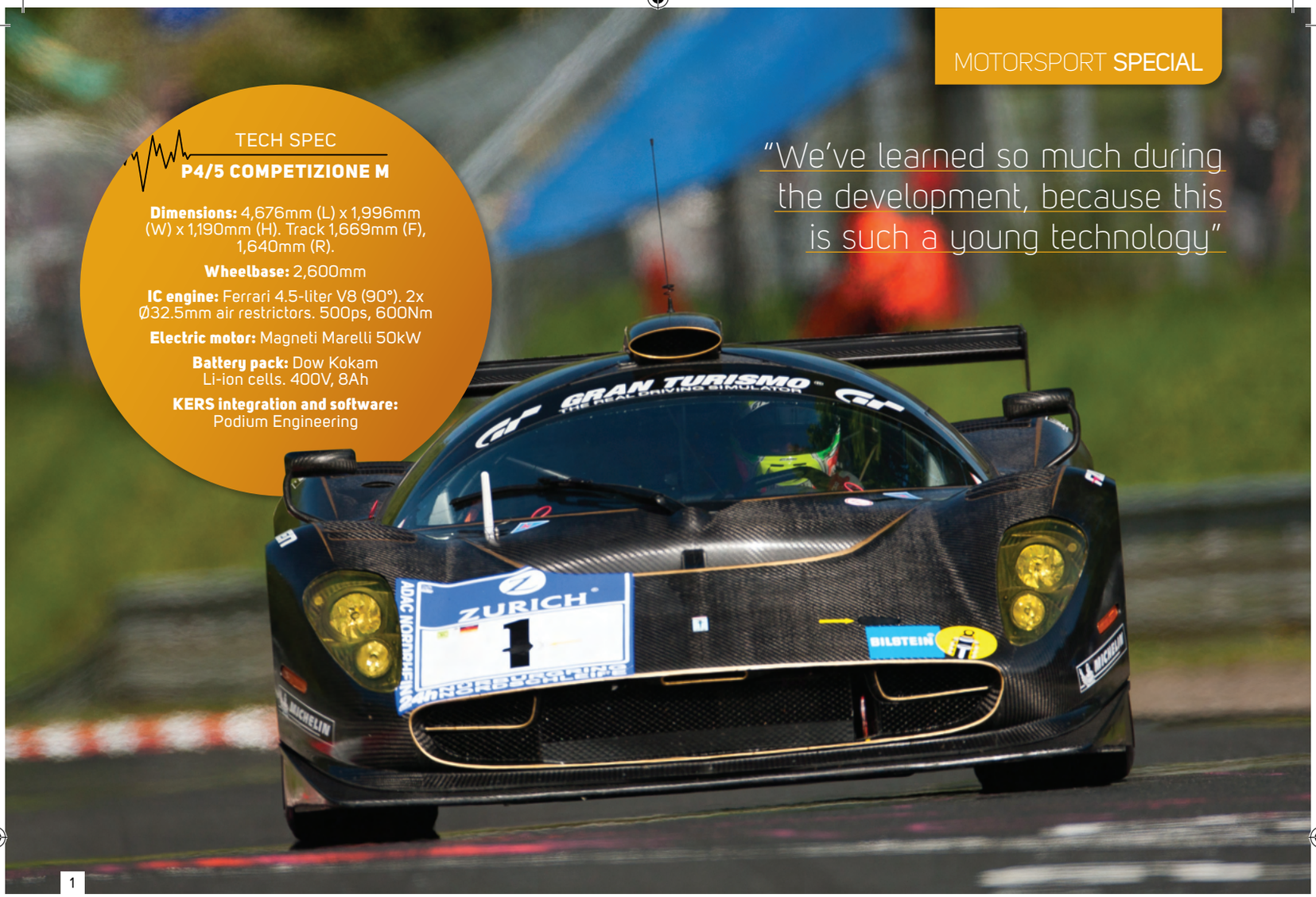
Action shots: Christian Moskopp/Trackshoots.de

Future past

The unique Glickenhaus P4/5 Nürburgring endurance racer has reached the zenith of its development with a bespoke and high-tech battery-based KERS system

WORDS: GRAHAM HEEPS



1

"We've learned so much during the development, because this is such a young technology"

TECH SPEC

P4/5 COMPETIZIONE M

Dimensions: 4,676mm (L) x 1,996mm (W) x 1,190mm (H). Track 1,669mm (F), 1,640mm (R).

Wheelbase: 2,600mm

IC engine: Ferrari 4.5-liter V8 (90°). 2x Ø32.5mm air restrictors. 500ps, 600Nm

Electric motor: Magneti Marelli 50kW

Battery pack: Dow Kokam Li-ion cells. 400V, 8Ah

KERS integration and software: Podium Engineering

Amid the familiar-looking Porsche, Audi and Mercedes GT3 machines at the head of the Nürburgring endurance race grids, the P4/5 Competizione run by Scuderia Cameron-Glickenhaus has cut a striking figure over the past two seasons.

But it's not just its retro looks, inspired by classic Ferrari sportscars from the late 1960s, that mark this sports racer out as unique. The technical package is also entirely bespoke, now that a battery-based KERS system has been added to the Ferrari 430-derived, 4-liter V8 that lies beneath the engine cover. The resulting vehicle has gained the suffix 'M', for 'Modificata'.

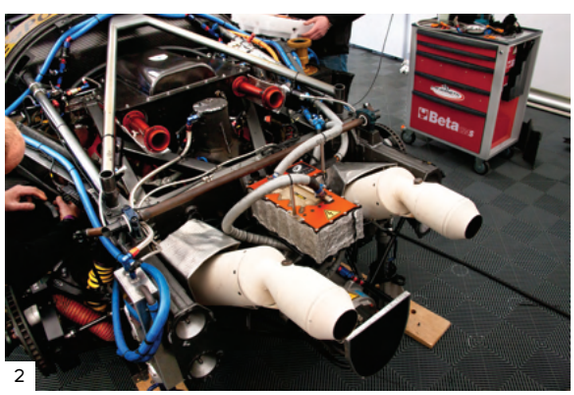
The brainchild of US Ferrari collector Jim Glickenhaus, the P4/5 started life as a Pininfarina concept car back in 2005. In 2009 Glickenhaus commissioned Paolo Garella, formerly Pininfarina's special projects chief, to take on the program management of a racing version to compete in the Nürburgring 24 hours. Incorporating elements of a Ferrari 430 Scuderia road car and 430 GT2 racer, the P4/5 Competizione hit the track in 2011, competing in VLN endurance races to develop the car before tackling the N24h, in which it finished 39th.

Coupling problem

For 2012 the car was hybridized. A regulation-specified 50kW electric motor – a standard Magneti Marelli road-car part – was coupled to the Hewland transmission, which had to be modified by Hewland to take care of a coupling problem caused by the weight of the electric motor's rotor.

1. The technical package of the P4/5 is entirely bespoke, with a battery-based KERS being added to the Ferrari V8

2. Unballasted, the P4/5 was already below the 1,350kg minimum weight assigned to it by the VLN, so the additional mass of the KERS has not impacted the performance of the race car in that respect



2

The inverter is a Formula 1 unit. Initially it was located in the engine bay, but as a result of a major evolution after the 2012 N24h, in which the car came home 12th, it has now been moved to inside the car on the passenger side, where the battery also sits. That evolution brought about a major redistribution of weight – 50kg was shifted from the rear to the center of the vehicle.

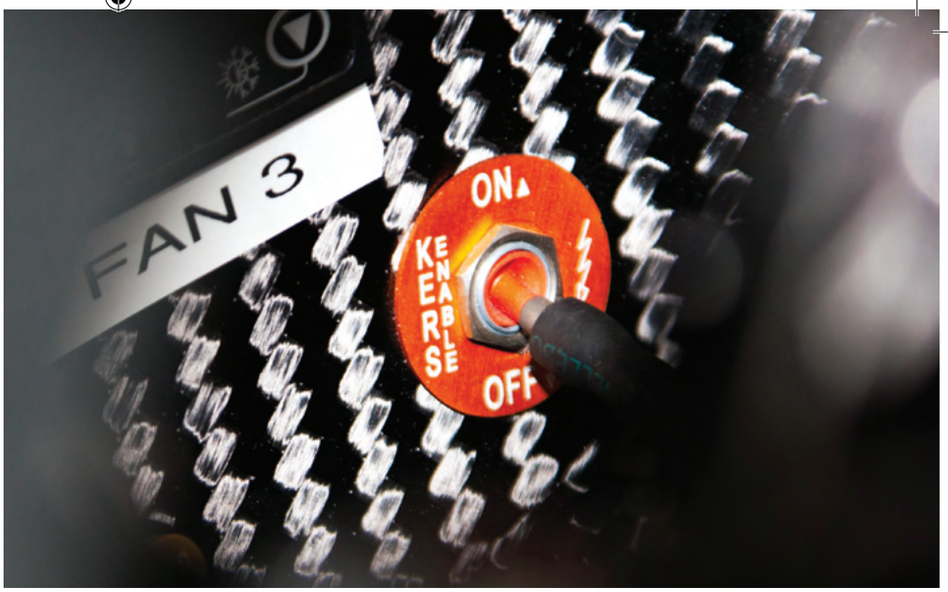
"There are some safety issues with the longer cables but it's solvable," says Garella. "We've learned so much during the development, because this is such a young technology. For example, we had a problem with a couple of battery

cells. We thought it was because of overheating, so we restricted the level of charge and boost energy to around 25kW. But we discovered it was actually a friction problem with the cell, so now we are running at 50kW."

Also new since the 2012 24-hour race is the introduction of automatic energy recovery and deployment. A manual override is retained should the driver need to deploy KERS in, for example, an overtaking maneuver. But software now takes care of balancing energy capture and discharge in the most efficient fashion over the course of a lap.

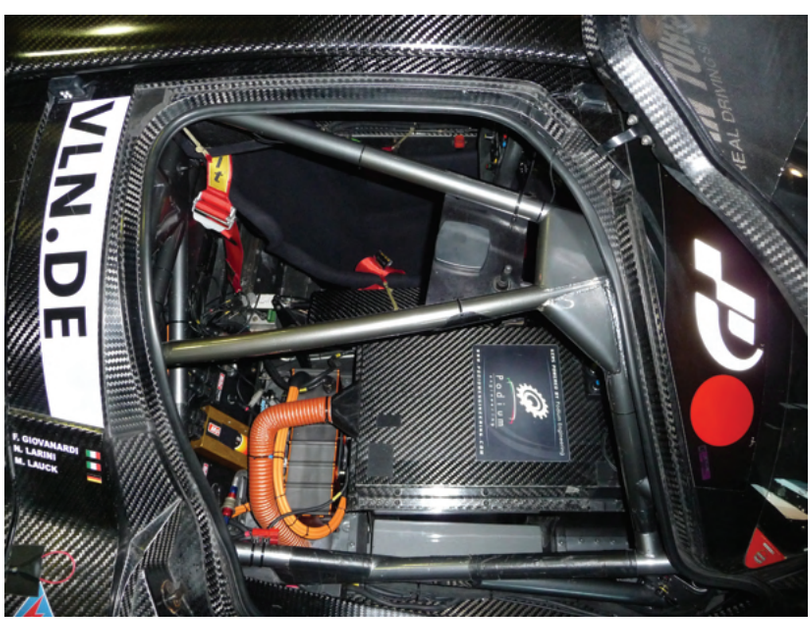
"In our case the level of charge is limited by the heat of the battery – it's warmed both by charge and discharge," says Garella. "There is however no degradation in battery performance [over the course of a race] – we are running the battery at a maximum of 42°C, when the maximum allowed is 52°C, so we're still very low, temperature-wise. The higher we go, the more its energy capacity is reduced."

The battery pack, based on cells from Dow Kokam, has been built specifically for the P4/5 by the team and its development partner, Podium Engineering. It's a 400V, 8Ah lithium-ion affair charged by regenerative braking out on the track. For safety and ease of charging, it's kept between roughly 30-90% of its capacity. Podium has worked with the team to build the battery-management software and inverter control strategy from scratch.



Theoretically, the P5/5 (right) can run in EV mode in the pitlane, Le Mans-style, but for safety reasons this function has been disabled, with KERS (above and below) only being live when the IC engine is switched on

"We had a problem with a couple of battery cells. We thought it was because of overheating, so we restricted the level of charge and boost energy to around 25kW"



Fantastic Nürburgring

"Bringing different components and technologies together is challenging but exciting," notes Garella. "The Nürburgring is fantastic not just for developing race cars, but road cars, too. The more you design a car that is close to a real [street] car, the faster you go. It's like an open road, so everything must be designed with that in mind.

"Our project is very focused on the 24-hour race – we do the VLN races to test and learn – so for us it's crucial to have components that can last 24 hours. And if it can last 24 hours here, it'll last for years in the real world. We are very safe in all of our settings."

He says that the performance benefit of incorporating KERS is two seconds per lap from the one-minute duty cycle – which means that the system is operating for around 10% of the time during a typical race lap of the Nordschleife.

At the time of writing it was not clear what 2013 holds for the P4/5 Competizione project, with a return to the Nürburgring as yet unconfirmed. The team has also been in contact with the organizers of the Daytona and Le Mans 24-hour races, with a view to building a new machine to fit the regulations of one of those events. Garella is confident of improved performance, should the current car return to the Ring: "We have spent a large amount of money, but with what we have learned already I think we can considerably improve our performance without any further great expense."

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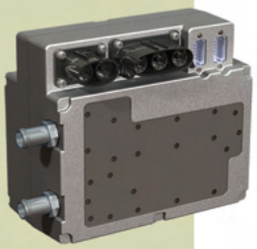
- Air or liquid cooled
- CAN communication
- Fully protected
- EMC compliant
- Group 31 size

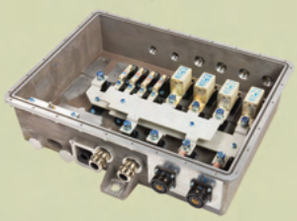
DC/DC Converters

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



Traction Inverters

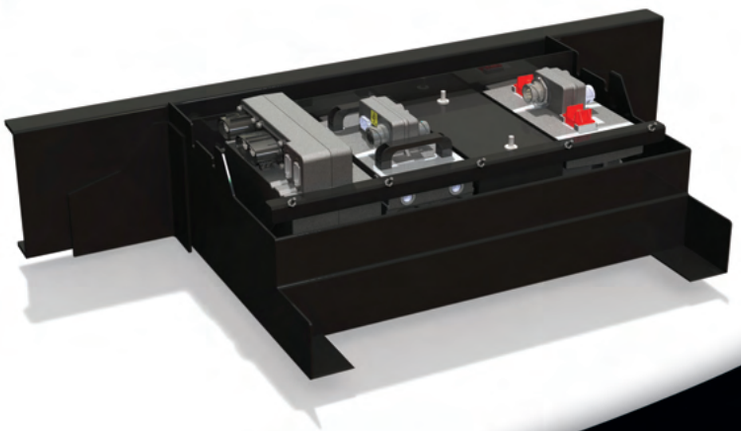
- 30KW-500KW
- 260-900VDC input
- Compact design
- IGBT based design
- Group 31 size



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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Audi e-tron quattro
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1
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Close-run thing

Analysis reveals that the Audi R18 e-tron's advantage over its 'ultra' sister car was not as great as it first appeared, despite its winning form at the Le Mans 24 Hours

WORDS: BRIAN LABAN

Main: Audi's eleventh Le Mans victory since 2000 came courtesy of the hybrid R18 e-tron quattro

Above: Audi's non-hybrid R18 ultras came third (#4) and fifth (#3) respectively

For 21 hours, the outcome looked open, but in the end the number 1 Audi R18 e-tron quattro of Lotterer, Fässler and Tréluyer won the 80th Le Mans 24 Hours (by a single lap), from McNish, Capello and Kristensen's accident-delayed number 2 sister car. But while a hybrid win on its Le Mans debut was hardly a shock, it begs an interesting question: how clear-cut was the e-tron's advantage – not only over Toyota's other hybrid newcomer, but also over the 2012 evolution of Audi's 'straight' diesels, the R18 ultras, which finished a battling third and fifth?

Once the ACO opened the door, Audi's hybrid program was inevitable; but even anticipating hybrid opposition from both Peugeot and Toyota, Audi wasn't ready to put all its Le Mans eggs in one basket – allowing a direct comparison between hybrid e-tron quattro and diesel ultra.

Both are state of the Le Mans art. Audi shed a remarkable 10% of the 2011 R18's weight, so the second 2012 variant could accommodate hybrid and quattro hardware, and still reach the 900kg LMP1 limit. Thus the '90% new' 2012 R18 base-car is the lightest LMP1 car Audi has built to current regulations. And Audi can run two variants identically except for the hybrid system – including the 3.7-liter mono-turbo V6 with over 510ps and 850Nm with 2012's reduced 45.8mm restrictor and 2.8 bar maximum boost.

The e-tron's flywheel storage is from Williams Hybrid Power, and as the company's general manager, Gordon Day, says, it differs considerably from an F1 KERS system. An F1 system is limited to 60kW, Audi's runs two 75kW motors, so 150kW in total; F1 limits energy release to 400kJ per lap, Le Mans allows 500kJ at seven defined zones on each lap – or 3.5MJ per lap. That potentially means a bigger influence on lap time and consumption. In the R18 e-tron, it is employed automatically and focused on energy efficiency rather than a push-to-pass boost; and while an F1 KERS can be serviced or replaced after every two-hour race, the Le Mans system must work for 24 continuous hours.

STACK ATTACK

Hot on the heels of the DeltaWing, the Automobile Club de l'Ouest's 'Garage 56' will next year offer the GreenGT H2 project – a prototype GT racer – the chance to become the first electric/hydrogen car in competition at Le Mans.

The project began 12 months ago. During the early stages of development, the seven-strong GreenGT team realized that the makeup and arrangement of lithium-ion batteries held the most potential for evolution and quickly adopted hydrogen as the car's power source. This choice saw a 100kW fuel cell being created in 2011, which subsequently evolved into a high-power variant, capable of delivering 340kW. Developed alongside this second-generation powertrain system was H2's 400kW, lightweight twin-electric motor unit.

At the heart of the GreenGT is an all carbon fiber chassis, developed by Welter Racing, the shape and layout of which was dictated by the car's fuel cell and ancillaries. The SymbioFCell stack is around 120cm larger than the equivalent IC engine and comprises a stack of 18 cells that feature experimental high temperature membranes. This is facilitated by an onboard water system (partially fed by the waste water produced by the combustion process) that helps keep the cells operating at their optimum temperature of 80°C.

GreenGT H2 currently weighs 1,230kg, which is much more than an LMP2

Mounted behind the linear power fuel cell is the direct drive transmission. Specifically designed for the GreenGT, the clutchless unit uses an electronic torque-vectoring differential to aid cornering stability and ability. The 12kg casing for the transmission is milled down from a 387kg solid block of billet aluminum. The lightweight transmission helps transfer the equivalent of 4,000Nm of torque to the Tarmac unit via the 13 x 18 BBS wheels, wrapped in specially developed Dunlop tires.

The cells are fueled by 4kg of hydrogen, which is the energy equivalent of 25 liters of petrol. This is stored in the two 350 bar high-pressure tanks, mounted prominently on either side of the car. These not only give the car a strong visual link to its hydrogen powertrain, but also aid the refueling process. "Refueling

"We can refill the hydrogen tanks within three minutes – enough to give a running time of around 40 minutes"

Day states that a flywheel enables higher power density than either battery or supercapacitor (Toyota's choice), where high-power systems are vital to capture sufficient energy during relatively short braking events. Flywheels also offer the lightest solution for given power or highest power for given mass, while flywheel performance doesn't degrade appreciably over sustained very high-duty cycles.

While Toyota (and ultra) adopt rear drive only, Audi's 'quattro' layout allows part-time all-wheel drive (the rules having long banned the full-time variety). That means Audi can't deploy front drive below 120km/h at any point but, frankly, there aren't many places on a Le Mans lap where that's an issue, even at the seven specified areas. The full 500kJ and 150kW per event, on the other hand, imply a maximum 'boost' time of 3.3 seconds per cycle. Over seven cycles, that adds up to around 11% of a three-minute 25-second lap – a 204ps advantage over the R18 ultra for as much as 11% of the time. The only glaring hybrid debits are the additional drag from cooling the hybrid system, and (under ACO rules) a 2-liter fuel-capacity reduction (to just 58 liters).

Now consider some key data, from test, practice, qualifying and race (plus Saturday warm-up, the only full-wet session). Assuming close driver parity (which is true), the differences in several areas tell an interesting story.

On test day, the 2 e-tron quattro was quickest, at three minutes 25.927 seconds, but the 3 ultra was only 0.634 seconds adrift – 0.3%. In free practice, 3 was 2.331 seconds (1.1%) down on the 1 e-tron, but matched its top speed – while the other ultra was 4.9km/h faster. The 7 Toyota was 7.9km/h faster than either breed of Audi.

In qualifying, the 3 ultra ran even closer: e-tron 1 topped the first and third sessions, ultra 3 stole the second. That left 1 on pole with 3 minutes 23.787 seconds (two seconds faster than 2011's R18 best), but 3 was just 0.291 seconds

The 3.7-liter V6 TDI engine (above and right) common to both R18 versions puts out 510ps while total torque exceeds 850Nm

(0.14%) shy. Again, both Audi's Vmax table-toppers were ultra, not e-tron, by up to 5km/h (with the 8 Toyota more than 4km/h faster still, and quickest overall in the middle, Mulsanne sector).

This is one factor in the hybrid equation. Hybrid power delivers acceleration, but by the time the car actually reaches maximum speed, engine power alone must overcome the limiting factor: drag. Hence the ultras, without the drag penalty of the hybrid cooling package, were frequently faster than the e-trons in a straight line.

Another factor is balance. Without the additional weight of the hybrid system, the ultra can deploy weight saved

At the heart of the GreenGT is an all carbon fiber chassis

is undertaken like any other car," explains Jean-François Weber, general manager and head of R&D at GreenGT. "We can refill the hydrogen tanks within three minutes – enough to give a running time of around 40 minutes." The 160-liter tanks are made of a carbon fiber and aluminum mixture that is around 4cm thick, and have been tested to withstand impacts three times stronger than those necessitated by FIA standards. "They cannot be penetrated and they do not hold enough hydrogen to cause serious injury or damage in the event of an accident," explains Weber.

The team has set three clear objectives for 2013: to have a running time of more than one hour; to lap Le Mans in under four minutes; and to get the vehicle weight below 1,000kg.

The H2's rear end wing milled billet casting

Toyota provided Audi with hybrid competition at Le Mans, and next year promises to be an even closer race between the two competing teams. Pictured here is the TS030 Hybrid's supercapacitor

"Hybrid power delivers acceleration, but by the time the car actually reaches maximum speed, engine power alone must overcome the limiting factor: drag"

The diesel powered R18 ultras pushed the hybrid Audi cars all the way

over last year's car mainly as ballast – and can put it pretty much anywhere. The hybrid hardware sits where it must sit, with little room for adjustment. And while all the drivers were universally positive about their cars' characteristics, at this stage in the program, there's obviously more to be learned in terms of the hybrid/quattro setup than on the ultra one.

In the wet warm-up, where you might have expected the quattro advantage to prevail, 3 ultra stole it again, by 1.2 seconds after three personal-best sectors back-to-back – although it's important to note that with three outright-best-sector times, the 2 e-tron's 'ideal' lap would have been enough by almost two seconds; and it was a thought-provoking 40km/h up on the 3 ultra's official top speed.

In the end, the race was a hybrid victory, but it was no walkover, especially taking into account the problems (mainly accidents rather than technical issues) afflicting each of the Audis, and the early demise of both Toyotas. Audi was also adamant that the cars were allowed to race on equal terms; a hybrid win was not pre-ordained.

Number 1 covered 378 laps, 5,151.8km, at an average 214.47km/h; 2 was one lap down, 4 (the first ultra) only three laps, holding station for many hours. The 3 ultra set the fastest lap, 3 minutes 24.189 seconds, 1.1 seconds faster than 2011's best, only 0.4 seconds off the hybrid pole. Leading hybrid and leading diesel matched each other almost stop for stop, 33 stops (and 41 minutes) for 1, 32 (and 40 minutes) for 4. There was rarely more than a lap in it on relative range, and nothing on tire stints.

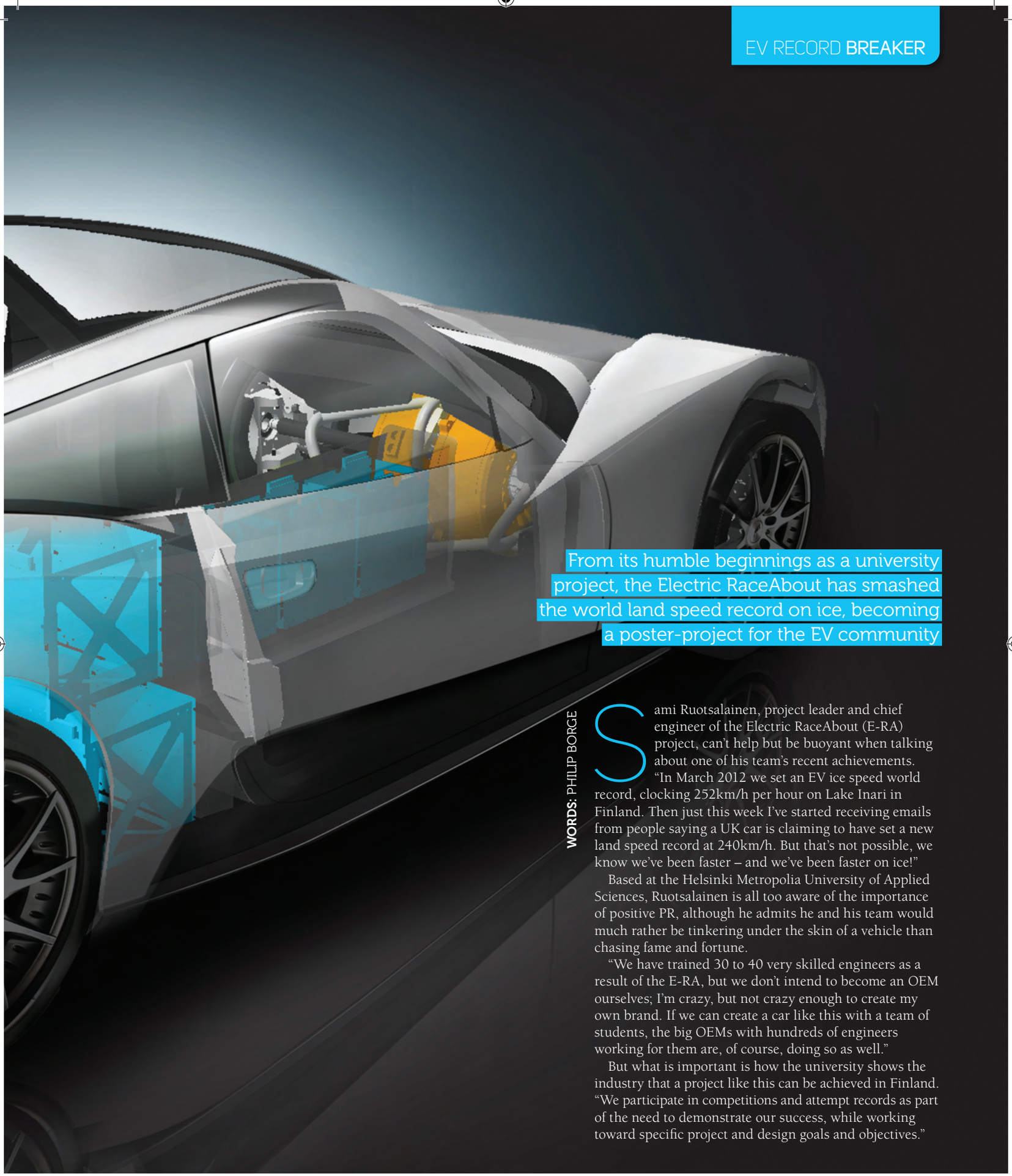
The winner averaged 33.34 liters/100km, 10% better than 2011's winner, but 6.4% quicker (albeit with half the safety-car interruptions). The 2 e-tron narrowly beat the 4 ultra to the Michelin Green X Challenge for the best performance on the least fuel.

Unsurprisingly, Audi did not want to compare the e-tron and ultra results directly, leaving technical director Ralf Jüttner to sum up: "We're very happy. The debut win of a hybrid car has marked another milestone at Le Mans."

Now the nagging thought, which in no way diminishes the R18 e-tron quattro's debut achievement, or likely development trajectory is that although the ultra could live with this year's Toyotas, it will clearly take another hybrid to do so long term. It was the brilliant evolution of the 'base' R18 that made 2012's Audi win possible. Without it, the hybrid would not have been viable.

Ice cool

Having taken second place in the Automotive X-Prize in 2010, the E-RA team set about creating a new EV speed record on ice. In March 2012, Janne Laitinen recorded 252.09km/h on Lake Inari, Finland, cementing the project's place in the record books



From its humble beginnings as a university project, the Electric RaceAbout has smashed the world land speed record on ice, becoming a poster-project for the EV community

WORDS: PHILIP BORGE

Sami Ruotsalainen, project leader and chief engineer of the Electric RaceAbout (E-RA) project, can't help but be buoyant when talking about one of his team's recent achievements. "In March 2012 we set an EV ice speed world record, clocking 252km/h per hour on Lake Inari in Finland. Then just this week I've started receiving emails from people saying a UK car is claiming to have set a new land speed record at 240km/h. But that's not possible, we know we've been faster – and we've been faster on ice!"

Based at the Helsinki Metropolia University of Applied Sciences, Ruotsalainen is all too aware of the importance of positive PR, although he admits he and his team would much rather be tinkering under the skin of a vehicle than chasing fame and fortune.

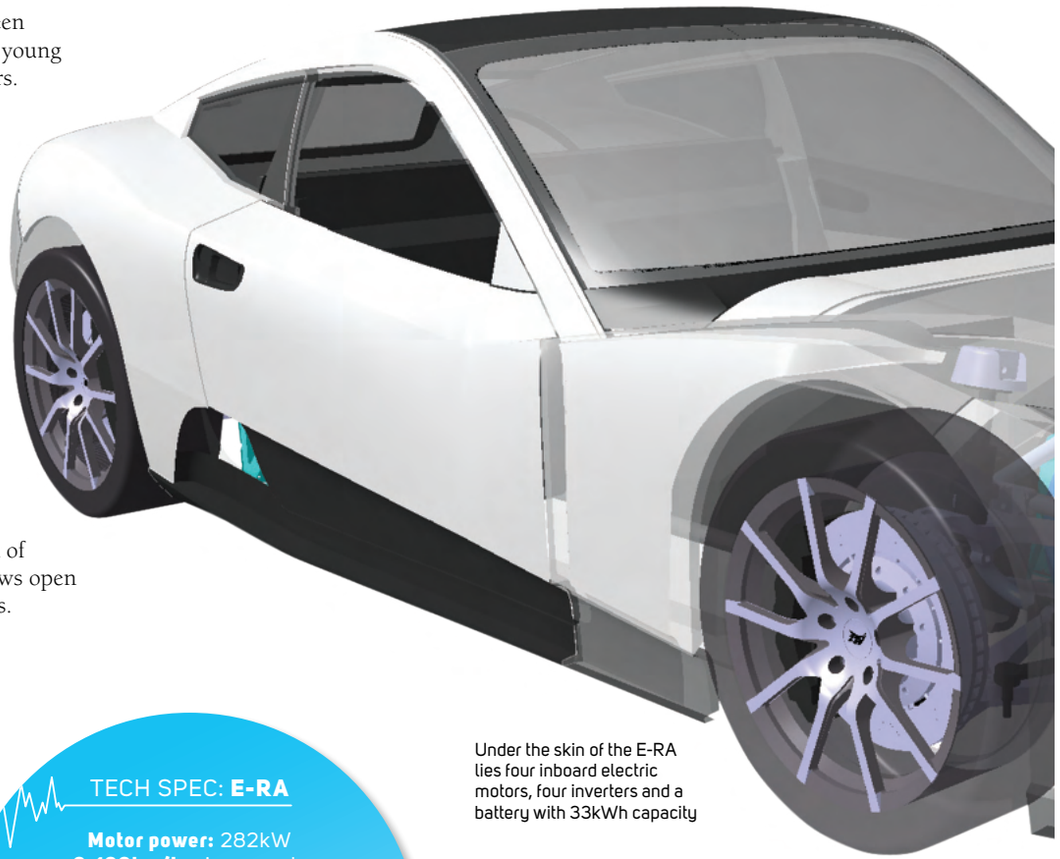
"We have trained 30 to 40 very skilled engineers as a result of the E-RA, but we don't intend to become an OEM ourselves; I'm crazy, but not crazy enough to create my own brand. If we can create a car like this with a team of students, the big OEMs with hundreds of engineers working for them are, of course, doing so as well."

But what is important is how the university shows the industry that a project like this can be achieved in Finland. "We participate in competitions and attempt records as part of the need to demonstrate our success, while working toward specific project and design goals and objectives."

And why an electric sportscar setup? "We've been taught to admire speed and fast cars. We educate young people so they are interested in speed and fast cars. Many of them dream of becoming motorsport engineers when they join the university, and this kind of project requires a lot of hours, a lot of work, so it has to be a dream project, otherwise people will tire of it."

A sportscar, at first glance, may seem an easy sell to interested organizations when it comes to securing funding and partnerships, but Ruotsalainen admits it's a risky strategy. "Think about industrial professionals; they will ask, why build an electric sportscar when you can build a city car that is a more manageable project? But that's boring for us. We have to think of the team and workforce, and keep them excited."

However, excitement is not the primary driver for this project. Ruotsalainen admits that the lack of limitations in the design of an exotic vehicle throws open the doors to all types of advances and innovations.



Under the skin of the E-RA lies four inboard electric motors, four inverters and a battery with 33kWh capacity

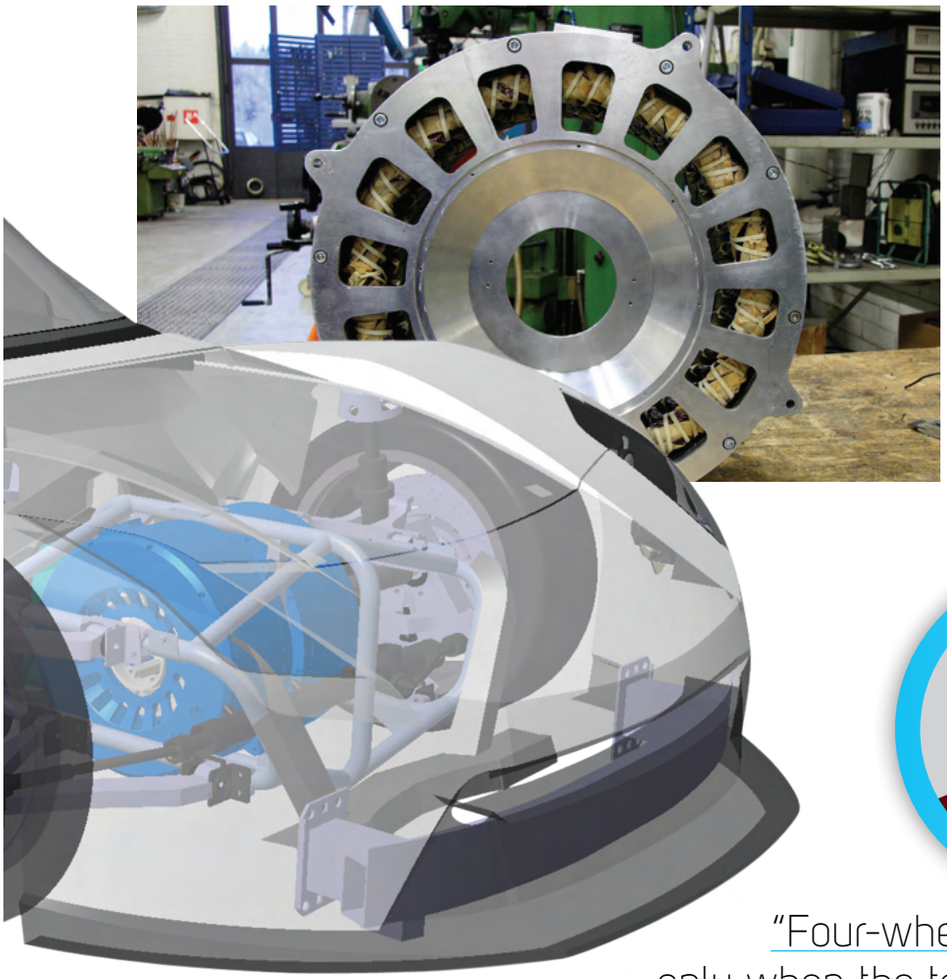
Of sparks and speed

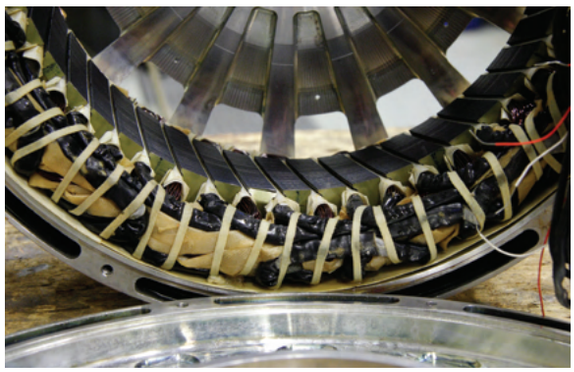
Part of the Stadia Automotive Engineering Team's RaceAbout family – and the newest of 12 automotive prototypes developed at the Metropolia University – the E-RA is a fully electric vehicle. It has a top speed of around 260km/h, and can speed up to 100km/h from standstill in just six seconds. Driven by four advanced inboard-mounted motors

TECH SPEC: **E-RA**

Motor power: 282kW
0-100km/h: six seconds
Top speed: 260km/h
Range: 200km
Consumption: 145W/h/km (fuel equivalent to 176mpg)
Weight: 1,720kg
Battery: lithium-titanate pack
Motors: four-wheel direct drive with four inboard-mounted motors
Monocoque: carbon fiber

The E-RA's total weight is 1,720kg, of which 620kg is the battery pack. Crucially, though, the lithium-titanate technology's operating temperature is rated between -60°C and 75°C





The permanent magnet synchronous motors have been jointly designed with Lappeenranta University of Technology. Each motor weighs 50kg and delivers 800Nm of peak torque

"Four-wheel drive will become widespread only when the technology has advanced enough to put the motors directly inside the wheels"

and powered by a lithium-titanate battery pack, its 100% carbon fiber monocoque chassis helps to keep its total weight down to 1,720kg.

Crucial to this reduced weight is the omission of any complex transmission system, instead opting for a direct-drive solution. Ruotsalainen explains, "The simplicity is key here. We chose to use a direct drive because we didn't want a gearbox or the need for oils, equaling simplicity and low service. The motors are installed back-to-back in the middle of the car, and they simply drive the wheels through a regular driveshaft. When we first started designing the E-RA [in 2006], nobody had done that this way before, as the motors were almost always centrally mounted."

Now Audi and Mercedes-AMG, with the e-tron cars and electric SLS AMG respectively, are pursuing a similar approach. "These are very similar – individual wheel drives, but they have reduction gears. They lose out in efficiency, because they have the gearbox and the extra parts and maintenance requirements. On the other hand, they will achieve better acceleration than we can with the E-RA."

However, the E-RA's unique design could still give it the edge at speed. "At the top end, because our motors are lower revving, they have the same rpm at the wheel, so I expect we have better acceleration at higher speed. Our motors are heavier because they need to produce more torque, but we don't have the heavy gearbox, so there are pros and cons. We wanted to take this approach because it is simpler, and perhaps more beautiful."

BATTERIES: THE KNOWLEDGE

Type: 286 Altairnano lithium-titanate cells (50Ah each at 2.3V in 143s2p configuration)

Capacity: 33kWh

Voltage: 243 to 415V

Power: 200kW continuous; 330kW for 10 seconds

Fast charging capability: 10 mins at 250kW

Weight: 620kg (1.6kg per cell)

Operating temperature: -60°C to 75°C

Charge temperature: -50°C to 75°C

Lifetime: 5,000 cycles

Additional data: Each cell is monitored and the entire system is balanced

Four motors good

Although the project was defined by a clear set of objectives, the brief was kept open enough to allow room for experimentation. The choice to use four motors in an electric vehicle, even with the consideration of the extra weight these would contribute, was deliberate.

"If you think about traditional cars developed for the consumer market," explains Ruotsalainen, "it's nice to have four-wheel drive because of the efficiency of traction and braking. In an electric vehicle on paper it's a good approach, but it's potentially very costly. I'm assuming, and as we are seeing, most electric vehicles reaching the market are two-wheel drive. I think four-wheel drive will become widespread only when the technology has advanced enough to put the motors directly inside the wheels." Until that point, it's likely to be exotics such as the SLS AMG that are not prohibited by standard development economics that will be four-wheel drive.

Designed jointly with Lappeenranta University of Technology, each permanent magnet synchronous motor weighs in at 50kg, delivering 800Nm in peak torque.

E-RA shattered the ice speed record for an EV with the help of its impressive 252kW of total motor power. The vehicle takes six seconds to do 0-100km/h

1

"It's very difficult to reduce motor size and weight – it almost requires a breakthrough in physics. Motors and electromagnets are made from heavy substances – copper, steel, rare earth powders – all heavy materials. There might not be very easy ways to get around that fact."

Ruotsalainen believes that the solution may instead come from the transformation of the vehicle itself. Even after investing so much into the development of an electric sportscar, are they simply a 'nice-to-have' as we gravitate more and more toward urban population centers? "I don't know if we'll still need a vehicle in 10 or 20 years' time that does more than 200km/h. People are moving more and more into cities, where the driving speeds are much slower. The car itself, and the need for it, is transforming, potentially into something that would then allow in-wheel drives with smaller motors – less power and a lot less weight."

Power to the people

The E-RA's batteries, Altairnano lithium-titanate cells, have a 33kWh capacity and weigh in at 620kg. Naturally, the battery is by far the heaviest component of the vehicle, and it's this limiting factor that continues to hold back electric vehicle development, according to Ruotsalainen. "Batteries are too expensive, the energy density is too low, and the power density is too low – per kilo you can currently charge and discharge too little power." However, it works in the E-RA because of its performance objectives – acceleration and speed.

While the hardware for controlling the four motors performed better than expected, it was the batteries and management system that caused Ruotsalainen and his team the most headaches. "In finding a partner, we were not that lucky. It was not a technological difficulty, but an issue with the supplier, based in the USA. It quoted the batteries for us, we paid, then it turned out that we didn't represent a positive business case for that organization, and it almost did not deliver the batteries to us. Often, companies like this, whether in the USA or otherwise, have very little interest in supporting something like a university project so far away. Some suppliers find it difficult to look far ahead to what will be the next generation of engineers, and their potential customers. Perhaps they are simply running their numbers for the quarter, not the future."

MOTORS: THE KNOWLEDGE

Type: Permanent magnet synchronous motors

Performance: 250Nm nominal/800Nm peak torque. All available from 0 to 1,800rpm

Weight: 50kg per motor

Additional data: Water-/air-cooled. Direct drive through driveshafts, so no need for gears or differential

An industry supporting innovation

The E-RA team fared much better when securing support from more than 60 industry partners, ranging from industrial engineering organizations, research institutes and government funding agencies, to a number of automotive supplier partners.

"Some of the partners provide us work free of charge, others offer direct financing, others parts and subsystems. The university has also put in a large amount of funding. In total I'd estimate we've put between €1.5 million and €2 million [US$1.9 million to US$2.5 million] into this project. That doesn't seem a lot of money, but from a car maker's point of view, you would have to put several zeros behind that figure."

It's clear that a project such as E-RA would only be possible with this generous level of industry support; one of the reasons why the Stadia Automotive Engineering Team continues to compete on a global stage. The E-RA ranked second in the 2010 Automotive X-Prize in Michigan, and won the EV rally and Design Awards at the Challenge Bibendum Berlin in 2011. It was also the only university car to take part in the 2012 Silvretta E-Auto Rally, alongside 30 OEM vehicles.

Improvement and innovation is ongoing, says Ruotsalainen: "We are constantly developing and improving the car. It's currently receiving new suspension geometry, new tires from Nokian, and this winter we are looking for a new battery supplier to increase our speed. Demonstrating the good work we've done, and continue to do, is valuable for the university and our industry in Finland."

Understandably, a dose of healthy competition, and a little self-promotion, is also a key catalyst for the team. Ruotsalainen admits, "Last September we set an EV lap record on the Nürburgring Nordschleife, but Audi took this record from us. We'll definitely be revisiting this."

1

Next up for the E-RA project is the development of a heat pump for car use and the further development of electric motors and inverters

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Kiss your bus goodbye!

WORDS: BERN GRUSH

The function of the urban transit bus is critical for cities but its physical and network form is increasingly undesirable. The driverless EV revolution seems certain to change all that

Illustration courtesy of Ben White

The city bus is a critical urban resource. Transit systems, including buses, stimulate economic development, create jobs, get people to work, reduce traffic congestion, foster more livable communities, boost real-estate values, ensure safety and enhance mobility for those who do not drive. Under the right average load circumstances, they also reduce energy consumption and are easier on air quality measures. But such conditions are seldom met in the USA, and it has even been argued by Thomas Rubin on the reason.org website that relative to the personal automobile, the public bus transit doesn't reduce greenhouse gas emissions.

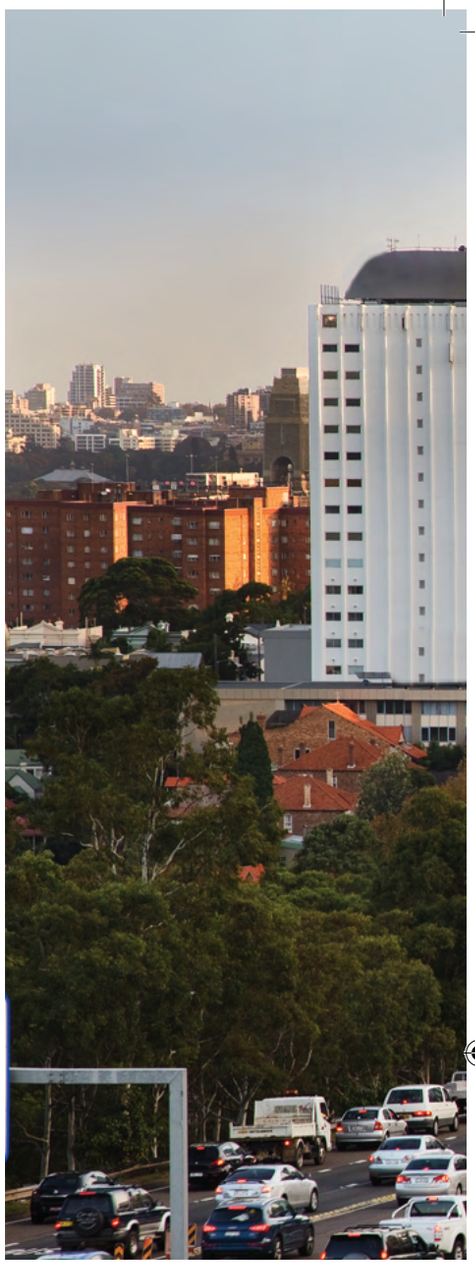
Crucial factors

Regardless, autonomous rubber-tired transit remains crucial in those urbanizations expecting or promoting densification, as enumerated in Alan Ehrenhalt's *The Great Inversion and the Future of the American City*. Inversion describes the reversal of the multi-decade trend for family, money and maturity to move to the suburbs. Some of this is younger people who are slower than previous generations to own personal vehicles; older people embarking on their post-driving years; and those wishing to adopt a car-free, eco-friendlier lifestyle. This matters because a portion of these people will consume more public transportation – and the hope is that this portion will be significant.

The car, too, is a vital urban resource, stimulating economic development, creating jobs, shortening travel times, increasing job reach, providing more choice of housing location and enhancing mobility for those who can afford them. Measured by its mass adoption rate relative to the bus, the car is currently the more critical resource.

The automobile is also undergoing far more rapid innovation and, as Rubin points out, is currently the cleaner environmental performer per passenger mile in the USA compared with the bus. As we expect to move toward increasing energy efficiency for the private automobile, the car/bus comparison will increasingly favor the car, unless there is a dramatic upswing in off-peak bus ridership. An increase in bus use may be what planners and urban advocates wish, but that is not what society is presently seeing.

"With an environmental focus, attention has been lavished on the electric powertrain, which is expected to make automobility more sustainable"



Experts say that the bus – as we know it – needs to quickly adapt in order to survive, starting with a clean propulsion system that replaces current diesel engines, which in some cases are decades old

Not so much to choose from

Although it's inconceivable going forward without shared, urban transit systems, the 50-passenger city bus is an endangered species. With few exceptions – NYC is notable – bus transit use continues to erode in the USA. They're getting more expensive to buy and operate, and are getting heavier as alternative propulsion systems are adopted. They've also lost a few seats as wheel wells intrude into seating areas to lower floors for accessible loading, and over the past decades they have generally been getting emptier.

The car has even more problems, though. It was associated with 369,000 deaths in the USA from 2001 to 2010. Around 50% of its total lifecycle footprint is in its manufacture

City planners are at a loss: buses in their current form are not working while cars (when not parked) clog roads. Is the solution driverless EV applications?

and another portion in its disposal. And it burdens society with an additional, even larger problem that's wildly mismanaged: parking. The average car is parked more than 95% of its useful life. As such, the fully accounted carbon footprint of parking infrastructure far outweighs the aggregated footprint of all of our automotive driving. Giving over a large portion of urban space to storing privately owned cars also distorts urban land values, harming lower-income earners.

As a result, the benefits of automobility may have plateaued – they are certainly tarnished for many – but they will not be wished away, and we are likely to continue seeing an outsized number of personal passenger vehicle trips. The big question is, can we make those trips with fewer vehicles and with less parking?

According to the 2010 Federal Transit Administration's (FTA) National Transit Summaries and Trends, transit revenue miles (all types) increased by 18% between 2001 and 2010. Growth, in order of increase, was experienced by vanpools, light rail, demand response (including taxis) and commuter rail. Bus revenue miles increased the least – just 5.3%. This is comparable with the nationwide increase in automotive VMT of 6.1% over the same period. Bus use is in relative decline even as its costs climb. What appears anomalous is that from 2001 to 2010, bus revenue miles increased by 5.3% (FTA) while bus UPT fell 4% (APTA) – with all of the fall taking place between 2008 and 2010. That could mean fewer people use the bus, and now live further from their jobs, such is the plight of lower-income workers in a recession. It's also been suggested that transit riders, especially bus riders, are last hired and first fired. Either way, it's another loss for the bus.

Where from here?

The bus's problem is that it's large, has fixed routes, needs to service non-uniform demand, arrives infrequently, is under-used, expensive to purchase and operate, and is the modality of last resort. But the car is unsafe, congested and smothers our cities while waiting for its owner to move it to its next parking location. Most importantly, though, is that both buses and cars are hard on the environment.

But to make matters worse, innovation in bus design is dwarfed by that of the personal automobile. As buses in the USA run with an average of only nine passengers, the environmental advantages of the rush-hour bus are as much overshadowed by the increasingly cleaner automobile as they are negated by the near-empty off-peak bus. Reducing off-peak bus operations – to which cash-strapped transportation authorities now resort – encourages further car use and continues to erode the bus's role.

The electric driverless vehicle

With an environmental focus, attention has been lavished on the electric powertrain, which is expected to make automobility more sustainable. It also promises to make automobility more desirable, again favoring the private automobile in the bus-versus-car debate. This will redouble the positive feedback loop for automobility and worsen road and parking congestion. If the EV is deployed in the same urban environments, with the same driver mentality, using the same road and parking facilities, and under the same driving and parking regulations, it would simply continue the bully tradition of its IC engine predecessor, albeit with fewer emissions. The greater problem is that automotive engineering needs to look past the singular focus on the automotive powertrain, or congestion will get worse.

In the SATRE project, on the roads outside Barcelona, Volvo recently used three vehicles that drove autonomously following a truck for 200km at 85/km/h

But another companion technology will play an even more effective role than fleet electrification in addressing the combined weaknesses in the competing systems of autonomous private vehicle and city-bus transit: the driverless vehicle.

Inventor Sebastian Thrun describes the value of the Google Driverless Car from a safety perspective, because machines (when perfected) do not make the number and nature of mistakes humans make; and also from a congestion perspective (when pervasive), as machine reaction times would allow us to reduce headway so that current road infrastructure could carry (according to Thrun's assertion) twice the traffic.

VIEWPOINT: DR PAUL SORENSEN, RESEARCHER AND ASSOCIATE DIRECTOR OF THE TRANSPORTATION, SPACE, AND TECHNOLOGY PROGRAM AT THE RAND CORPORATION

The vision of driverless cars replacing buses is intriguing, appealing on many fronts, and perhaps inevitable. With the rate of progress being made by Google and others, it's not difficult to imagine that the technology required to support fleets of self-driving vehicles will be in place by 2025. Far less clear, though, is whether our regulatory systems will be able to adapt by then. Developing a framework to address liability issues should be a priority for policy makers.

In addition to supplanting under-used bus transit, it seems likely that autonomous vehicles will also result in a merging of car-sharing and taxi service (with the former advancing to replace the latter).

The resulting service would be cheaper than a taxi – no need to pay for a driver – and more convenient than current car-sharing, with the ability to be picked up/dropped off anywhere.

Driverless car-sharing would also eliminate the high fixed costs of auto ownership, to be replaced by higher marginal costs for each trip. For current vehicle owners switching to car sharing, this would create an incentive to reduce vehicle travel, helping to mitigate traffic congestion. This effect is uncertain, though, as driverless car-sharing could also increase vehicle travel among those who do not currently own a car.

All this would be an excellent market for EVs. The cost of electricity on a per-mile basis is much less than gasoline or diesel to power a conventional vehicle, but EVs also cost much more and offer relatively limited range between recharging. The ideal application for EVs thus involves relatively short trips between recharging opportunities combined with high annual mileage to amortize the vehicle price premium – very different from the travel patterns of a typical prospective owner, but just what you would see in a fleet of shared autonomous vehicles serving urban mobility needs.

Barring NYC, bus transit use continues to erode in the USA as they get more expensive to buy and operate. The impact of electric powertrain technology means that they are getting heavier too

However, most see the automobile as technology – whether cool, horrific or just utilitarian. But automobility is a sociological force, and the driverless vehicle will end up being much more about society than technology. The car we have known so far structures our cities, organizes us demographically and provides greater job opportunities.

The first response to the self-driving vehicle is usually fear of not being in control. Thrun points out that the tolerance for accidents while under driverless control will be far less than that under human control. But the driverless vehicle will have to evidence a near-zero accident rate for millions of miles in all sorts of conditions before it becomes pervasive. This may take another five to seven years. Thrun himself said, "The car will be ready when the car is ready," as he pointed out that his team still needs to address driving in snow and avoiding obstacles such as a mattress in the roadway.

The second response, 'Not for me – I enjoy driving', may be true, but three things will change this attitude: people who give up driving will have more time for other work, social or leisure activities while traveling; secondly, those in driverless cars will notice trips are more time- and power-efficient due to constant optimization; but most importantly, insurance rates will be lower as death and injuries fall dramatically.

The third response – 'It'll never be allowed' – is already evaporating as one state, Nevada, has provided the first license for one of these machines as of May 7, 2012.

Once the EV becomes a staple of our urban fleets, self-driving EVs (SDEVs) operated by entities such as Zipcar, Hertz or Yellow Cab will soon form the bulk of non-rail public transit in most cities, with large-format buses relegated to increasingly specialized roles. They'll cluster around charging stations or battery swaps. They'll automatically respond to calls and then return to a charging station or continue to another call. They'll self-distribute and self-assign based on distance, residual charge and customer demand. Depending on willingness to pay, some riders might even specify 'no sharing' or an upscale vehicle; others the opposite.

1

VIEWPOINT: PHIL CHARLES, PROFESSOR OF TRANSPORT AT THE UNIVERSITY OF QUEENSLAND, AUSTRALIA

Although similar in terms of standard of living, Australia has many differences to the USA – a much lower population density and tax base; vehicles, labor and fuel are more expensive; and there are fewer freeways.

In the eight-year period to 2008, public transport (bus and rail) grew by 24.9% in Australian capital cities due to many factors, primarily increased investment by governments into public transport service levels and increasing road congestion.

Urban public transport is about moving large numbers of people. Current systems need to evolve to be effective into the future. Having large buses serving fixed routes and providing services that don't match demand must change – and in Australia they are. Different types of services and routes are being deployed to match demands with success.

There is no simple answer to the challenge of moving people in major urban areas. A combination of large buses (200-seater buses are in regular use in Brisbane), regular-sized, and smaller buses are needed to match demand. Frequency of services varied according to demand, with greater use of demand-responsive services during certain times of the day and in specific areas.

Increasing patronage requires improved levels of service – one major shift available from technology is providing comprehensive, accessible and real-time data on services. Reliability of services and comparable travel times to the car are critical.

Work patterns should change to spread the demand and avoid the 'super' peak periods, developing dispersed employment activity centers across the city, to move away from a few concentrated business districts. As such reports of the death of public bus transport are greatly exaggerated!

The next two decades

Today, large groups of people are constrained to use specific routes. Breaking these into smaller groups provides more room for optimization, with each passenger traveling fewer miles as routes become more effectively optimized segments. No one need wait through a 10-mile trip to complete a seven-mile journey, with SDEVs being able to stop in many more locations for both pick-up and drop-off.

Variable trip pricing can spread peak-hour loads, so there would be no need to replace traditional buses on a seat-count basis, meaning the 50-seat bus that carries 70 riders for 60 minutes each day would need far fewer than 50 seats in replacement.

Most SDEV trip segments would be relatively short. They'd connect with both light and heavy rail lines, and could connect at SDEV hubs for cities without rail.

2

1. Would the general public be at ease in boarding a bus with no driver?

2: Google's much talked about Driverless Vehicle

Alternatively, convoys of SDEVs could complement or replace light rail, reducing the cost of mid-volume transit, while greatly increasing its flexibility.

Personal safety would be managed by video cameras, and motion and sound detectors. Labor costs per passenger mile would drop, but a dramatic increase in passenger miles would counter that to retain employment numbers. The big loser would be parking, but unless municipalities change the parking model, it's already a loser.

The skeptic will no doubt find fault with the enthusiasm for such a vision, but the optimist is more likely to see opportunities. Vitally, there is no reason to think that the public transportation of 2025 should be any less changed than the automobility of 2025. Innovation, cost, convenience and consumption preferences will drive these changes more than sustainability will. The driverless vehicle can soon align these forces to move in the same direction.

• *Bern Grush is the principal of Bern Grush Associates, Toronto*

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IGBT power modules update

A compact and cost-effective system design can be achieved with the Easy automotive power module for high-voltage DC/DC applications

In recent years, huge efforts have been made in the design and development of compact and efficient main inverter and generator solutions within the xEV architecture. Looking at the overall architecture, there are several lower-power, high-voltage auxiliary applications that co-exist beside the main inverter and these demand low-cost solutions. The increasing market requirements for packages with a power capability of up to 10kW and superior reliability led to the introduction of Infineon's Easy Automotive power module family.

The Easy 1B/2B power modules are well-known and proven packages in industrial applications (industrial drives, UPS/power supplies, air-conditioning, welding, battery chargers, inductive heating, and solar inverters) and have been available on the market for several years. The Easy 1B/2B automotive power module version builds on this proven engineering technology with significant improvements to fulfill the requirements for automotive applications and qualification needs.

These modules have housing-integrated screw clamps and press-fit pins to provide a fast, reliable and low-cost mounting concept as outlined in Figure 1. The main features of Easy 1B/2B automotive power modules can be summarized as follows: a compact module design; flexible pin-out that enables different converter topologies to be addressed through a standardized package footprint; well-established packages for automotive and industrial applications; isolated module; housing with integrated screw clamps; PressFIT pins; low stray inductance module design; and green (RoHS-compliant) modules.

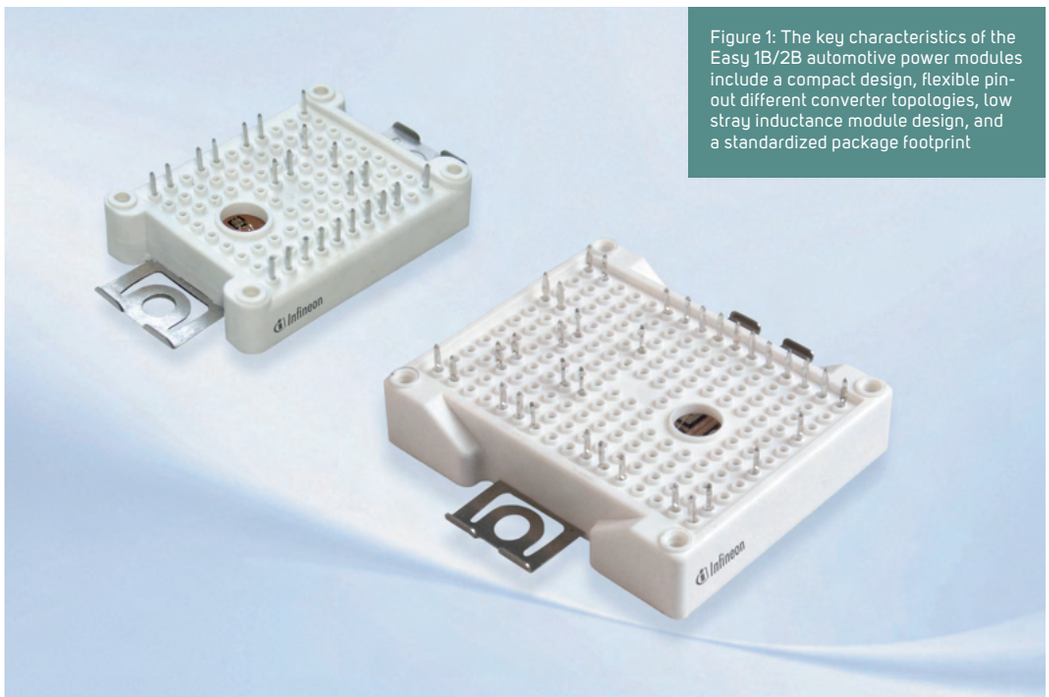

Figure 1: The key characteristics of the Easy 1B/2B automotive power modules include a compact design, flexible pin-out different converter topologies, low stray inductance module design, and a standardized package footprint

The Easy automotive power modules have to pass strict qualification tests in order to fulfill automotive requirements for lifetime and reliability. The automotive qualification includes different chip and package relevant tests. In order to pass the automotive qualification, an improved direct copper bonding (DCB) ceramic is used to reduce copper delamination and DCB cracking. As part of the automotive requirements, the Easy automotive power modules come with a seamless traceability concept that keeps track of applied materials, processes, manufacturing equipment and testing data.

A summary of applications that can be addressed with the Easy 1B/2B automotive packages is shown in Figure 2 (next page).

The B6 bridges with standard IGBTs in the Easy automotive power module series were released at the end of 2011 as a solution for auxiliary drives for xEV applications up to 10kW. Another available module solution in the same package addresses PTC heater applications in the xEV architecture. To further complete the targeted applications, the most recent product development for Easy 1B automotive power module addresses DC/DC converter applications. (A list of available topologies is shown in Figure 3.)

In a typical xEV architecture, the former belt-driven alternator is replaced by a DC/DC converter. This converter supplies the 14V power net directly from the high-voltage (HV) power net with a power capability of up to 3kW. As well as low system cost, aspects such as very high reliability, compact size, high efficiency at high ambient temperatures, and high switching frequencies, are of great importance. To address these requirements, a product based on

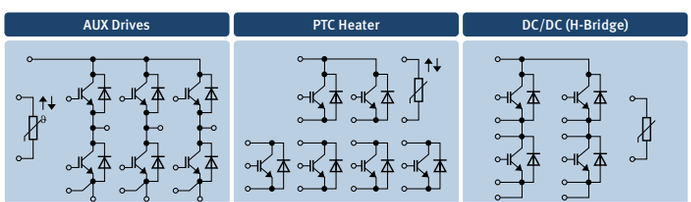

Figure 3: The available configuration options in the Easy 1B/2B automotive

Figure 5: EasyKIT DC/DC evaluation kit. Picture belongs to EPCOS

the Easy 1B automotive package (F4-50R07W1H3_B11A) that is capable of switching frequencies of about 100kHz is in development. The internal DCB layout, bonding, and the positioning of the pins is optimized so that the PCB can be easily designed while keeping the stray inductance on a system level below 25nH. In comparison, a classical system setup with discrete devices shows, in general, a higher system stray inductance in the range of 50-100nH. The lower stray inductance of the power module has the important advantage of lower over-voltage peaks, which enables higher switching frequencies.

For developers who design with the Easy power modules, a new generation of high-voltage ceramic capacitors (Ceralink, from Epcos/TDK) is available with a form factor and PressFIT technology that perfectly matches to the Easy package family. This will enable additional benefits and synergies in the mounting of the components, optimization of system size, and improved switching properties.

For the Easy 1B automotive power module DC/DC solution, semiconductors of the automotive qualified HighSpeed IGBT3 family are used. These are based on the established standard automotive IGBT3 chips. The chip technology is also used in many inverter and generator power modules, such as the HybridPack family (HybridPack 1, HybridPack 1 Pin-Fin, HybridPack 2). The difference is a change in the doping profile optimized to enable the required switching frequencies of 100kHz. As anti-parallel diode, a fast-switching silicon diode (rapid diode) was developed and qualified for automotive applications. With a diode thickness of only 55µm, but a blocking capability of 650V, the thin rapid diode enables a higher turn-off speed and lower conduction losses. Despite the higher switching frequencies of the diode, a similar soft turn-off waveform is achieved, as seen in the emitter controlled diode 3 for inverter and generator applications.

With the combination of the HighSpeed IGBT3 and the rapid diode, the power module can be

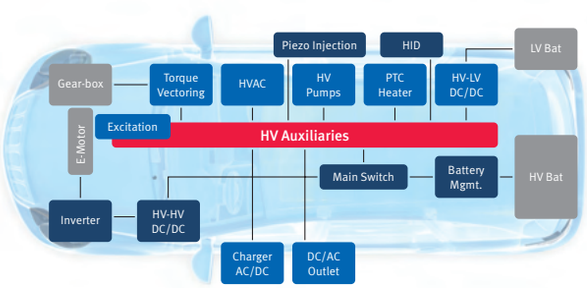

Figure 2: The xEV applications that demand power solutions up to 10kW

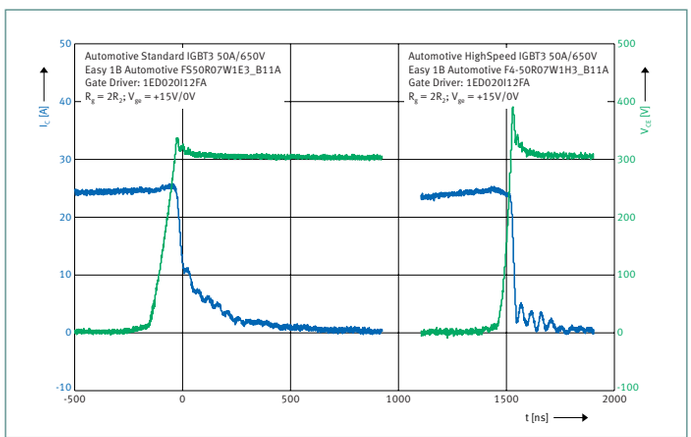

Figure 4: IGBT turn-off waveform with standard IGBT3 and HighSpeed IGBT3

used for all hard-, soft-, and resonant switching topologies. In this respect, the soft turn-on and turn-off behavior with the implemented chip technologies opens the door for use in automotive applications, where robustness at wrong PWM patterns for short-term operation is desired. At the high ambient temperatures seen in applications such as HEVs, the switching losses of the bipolar components such as HighSpeed IGBT 3 and rapid diode increase, but are well compensated by the lower conduction losses at high temperatures compared with MOSFET-based converters. As well as the technical and engineering advantages of this solution, it is also commercially attractive.

To support development teams around the world in designing the Easy power modules into their applications, EasyKITs for both auxiliary drives and for DC/DC converter applications are available and can be used as a starting point for the development. The EasyKIT DC/DC is implemented based on the established Phase Shift Full Bridge Topology and is capable of switching frequencies up to 100kHz and output currents of 170A.

As for all automotive components, highest quality at commodity cost is a strong requirement. The Easy 1B/2B automotive power modules fulfill these requirements and drive standardization of packages at attractive costs.

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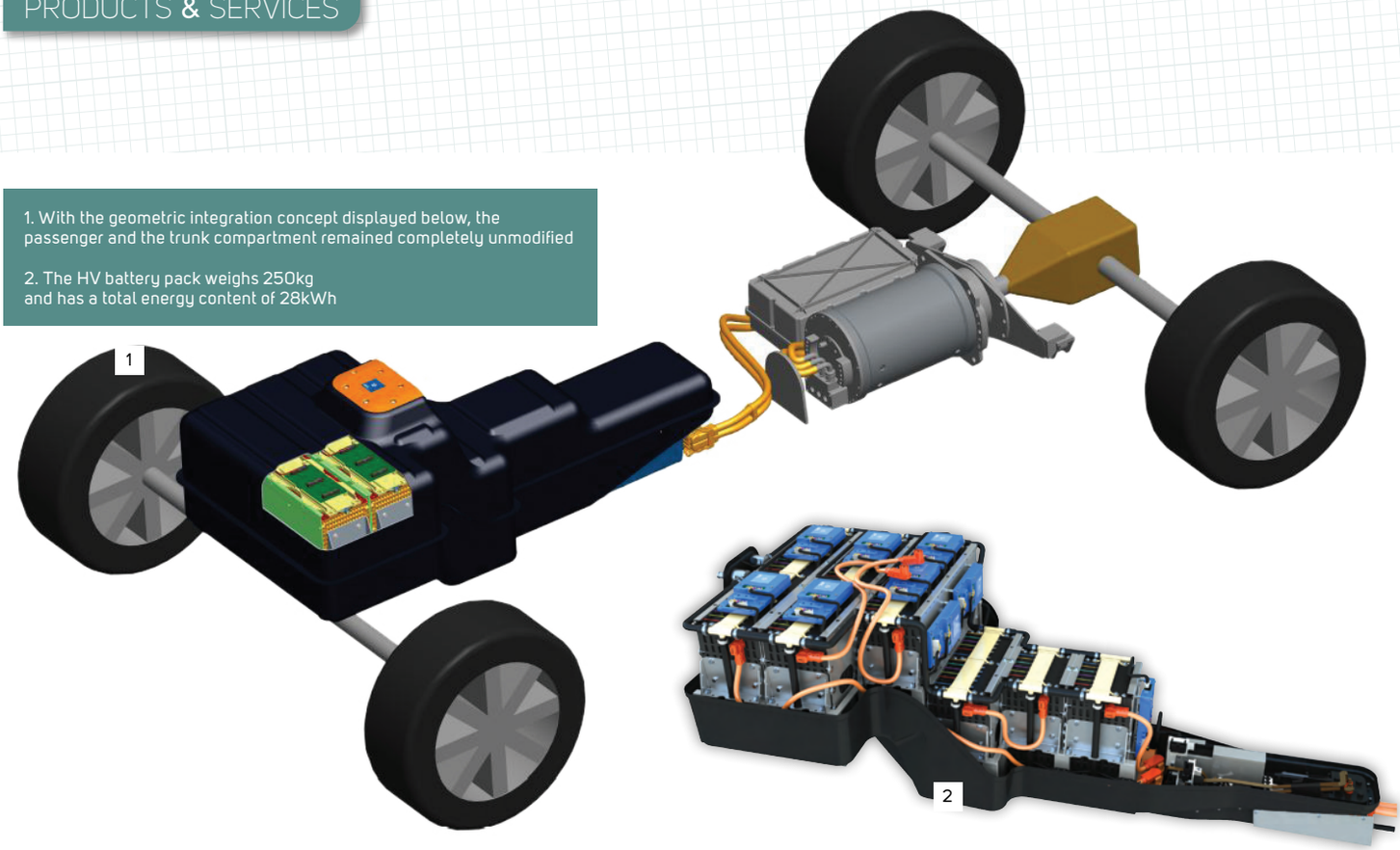
Electric concept revelation

A groundbreaking electric high-performance demonstrator vehicle has been created, offering 210kW of peak power and a maximum velocity of 180km/h

Based on the Mercedes C-Class SportCoupé platform, AVL's rear-wheel drive tech demonstrator electric car features 1,200V IGBT technology and a nominal voltage of the HV battery of 675V

The average traction power of a new car being sold in Germany in the first quarter of 2011 was nearly 100kW, and this type of consumer demand for racy and dynamic vehicle concepts is going to remain intact even for the upcoming new generation of full electric vehicles. Realizing electric driving performance above 100kW implies an electric current of more than 350A in the HV power net (DC) if 600V-IGBT technology is being used in the inverter of the traction motor. Notwithstanding extensive progress in the development of high-power battery cells, these current rates still remain the limiting factor considering the desired operating life of the HV battery. Whereas battery cells are only one example, resistive power losses in HV cables and power semiconductors, as well as bending radii and the weight of wiring harnesses, also face specific technical problems with high current load levels.

Managing the trade-off between customer requests on one hand, and technical practicability on the other, AVL has developed a rear-wheel-drive electric car that is based on the Mercedes C-Class SportCoupé platform, and features 1,200V IGBT technology and a nominal voltage of the HV battery of 675V. The consequent design of all the core components of the electric



1. With the geometric integration concept displayed below, the passenger and the trunk compartment remained completely unmodified

2. The HV battery pack weighs 250kg and has a total energy content of 28kWh

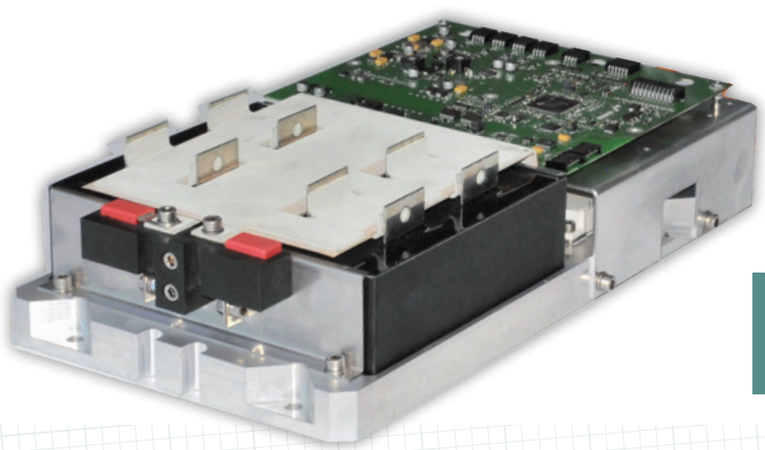
powertrain – HV battery, electric motor, and the inverter – for the 800V powernet guarantees dynamic driving performance that offers unequaled opportunities in the area of electric car design. Accelerating 0-100km/h in about six seconds, the AVL Coup-e 800 reaches a maximum speed of 180km/h and boasts a driving range of 135km with one battery charge.

These impressive vehicle parameters are enabled not only by the higher system-voltage level, but also by a consistent component design in the sense of improved power and energy density. The traction motor of the Coup-e 800 features direct fluid cooling of the stator winding. This cooling concept realizes a peak output power of 210kW and 750Nm at 2,700rpm with an electric motor diameter no bigger than 245mm and a total electric motor length of 390mm. The continuous power of the traction motor in the Coup-e 800 is set at 140kW (500Nm at 2,700rpm) and this rating takes into consideration the respective cooling circuit design of the car. In order to avoid plashing losses, the permanent magnet rotor is not surrounded by the cooling fluid but instead rotates dryly. The isolation between stator and rotor is realized by a sealing-tube that has been integrated into the air-gap of the electric motor.

Innovative cooling

The traction motor of the Coup-e 800 is powered by a high-energy battery pack that consists of 180 pouch cells all connected in series. The cells offer a nominal capacity of 41Ah resulting in a total energy content of the HV battery of 28kWh. The complete battery pack (including housing) weighs approximately 250kg, with each battery cell weighing about 1kg. For the cooling concept for the HV battery, a conductor cooling process was developed where the cooling tube is fixed to the positive and negative pole of each battery cell. As a result, the core of the battery cell is cooled via the positive/negative pole (lead) and the electrode. This intelligent cooling method is highly efficient, especially because good electric conductivity is physically correlated with a good thermal conductivity.

In creating the Coup-e 800, AVL has introduced the first 'six-cylinder' all-electric powertrain into the heart of a Mercedes SportCoupé model. The vehicle is suitable for everyday use because the passenger and trunk compartment of the Mercedes C-Class Coupé have remained unmodified by the powertrain electrification. Starting with eCarTec 2012, the demonstrator vehicle will be available for various customer presentations.



Advanced 1200V IGBT technology is being used in the inverter of the traction motor

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Inverter and motor testers

Introducing a new line of automotive testing equipment that's designed for validating the durability of starter-generator belted and direct-drive machines for stop/start systems

The EPT-135 series of inverter/motor testers for the hybrid electric vehicle market is new from Toronto-based D&V Electronics.

The main impetus for developing this innovation comes from the emerging trend of vehicles that use light/mild hybrid systems. There has been an expanding opportunity for D&V Electronics to provide specialized test equipment that suits multiple stop/start architectures. OEMs and suppliers developing these products need to be able to evaluate and stress their newest starter-generator or motor-generator (MG) products, during extended testing phases. D&V Electronics has been in tune with the hybrid/electric vehicle market for more than seven years, and the result of this is the EPT-135 tester.

The new EPT-135 platform is an ideal option for the reliability testing of hybrid powertrain devices, due to D&V Electronics' multiple design achievements in integrated test systems. For example, emerging requirements for being able to sample precise measurements at a very high frequency are met by incorporating D&V proprietary electronics to introduce a full suite of measurement capture devices. The D&V software open architecture environment, synchronous data acquisitions, and hardware systems make the EPT testing platform a cohesive package due to the extended scripting capabilities, re-vamped graphical measurement displays, and numerous reporting functions. Simply put, there are more next-generation features and options that incorporate the utmost flexibility with true functionality. Innovations and breakthroughs in improving workflow and data representation make this system a truly scientific tool for powertrain endurance testing applications.

The new EPT-135 platform is an ideal option for the reliability testing of hybrid powertrain devices

In mechanical and engineering terms, the unique front fixture design functions to accommodate two MG products, by having two test platforms available side-by-side. This feature allows for two MG devices to be tested at the same time with a single load motor. After the MG device is fixed on the platform, a synchronous belt runs from the MG shaft to a custom gear, coupled to the tester driveline. This particular setup can be performed on the left and right side of the test area. For ISG-type belted motors and direct drive motors, custom fixtures, with or without spindle assemblies, can be attached to each test platform through T-slot features. There is an included belt-tensioning system that is driven by temperature compensating pneumatic actuators. Each pneumatic rail uses an electronic valve system to provide pressure adjustment settings. As evidenced by the unique front-end mechanical features, the EPT-135 is an innovative, high-tech machine that is able to test two products for reliability at the same time with a dual-belted driveline.

Optional ancillary modules can be added to the test system after delivery, as it is likely that testing requirements will change over time. D&V Electronics' design philosophy has always been to incorporate a modular concept of integration. Test article inverter modules can also be implemented with each system to address specific motor or product testing specifications. Thermal chamber and coolant chiller system connections are integrated into the tester to establish proper environmental loading conditions and profiles. Lastly, the included battery simulator module used to precisely control DC power with customer-controlled parameters can be upgraded with additional power modules. This opens up the capability for testing solutions with higher rated devices by using increased levels of voltage or current settings.

Ultimately, D&V Electronics has designed and optimized the EPT-135 tester for full-featured reliability testing of inverters or starter/generator products for the next generation of stop/start EVs and HEVs. As such, the company specializes in the design and integration of mechanics, electronics, data acquisition systems, and software applications to produce test machines at the highest level of performance and technology.

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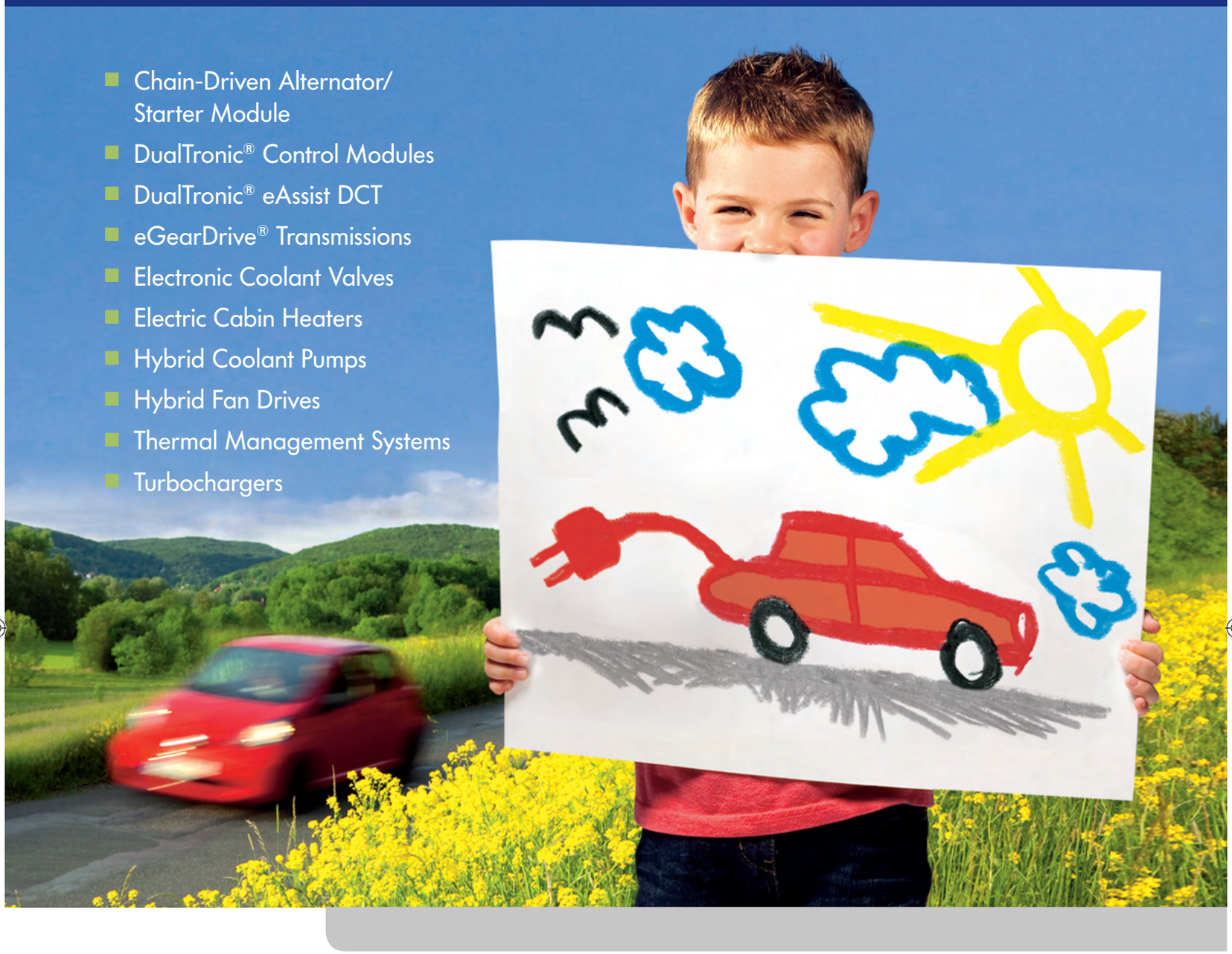

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Mobility that makes sense

Inductive charging boosts the efficiency of public service buses and keeps electric cars permanently ready to go – and all this is achieved with no cable clutter

The first ever field trials of a 12m (40ft) electric bus that uses inductive opportunity charging are currently underway in the Netherlands. The suitability of the system for everyday service has already been demonstrated in Italy for more than 10 years, although to date only smaller buses of 7m (22ft) in length have been assessed for this particular study, which is important to note as most regular service buses are between 12m and 14m in length.

In this field, green electricity makes the bus absolutely climate-neutral. By using opportunity charging during the day, an electric bus that is charged by cable overnight can operate three to five times longer, depending on the number of charge points available.

In the Netherlands, the electric bus, which is a modified Volvo diesel application, runs reliably for 18 hours and covers over 280km (173 miles) a day when in operation without the need to stop for a prolonged period to charge. Opportunity charging means that the electric bus invisibly receives a 120kW top-up charge within the space of a few minutes while at a bus stop. As a result, batteries can be significantly smaller, which drastically reduces the purchase price and the overall weight (as a result of the smaller battery packs), as well as cutting the overall energy consumption levels.

The Mercedes A-Class E-Cell charging automatically in front of the Efficiency House Plus in Berlin

Cable-free charging technology is the final rung in the ladder to the widespread acceptance of electric mobility. This was demonstrated by a recent project funded by the German Ministry of Transport, Building and Urban Affairs in March of this year, in which Daimler provided a family in Berlin with its all-new Mercedes A-Class E-Cell, which uses automated induction charging technology developed by Conductix-Wampfler.


An electric bus – featuring a lowered pick-up coil – charging at the bus stop

The family resided in an Efficiency House Plus that allowed the electric car, which is fitted with a special charging coil, to simply be parked in front of the house and above the charging coil in the ground – and this was enough to ensure it was always charged and ready to go. During the study, the family blogged enthusiastically about the inductive charging a number of times: "You just park, there's no cable to connect, you don't spare a thought for it anymore, and in the morning the vehicle is 100% ready to roll," read one post.

Every member of the family was convinced by the charging technology setup of A-Class E-Cell, especially as there are additional advantages to inductive charging than just the high convenience factor that was already blogged about. Factors such as tripping hazards and electrical accidents, as well as vandalism and metal theft, are ruled out from the start by this invisible, easy-to-implement technology. Moreover, automatic charging is an indispensable element of technology for smart homes: automatically controlled, inductive charging requires no manual intervention to manage the constantly fluctuating supply of electricity from renewable energies. It excludes any risk of deep discharging, and electricity can be stored in the vehicle battery precisely when it is most abundantly available and therefore cheap.

Since most cars do not move for 23 out of 24 hours, and they are almost always in designated parking spaces, automatic charging makes their availability extremely high. As a result, the parking behavior of electric car owners will have a significant influence on the charging infrastructure as a whole.

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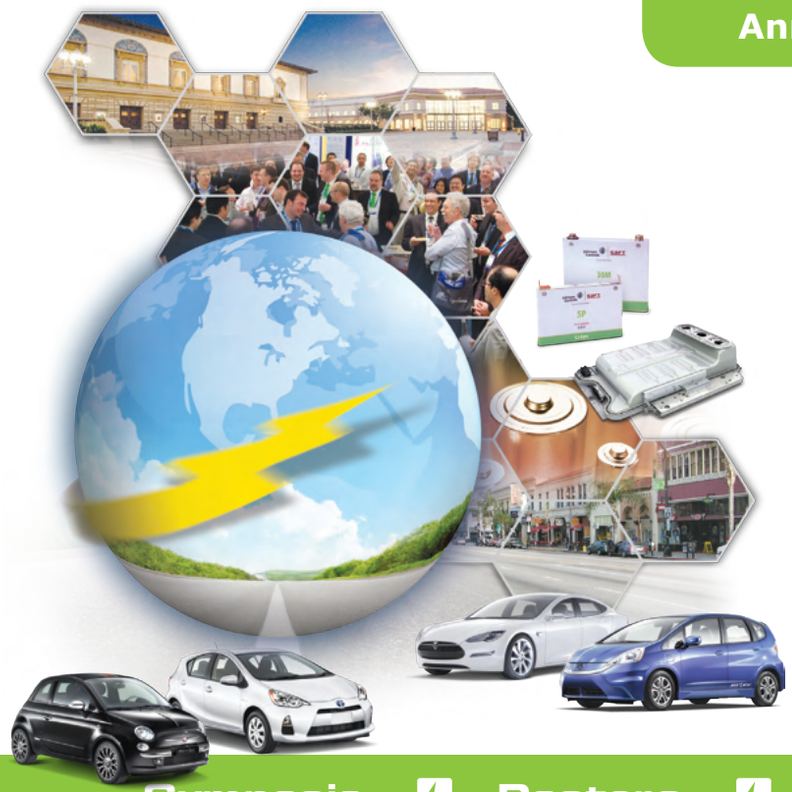

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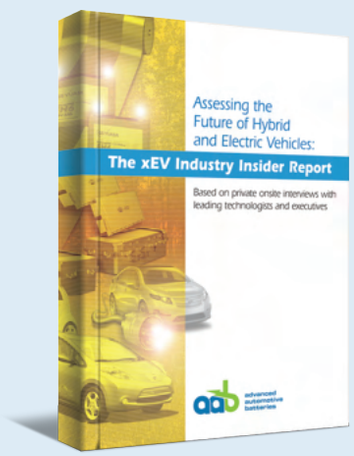

Assessing the Future of Hybrid and Electric Vehicles: **The xEV Industry Insider Report**

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Power electronics for EVs

The automotive world continues to ramp up the amount of power electronics in mechatronic applications as it keeps up with consumer, environmental and government demands

Today's rapidly evolving products are getting smarter and often include complex interactions between components, subassemblies, and systems. In industries such as automotive, aerospace, and industrial automation, organizations use robust systems-level simulation to identify potential problems early in the design stages, which other simulation or build-and-test methods cannot detect.

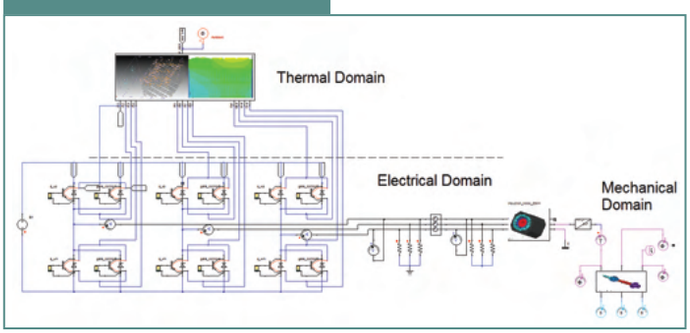
In particular, the automotive industry is steadily increasing the amount of power electronics in mechatronic applications as it keeps up with consumer, environmental, and government demands. Engineers and system designers are turning to electric-drive systems for significant benefits in weight and cost reduction, increased reliability of electrical systems, and convenient control and automation via electronic means to improve overall efficiency.

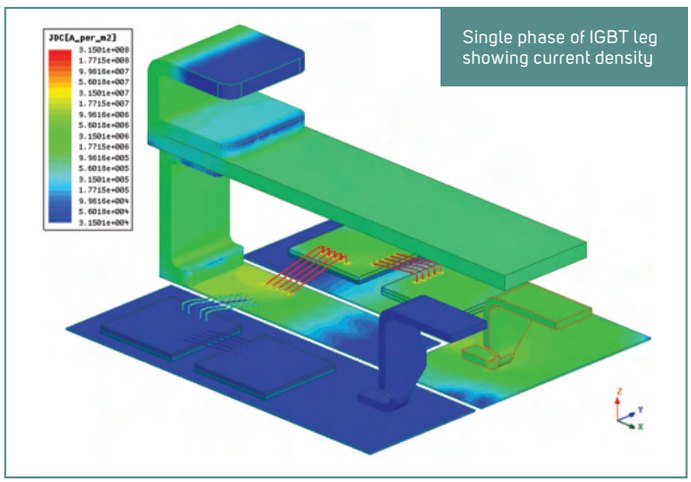
A multi-domain approach to simulation with tightly integrated solvers enables engineers to model, simulate, analyze, and optimize complex systems, such as electromechanical, electromagnetic, power electronics, and other mechatronic designs. Design engineers can create efficient yet highly accurate models across multiple domains, leading to high-fidelity simulations of entire complex systems.

Power electronic systems often include inverters, converters, electric machines, related mechanical or hydraulic loads, sensors, semiconductors (such as IGBTs switching at requested PWM frequencies), parasitic effects from circuit boards and cables, as well as control algorithms. Important issues to consider for the design and management of these systems include semiconductor loss and thermal performance during cycling, surge currents and voltages during switching, and conducted and radiated emissions (EMI/EMC) due to higher switching frequencies.

Simulation software should support device and component characterization tools, including IGBT model generation of behavioral, average, and/or dynamic models. Such capabilities enable users to easily select the fidelity of the simulation. These detailed models represent the electrical and thermal performance of the switching semiconductor device and, therefore, are suitable for predicting thermal performance of the system.

A system simulation example of the inverter, coupled with an Ansys Icepack thermal model, electric machine model and reduced-order model shaft





Single phase of IGBT leg showing current density

Thermal performance is enhanced by extracting the thermal network of the power electronic enclosure. Methods of reduced-order modeling can very efficiently extract data from detailed CFD models for use in a system simulation, resulting in very robust electrothermal simulations of the power electronic systems. Using reduced-order models from detailed finite element or CFD models also yields benefits in other applications, such as modeling the electrothermal performance of battery systems, incorporating mechanical parts from FEA, and including frequency-dependent magnetic models in the system simulation.

Parasitic extraction of impedances (R, L, C, G) of printed circuit boards, cables, and bus bars are also important. Tools should provide a streamlined method for extracting these impedances as a function of frequency and include them, for example, in a system analysis, or study high-frequency power and signal integrity of circuit boards. Such capabilities are instrumental in addressing the design of circuit layouts, DC bus structures, IGBT power module structures, and the interconnection of variable frequency drives and grounding structures. Using these calculated impedances in power electronic system simulations can help designers to increase power ratings and reduce or eliminate the use of snubber circuits.

In addition, a coupling functionality is essential to enable designers to include the detailed electromagnetic performance of transformers, inductors, and electric machines into their system simulations. Finally, a flexible platform provides users with a schematic view of the entire simulation. Benefits include incorporating specifications of different system architectures and system performance when using different components.

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Hybrid calibration solution

Already operating on several engine testbeds for light vehicles, D2T's dynamic engine testing technology is now available for truck testing – and particularly for hybrid applications

The number of hybrid trucks is increasing on city roads in Japan and is likely to do the same in Europe and the USA very soon. In Japan, regulations are based on the JE05 cycle, while in Europe such legislation is still being developed.

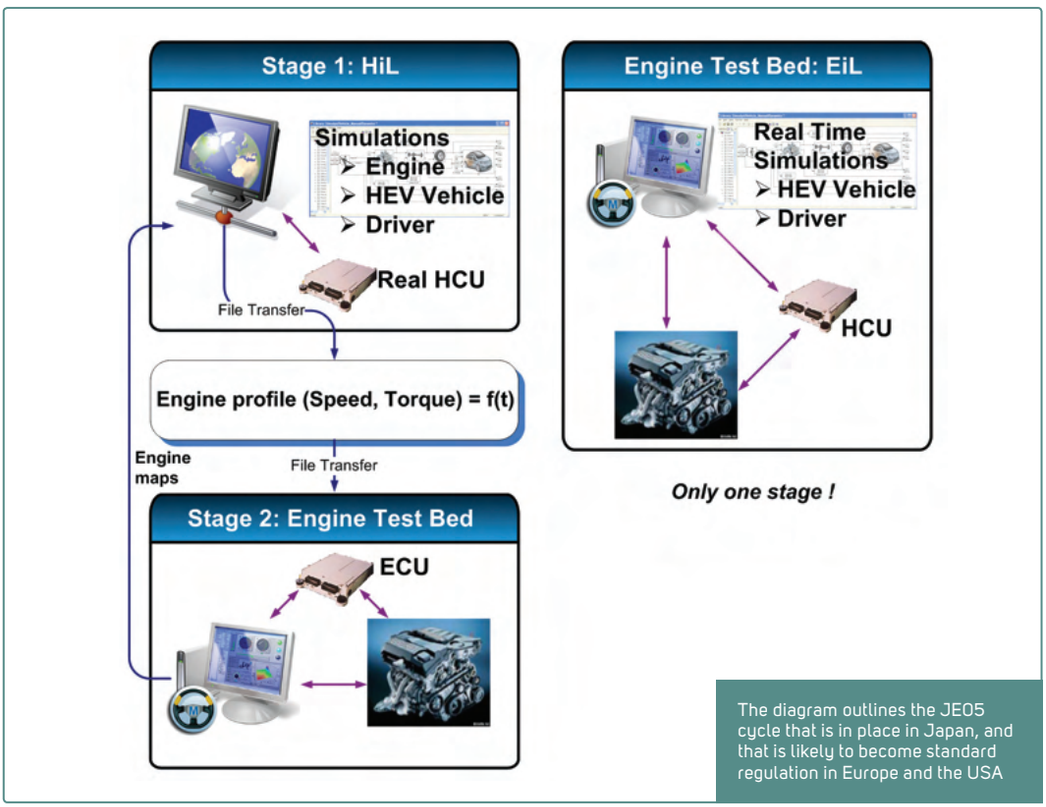
The Japanese regulation requires two stages. In the first stage, a speed/torque profile is determined for the IC engine based on the execution of the cycle on a HIL testbed – simulating an IC engine, an electric engine, a battery, the vehicle, and the driver. The only real system is the energy management system, which controls the whole hybrid engine. In the second stage, the speed/torque profile calculated in this way is applied, and the engine's true emissions level is measured.

Certification is only the final step in a long process: before that, the engine manufacturer has already spent hours at the testbed to determine the optimum pollution/consumption parameters for the engine and the energy management system. The challenge is to decrease the time spent at the testbed, and it must be said that the standard two-stage solution, if used during the calibration phases, greatly impairs productivity. In the first place, it is necessary to determine complex physical models, particularly those of the engine and combustion. Then they have to be applied to a first testbed – the HIL testbed. After that, the speed/torque has to be redone on a second testbed – the engine testbed. And if the best compromise is not arrived at, the approach has to be repeated, applying a new engine control strategy.

The solution proposed by D2T seems to come naturally based on the situations already described: essentially, to perform both stages in a single pass – that is, running the standard road cycle on the engine testbed, while simulating only the driver, the vehicle, and the electric part of the engine (the battery and the electric engine). Is this a simple process? The answer is yes, but it is simplicity made possible by the unrivaled open character of Morphee 2, D2T's automation system. A powerful object structure allows for the easy integration of models – from both D2T and its customers – into the Morphee technology.

In short, it is a big win for the engine manufacturer. A win in terms of calibration time, because there is now only one operation to perform. It is a cost win too, because it avoids using a costly high-tech HIL testbed. And just as importantly, it is also a win for precision, as it is no longer necessary to use an engine model, which is a source of recurring inaccuracies.

From now on, with Morphee, engine manufacturers' heavy-duty engineers have a solution for the calibration of their future hybrid vehicles. It is already capable of running on the testbed, like many other solutions that focus on engine testbeds for light vehicles. However, Morphee has the advantage of being available for any type of hybrid architecture: series, parallel, parallel with dissociated axles, and much more. What is more, D2T proposes its own models from its long experience in powertrain development, but customers can also propose their own. Morphee technology is also scalable, and some elements, such as the battery and the electric engine, can be replaced with real components. Lastly, it is flexible, as it can adapt to any road cycle, and to the test center's existing methods.



The diagram outlines the JE05 cycle that is in place in Japan, and that is likely to become standard regulation in Europe and the USA

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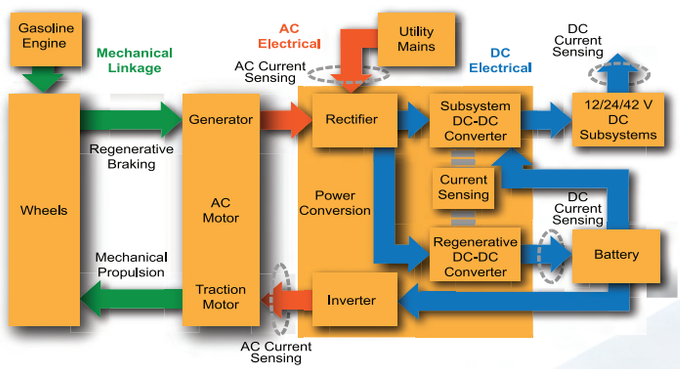
Innovative Integrated Current Sensor IC Products

Hybrid Vehicle Current Sensing

Consumers are embracing environmentally friendly "green cars" as a result of the rising cost of fossil fuels and a growing concern for the health of the environment. Hybrid electric vehicles (HEV), quickly becoming the most popular green car, employ complex power electronic circuitry to control the flow of electric energy through the vehicle. In a single electric motor HEV, the motor acts as a drive motor in parallel with the internal combustion engine in the drivetrain, or as a generator to charge the battery during regenerative braking.

A typical HEV also contains various sub-systems that require electrical current sensors for maximally efficient operation; including AC motor and DC–DC converter applications. Read the entire article explaining recent advances in Hall-effect current sensor technology and the use of unique, high bandwidth, enhanced resolution current sensors in HEV applications by visiting **www.allegromicro.com/promo1075.**



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Concept engineering

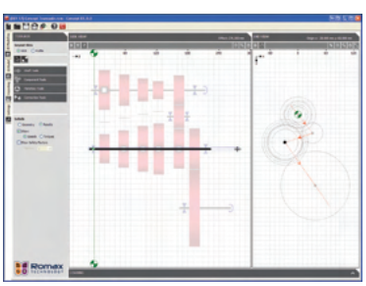
A brand-new product promises to help steer the crucial early stages of design, delivering improved quality, innovation and a faster time to market

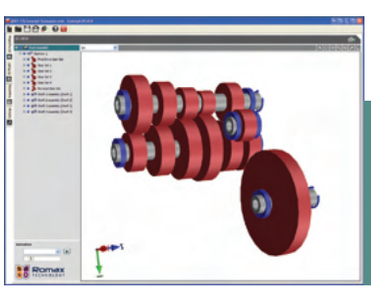
For complex and highly refined engineered products such as automotive transmissions, concept design is arguably the most important part of the development process. Here, more than at any subsequent stage, the scope for innovation is at its greatest, being constrained solely by basic design parameters such as performance, packaging, durability, refinement, and cost requirements.

But while the concept stage can be crucial in shaping key value-adding product attributes and functionality, it can also be expensive and time consuming. The concept stage lacks the type of integrated CAE-driven tool chain and streamlined methodology that is used extremely so in detailed design. Instead, concept engineering typically involves a wide range of systems, processes and ad-hoc methods – from hand calculations and spreadsheets to CAD packages – in which successive iterations are frequently required. Crucially this current approach limits the potential to leverage the results of previous iterations and learn from other programs, stifling the scope for innovation and creativity while adding cost. This is further compounded by the fact that new product programs compete for finite design resources; compromises are inevitable because in the absence of structured CAE validation data, designers seek to avoid uncertainty and risk. As a consequence, many engineered products take too long to reach the market and fail to reach their full potential. Until now.

Romax has long been known for its advanced CAE software – RomaxDesigner, which has become an industry standard in gearbox and driveline design. This software has transformed detailed design and optimization processes, with analysis operations that previously took hours or even days now being accomplished in a matter of minutes. This has helped spark the innovation that has occurred in transmissions over the past decade.

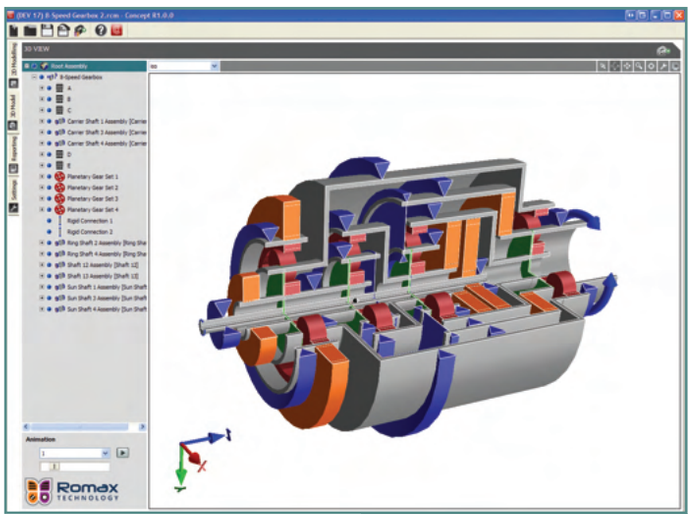
In seeking to extend this tool chain to support the concept engineering stage, Romax set out to establish an ideal requirements specification by talking to some of the world's leading ground vehicle, wind turbine, geared transmission and component manufacturers. Using this clean-sheet approach – which itself emulates the best principles of concept design – the company developed a vision for a completely new type of CAE tool.





Top left: Editing shaft length takes place within the Romax Concept package

Left: A 3D view of a gearbox model in Concept provides key technical insights



An advanced planetary model is outlined in 3D view in Concept

Romax's new Concept product brings this vision to reality by delivering a highly intuitive drag-and-drop visual concept design environment, incorporating many of the advanced analytical algorithms proved in the company's detailed design software. Concept enables the rapid creation of concept models, including semi-automated sizing, definition and rating of gears, shafts and bearings. It includes an advanced 3D visualization capability, enabling designers to manipulate their chosen configurations on screen and to evaluate key parameters. Crucially, Concept balances the need for creativity, innovation and flexibility in concept design, with the requirement to deliver a practical and implementable solution for detailed design, enabling initial NVH assessments as well as preliminary mechanical design assessments of alternative concepts.

Integrated with RomaxDesigner to provide a seamless CAE workflow and methodology, Concept is equally useful as a standalone concept-engineering package. Romax has therefore extended its well-proven CAE tool chain to provide a product that helps users navigate the concept design process, enabling them to be more innovative and efficient in producing robust and highly optimized concept designs capable of subsequent detailed product development. In short, this advanced new concept engineering package is an advanced CAE tool with the potential to help transmission and driveline designers deliver faster to market more and better engineered products.

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Clean drivetrains for buses

The city bus – from hybrid through to all-electric – is a story of engineering evolution

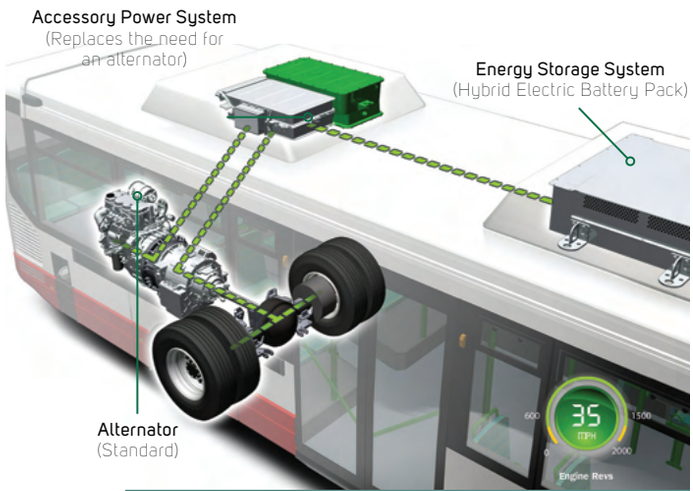
BAE Systems has been powering hybrid buses across the globe for more than a decade – ever since the company's HybriDrive technology first entered service on New York City buses in 1998. The latest generations of its HybriDrive products have been continually enhanced as technological capabilities have advanced. As the industry has matured, it has become increasingly clear that hybrid is not the final word in urban mobility. While serial hybrid-powered buses are known to consume far less fuel and release far less harmful emissions than a standard bus, the ultimate goal must be zero local emissions from the bus. This has the potential to improve living conditions for the growing percentage of those who live in the world's most densely populated areas.

The exciting challenge for technology companies is to realize this zero-emissions future vision by developing state-of-the-art products. But making quantum leaps in the transport industry has rarely proved to be a success – after all, this is a business run on fine commercial margins, and technical risk is not something that fits easily into such a model.

The key to success, therefore, is to develop products that first and foremost work well from day one and offer real benefits to transport operators – while successfully reducing environmental impact. These products will generate revenues that can be re-invested in the next generation of products, enabling the goal of all-electric city center mobility to be realized.

BAE Systems recognized from the outset that, although it offers advantages to the hybrid-only market, the parallel architecture was not capable of enabling the all-electric goal. As such, a serial hybrid bus – with its fully electric final drive – offers the ability to achieve this through a series of progressive steps toward zero emissions.

The first step beyond a standard hybrid bus is to enable stop/start. This eliminates emissions while the vehicle is stationary and also saves fuel. Using energy stored in the batteries, power can be supplied to standard electrical components even when the engine is shut down. This enables the system to save fuel by eliminating idle fuel use while the bus is stationary.



With the addition of the Level 1 accessory power system, the alternator is no longer required. As a result, all vehicle power is now supplied from the HybriDrive propulsion system

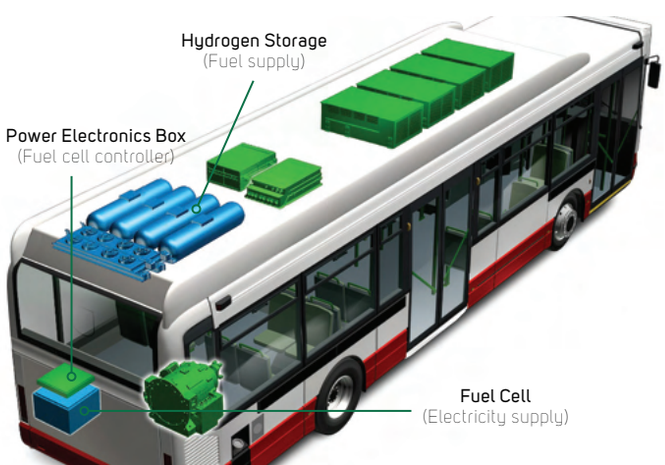
The next step is to shut the engine down shortly before it arrives at a stop. The engine remains off at the stop and is re-started only after the bus has pulled away – BAE Systems terms this 'arrive and go'. To the passengers boarding and alighting, the bus appears quiet and smooth, with no exhaust emissions.

The next step toward the zero-emissions bus is achieved through greater electrification levels. All ancillary systems are now powered by electric motors, not by the diesel engine. Using grid power to charge the hybrid batteries offers a source of power with much lower carbon emissions than the onboard diesel generator.

The hybrid drivetrain and electrical ancillaries remain unchanged. Either conductive or wireless inductive charging stations are required within the city, but compared with a full tram or trolleybus network, the infrastructure cost of these is extremely low.

The final stage is a bus that requires no onboard diesel generator at all. This could be achieved by adding more energy storage or through cleaner onboard generation such as a fuel cell. The hybrid drivetrain and electrical ancillaries remain unchanged.

Society is in transition from buses enabled with stop/start systems, to those with extended engine-off mode capability. Buses capable of receiving fast charge from the grid are starting to see deployment in Europe. The HybriDrive Series system has been designed from the outset to enable this progression to zero-emissions urban mobility.



For an all-battery electric bus, the only additions to the setup are the larger battery and charging components

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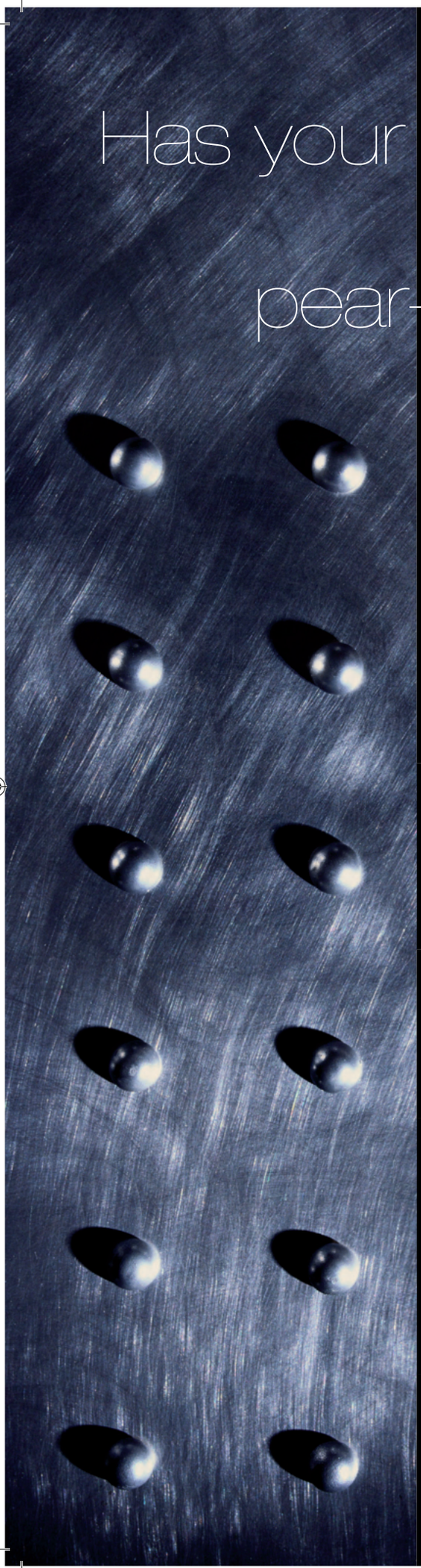

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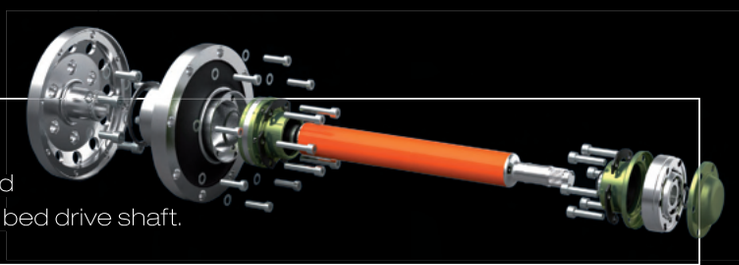

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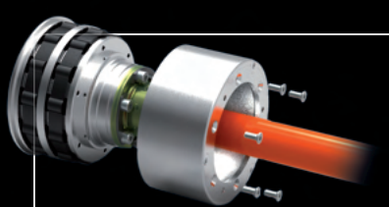

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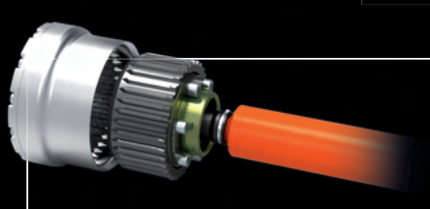

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Protean partner

Leading global supplier delivers flexible solutions based on proven technologies

Left and below: Sierra CP has installed test equipment at Protean Electric's technical headquarters in the UK

For many engineers that are associated with the further development of hybrid and electric motor technology, Sierra-CP Engineering may be a new name. But in truth the company has been actively engaged in providing advanced auto testing solutions and products to the industry for over 30 years. In late 2011 USA-based Sierra Instruments, a world leader in flow measurement technology, greatly expanded its global capabilities with the acquisition of UK-based CP Engineering Systems. By merging Sierra-CP's Michigan-based emissions group with CP's technical centers in the UK, USA, China, and India, Sierra has been able to create a worldwide service and support platform for its newly expanded automotive testing division.

Sierra-CP continues to build on its international reputation by providing customers with innovative test system solutions that employ proven CP technologies to meet the exacting needs of global customers. With the broad range of clients that Sierra-CP works with, design flexibility is crucial. Custom solutions from product to turnkey are developed to meet present and future customer needs, but recognizing the realities of today's economically challenging times and its impact on investment decisions, without compromising quality, is a high priority for every project that Sierra-CP takes on.

An example of this approach is Sierra-CP's recent installation for Protean Electric at its technical headquarters in the UK. As a leading global clean-technology company, the organization designed, developed and manufactured the Protean Drive. Winner of the World Economic Forum's prestigious 2012 Technology Pioneers Award, the Protean Drive is a fully integrated, seamless in-wheel motor and direct-drive solution.

As Protean's Mark Potter explains, "We didn't have the time to fully develop a detailed scope of supply document, so we needed to select a supplier that we could partner with, who had the experience to interpret the brief technical scope of requirements and the expertise to deliver a system that could meet our current and future testing needs. Sierra-CP gave us the confidence we needed to trust them with this critical project."

Sierra-CP initially looked at a conventional chassis dynamometer for this application, but after considering the aspects of location and client deadlines for operational use, chose to propose a powertrain system that could accept full vehicle installation by connecting to the test vehicle's wheel hubs.

Four fully independent AC dynamometers were incorporated to provide individual control of each wheel hub. This enables the client to test 2WD and 4WD test vehicles with adjustable track and wheel base for a wide range of vehicle sizes from compact to light-duty trucks. The overall system is controlled by Sierra-CP's CADET V14 test-automation software, which provides the platform for the system control, test scheduling, safety protection and data acquisition. This system is capable of steady-state operation for durability and key life evaluation. The transient dynamometers also provide the increased capability of simulating road load cycles for product development and benchmark evaluation against other more conventional vehicle systems. Additionally, this approach can provide the added benefit of increasing the level of discrimination by eliminating the potential test influences that testing on the tires introduces.

"Sierra-CP has met the scope of the brief and produced a test system that provides the ideal platform to enable Protean to develop and showcase its technologies for many years to come," concludes Potter.

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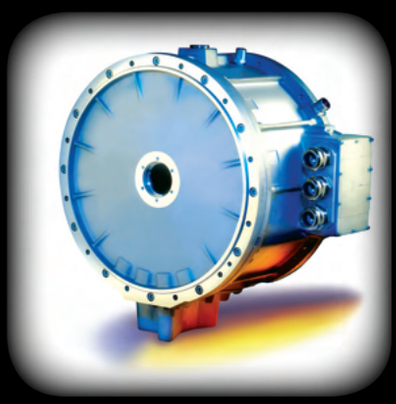

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Development partner

Not many organizations have the capability and intellectual know-how to deliver full vehicle programs that include hybrid and electric vehicle technologies

Lotus Engineering today conducts 95% of its work with external clients and virtually all remains confidential. In fact, the company can boast all the world-leading vehicle manufacturers among its extensive client base.

Within Lotus Engineering there are four areas of core competency: lightweight architectures, driving dynamics, efficient performance, and electric and electronic integration. These all overlap to give Lotus Engineering the capability to deliver full vehicle programs including advanced hybrid and electric vehicle technologies.

The company prides itself on vehicle integration, bringing technologies together, making them work effectively and efficiently. In addition to concept work, the company has designed and built demonstrator vehicles using a variety of alternative drivetrains.

A typical electric motor configuration is a single motor driving through a single-speed gearbox or driving through conventional mechanical or CVT. Other examples include multiple motor configurations where two inboard motors drive through a transmission. The Lotus 414E deploys two inboard motors that drive two independent reduction gears so each wheel of the vehicle is independently driven. Lotus Engineering has conducted programs deploying wheel-motors – both 2WD and 4WD examples.

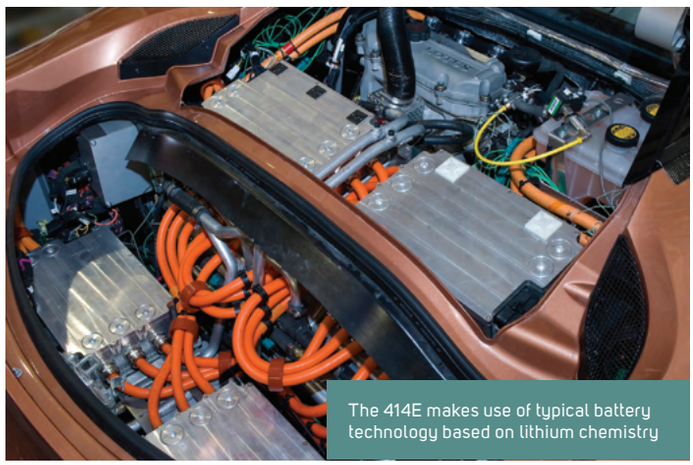
The typical battery technology is based on lithium chemistry, although Lotus Engineering has also used nickel metal hydride and other chemistries. The key is to have the skills and ability to choose the most appropriate cells for the application, managing the trade-offs between the major characteristics of cost, safety, power density, energy density, performance, and lifetime.

The mechanical design of the pack needs careful consideration, as the vehicle is a very harsh environment with dynamic forces, crashworthiness, and environmental conditions to be encountered and withstood. Design for safe assembly needs thought too, because lethal levels of voltage are present. The health and safety of dealing with 400+ volt systems is paramount.

A sophisticated BMS is integrated into the pack, ensuring cells are always operated within their specification. If not, cells may become damaged beyond safe use. Lotus Engineering has a deep understanding of the BMS, how it controls cell usage, and how it needs to communicate with the hybrid supervisory controller.

Lotus employs simulation software developed in-house to accurately predict vehicle performance. Using various building blocks, a mathematical vehicle model is created which can be analyzed in a number of ways. It can be used to develop specifications of the hybrid drivetrain in whatever configuration is chosen – be it pure EV, series, parallel or multimode systems. Systems can be sized, optimized, and analyzed for fuel consumption, energy usage, performance, drive or usage cycles.

The engineering setup of the Lotus 414E deploys two inboard motors that drive two independent reduction gears so each wheel of the vehicle is independently driven



The 414E makes use of typical battery technology based on lithium chemistry

Control strategies for power and energy management can be investigated depending on whether the primary objective is economy, performance or other parameters. This has led Lotus Engineering to develop sophisticated algorithms for adaptive energy management with dynamic system models. Optimized control techniques have been developed for energy consumption and battery lifetime.

Control strategies can be developed and verified using real-time controllers within the loop environment. This allows verification that is much faster and safer than building and testing actual vehicles.

Lotus Engineering has developed methods for fast, flexible integration of high-tech electronic controllers for lower-volume applications. Hardware and software development is a specialty and Lotus Engineering successfully applies its production controllers to control the functionality of many EV and HEV demonstrator vehicles.

Lotus Engineering is creating advanced development facilities, including battery simulators, motoring dynamometers, and emissions laboratory, where full vehicle testing including range, drive cycle, and emissions is conducted. A safety management system has been developed, and the company has invested in equipment, so battery, vehicle assembly, and use are strictly controlled.

Lotus Engineering has the expertise and facilities to conduct all aspects of work on EV and HEV work, ranging from research studies to full production programs.

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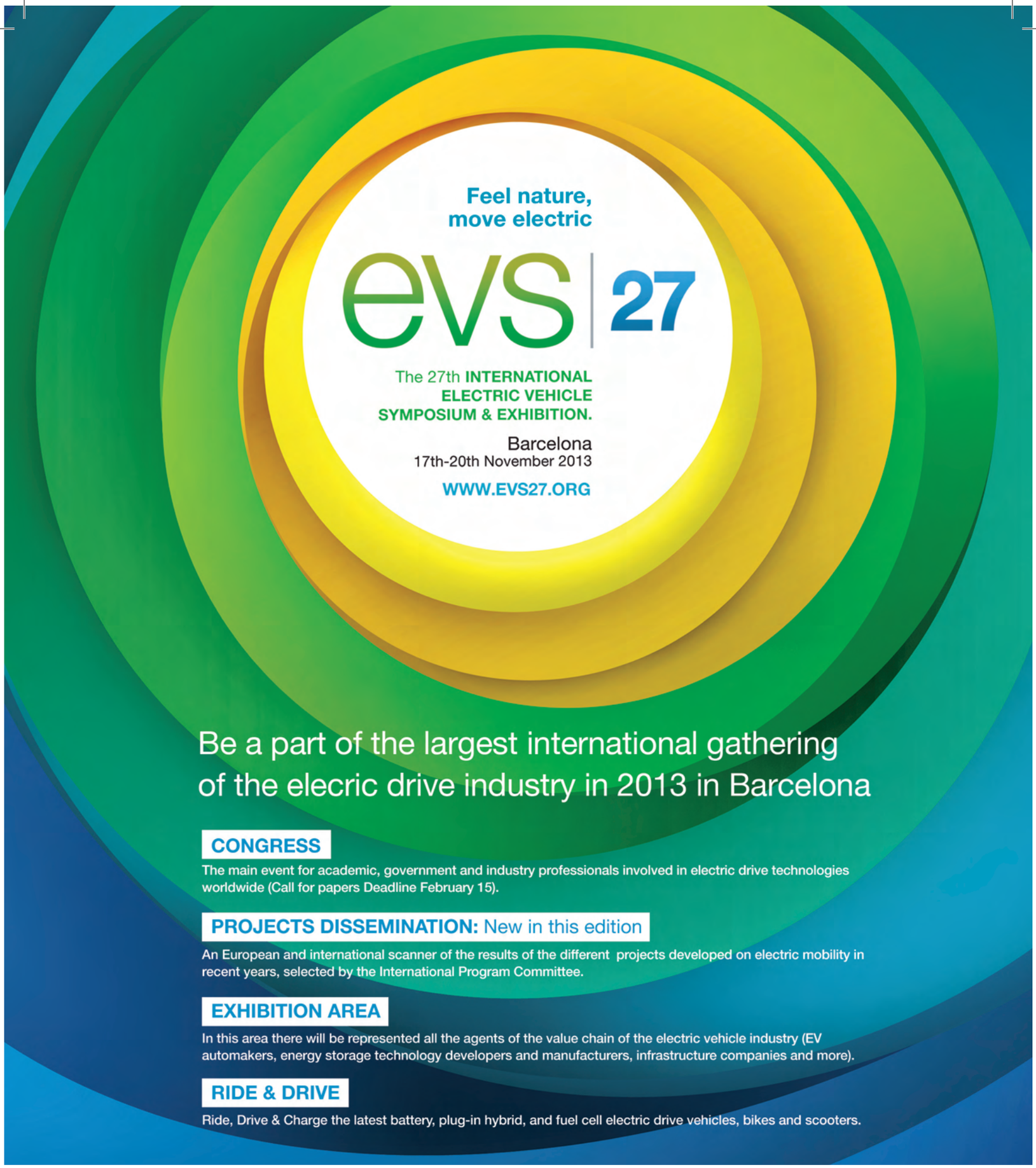

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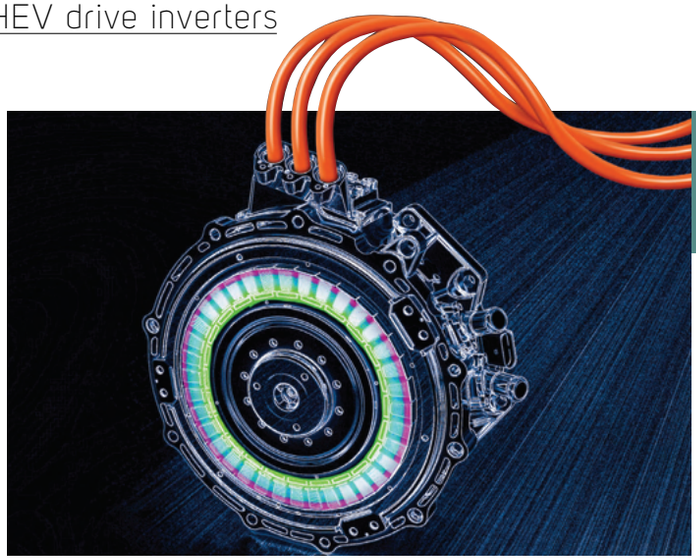
Emulating electric motors

A new technology is permitting close-to-reality testing in the laboratory for EV and HEV drive inverters

The key component that determines the range and driveability of EVs and HEVs is the drive inverter. The relationship of the inverter to the electric motor is very much like that of conventional EMS to the IC engine: the inverter controls the energy flow to the motor and energy recuperation, thus directly affecting the driving experience and customer acceptance.

Correspondingly, much engineering effort is currently being devoted to the development of such inverters. However, how can the behavior of the inverter in safety-critical situations be tested in the laboratory under real-world conditions? Moreover, how can this advanced testing be done far upstream in the development process where the final electric motor is perhaps not yet available in a suitable form for testing?

At first sight, the simplest way to test such inverters would be to couple an existing electric motor up to the inverter to be validated. This method would require an electric motor, which may not yet exist in its final form, and a control system to subject the electric motor to load in order to recreate conditions in the real world.



The innovative electric motor emulator technology represents a new generation of Power-HIL emulators that are capable of emulating up to the 600V level

If the production version of the electric motor is not yet available, then a dummy motor must be used with the disadvantage that any last-minute changes in the final motor design may adversely affect the control capability of the inverter. Furthermore, a mechanical setup is required to physically subject the dummy to a load. This would take the form of another motor acting as a dynamometer connected via a drive shaft with all the accompanying safety issues and space requirements of having rotating parts in the laboratory together with interferences of a second drive.

An electric motor emulator all set and in place for work to commence in a research and development laboratory

Luckily, new technologies have appeared to make the task of providing a close-to-reality testing environment for inverters much more simpler.

Developments in software modeling now permit the emulation of non-linearities in the form of harmonics and back-EMF. The inverter under test is subjected to the resulting waveforms, which, due to the high dynamic response of the emulator, can model driveline oscillations and even acoustic effects.

Advances in computing hardware and the outsourcing of number crunching activity to dedicated FPGA boards provide the huge computing power that's required to correctly emulate the torque profile of the motor.

Conventional systems, such as approaches using HIL, could only emulate on the 12V level. However, improvements today in power electronics permit Power-HIL systems to emulate phase line output with real power from 48V up to 600V and 600A.

Thanks to its controllability, a virtual electric motor offers new possibilities, not recognized so far, of safely 'injecting' even safety-critical fault scenarios, as they really occur in the real-world situations. The spectrum of situations that can be emulated range from faults such as cable breaks, short circuits, or even complex fault scenarios such as changes in impedance, to diverse mechanical anomalies, including bearing imbalance, rotor jams, or stiffness. Faults pertaining to rotor position sensors – depending on the sensor type – can also be produced. This includes cable breaks, typical signal anomalies, and disturbances such as noise or EMV peaks, whose amplitude can be superimposed in a controlled manner.

The electric motor emulators from SET Power Systems represent a new generation of Power-HIL emulators capable of emulating up to the 600V level. They have a variety of applications, from the development of system tests, to end-of-line tests and drive inverter lifetime investigations.

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Current sensing products

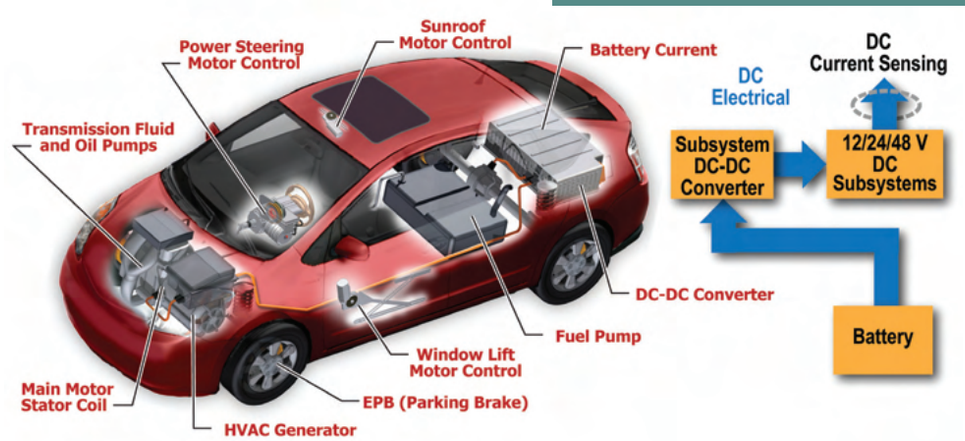
Increased electric motor content in HEV subsystems requires advanced current sensing

To control the drivetrain in HEV and full EV applications, it is well-known that current sensing is required particularly in starter generator and main electric drive motor generator applications. However, even in mild hybrids, in order to maintain system operation when the IC engine is not in use, many subsystems have become fully electric. For example, HVAC systems must be operational during IC engine idle periods if drivers and passengers are to remain cool in hot weather when sitting at a stoplight. Thus, these subsystems also require accurate current sensing to ensure efficient and accurate control of the electric motors. Allegro MicroSystems has developed a family of fully integrated current sensing ICs that are ideally suited for HEV subsystems.

Figure 1 shows a simple block diagram of a DC subsystem run off of the main battery through a DC-to-DC converter, and indicates potential current sensing applications. In transmission fluid and engine oil pumps, as well as in HVAC systems, peak load motor currents can be up to 150A, and range from 20 to 50A in normal operation. Parking brake motors typically run at 30 to 50A peak, and at 10 to 20A normally. For battery voltages far above 100VDC, as in some HEVs and full EVs, sensing battery current and DC-to-DC converter current also requires galvanic (high-voltage) isolation.

Conventional Hall-effect sensors, when used in current sensing applications, have exhibited general limitations in both accuracy and output signal bandwidth. However, Allegro MicroSystems has developed a broad family of Hall-effect current sensor integrated circuits (ICs) that overcome these issues. The features and benefits of these industry-leading Allegro current sensors include: signal processing and package design innovations that enable >120kHz output bandwidth; the highest current resolution and the lowest noise spectral density Hall sensors in the marketplace; proprietary, small footprint sensor packages with galvanic isolation; reduced power loss, through-hole and surface-mount low-resistance integrated conductor packages; and precise factory programming of sensor gain and offset across full temperature range.

Figure 1: HEV and EV current sensing applications



A key advantage of the full integration of the current sensor IC is the testability of the device, which is factory trimmed at both room and hot temperature to optimize the gain and offset of the sensor across operating temperature conditions. This provides a highly accurate solution in a very small package. There is a wide range of proprietary package configurations in the Allegro current sensor IC family that can be used to sense a wide range of currents depending on application.

The required current sensing and isolation voltage ranges determine the optimum Allegro current sensor IC solution. In low-current applications, such as fuel pumps or plug-in vehicle chargers, fully integrated surface-mount sensors can be employed. Flip-chip technology is employed in these surface-mount sensors and they have integrated 1.2mΩ conductor resistance for low power loss. The innovative flip-chip construction improves the magnetic signal coupling and provides isolation because the die is located above the primary current conductor, and plastic mold compound fills the space in between.

For medium current sensing, between 50 and 100A, the ACS758 family of devices in the CB package can be employed. The ACS758 can be used in HVAC, as well as oil and transmission fluid pumps. The device incorporates a 100μΩ conductor, a ferromagnetic core, and a Hall-effect linear sensor into a small form factor, galvanically isolated package. This package is capable of operating at the higher HEV battery voltages: it can survive standard UL type testing for one minute at 4,800VRMS applied between the current lead frame and the signal leads. This sensor IC has been used in DC-to-DC converters, as well as main inverter motor stator coil applications at battery voltages exceeding 350VDC. Motor stators are typically made with expensive rare earth magnets such as nickel-plated neodymium. Replacing the stator with a coil not only eliminates exposure to rare earth metal price and supply fluctuations, but also provides a means of taking active control of the stator, which improves motor efficiency and torque profiles in HEVs.

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Sophisticated analysis

Innovative design techniques optimize pulsewidth modulation measurement

Rapid developments being made in pulsewidth modulation (PWM) motor drive topologies combined with a need for better inverter efficiency place increased pressure on design and test engineers of automotive power electronic systems to more accurately quantify the true value of electrical power.

This need focuses attention on the accuracy of power measurement instruments, and it becomes clear that the complex power characteristics associated with modern power conversion techniques require high-frequency performance that is beyond conventional analyzer design.

To illustrate this pressing need, it's important to consider the voltage signal associated with a variable speed PWM inverter drive. For example, if an engineer wishes to accurately quantify total power, it is important to include all frequency components of the signal. This may at first appear straightforward since many power measurement instruments offer an appropriate frequency range, but in most cases, high-accuracy power measurement is only achieved over a limited frequency range. This is illustrated by response line one (in the diagram), which represents the typical high-accuracy range of many power analyzers compared with response line two, which represents a power analyzer that maintains high accuracy over its complete operating frequency range.

Established in 1997, Newtons4th has become a leader in the design and manufacture of innovative electronic equipment to a worldwide market

Achieving high accuracy in power measurement over a wide frequency range requires great attention to the voltage and current input hardware design. For the voltage input, the frequency response is largely influenced by parasitic capacitance; for the current input where a low-resistance shunt is used, the frequency response is largely influenced by parasitic inductance.

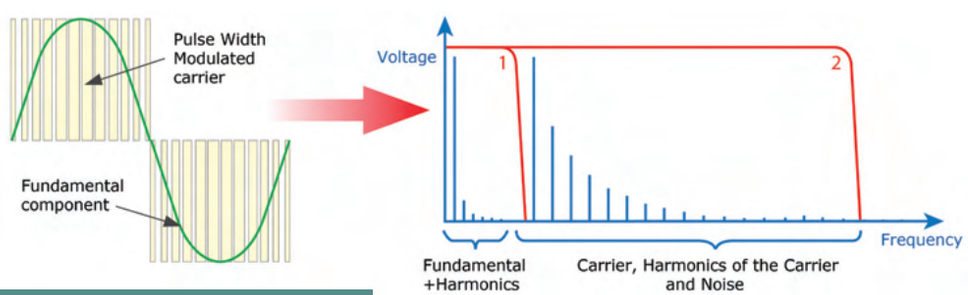
Usually, the greatest challenge for a precision AC power analyzer designer is to achieve a low-inductance current shunt. This is particularly difficult in power analysis products because the shunt resistance needs to be low in order to minimize shunt power dissipation and circuit burden. However, since the parasitic inductance of a component is a function of its geometry, it follows that a shunt of any particular physical geometry will have a greater phase error as the shunt resistance is reduced, because the same inductance will represent a greater proportion of the total impedance.

Since inductive impedance increases with frequency range, the error associated with parasitic inductance also increases with the overall frequency.

It follows that the wideband performance of a power measurement instrument can be optimized by minimizing the capacitive reactance of the voltage input and the inductive reactance of the current shunt.

Newtons4th, an innovative power measurement instrumentation company in the UK, has developed a shunt design that achieves field cancellation equal to that of the best coaxial shunt, while maintaining a manufacturing cost that is viable for use in commercial power analyzers.

This new shunt design combined with zero-gap high-frequency sampling and wide dynamic range provides a solution for power measurement applications requiring high wideband power accuracy.



PWM realizes many benefits for the engineer

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Reliable test equipment

Training the engineers of tomorrow requires high-tech equipment that can stand rigorous use

Watching the US 'big three' auto makers descend in painful free-fall a few years ago, the faculty of Detroit's Wayne State University (WSU), which has long inspired a strong automotive engineering curriculum and research work vital to OEMs and suppliers, knew that an industry in such transition needed an entirely new kind of engineer – and fast.

To that end, in 2008 WSU's College of Engineering recruited Dennis Corrigan, a 30-year industry veteran, to design the school's first coursework in hybrid and EV batteries and co-write the school's innovative grant proposal to develop a degree program to retrain older engineers and turn out new ones for a new type of automotive industry. Three years later – and with WSU's US$5 million US Department of Energy grant in hand – Corrigan realized that he was being handed a rare opportunity: the chance to create both the curriculum and a state-of-the-art advanced research lab. It would equip a new generation of engineers with unprecedented hands-on experience in testing emerging battery technologies for the EV applications being developed in their own city.

But he also knew from his R&D experience with General Motors and Energy Conversion Devices that building a testing facility as a learning environment for such a wide-ranging electric drive vehicle-engineering program presented certain challenges.

Dennis Corrigan, Wayne State University research professor

"When you are training engineers to work in a cutting-edge technology, you need state-of-the-art equipment that can take a lot of rigorous use," Corrigan explains. "It has to be sophisticated but also flexible enough to handle a variety of tasks, many of which we've not even thought of yet."

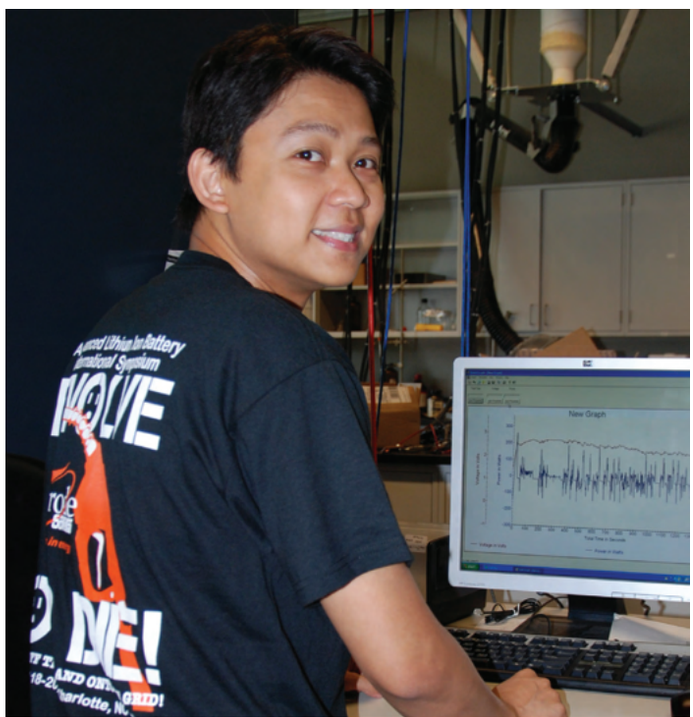
After considering several major brands, he chose Bitrode to provide the lab with several cabinets of high-power test equipment aimed at testing battery cells, modules, strings and packs.

"In manufacturing, there are winning and losing traditions," he says. "Over the past 50 years, Bitrode has steadily built a winning tradition in performance and reliability, both absolutely essential in a teaching facility. There is nothing worse than test equipment that fails. The fact that Bitrode equipment is now an industry standard, used extensively in battery and auto companies engaged in the electric-drive vehicle industry, was a major plus."

Especially important for students, he says, is that Bitrode equipment is capable of subjecting battery hardware to complex power transients with versatile data collection and analysis.

"They can use the same versatile but user-friendly software for testing a wide range of battery hardware, from single cells at the level of a few watts to full battery packs delivering 80kW at 350V. We're not just researching things with little laboratory cells of a few amp hours.

"We try to use real electric vehicle and hybrid vehicle industry hardware to test it on a device at the module and system level to show how these things work, especially in cars. Bitrode is very good about getting their testers to do what they weren't designed to do. Bitrode engineers are always eager to help us use the equipment beyond our original objectives."



Rhet DeGuzman, PhD candidate for chemical engineering, doing thesis research on novel lithium-ion anodes composed of lithium nanoparticles and graphene. He used Bitrode equipment to assist with battery laboratory exercises for students taking graduate engineering courses in batteries and electric drive vehicles

The school has used a Bitrode FTF pack tester capable of charge and discharge at 200A up to 450V to do demonstration testing of a Toyota Prius HEV battery pack for one of the classes. Corrigan adds: "We were able to run a power profile provided by Argonne in dyno testing of the Prius on the EPA urban driving cycle. This profile has 1,369 power steps and we were able to record voltage, current and power as well as 24 module voltages and four temperature inputs."

The Bitrode LCV 100A channels allows students to test lead-acid, nickel metal hydride and lithium-ion batteries for classroom exercises in their electric vehicle and battery systems classes. Bitrode's reliability and versatility are key, concludes Corrigan. "Students enjoy seeing not only how the real hardware works, but also how to use all the data they gather to fully analyze power capability and efficiency."

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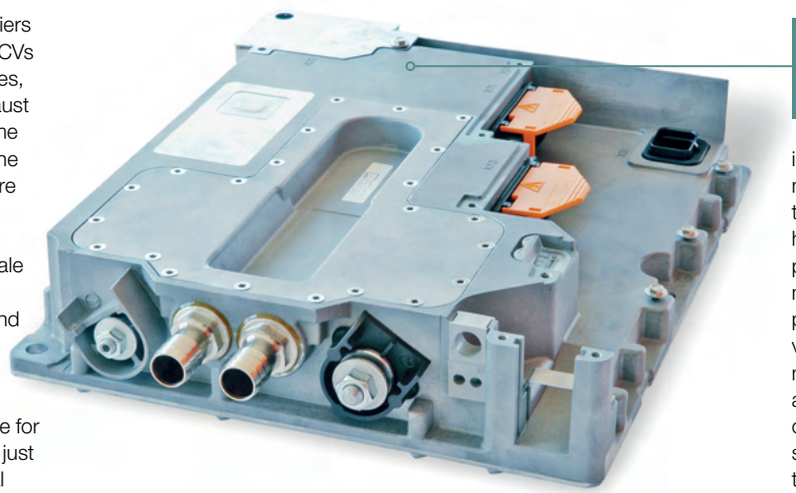
Power electronics for CVs

A modular platform that includes multi-inverters and DC/DC converters that can be combined with each other as required increases flexibility in automotive applications

Manufacturers and suppliers are increasingly creating CVs with hybrid or pure electric drives, the aim being to lower the exhaust emissions of vehicle fleets. Some of these new drives are still at the prototype stage, while others are already being made in small to medium-sized batches. In contrast with classical large-scale production, design engineers need solutions for the supply and control of electrically operated auxiliary components in commercial vehicles, and these solutions must be suitable for different drive versions and not just be designed for a single special application. The flexibility needed for this is offered by the new modular mobile system from Lenze Schmidhauser. This platform includes different types of multi-inverters and DC/DC converters that can be combined with each other as required and have been specifically designed for use in CVs.



The all-new mobile product family from Lenze Schmidhauser for use in commercial vehicle applications

Catering to market demand means that auxiliary components and subsystems such as air-conditioning compressors, power-steering pumps, and air compressors are activated only when necessary. It is therefore not only essential that they be switched on and off at the right time but that the revs are adapted to the power that is actually required. The power input and therefore the fuel consumption can be substantially reduced because the coolant pump is not switched on until the engine is warm and/or until the flow rate is being regulated according to the temperature levels of the engine. As a pleasant side effect of electrification, the dynamic behavior and responsiveness of the vehicle undergo a noticeable improvement because, in contrast to more conventional vehicles, the speed-up of crankshaft rotation during acceleration is no longer inhibited due to auxiliary components that are being operated at the same time during this process.

Unlike the many inverters already available on the market, all the devices from Lenze Schmidhauser's mobile portfolio have been specially designed for use in vehicles; this was also the case for the preceding generation, the MCB series. The new devices have been certified to ECE R100 and meet the quality standards required in CV construction, while satisfying the requirements regarding the specific use profiles of such vehicles. The liquid-cooled (water, glycol) devices are characterized by their special resistance to temperature fluctuations and mechanical vibrations, and also have a high degree of protection (IP6K9K).

The modular product range currently includes several dual inverter units (DCU), two DC/DC converters (PSU), and various combination modules. The dual inverters are each equipped with two motor or generator outputs in the power range from 7.5 to 60W. They work directly from a shared DC bus (up to 850V, 112A), which can also be used to operate all a vehicle's high-voltage components such as a traction inverter.

Two integrated resolver inputs make it possible to create very precise control relating to the inverters. The inverters can be used to operate synchronous and asynchronous motors (three phase; with or without encoder). They are therefore suitable for operating auxiliary components (in U/f or vector mode) as well as smaller main drives.

The 5kW versions with a 14 or 28V DC output (200A) are available as DC converters. The converters make it possible to create an onboard power supply system or can be used as a substitute for the alternator. An even higher-powered unit with 10kW (400A) will soon be made available.

Several combination modules, each of which combines a 5kW DC/DC converter and a single inverter in one module, round off the range of products on offer.

All the modules of the product platform are accommodated in identically structured housing, which means the modules can be stacked to save space and thus enable high-density integration. A cover protects the terminals of the modules against jets of water. For purposes of integration into the vehicle management system, the modules have a CANopen interface and a J1939 interface. A wide range of sensors, such as temperature sensors, digital I/Os, and rotary transducers, can also be connected to the module. In addition, the modules feature Unified Diagnostic Services interface. They can therefore be easily analyzed with a suitable external diagnostics device and integrated into an overall diagnostics concept. This means that developers can carry out improvements to the system and do maintenance work much more easily and with greater specificity.

The mobile products feature two independent controllers. CV manufacturers can use them to flexibly adapt their systems to the individual configuration and the operating conditions of the respective application. The experts of Schmidhauser can also help the end customer when it comes to system integration and, if necessary, can also modify software and hardware.

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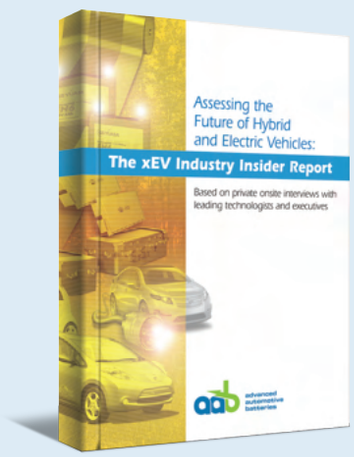

Assessing the Future of Hybrid and Electric Vehicles: The xEV Industry Insider Report

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Lithium-sulfur advances

A new high-energy battery chemistry is set to be launched, promising to be extremely tolerant of physical abuse while surviving long-term storage with zero maintenance

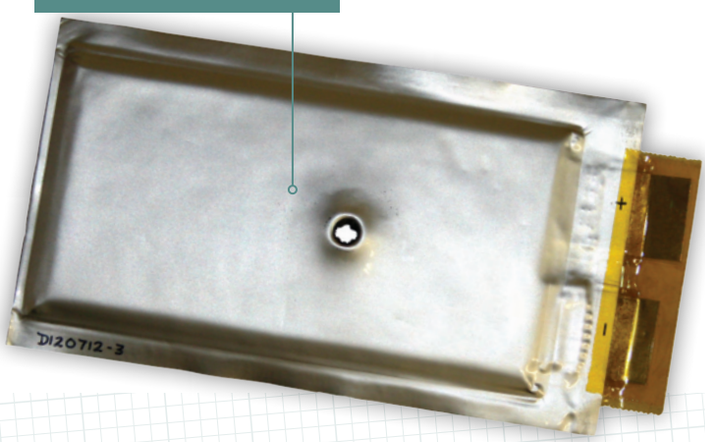
Warranty claims and the safety of batteries are a major concern for vehicle manufacturers and customers. The manufacturers do not want to see lots of claims on the warranty because the battery has died, or indeed for it to become a news story because the battery has burst into flames. Consumers' priorities, on the other hand, are related to safety and longevity. Consumers want to know that in the event of an accident, they would not be in any danger from fire if the battery got damaged, and that when their vehicle is left unused for many months, it would still work when recharged.

A new battery technology developed in the UK by Oxis Energy can solve both these problems while offering a lighter battery with more range due to a very high power density. Oxis is developing lithium-sulfur batteries that will potentially have five times the capacity of even the best lithium-ion battery. The new battery will also be extremely abuse tolerant.

To prove the safety and capability of lithium-sulfur battery technology, it has already been subjected to stringent testing. So far, Oxis has proved that the cells alone can withstand 18 months' unattended storage at zero charge with no adverse effects. They have easily passed standard safety testing such as short circuit, overcharge and nail penetration without reacting, and they even recently survived the extreme violence of being shot by a rifle to prove that they can absorb the worst kind of abuse.

Oxis has teamed up with QWIC Hartmobile BV to develop a new electric scooter called the Wesp, which will be powered by the Oxis technology. Shown here is the electric scooter being charged

The cells in the Oxis technology can withstand extreme environments, surviving even when being shot at



As lithium-sulfur batteries are now becoming a reality, Oxis has teamed up with QWIC Hartmobile BV to develop a new electric scooter called the Wesp, which will be powered by the Oxis technology. This partnership also came about because of the advantages that lithium-sulfur battery technology offers to the end consumer. For example, the scooters can be left unattended for months on end and afterwards be charged up and used as normal. This would drastically reduce warranty claims for dead lithium-ion batteries. In addition, should an accident occur with the battery getting damaged, there would be no danger of either a fire or explosion. The low weight of the battery (which is at least half that of a lithium-ion battery) reduces the weight of the vehicle, therefore improving the performance and handling. There is also the added benefit that the packs can be changed or removed easily. Finally, the very high energy density of the Oxis technology means that the battery is lighter and can hold more charge, making it last longer so that drivers can ride further. All of this combines to make a scooter that is safe, quick, has a long range, and is hassle-free, which is exactly what the customer wants.

Oxis is now looking to work with new companies to bring the benefits of high-energy, light, safe, zero-maintenance batteries from lithium-sulfur technology to other applications.

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ONLINE READER ENQUIRY NO. 516

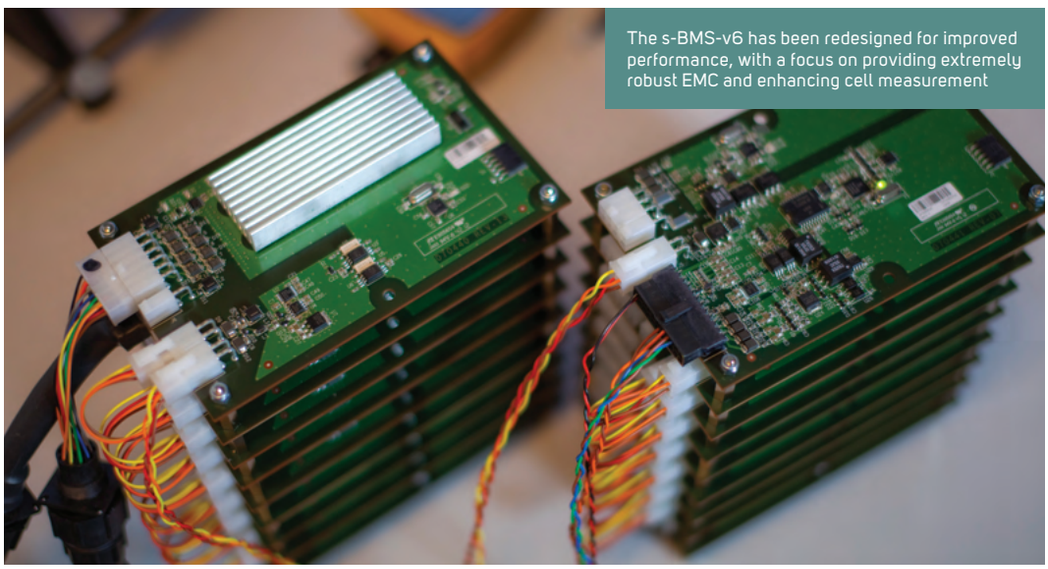
Lithium-ion revolution

When discussing applications for large-format lithium-ion battery technology, electric mobility – including EV and HEV applications – continues to dominate

Specialist, industrial device suppliers have been forced to think electric, as they have found the price of their IC engines has doubled with the introduction of Euro 6. Others, who have previously offered lead-acid battery-powered solutions, are being challenged by their customers to deliver lithium-ion battery-powered solutions. Beyond this there are many who are simply trying to achieve efficiency gains by going full or hybrid electric.

Implementing lithium-ion technology typically involves dimensioning the battery so that performance and cost both fit the application. Next comes the development of a functional safety concept and the integration of the battery pack with the charger, load, and peripherals.

Lithium Balance has a strong track record in this business and there are several examples that can illustrate this, such as the EZ500, the world's first lithium-ion battery-powered street sweeper. Lithium Balance worked with Tennant Green Machines to develop a novel and high-tech twin battery pack, high-capacity solution that enables the EZ500 to operate all day without a recharge.



The s-BMS-v6 has been redesigned for improved performance, with a focus on providing extremely robust EMC and enhancing cell measurement

Another prime example of Lithium Balance's pioneering efforts in Li-ion technology comes with the creation of the world's first manned electric helicopter, with partners Pascal Cretien and Solution F.

Lithium Balance has also recently had input on another world first: an innovative E- PTO garbage truck compactor. Working with Banke Accessory Drives, Lithium Balance developed a 750V battery solution for powering a garbage compactor, allowing garbage to be collected without the usual revving of diesel engines and the attendant emissions.

Another good example of Lithium Balance's recent work is found in Toyota Material Handling Europe's (TMHE) first Li-ion battery-powered reach truck. By working closely with TMHE and its end customer SuperGros, Lithium Balance helped develop a technical solution that radically changed the economics of operating forklifts in cold stores.

These cases, along with around 145 other projects completed by Lithium Balance, have shown that the need for a flexible battery management system, suitable accessories and a good knowledge of battery characteristics. This has helped Lithium Balance deliver the right engineering concept at the right price point, whether in small numbers or large volumes.

With the launch of the updated s-BMS, Lithium Balance is in a stronger position to take project developments from its customers from prototype into production in the shortest possible time.

The s-BMS-v6 has been redesigned for improved performance, with a focus on providing extremely robust EMC performance, enhancing cell measurement with a calibrated measurement circuit and extending the functional safety suite to cover more battery and system failure modes.

These improvements have been made while keeping the traditional virtues of the s-BMS intact, including low power consumption, easy configuration for any lithium-ion cell type, wide selection of chargers supported, and great cell balancing performance.

Lithium Balance technology helps to power the world's first all-electric manned helicopter

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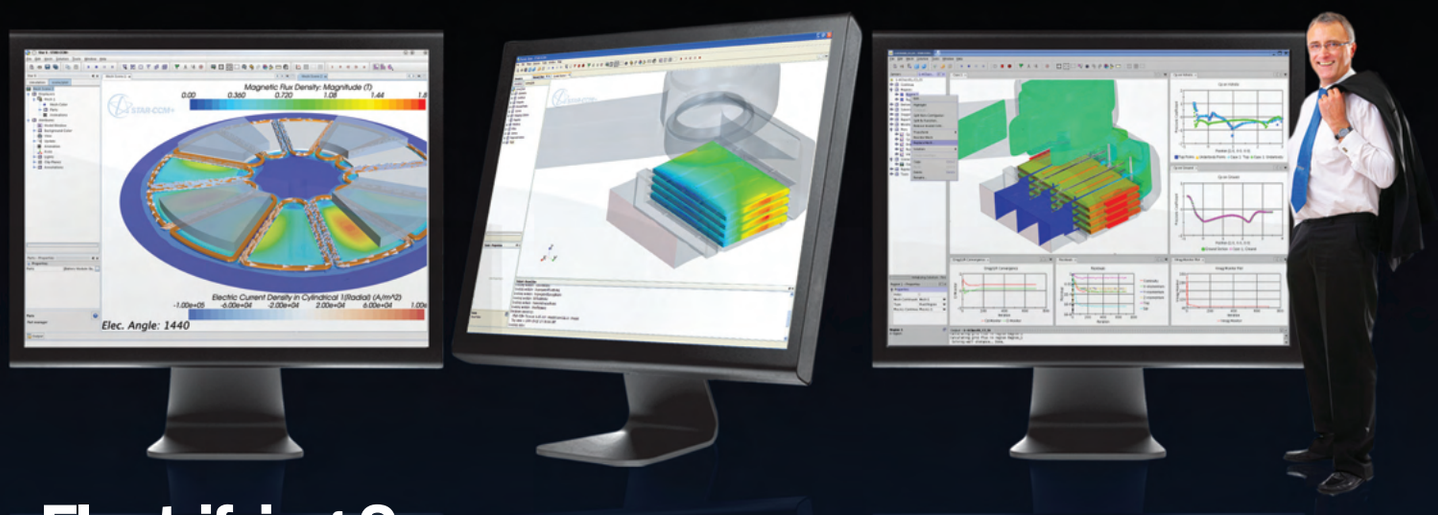

Electrifying Success

CD-adapco has embarked on a journey of collaboration to create a simulation system which is relevant and focused on today's trends within the automotive marketplace. The journey so far has taken in energy storage technology, electric machines analysis, electro-thermal behaviour and continues apace to deliver engineering success to all our users.

The system is built around the class-leading CAE tool STAR-CCM+, a tool which deals with complex, heavy weight 3D resolved physical phenomena. These could include a tightly coupled thermal-electromagnetic problem or an electrochemical-thermal process, all solved within one code, STAR-CCM+. Aligned to this complex 'heart' of the solution are specific design level tools which are focused on the problems design engineers face in the early part of a project. Such tools allow a subsystem to be developed which 'parachutes' the user into the correct design space before deploying STAR-CCM+ to gain those final few percent that make the difference.

The value of such a simulation ecosystem is that there is no duplication. Information entered at the component level is directly interpreted into the complex 3D simulation, allowing a range of engineering groups to use the same models in differing circumstances. This is evident in electric machines design where the upfront analytic tool is used to create a machine which delivers the required torque/speed characteristics. The model is then passed to a thermal group who seamlessly transfer it into a detailed 3 dimensional analysis, adding surrounding cooling systems and componentry, which is used to understand local maximum temperatures within the proposed machine under previously defined operating loads.

Such a tight integration between 'design' tools and 'analysis' tools provides the most value from a group's investment in analysis while avoiding redundant calculations.

CD-adapco

For more information on this growing simulation system designed by world-renowned leaders in analysis with the simple aim to solve your engineering problems and ensure you achieve engineering success, please visit: www.cd-adapco.com.

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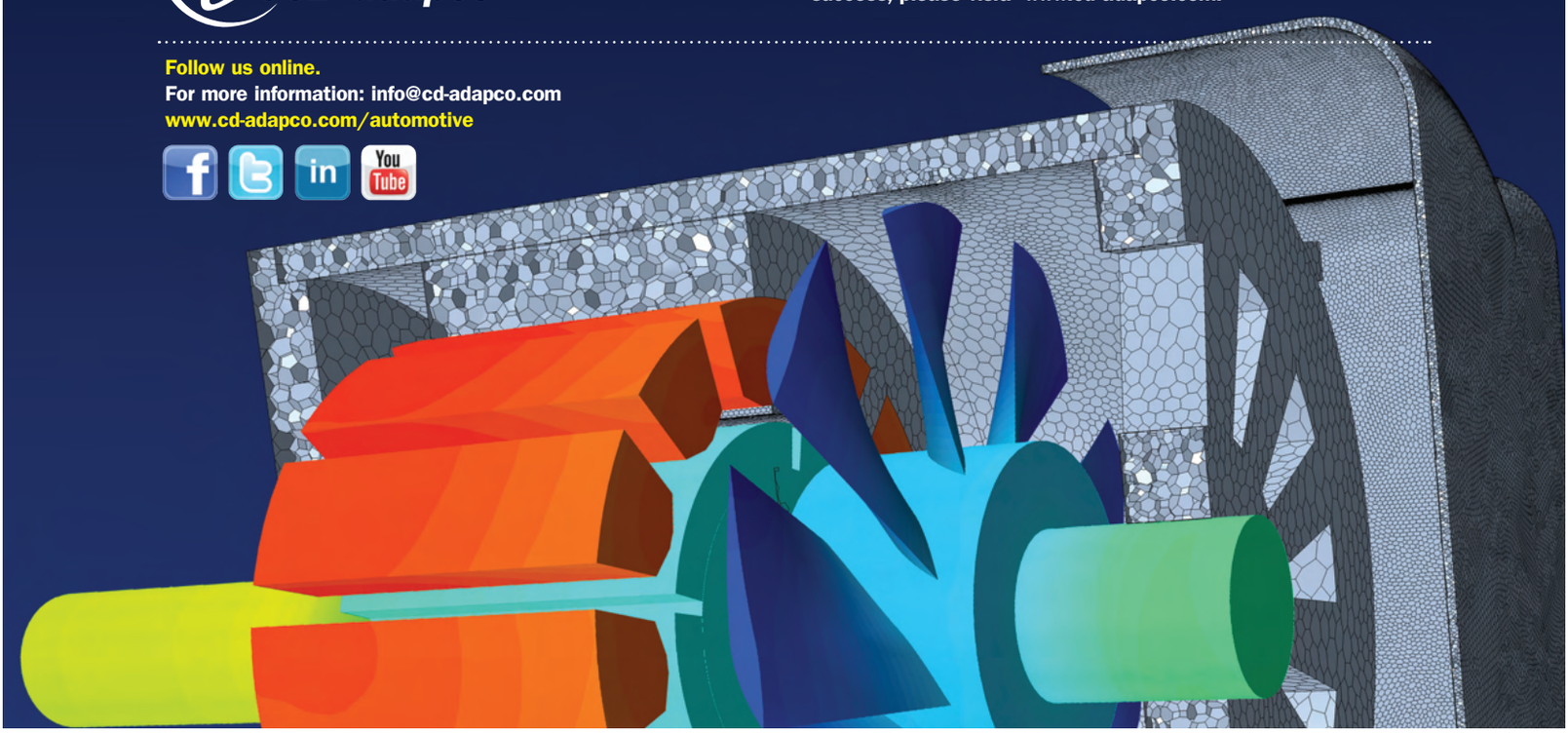


Future testbed solutions

Companies have been testing conventional IC engines for many years and the test process is well established. But what about the new generation of electrified vehicles?

Unlike conventional vehicles, which are powered almost exclusively by IC engines, electric and hybrid vehicles are still in their infancy. The testing of powertrains built with this new technology presents a new set of challenges for the testbed designer. For example, IC engine downsizing results in fewer, smaller cylinders, pushing vibrational behavior to new limits. And electric motors, which can reach high speeds (sometimes in excess of 20,000rpm), introduce a new set of behavioral criteria and testing requirements.

"Using 20th century testbed solutions for 21st century vehicle technology will inevitably lead to frequent failure, resulting in more downtime and higher costs," warns Dieter Höfler, managing director of tectos, a leading engineering company located in Graz, Austria.

Fortunately for the industry, highly specialized engineering companies such as tectos are well equipped to meet these challenges. Since 2004 the company has been providing testbed solutions to the global automotive industry by supplying specialist testbed components and offering a range of highly advanced simulation services.

Among other things, tectos has developed a comprehensive range of innovative drive shafts, docking mechanisms and couplings using state-of-the-art technology and materials, all of which help to minimize the testbed costs and greatly reduce downtime. For example, one of tectos's coupling products limits wear and tear to the elastomer part alone, which is very cheap and quick to replace. And the tectos-patented t900 torsion bar shaft affords low torsional stiffness even at very high rotation speeds, which could be very desirable for testing electric motors.

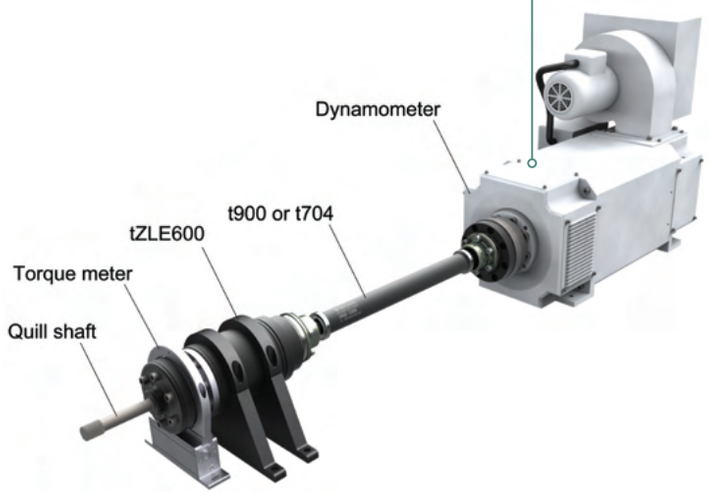
One area in which tectos is leading the industry is simulation – including torsional vibration analysis (TVA), time domain simulation and FEA. The company's extensive expertise in simulation can be used to accurately calculate stresses on the drivetrain components, permitting optimal dimensioning of the testbed setup even before construction begins.

TVA is arguably the most important area of simulation. Armed with the technical specifications of the unit under test, and knowing the inertia of the dynamometer, tectos can accurately identify the torsional eigenfrequencies of the system and thus model the steady-state vibration behavior of all testbed components. Using the results, tectos can then optimize the choice of the required drivetrain subsystems and components to be used in the testbed. Furthermore, time domain simulation can be used for highly dynamic events such as cylinder misfiring and gear changes. Finally, FEA can be used for in-depth structural investigations.

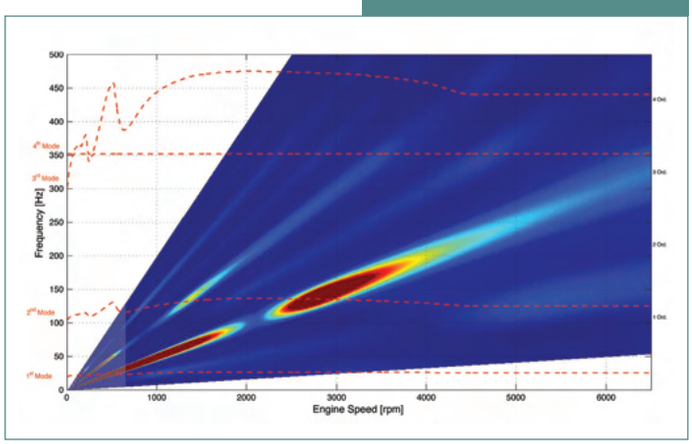
Another key area where tectos leaves the competition behind is customization. After accurate modeling of the testbed setup, tectos will design the elements using the most appropriate products from its range. If the simulation results indicate that the ideal testbed configuration needs custom components, tectos can design and manufacture the required components very quickly. This makes tectos the ideal choice for companies wanting to test the very latest vehicle technology such as electrified powertrains.

As shown above, the t900 shaft has been specially designed and developed to run at very high speeds, while the t704 can provide complete electrical isolation. The tZLE600 is a high-speed intermediate bearing, which would be necessary to couple the drive shaft with the rest of the test setup. Finally, a custom ultra-low weight quill shaft, designed and manufactured by tectos, would be necessary for connecting the unit under test.

An innovative concept solution for testing electrified powertrains



The graphic below outlines torsional vibration analysis – order analysis



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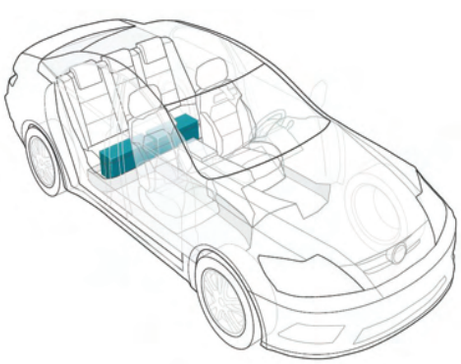
Setting new standards

The principle of battery modularization has led to the creation of advanced lithium-ion batteries that are helping electric vehicles go further with more power available

The work that Goodwolfe Energy, formerly known as LiFeBATT, has carried out in producing class-leading lithium-ion battery systems for the automotive industry has enabled the company to expand its customer base to wider markets, such as the marine and military sectors. This diversification has enabled Goodwolfe Energy to broaden and develop its general product offering, increasing the options available for automotive applications.

At its core, Goodwolfe Energy works on the principle of modularization of batteries. The battery modules offered by the company can be configured to any voltage or capacity to meet a customer's specific requirements, whether the application is for a car, bus or bike. The team is able to develop rapid prototypes for customers, which is made possible by the adaptability of the cells and battery packs along with user-friendly integration hardware. The engineering team at Goodwolfe Energy is able to build bespoke solutions to suit almost any application. The shape of the cells includes an innovative packaging system that enables battery packs to be designed in a variety of shapes and sizes, ideal for projects with tight or unusual space requirements.



Lithium battery solutions can be designed by Goodwolfe Energy to fit a customer's specific requirements

Goodwolfe Energy's battery systems are built as user-friendly plug-and-play solutions

The CANbus Battery Integration System offers the vehicle integrator or OEM a class-leading interface

In terms of technology, the cylindrical cells used by Goodwolfe Energy have a long calendar life, offering more than 2,000 cycles to 80% of the original capacity with a discharging temperature range of -20°C to +60°C. In addition to this, the cells have a low self-discharge rate and a charge efficiency of more than 95%, highlighting how well the cells retain their energy. Goodwolfe Energy also uses a range of prismatic cells, available in sizes from 60Ah to 1,000Ah; the greater capacity of these cells makes them suitable for larger automotive applications such as goods vehicles.

The key to any lithium-ion battery pack is its BMS and its cell management procedures. The core cell management modules (CMMS) allow for aggressive balancing of battery packs, ensuring that the end user always has the full amount of energy available. This is achieved through employing a very high balancing current and by using innovative algorithms that are constantly calculating the optimum balancing routine. Cell isolation is then achieved at the module level, with all communication carried out over CANbus; the CANbus battery integration system (CANBIS) controls more detailed safety and diagnostic features.

The state-of-the-art CANBIS offers the vehicle integrator or OEM a class-leading interface using standard CAN2.0B or J1939 protocols. The intelligent system updates every 20 milliseconds and provides state of charge, state of health, live voltage, current measurement, and regenerative braking parameters. A user-friendly alert system has been integrated into the CANBIS to alert the customer to any issues being experienced and the severity of the fault. The PC-based configuration tool saves hundreds of man-hours during the installation process and allows the user complete customization of the system. Over two million miles of vehicle testing have been used to further develop advanced cell-balancing strategies for HEV and PHEV applications. In addition, in-house cell testing and characterization allow the BMS to accurately monitor the condition of the battery and warn the vehicle of any problems before they happen.

As a leading developer, Goodwolfe Energy has proved that lithium-ion battery systems, based on automotive design principles, can be used in a variety of industries and sectors. This use in other industries has led to important development in the range of products that can be offered to automotive customers.

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koelnmesse

Flywheel hybrids for buses

An engineering specialist reveals a bus development partnership and plans for low-volume production

Bus manufacturer Wrightbus, gearbox supplier Voith, low-volume manufacturing specialist Productiv, and bus operator Arriva have teamed up with Flybrid Automotive to co-develop a mechanical flywheel hybrid bus application

Top: Flybrid Automotive is developing a heavy duty flywheel hybrid system for a bus with a life of 965,000kms

Above: The energy storage flywheel has been designed to perform 1.2M charge and discharge cycles

A consortium of UK companies has recently announced a collaborative project to build, test, and run in service a mechanical flywheel hybrid bus. The consortium includes flywheel hybrid developer Flybrid Automotive, bus manufacturer Wrightbus, gearbox supplier Voith UK, low-volume manufacturing specialist Productiv, and bus operator Arriva.

The consortium project, which has secured financial support from the UK innovation agency Technology Strategy Board, aims to pave the way for production of low-cost buses that use up to 20% less fuel than standard vehicles. It is anticipated that such vehicles will repay the additional up-front cost compared with a standard bus within five years based on fuel cost savings alone. The partners believe that this business case is key to unlocking the hybrid bus market in a post-government subsidy regime.

The Flybrid project is part-funded through the Low Carbon Vehicles Innovation Platform program managed by the Technology Strategy Board, the UK's innovation agency, which has provided funding of US$1.1 million for this project. This amount was matched by the project partners, bringing total investment to US$2.2 million.

Buses are a great application for KERS. "Big, heavy vehicles that stop and start every few hundred meters provide plenty of opportunity for energy harvesting, but in many ways it is a very challenging application for hybrid systems of any type," says Jon Hilton, managing director of Flybrid Automotive. "There are many opportunities to store energy but the absolute amount of energy is smaller than one might think. A bus is usually braking from a relatively low speed, and kinetic energy is proportional to speed squared, so the energy storage requirement is not much more than a large car, but the duty cycle is very much more severe."

Bus operators are expecting a 12-year life for the vehicle, equating to as much as 600,000 miles and an energy store life of 1.2 million full charge and discharge cycles. Flybrid is taking pragmatic steps to ensure this life expectation can be met, reducing the flywheel speed from the normal 60,000rpm and increasing the inertia of the flywheel to achieve the storage requirement. The rest of the hybrid system is being designed with long-term service in mind and is expected to fall in line with the regular maintenance schedule of the vehicle.

The target vehicle for the demonstration project is the Wrightbus StreetLite vehicle, a lightweight, single-deck midibus that already displays class-leading fuel economy, and which is expected to yield very impressive results as a flywheel hybrid vehicle. This class of vehicle has traditionally proved very difficult to hybridize as the low base price, combined with the inability of the bus manufacturer to remove many expensive components during the conversion, has made electric hybrids unaffordable.

Speaking about the Flybrid engineering project, Wright Group engineering director Brian Maybin says, "When we originally launched StreetLite two years ago, we brought fresh thinking and new technology to this sector of the bus market. This latest project, bringing hybrid technology to our midi model range in an innovative and cost-effective way, continues this philosophy of product development designed to deliver considerable efficiency and whole-life cost benefits for bus operators."

The consortium project will not only develop technology and prove that it works, but also run it live in public service under the guidance of project partner Arriva.

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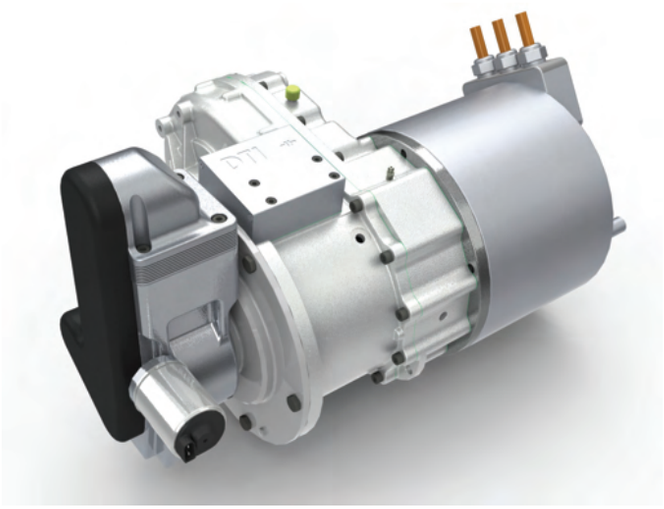

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Advanced HIL battery testing

Delivering Autonomie models in a motor/battery hardware-in-the-loop test system is enabling engineers to test performance in various virtual design environments

Faced with increasingly demanding time-to-market goals every year, a major hybrid and electric battery manufacturer needed to accurately test battery performance for vehicles that were still in development and not yet available for testing – or that would be too expensive to test using the vehicle itself. The organization also wanted to be able to test field performance under a full range of operating conditions. Furthermore, company engineers felt it was critical to the project that a real inverter and motor were used to apply loads during testing.

Drawing on more than 30 years of experience in the development of powertrain test systems, A&D engineers created a unique HIL simulation testbed using A&D's Procyon ultra-high-performance real-time simulation and control platform, along with the Simulink-based Autonomie modeling tool. Developed by Argonne National Laboratory, Autonomie is a powertrain and vehicle model architecture and development tool that enables engineers to easily test performance in a variety of virtual design environments.

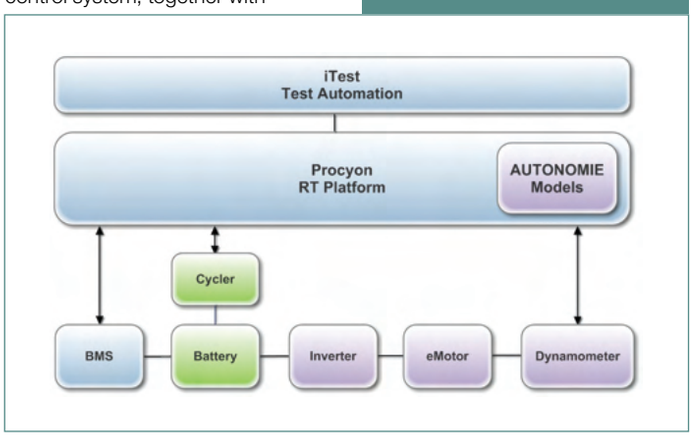
A&D's iTest data acquisition and control system, together with Procyon, a battery cycler, dynamometer, and an off-the-shelf vehicle electric motor/generator and inverter, comprise the major components of the HIL test system. Vehicle models and drive cycles – developed in Autonomie and deployed on Procyon for real-time execution – control the system components in order to apply loads to the battery under tests that reflect real-world conditions. The use of a simulated vehicle and the cycler allows for testing batteries in new vehicle concepts, as well as scaling system loads to vehicles that might use motors of different sizes. The ability to test batteries outside of vehicles also enables the manufacturer to reproduce and diagnose problems discovered in the field in a controlled environment.

A&D's Procyon ultra-high-speed real-time measurement, simulation and control platform

The scalability and flexibility of the A&D HIL system enables testing of many performance areas, identifying issues that otherwise might not surface until the much later, and more costly, stages of development. Extensive experience and know-how in both testing tools and real-time simulation make A&D Technology uniquely positioned to provide a solution that addresses a broad range of requirements in a single system.

A&D Technology provides complete turnkey solutions for HEV applications, including component testing, controls validation, and component performance simulation. These solutions shift component and vehicle integration, optimization, and validation activities into an earlier phase of the entire development process.

Based on iTest, A&D's proven data acquisition and control system, iTestEV is a high-quality, flexible tool ideally suited for HEV powertrain testing. Advantages of using iTestEV include shorter development time, more reliable products, and complete integrated test process from a single supplier.



A motor/battery HIL test system including the Autonomie model

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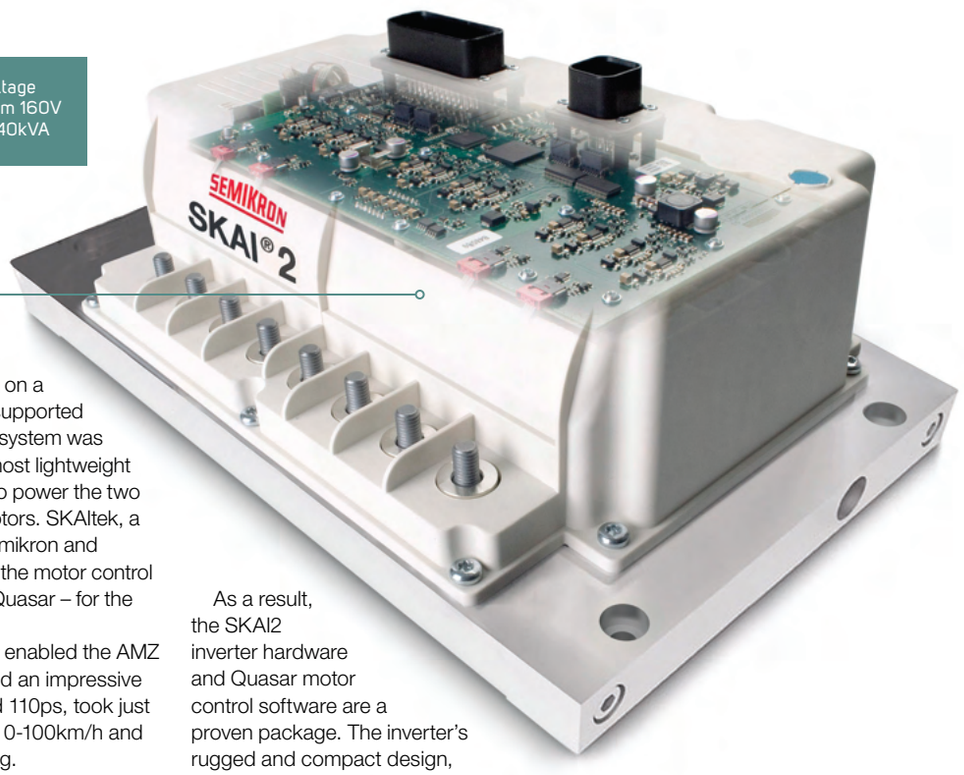
Electric mobility racing

Featuring leading subsystems, the AMZ racing team of the Swiss Federal Institute of Technology Zurich achieved second place in the 2012 Formula Student Electric

The question is no longer whether electric mobility will become an everyday standard – it's rather when and how this will happen. The Formula Student Electric (FSE) has taken a fast approach on this topic, with ambitious teams from universities worldwide competing in many categories, with the overall aim for the best engineering work to create the best race car. In 2012, a total of 89 teams took up the challenge.

Fitting a random turnkey system onto a chassis and driving it around will not do the trick in a competition like the FSE. Winning requires sophisticated engineering skills that will allow for a competitive car to be designed and built featuring all the leading and correct components and subsystems. The heart of a race car is its drivetrain, and with support from Drivetek AG, a Swiss specialist for electrical drivetrains, a winning solution for the inverter could be found.

A race car requires power and control to be realized with minimum weight and space consumption. Armed with the 120V dual-inverter with integrated water cooler – the leading product in Semikron's off-the-shelf SKAI2 low-voltage inverter product family – Drivetek engineers were presented with the correct answers to these demanding requirements. Two inverters operating on a 120V battery and supported by a liquid cooling system was the smallest and most lightweight solution available to power the two AMZ 40kW AC motors. SKAItek, a joint venture by Semikron and Drivetek, provided the motor control software – called Quasar – for the two motors.



The SKAI2 low-voltage dual-inverter system 160V DC (120V nom)/2*40kVA

This technology enabled the AMZ racing team to build an impressive car that developed 110ps, took just 3.3 seconds to do 0-100km/h and weighed only 171kg.

At the end of the racing season, after competing on tracks in Spielberg, Austria; Silverstone, UK; Hockenheim, Germany; and Barcelona, Spain, the engineering setup of the car proved its worth by finishing second in the overall FSE competition, as well as winning the Endurance racing, Autocross and Best E-Drive Packaging categories.

The SKAI2-powered race car in the Formula Student Electric

As a result, the SKAI2 inverter hardware and Quasar motor control software are a proven package. The inverter's rugged and compact design, combined with the Quasar software's accuracy, makes this package the ideal fit for vehicle designs requiring high reliability and precise control. The race car's success is an example of how the network of partners – Semikron as the inverter manufacturer, SKAItek as the software provider and Drivetek for engineering services – brings several benefits to the customer.

The SKAI2 LV product family supports battery-powered drive applications with an extensive range of robust inverters, each fitted with a wide set of freely programmable additional functions beside the main inverter. Built for batteries from 48-120V and supported by either air or liquid cooling, the systems come with an IP67-rated enclosure that is able to withstand vibration amplitudes of up to $10G_{rms}$. The systems can be single inverters, but are also available as dual inverters to operate two motors completely independently.

The SKAI2 product family offers a wide range of versatile highly integrated inverters. These inverters fit smoothly into many applications, such as auxiliary drives or powertrains of materials handling machinery, small off-road vehicles, or boats.

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ONLINE READER ENQUIRY NO. 522

PLUG-IN 2013

September 30 – October 3, 2013
San Diego Convention Center
San Diego, California USA

WHAT'S NEXT FOR THE ELECTRIC HIGHWAY?

Plug-in electric vehicles are at a crossroads.

Sales are accelerating, but questions remain about technology costs, market evolution, consumer education and infrastructure development. At Plug-In 2013, we will discuss, debate and, ultimately, answer these questions.

- Join us for real-world reporting as we analyze how best to move forward using the data collected over the last three years.
- Secure your spot on our diverse exposition floor to connect with and develop long-term relationships with decision-makers who drive the vehicle and infrastructure markets.

It's all here at Plug-In 2013 – the international gathering of automakers, utilities, EVSE and other component manufacturers, policymakers and key stakeholders – so mark your calendars now!

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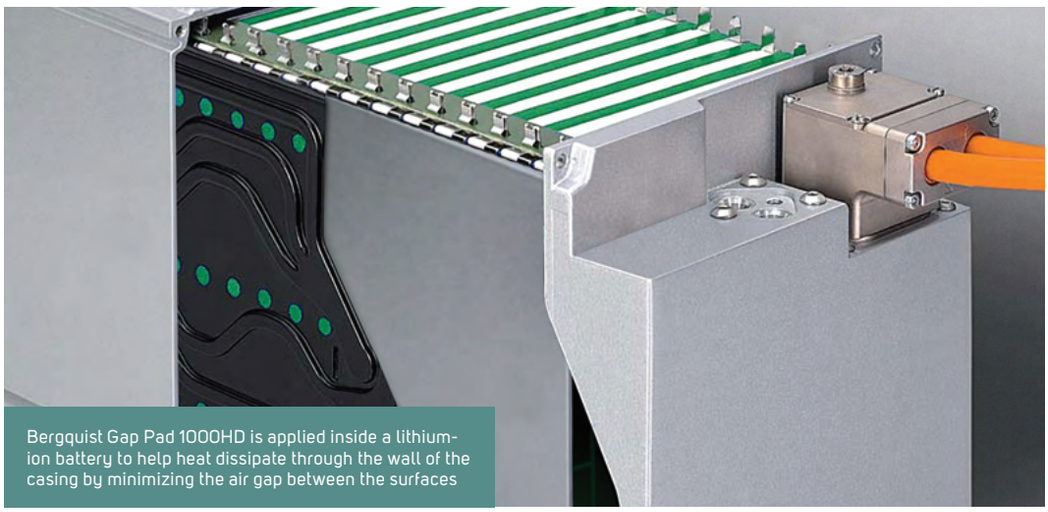
Thermal material matters

The next generation of gap-filling materials for the expanding EV and HEV automotive sectors

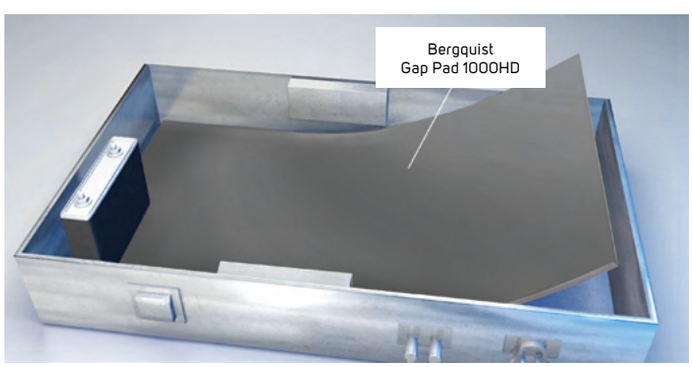
The Bergquist Company recognizes that with the high price of fuel, consumers are turning to higher efficiency means of transportation such as HEVs and EVs. With the growing consumer demand for better fuel consumption and cleaner emissions in the coming years, more OEMs are investing heavily in producing cost-effective, reliable, and safer alternative batteries. The use of lithium-ion batteries is considered the most attractive solution, and they are used in current and next-generation HEVs and EVs. However, Li-ion batteries need to be maintained at a certain temperature for long lifespan and efficiency.



Bergquist Gap Pad 1000HD is applied inside a lithium-ion battery to help heat dissipate through the wall of the casing by minimizing the air gap between the surfaces

Without adequate battery thermal management, the lifespan will dramatically shorten. In order to meet these requirements, the battery cells have to be kept in a thermally non-critical state in all operating conditions. Hence, OEM manufacturers have to overcome challenges in designing efficient thermal management.

Cooling is generally implemented within the systems to keep lithium-ion batteries at the desired temperature. In order to minimize the surface roughness between the lithium-ion batteries and cooling contact area, it is common to use a thermal interface material to bridge the gap. Hence, most OEM manufacturers use a thermal interface material placed between the batteries and the base plate for conduction or convention cooling. The thermal interface material needs to have characteristics such as being highly isolative, while also having a high cut-through resistance and high breakdown voltage to avoid any damages due to shock, vibration and temperature.



Bergquist Gap Pad 1000HD is applied to the battery casing floor, maximizing the surface area of the batteries to the casing. Combining the maximized surface area with the thermally isolating properties of the Gap Pad material will reduce the battery temperatures, causing increased life expectancy and performance

Bergquist's Gap Pad provides an effective thermal interface solution between heat sinks and electronic devices where uneven surface topography, air gaps, and rough surface textures are present. Some of the key parameters that Gap Pad includes are the elimination of air gaps to reduce thermal resistance; high conformability to reduce interfacial resistance; low-stress vibration dampening especially in automotive environments; and compatibility with automated dispensing equipment if needed.

One of the newest products is Gap Pad 1000HD – an innovative thermal management product for automotive applications. Gap Pad 1000HD is designed for high durability, with one side coated with a polyimide carrier that not only allows for easy rework, but also has excellent handling characteristics. The coated polyimide carrier reduces puncture and has high tear resistance that meets the needs of automotive engineering conditions. Gap Pad 1000HD provides a high dielectric breakdown voltage (exceeding 9,000V AC) with a volume resistivity of 1,011Ωm.

Gap Pad 1000HD comes with high conformability and is available from 0.5-3.175mm thickness. In addition, its elastic nature allows for excellent interfacing and wet-out characteristics. One side has high inherent tack, while the other side has minimum tack, which enables the flexibility for manual or automated processes.

As battery technology evolves, Bergquist continues to provide thermal performance solutions that can meet the needs of the EV and HEV markets as the next generation of technology moves forward.

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ONLINE READER ENQUIRY NO. 523

Critical battery testing

A successful global partnership between two organizations has led to new benchmarks being made in battery validation equipment and techniques

Intertek offers international industry-leading, independent consulting and testing for batteries, fuel cells and supercapacitors. The company performs battery testing for manufacturers of energy storage devices ranging from electric vehicles to personal electronics and renewable energy. Expert engineers provide a depth of experience in battery testing services that ensures energy storage technologies meet performance, reliability, and safety requirements for OEMs and Tier 1 suppliers, as well as cell and battery manufacturers, and aerospace/defense players.

PEC provides Intertek with multiple channels of testing equipment to charge and discharge batteries for testing. Intertek uses SBT 8050 cyclers from PEC to run overcharge and over discharge tests as well as client-specified battery lifecycle tests.

Intertek serves its customers by providing comprehensive safety testing to national, international, and industry-specific standards.

The equipment from PEC provides Intertek with the capacity to perform safety, abuse, and performance testing for energy storage solutions. The SBT 8050 system used by Intertek allows for charging batteries up 80V and discharge down to a true zero volt level. Current ranges can be paralleled in 50A increments, with current measurement ranges down to micro-amps. This allows Intertek to use the same equipment to test any type of battery system – from small consumer applications through to large EV module applications. Intertek relies on PEC testing equipment for the flexible architecture needed to establish battery testing services to more complex energy storage systems.

Helping to serve the needs of HEV, PHEV, and EV manufacturers and suppliers on a global scale are Intertek's centers of excellence in Shanghai, China; Kaufbeuren, Germany; Stockholm, Sweden; and Detroit, Michigan. Through their joint partnership, PEC assists Intertek with the global service it needs to manage costs, reduce errors, and provide excellent customer service to its clients. Intertek employs identical systems to serve vehicle battery customers in key automotive regions, complementing large- and small-format battery performance, safety, and abuse testing capabilities.

Engineer Kirk Palmer attaches a voltage sensor connector to the PEC 8050 in order to monitor voltage levels during the testing of a battery

Energy storage device manufacturers face numerous challenges in shipping their devices at the prototype stage of a development program. However, the ever successful partnership between PEC and Intertek provides identical capacity and technical services in key international manufacturing cities, therefore creating the same data on a common platform and helping to get customer products to market more efficiently and quickly. An efficient test cycle is powered by an active and involved partnership between the manufacturer and testing lab, including a certification partner who will identify exactly which tests and validations can be done for the greatest number of markets in order to save time, cut overall costs, and increase the distribution channels.

Intertek has been helping global manufacturers meet national and international standards for over 100 years. With unsurpassed expertise in this area, Intertek helps customers cut through the incidentals and provide the critical data they need. Intertek empowers customers to make choices about testing, approval, and listing that will help drive products to market faster than the competition. Intertek is recognized as an NRTL in the USA, and in a similar capacity as a Testing Organization and Certifying Body in Canada, as well as being a Notified Body in Europe.

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ONLINE READER ENQUIRY NO. 524

Small-scale electrification

Custom-designed existing technologies and systems can help power society into the future

Vehicle electrification is a worthy and well-publicized cause. The ongoing political struggle over oil, combined with the pressure to make more environmentally responsible vehicles, has given the global transportation industry unprecedented technical and manufacturing challenges. The prospect of changing the fundamental nature of how society powers its cars and trucks has also presented new opportunities.

But revolutions are tricky, even when the causes are undeniable. It's a whole lot easier to throw down the gauntlet – and even to pick it up – than it is to actually make a change; it's harder still to make a profit on it.

The transportation industry deserves credit for the remarkable HEVs and EVs that are now available. These vehicles run clean enough to satisfy the greenest aspirations and to delight those who seek to end reliance on the volatile oil industry. They also deliver the power and reliability that customers require.

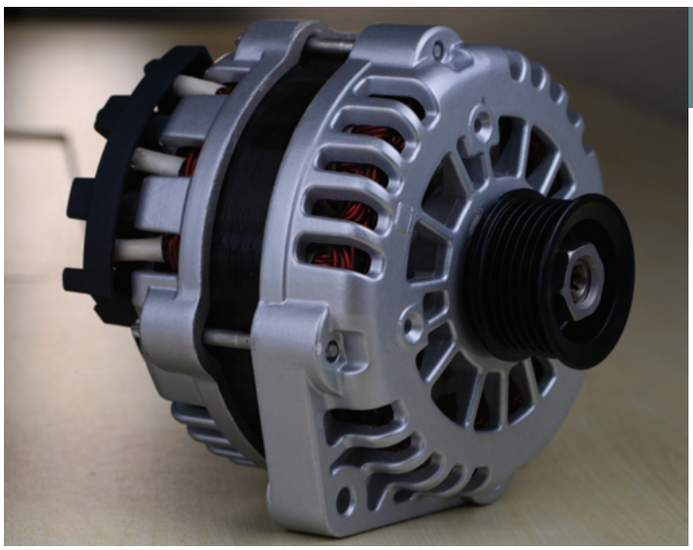
So what could be wrong with that kind of progress? Nothing – but as an industry, we are simply not seeing enough consumer adoption of hybrid and electric vehicles. Most people are not willing to make the additional investment in these vehicles, choosing IC-powered products instead. Without the tax incentives and government subsidies, the cost of these modern machines would put off even more people and manufacturers.

Then there's that problematic infrastructure issue that is required for mass acceptance of EVs. There are gas stations everywhere, but if an EV owner needs a charging station, then the options are mainly limited to the home and the garage.

The market is, however, seeing the popularity of hybrids grow quickly, and the same is true for certain EV applications, but how much change amounts to a revolution? The answer is more than what we have at present, it would seem. Even President Obama's personal gauntlet of putting one million electric vehicles on America's roads by 2015 is a fraction of the 250 million registered vehicles in the USA alone. That one million figure looks unreachable at present.

Perhaps it's time to accept, and even embrace, the long-range plan. This process is evolutionary, and the industry is doing its job very well. Small-scale electrification, or mild hybrids, will play an important role in this evolution. Smaller, less expensive, highly efficient motors can be used in many different ways to improve fuel economy. There are multiple examples of such systems today, including the belt alternator starter, stop/start alternators, and change-of-mind starters. Some of these systems are already in production, and they are typically installed in the same position as a traditional alternator or starter, therefore eliminating the expense of new manufacturing designs. Furthermore, they are much less expensive than traditional hybrids.

The first-generation BAS adoptions were classified as mild hybrid technologies, and used successfully on the Chevrolet Malibu Hybrid and the Saturn Aura Green Line models.



Remy's acclaimed BAS technology has proved its worth, reliability, durability and performance in a raft of vehicles

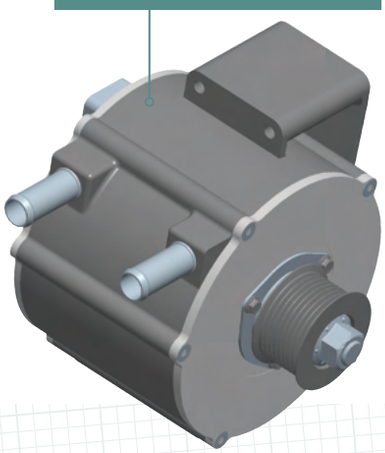
Remy International is excited about the possibilities of small-scale electrification and mild hybrid applications. These smaller motors can make a significant difference in vehicle efficiency, without the engineering expense and complexity of traditional hybrid systems. Additionally, these motors can be easily modified and adapted to meet a wide range of vehicle electrification needs.

The manufacturers of HEVs, PHEVs, and all electrified vehicles, are pursuing the same goals of efficiency and performance, and the industry as a whole needs to continue in that pursuit.

Remy is proud to partner with many global manufacturers and deliver more than 17 million rotating machines a year. The company's innovative, patented HVH line of motors has become standard for commercial, recreational and consumer hybrids and EVs, and has logged over several billion real-world miles.

Remy believes it is important to take advantage of all available technologies. Small-scale electrification can make a big difference without a big cost of entry. Improvements and progress will evolve into revolutionary change.

High-tech innovation from Remy, such as the company's HVH line of motors, is helping its global partners to reduce emissions



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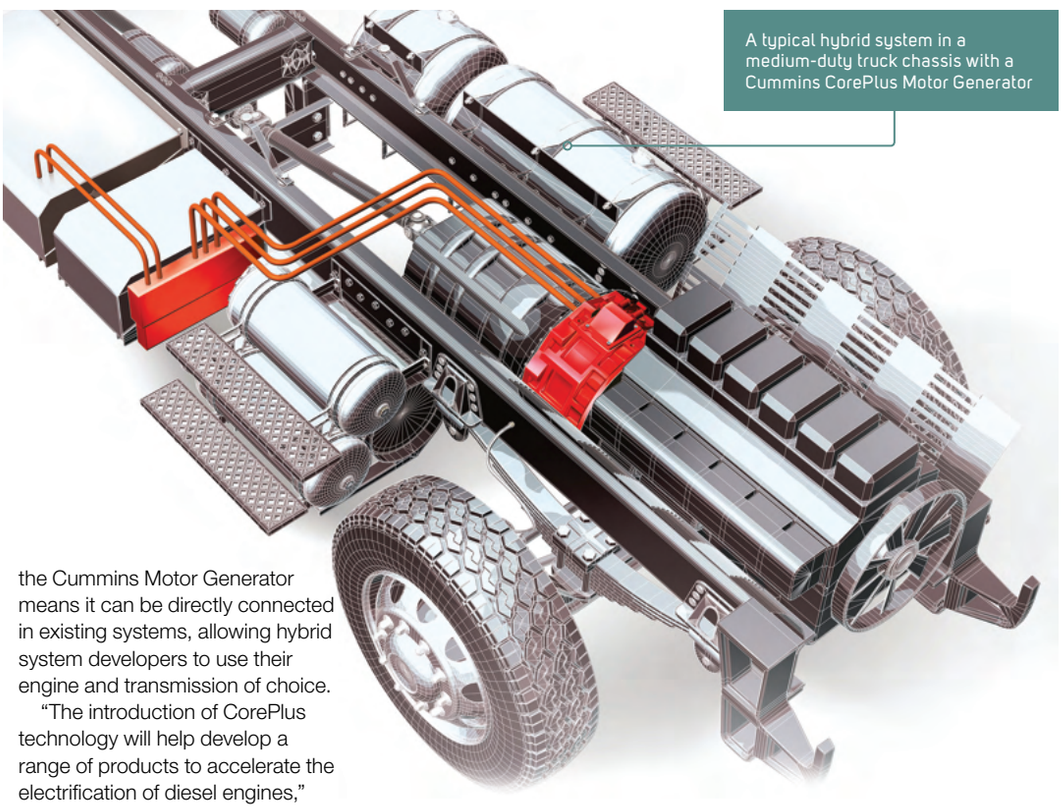
ONLINE READER ENQUIRY NO. 525

CV engine electrification

All-new motor generator technology offers a high-torque solution for commercial vehicle manufacturers that are seeking the electrification of their drivetrain systems

The combined challenges of spiraling fuel costs and ever-tightening laws on exhaust emissions is forcing commercial vehicle operators to look for leaner, greener alternatives to conventional diesel engine arrangements. Incorporating an electrical motor generator into the drivetrain of an existing commercial vehicle has specific requirements. The new Cummins CorePlus radial-flux Motor Generator, with its peak power of 90kW and 660Nm torque, and measuring only 200mm in length, meets all these needs.

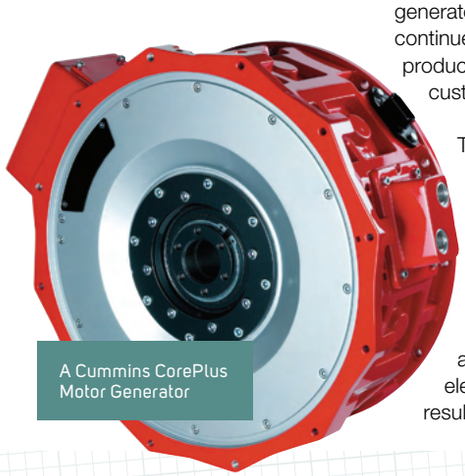
Launched in September 2012 by Tom Linebarger, CEO of Cummins, at the IAA in Hanover, the Cummins Motor Generator is suitable for hybrid commercial vehicles, range extenders, super alternators, and full EVs. A robust product validation process has ensured the CorePlus Motor Generator meets the rigorous quality requirements of the automotive industry. Furthermore, with over 100 years of experience in manufacturing electrical machines and leveraging on Cummins' expertise in the automotive industry, Cummins Generator Technologies has developed a new standard of universal integration. Unlike its counterparts, the unique design of the Cummins Motor Generator means it can be directly connected in existing systems, allowing hybrid system developers to use their engine and transmission of choice.



A typical hybrid system in a medium-duty truck chassis with a Cummins CorePlus Motor Generator

"The introduction of CorePlus technology will help develop a range of products to accelerate the electrification of diesel engines," says Linebarger. "The Cummins Motor Generator, the first product under the CorePlus umbrella, encompasses the best of Cummins' expertise in both engine and generator markets, and will help us continue to deliver excellent products and services to our customers across the globe."

Cummins Generator Technologies' motor generator developments stretch back to 2000 with the formation of a dedicated R&D team to examine new market opportunities for permanent magnet alternators and power electronics converters. The result was the development of CorePlus technology to accelerate engine electrification with an array of new products, of which the Cummins Motor Generator is the first.



A Cummins CorePlus Motor Generator

The Cummins Motor Generator can be used in either series or parallel hybrid drivetrain configurations, or a combination of both, with its universal hollow rotor design enabling it to fit application-dependent driveshafts. Weight has also been saved in the machine rotor casting, which only has to handle the torque produced by the electric motor rather than the torque from the diesel engine. The electric machine is complemented with power electronics embedded with Cummins control algorithms to further extend performance, capability, and protection.

The result is a lightweight and dimensionally compact motor generator that can be fitted to any manufacturer's driveshaft, delivering class-leading peak torque and efficiency ratings over the entire torque-speed range, and enabling vehicle OEMs to develop a highly flexible hybrid drivetrain that is capable of delivering impressive fuel savings and CO_2 reductions.

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ONLINE READER ENQUIRY NO. 526

New EVSE standards

Testing to the SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler Standard is set to benefit the further development of eco-friendly vehicles

Following the much-anticipated revision of SAE J1772, the new North American safety standard for PHEV and EV conductive charge couplers, in October 2012, manufacturers from around the world are working hand-in-hand with Intertek's vehicle test engineers to meet the growing demand for innovative EV technology.

SAE J1772 provides critical safety guidelines for charging controls and connectors that are used to charge plug-in vehicles. It was developed to accommodate the latest generation of plug-in vehicles with high-energy batteries. The new Combo coupler combines the interfaces of the existing SAE J1772 AC connector with new direct DC coupling terminals. More plainly, the Combo system must incorporate both the AC and DC output circuits and corresponding communication circuits, as well as use the new-format connector.

Most notably, this standard has reduced charging time from as much as 8 hours to as little as 20 minutes.

SAE J1772 benefits the industry by providing a standard for both AC and DC charging stations, which gives direction to OEMs and certification bodies, as well as guidance on charging infrastructure. But as with any new standard, manufacturers are now faced with the challenge of understanding new safety requirements and their impact on compliance in the USA. However, with the guidance of an experienced testing partner, electric vehicle supply equipment (EVSE) manufacturers can simplify their certification processes and learn to adopt the new harmonized standard. Rich Byczek, technical lead for electric vehicles and energy storage at Intertek, and author of *The Q&A Guide to Electric Vehicle Supply Equipment Certification in North America*, outlines a customizable testing regimen for an application covering primary EVSE standards for AC and DC circuits. The regimen includes: UL Subject 2594 – covers the AC pass-through circuit; UL 2202 – covers the DC charger circuit; and UL 2231-1 and 2231-2 – covering the CCID circuits, and can be separate devices for each AC and DC output circuit.

Engineer Nick Van Klompenberg of Intertek tests the safety circuits within an EVSE, using custom-fabricated test fixtures capable of simulating various environmental and fault conditions that may be seen in the real world

Fortunately for existing listed AC charge stations, the new standard is backward compatible, meaning that there are no changes needed to comply with the latest SAE standard if the equipment is already using the J1772 AC connector. However, existing listed DC charge stations (CHAdeMO or other) need additional testing to verify continued compliance per the following: if greater than 80A/40kW, change to new combo connector to UL 2251; if less than 80A/40kW, change to the standard J1772 connector to UL 2251.

Additional requirements for existing DC charge stations include an update to the control software, necessitating a change from CAN interface to PLC communication, with the potential for testing to UL 1998. Similarly, manufacturers need to update their existing UL 2202 certification to include the alternate new-format connector.

Specifically regarding new combo systems, control and power circuits must be evaluated to a combination of UL 2202 and UL Subject 2594; AC and DC CCID circuits must be evaluated to UL 2231-1/-2. However: if DC Level 1 – can maintain the standard J1772 connector, UL 2251; if DC Level 2 – use the new combo connector, UL 2251.

With the advancement of EV technologies and increased acceptance for hybrid and electric vehicles throughout North American consumer markets comes a growing concern over the safe use of EVSE, including charging systems/stations, cord sets, plugs, and ancillary components. A testing and certification laboratory can help ensure that the customer's EV-related products and components are certified compliant with SAE and UL standards, allowing the customer to stay competitive and accomplish market goals without delays.

Intertek is a nationally recognized testing laboratory in the USA, with more than 50 years of experience in the automotive testing industry. It is one of the first labs to significantly invest in state-of-the-art capabilities across North America, Europe, and Asia for testing EV supply equipment to the following standards: on-board battery chargers – SAE J2894 and UL 2202; charging inlet – SAE J1772 and UL 2251; charging station/cord sets – SAE J2293 and UL Subject 2594; charging plug – SAE J1772 and UL 2251; and personnel protection circuitry – UL 2231-1 and UL 2231-2.

With unsurpassed expertise in helping manufacturers meet national and international standards testing and certification, Intertek can work with manufacturers to cut through the incidentals and provide the critical data they need. Intertek empowers customers to make the choices about testing, approval, and listing that will help drive the product to market more quickly.

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ONLINE READER ENQUIRY NO. 527

Exterior sound simulation

A comprehensive suite of virtual development tools is now available for designing and evaluating the sound of quiet vehicles, including HEV and EV applications

The acclaimed Desktop Simulator is part of Brüel & Kjær's unmatched suite of four high-tech solution families

Correctly engineering the sound of a vehicle is vital to meet brand and customer expectations, and here simulation can greatly ease the process – reducing prototyping requirements and speeding up quality decision making. Simulation assists better decisions on target specifications early in the concept stage, efficient engineering during development, and final sign-off with a high confidence of success.

Brüel & Kjær offers an unmatched suite of four solution families: the Desktop Simulator, the Full-Vehicle Simulator, the On-Road Simulator and the Exterior Sound Simulator. The Exterior Sound Simulator is of particular interest to electric, hybrid, and quiet vehicle engineers as it enables easy assessment of external noise, taking the point-of-view of a pedestrian in urban environments. This is ideal for vehicles where the noise profile is too quiet to give warning of approach and can represent a hazard, especially to sight-impaired people.

In the virtual world, the vehicle can perform any driving maneuver in any situation, such as starting and moving away in a car park, or rapidly accelerating past a house. The observer can be at a stationary point, or be a pedestrian walking through the scene. With pre-defined paths for both observer and target car, the scenario can be exactly repeated for accurate comparisons between design alternatives.

The software transforms the vehicle's different sound sources into contributions heard at the observer's location, taking into account factors such as speed and load of the target vehicle, the relative speed and heading of the source and observer, the directivity of the source, and the head-related transfer functions to the observer.

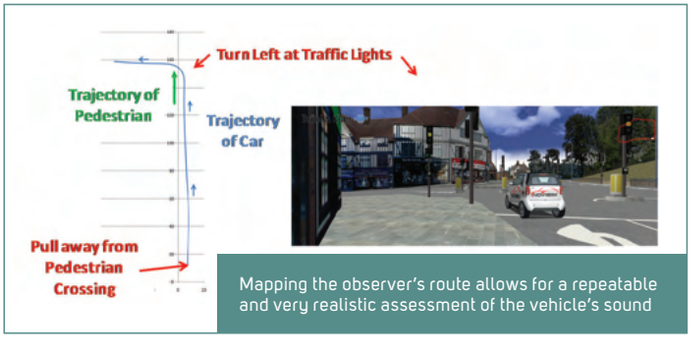
This means that distance attenuation, pan effects, Doppler shift, and source attenuation are all included in the synthesized sound, just as they would be experienced by an observer in the real world. Additional environmental sounds such as traffic noise and crossing warnings can be added to the simulation to make the aural and visual cues as realistic as possible.

Realism is key, and that is where all of the simulators excel, offering incomparable context that decision makers can easily experience – rather than abstract numerical figures. With a binaural or 3D sound replay and dedicated jury evaluation tools, it enables the controlled evaluation of many alternative vehicle sounds. A range of engineering and jury evaluation interfaces allow assessors and engineers to interact with the NVH data in real time. Simple data preparation tools and user-definable traffic sound and behavior make the virtual models highly interactive.

The sound sources assigned to the virtual vehicle can be measured from an actual vehicle, such as in a pass-by source decomposition test, modeled and improved based on previous vehicles, or artificially created such as when assessing potential warning sounds on an electric vehicle. In every case, the ability to virtually interact with the virtual model and then auralize the designed sound can bring a step-change in the work processes of automotive engineering departments. It allows a wide variety of realistic scenarios to be experienced by a large number of people – in a very short time.

The NVH Simulator suite has been under development for more than 10 years in close collaboration with vehicle manufacturers and suppliers, to ensure that it fits the automotive market's need for faster, lower-risk development. A positive reception from customers has seen a significant number of automotive OEMs understanding the unique benefits offered for their vehicle development programs.

In addition to quiet vehicle applications, the Exterior Sound Simulator assists with evaluating the critical exterior sound quality of IC vehicles, and enables auralization of pass-by source-path contribution data obtained with Brüel & Kjær's other unique powertrain development systems.



Mapping the observer's route allows for a repeatable and very realistic assessment of the vehicle's sound

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ONLINE READER ENQUIRY NO. 528

Meeting market needs

Standardized, off-the-shelf products, as well as bespoke systems, are helping the key players in North America to push ahead with new EV and HEV designs

With its HQ in Tulsa, Oklahoma, Maccor designs all its own hardware and software inhouse, safeguarding the company's core expertise

Maccor started operations in Tulsa, Oklahoma, in 1986. As a company dedicated to the development of high-performance battery test systems, it had a nucleus of engineers experienced in emerging battery technologies and computer control systems, and has experienced continued and rapid growth.

In the past, the only commercial products available to evaluate battery performance had been designed and built specifically for lead-acid vehicle battery applications. These were relatively high power units without any high degree of accuracy; they had limited test programming capabilities, and collected data relatively slowly.

In the mid-1980s, when there was a resurgence in new battery technologies, it became obvious that the available battery test systems were inadequate. As a consequence, the founders of Maccor conceived an entirely different design for battery testing. The result was a system that provided extremely accurate results, collected test data at high speed, would test large numbers of batteries at the same time, and could be programmed to perform virtually any test sequence required.

Over the past 25 years, Maccor's innovative technology has enabled the developer to become the standard for most companies involved in the further research, development, and quality control of cells and batteries for a wide range of products and cell chemistries. This solid foundation provides the company with the knowledge, experience and resources required for the future. Maccor has earned a greater than 80% share of US-based business in its product area, and has a major share of the European market, as well as an expanding portfolio in Asia. The company has nearly 1,500 systems in regular operation in more than 45 countries – including the first system ever built.

Maccor designs all its own hardware and software, and this is an ongoing process. Most of the systems are customized to meet a customer's specific requirements, and from time to time customers also request customized features within the software. Over the years this has provided Maccor engineers with a wealth of knowledge and experience in the design and performance of these systems. This experience is being used to develop systems for the future, with even higher levels of performance, and additional features and capabilities, all using new computer technology.

Maccor is confident that it offers the widest range of features and capabilities of any manufacturer for this type of equipment, and if its standard equipment doesn't meet the exact needs of the customer, the company will customize its equipment to specific requirements.

In 2009 Maccor moved to a newer and larger facility due to increased sales volumes. This new facility has the capability to handle the present manufacturing demand, as well as having room for expansion to handle any future increase in demand.

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ONLINE READER ENQUIRY NO. 529

Meeting power challenges

A new transaxle design is realizing higher torque and better acceleration for electric vehicles

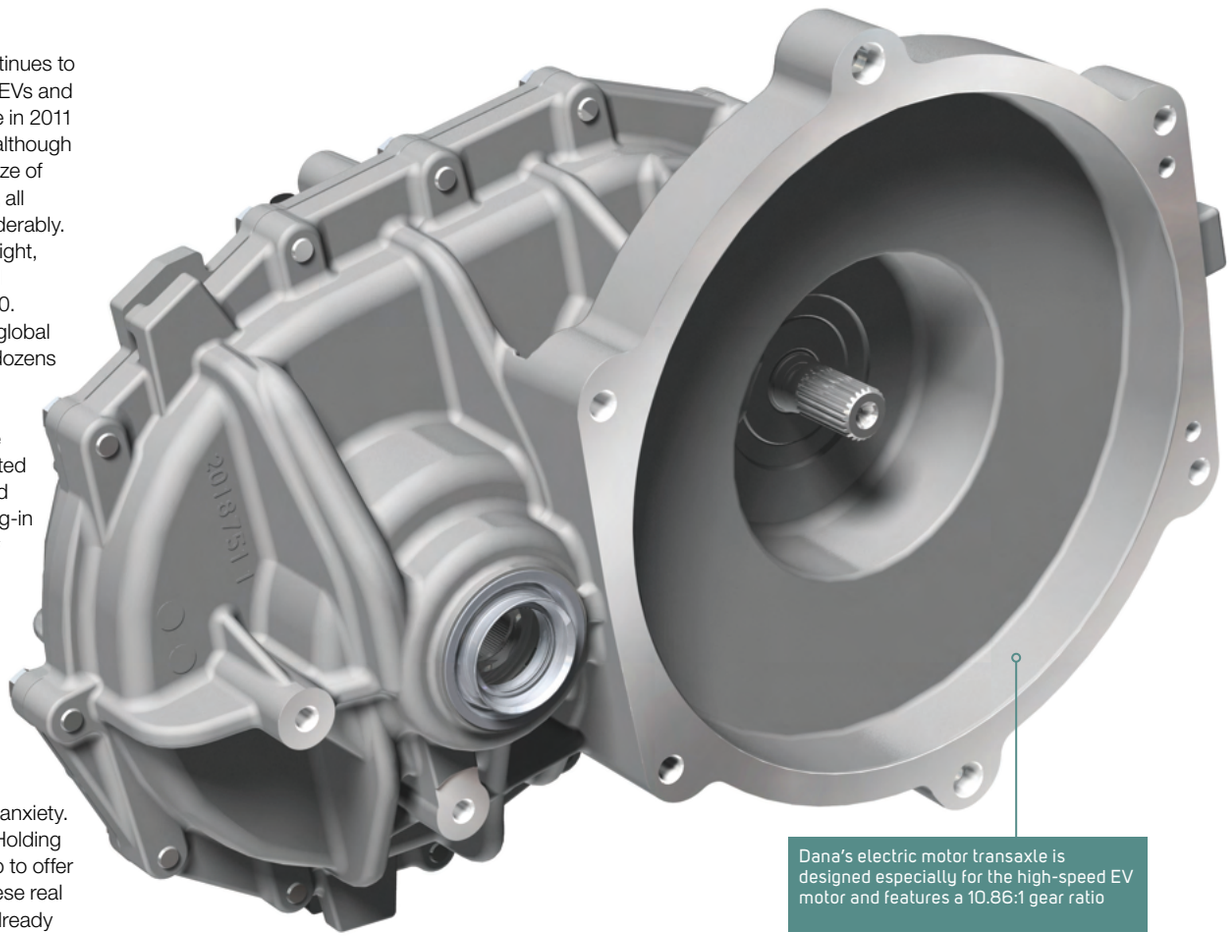
As interest in EVs continues to grow, around 40,000 EVs and PHEVs were sold worldwide in 2011 – the most in any year. And although reports vary on the actual size of the future global EV market, all agree that it will grow considerably. According to IHS Global Insight, EVs will make up 9.9% of all vehicles on the road by 2030.

Over the next few years, global auto makers will introduce dozens of models of EVs, fueling consumer interest and increasing sales. Overall the Asia-Pacific region is expected to experience the most rapid growth in the number of plug-in electric models, followed by Europe and North America.

As demand for these vehicles grows, so too will consumer expectations for performance and power. Auto makers will need to find ways to overcome consumer perceptions that most EVs are sluggish and reassure them about range anxiety.

Suppliers such as Dana Holding Corporation are stepping up to offer global OEMs answers to these real challenges. The company already supplies several key components to HEVs, including electronic cooling plates, electronic control units, stator coolers, chillers and inter-element cooling plates.

In 2013 Dana will launch its latest product offering for the EV market. The company's new single-speed, electric transaxle is designed especially for the high-speed EV motor and features a 10.86:1 gear ratio. This deeper gear ratio, coupled with a maximum torque of 265Nm, provides power and increased acceleration to EVs, enabling drivers to reach highway speeds more quickly. In addition, the electric transaxle's custom-made gearbox and high-quality helical gears provide improved NVH performance.



Dana's electric motor transaxle is designed especially for the high-speed EV motor and features a 10.86:1 gear ratio

"Our electric motor-driven transaxle offers major performance benefits over competing axle and transmission products for electric vehicles," says Steve Wesolowski, senior director of global engineering for Dana. "By combining the two components we've engineered a product that offers superior torque and power and delivers improved acceleration capabilities in electric vehicles."

Dana's electric transaxle will first be introduced on a front-wheel drive passenger van being launched in Taiwan and China, but eventually will be available globally. It is being manufactured at Dana's ROC Spicer facility in Taiwan, part of the company's global network of engineering, manufacturing, and distribution facilities providing original-equipment and aftermarket customers with local product and service support. As a world leader in drivetrain, sealing, and thermal-management technologies that improve fuel efficiency, reduce emissions, and lower the cost of ownership in passenger, commercial, and off-highway vehicles, Dana is developing advanced technologies to power electric vehicles. Based in Maumee, Ohio, USA, Dana employs approximately 25,000 people in 27 countries and reported 2011 sales of US$7.6 billion.

CONTACT

W. www.dana.com

ONLINE READER ENQUIRY NO. 530

Permanent magnetization

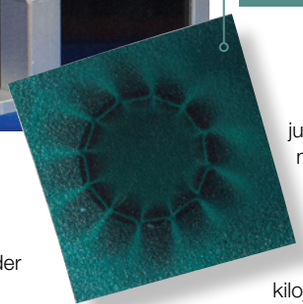
The process that involves magnetizing all magnets that are found within a vehicle is growing in importance as the industry demands ever more powerful batteries and electric motors

There are hundreds of permanent magnets in a vehicle. For example, they are in the DC motors that move the wipers when it's raining, they're in the DC motors that power the electronic windows, they are located in the tachometer, and they're even in the multimedia subsystem. Crucially, permanent magnets are also helping to fuel the growth of next-generation electric and hybrid vehicles, with the technology also featuring heavily in hybrid and electric motors and KERS.

However, it is vital that permanent magnets 'move' in an unmagnetized manner, and as such, they must be magnetized only at the last minute (or better still, once they're in their final position). Magnetization takes place by applying – even for a very short period of time – a magnetic field that's strong enough to move domain walls within grains. But what exactly is meant by the term domain walls?

Permanent magnets are usually composed of powder. It could be ferrite compounds, AlNiCos, or rare earths compounds. Powder can be isotropic or anisotropic, and can be mixed with plastic for molded bonded magnets, or pressed to obtain sintered, usually anisotropic, magnets. They can even be cast, but that is a much more complicated process.

Magnetizing rotors or stators of electric motors is easy, so long as the engineers have the right equipment available



Permanent magnets are usually composed of powder, such as ferrite compounds, AlNiCos or rare earths

At this point, it's important to note that the magnet has to be magnetized, but how is that made possible? Simply put, an engineer needs to take a solenoid and a current, and then create a magnetic field. But it's not enough. High power is needed and this high power is realized for a short time using a capacitor-discharging unit, where a large capacitor bench of capacitance is slowly charged for voltage in order for it then to discharge abruptly into a coil of inductance by means of a thyristors set.

Laboratorio Elettrofisico Engineering has the capacity and capability to perform full magnetization of rotors or stators of advanced electric motors

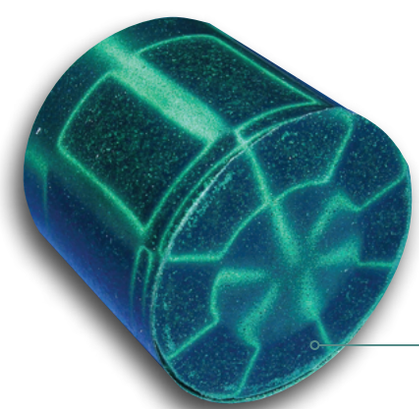
By properly setting the thyristors triggers, one can select either pulse or oscillating mode in order to magnetize or demagnetize the entire system. But this is only known as a principle circuit, which is quite complicated in terms of actual configurations.

Charged capacitors have an energy of 0.5*C*V^2 and it transforms in magnetic energy of 0.5*L*I^2, exactly when the current pulse reaches its peak. It is the peak current that magnetizes, so the higher the capacitance and the voltage, the higher the current.

The question then becomes, what is energy? Take a kilogram of iron and lift it 1m from the ground and you will be consumed by an energy output of 10J. By performing that maneuver, you will burn around 2.4 calories. Now, if you lift the iron for just one second, it will consume 10W of power, but lift it for 10 seconds and it will take a total of 1W of power.

Even if a magnet can retain just a few joules, in order to magnetize a 1cm^3 magnet, it essentially needs hundreds of joules; in exceptionally few cases, with very big magnets, a few hundred kilojoules will be required.

It's important to take into account that magnetization is instantaneous, so currents that are in the output of thousands of amps are able to do their job in just a few microseconds. Magnetizing rotors or stators of electric motors is easy, even in situ, and that's especially true if there are multipolar patterns. More interesting is the case of the sensors: in any given car, magnetic sensors read magnetic fields produced by permanent magnets. In this case, the magnet must be properly magnetized in well-spaced and aligned patterns, and this is the exact job that the specialist engineers at Laboratorio Elettrofisico Engineering perform on a daily basis for customers worldwide.



Permanent magnets are helping to fuel the growth of next-generation electric and hybrid vehicle applications

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Intelligent load management

The topic of energy management is an important area with regard to electric mobility. User requirements and behavior deviate frequently from the capacity of the energy network. As a result, intelligent load management is essential.

Cost-efficient concepts are required for the holistic and practical use of electric mobility and the exploitation of its advantages. These concepts must have the optimization and adjustment of maximum charging performance and the corresponding load profile as their objective, and this is precisely the goal of load management.

Load management enables the smoothing of the load curve of the connected vehicle by means of peak shifts, prioritization or distribution. Capacity is therefore employed in the best possible manner – costs are subjected to sustained reduction and resource consumption is optimized. The objective of load management is to reduce load peaks and thus smooth the volume of purchased electricity.

Intelligent charging solutions are charging points, which both now and in the future will fulfill more functions than merely the supply of power. Against the background of load management, they will serve primarily as a communication interface between vehicles and the load management computer. KEBA's KeContact P20 meets exactly these needs. The smart charging point enables easy, safe and fast charging – up to 10 times faster than with a standard socket. KeContact P20 is certified for the global market and offers a range of new and convincing features such as RFID, key switches, a PLC modem and Ethernet, and is available in several variations (Type 1, Type 2, and with fixed cable). However, the simultaneous charging of several electric vehicles may lead to charging capacity that exceeds the volume of power available. In order to avoid such cost-intensive load peaks and maintain charging power, a solution is needed that furnishes protection against overloads through intelligent compensation and thereby facilitates efficient, cost-optimized charging. KEBA's KeContact M10 represents the ideal solution as it distributes the available connected power to the vehicles undergoing charging in the most efficient manner. First and foremost, however, this prevents high load peaks and related expenses. Leading automotive manufacturers such as Daimler, energy supply companies such as Vattenfall and Verbund, and retailers such as Conrad, already trust KEBA and the company's high-tech smart charging solutions to meet future requirements today.

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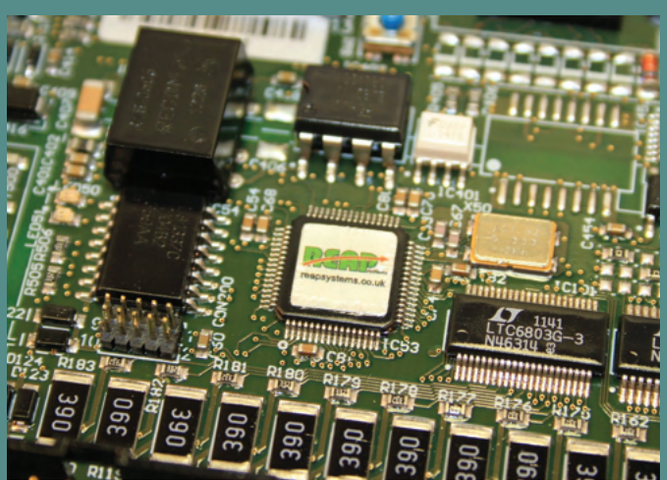
ONLINE READER ENQUIRY NO. 532

Lithium-ion systems and battery management



REAPsystem's core expertise is in systems with large lithium-ion cells. Since 2003, the company has established itself as a leader in the field of battery management electronics and its know-how encompasses a range of applications: including boats, underwater vehicles, stationary energy storage, military vehicles, racing, and other electric and hybrid automotive applications.

REAP's worldwide customer base consists of cell manufacturers, vehicle manufacturers, and research and development institutions. The company's engineering ethos is based upon an excellent knowledge and technical understanding of lithium-ion batteries and this is seen through the continued development of REAP's products. In 2013, REAP plans to launch its next-generation BMS product, called BMS21, which is able to manage up to 21 battery cells. The advanced technology allows for several BMS solutions to be connected in series to manage high voltage systems. In comparison to its predecessor (BMS14) BMS21 has simplified connections, a range of new functionalities, and other key improvements such as very low power consumption and data-logging.

REAP's technical engineering support team will enable customers around the world to produce prototypes within short timescales using their versatile and parameterizable BMS products. Based on customer requirements, REAP engineers can also offer customized solutions for series production.

REAPsystems
T: +44 23 8063 8527
ONLINE READER ENQUIRY NO. 533

DID YOU KNOW?

Ford unveils carbon fiber creation

Ford has unveiled a prototype carbon fiber bonnet that could help lower fuel consumption. The carbon fiber reinforced plastic Ford Focus bonnet is constructed from the super-strong material more usually associated with hand built racing vehicles or high-performance supercars. The prototype bonnet is 50% lighter than a standard steel part. As a result of an ongoing research project involving engineers from the Ford European Research Center, production time for an individual carbon fiber bonnet is fast enough to be employed on a production line – a major step toward using more lightweight materials, says Inga Wehmeyer, advanced materials and processes research engineer for Ford.

Stable and proven battery manufacturer

As a wholly owned subsidiary of the GP Batteries Group, EVB Technology benefits from the wide range of battery chemistries and types manufactured by the group to deliver confidence in its products. The selection of lithium ferro phosphate (LiFePO4) chemistry by EVB comes from extensive research into the characteristics of potential lithium options to provide a beneficial mix of price, performance, stability, and overall safety.

EVB's cells are constructed from a holistic approach with the notion of minimizing all elements of battery performance and harm in the system. The use of the prismatic cell format and black coated cans addresses the concern of internal heat build up by offering the most efficient, non-external assisted method for heat transfer out of the cells in order to keep the cells performing under demanding applications. The steel can gives robust protection against corrosion, as well as against chemical, mechanical, and environmental impacts without a bulky casing.

Learning from and engaging the whole manufacturing expertise of the GP Batteries Group, EVB can produce the cells in the most cost-effective way while enabling small batch runs to move your project from idea to testing to production without the heavy cost associated with greater flexibility.

EVB Technology
W: www.evbtech.com

ONLINE READER ENQUIRY NO. 534

Next generation ERA

In July 2012, Honda announced a technical partnership with Zytek to develop an Energy Recovery System (ERS) for its SGT 300 racing team. Having deployed the system initially at Sugo, the team completed the remainder of the season with the ERS system installed, demonstrating major performance advantages while exhibiting a perfect reliability record, and meeting the aggressive performance targets set by this ambitious team.

The compact, power dense 50kW hybrid traction drive motor has been developed to generate not only high levels of peak power, but also a high continuous power rating using advanced machine thermal management. Weighing just 8kg, the machine is directly coupled to the gearbox input shaft enabling not only high levels of energy regeneration and acceleration boost, but also operation in full electric mode if required.

The hybrid traction machine is controlled by the state-of-the-art power electronics controller, which weighs only 6kg, located adjacent to the high-voltage energy storage to minimize cable runs within the confined cockpit of the vehicle. Electrical energy is stored in Zytek's lightweight, 0.9kWh battery, combining not only state-of-the-art Li-ion cell chemistry, but also using a highly sophisticated battery-management system to ensure that cell performance is maintained during a race of up to six hours.

Total battery weight is kept down to 24kg through extensive use of lightweight materials and optimized internal cell cooling circuits. The total weight of the water-cooled ERS components is only 38kg.

Zytek Automotive
W: www.zytekautomotive.co.uk

ONLINE READER ENQUIRY NO. 535

Powering the Jaguar XJ_e

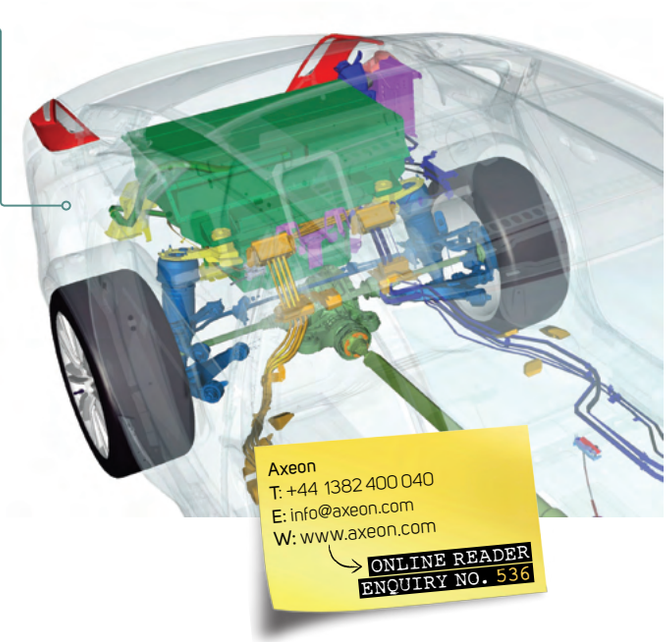
Jaguar Land Rover's XJ_e engineering research vehicle, an experimental plug-in hybrid version of its luxury Jaguar XJ saloon, is powered by Axeon, Europe's largest independent supplier of lithium-ion battery systems. The battery provides the Jaguar XJ_e with an electric driving range of up to 40km (25 miles) on electric power.

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

Batteries for both range-extended and plug-in hybrid vehicles need to offer a balance of power and energy, which is a more complex technical challenge than batteries for pure EVs that require high energy density, and batteries in hybrids, where high power density is needed. Therefore determining the most suitable cells and managing them is critical to developing a battery that meets the customer's requirements.

Two of the key challenges in developing this battery were: first, ensuring that the battery fitted into the minimum 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 performance. The tighter control through the thermal microgen software for cold and hot use is a new concept.

The demonstrator vehicle is the result of a collaborative R&D project funded by the Technology Strategy Board into range-extended electric vehicles and plug-in hybrid electric vehicles.



Optimal batteries for electric and hybrid vehicle designs

Maxwell Technologies' environmentally friendly ultracapacitor technology enables maintenance-free energy storage and power delivery solutions that improve performance, extend battery life and decrease weight and volume in electric and hybrid vehicles. Already applied to hundreds of thousands of vehicles, Maxwell's ultracapacitors are proved to enhance efficiency, safety, and reliability in regenerative braking, stop/start, peak-power support and boardnet stabilization systems.

Until recently, batteries such as lead-acid, nickel-cadmium and lithium-ion units have been the primary energy storage and power delivery source for these systems, but they are being reconsidered as the solitary solution to these applications as heavy cycling and temperature variations have proved detrimental to their overall performance and cycle life. Additionally batteries as the sole source of energy storage and power delivery in these systems have added weight and volume that are difficult for vehicle manufacturers to efficiently integrate into their designs.

Now, ultracapacitors and batteries are being combined to work highly efficiently together in these systems. Promising designs and hundreds of thousands of production vehicles are now using smaller, lighter ultracapacitors to provide burst power and quick energy storage, and fewer or smaller batteries to supply long-term energy.

Ultracapacitors with high power density and durability levels, cycle lives of more than one million charge/discharge cycles, broad temperature stability (-40°C to +65°C) and small, lightweight form factors, are helping batteries to perform far better and last much longer in today's best-performing electric and hybrid vehicle design applications.

Maxwell Technologies
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W: www.maxwell.com

ONLINE READER ENQUIRY NO. 537

Fuel cell power module development

The number of drivers for the adoption of fuel cell technology for commercial and hybrid vehicle power generation is continually increasing, opening many opportunities for OEMs to lead the development curve, offer distinct differentiation, and lead the way by demonstrating progressive innovation.

Rather than bare fuel cell stacks that are comparable to engine blocks without pistons, spark plugs, or fuel injectors, vehicle OEMs require fully functional fuel cell 'engines' – fuel in, power out – that can be easily integrated into existing hybrid electric platforms.

The Hydrogenics HyPM Power Module is a fully operating 'engine' that includes all components and subsystems required for the stack to operate, with options that vary in each integration, all of which enables integrators to tailor it to their own application.

The HyPM product, which was launched in 2002, has been a great success, and today the family of modules had grown to six stationary versions of 4, 8 and 12kW and over nine mobility variants rated 4, 8, 12, 16, 30, 90 and 180kW.

In comparison with other systems, the HyPM has enabled unmatched ease of integration. There is no need for onboard water, as humidification components are not required by the Hydrogenics design. There is also no need to source, test and validate air compressors, water pumps or other such components as they are all included within the HyPM design. Furthermore, the HyPM can be started/stopped at will – with no limitations – a great advantage for today's hybrid systems, with fuel economy under the microscope.

Hydrogenics
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ONLINE READER ENQUIRY NO. 538

Strong connections for electric mobility

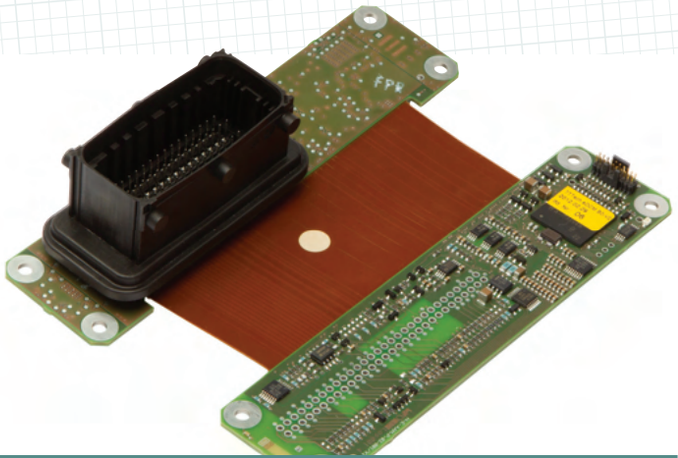
The future will run on electricity, and as a result the industry will very soon require a customized infrastructure for charging vehicle batteries. As a global specialist in connection technology and with more than 50 years of experience, Bals is already offering a comprehensive range of system components and the appropriate solutions for electric mobility.

As one of only a few manufacturers in this area, Bals offers the appropriate systems according to Type 1 as well as Type 2 standards and can thus provide plug-in devices as per IEC 62196-2 for European car models as well as for overseas electric vehicles. The Type 1 coupling SAE J1772 corresponds to the standard developed in Japan and the USA. The charging plug-in device can be easily assembled and designed for single-phase current with 250V and 30A. Additionally the plugs have two signal conductors for communicating with the vehicle.

The Type 2 charging system is a seven-pin plug-in device with three phases, neutral conductor and earth conductors as well as two signal conductors. The charging plug is designed for single-phase current with 230V and three-phase current with 400V. The charging currents range from 13A to 63A and are suitable for single-phase as well as three-phase terminals. In addition Bals also offers an EVCP2-Controller, which is responsible for communication between the vehicle and the charging station. Using the controller, the current levels can be continuously adjusted from 6A to 80A, so that only one component is needed for the different current strengths.

Bals Elektrotechnik
W: www.bals.com

ONLINE READER ENQUIRY NO. 539



Platform control units 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 safety levels (ASIL C or D). The hardware for the unit was developed in compliance with the current safety standard ISO 26262 ASIL D. The powerful controller kernel of the ePMU was specifically designed for safety-relevant applications in the automotive field.

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, which was jointly agreed with the vehicle manufacturer, 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 default set-point torque (set by the driver and measured at the pedal position and angular velocity of actuation) with the actual torque at the drive wheels. A particular challenge is the safe detection of the rotation direction in the speed range close to vehicle standstill (0 to 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
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ONLINE READER ENQUIRY NO. 540

Advanced solutions for electric mobility

Phoenix Contact is a worldwide market leader in the field of device connection technology and industrial automation solutions. Pluscon Power offers an extensive portfolio of products and technologies that enables the flexible, modular and efficient implementation of various concepts for a charging infrastructure.

The most important requirement for setting up a modern electric vehicle charging infrastructure is a reliable and universal connection system for charging stations and vehicles.

The new Pluscon combined AC/DC charging system supports the charging of electric vehicles with both DC and AC technology. Thanks to the inlet's universal pin connector pattern, only one charging socket is required for AC and DC charging, thus saving space and weight in the vehicle and the charge station.

If AC charging is taking place, the AC connector can be plugged into the inlet. The DC connector can be plugged into the same inlet for fast charging when on the move.

For solutions in charging stations, Phoenix Contact offers an extensive range of high-tech device connectors, cable assemblies and automation products including the new integrated EV Charge Controller.

Phoenix Contact is at the forefront of product innovation, offering solutions to meet the demands of the interconnected power infrastructure for today and into the future.

Phoenix Contact
W: www.phoenixcontact.co.uk

ONLINE READER ENQUIRY NO. 541

Technical recruitment services

Consilium Group (UK) provides an innovative recruitment service to HEV and EV organizations and professionals, both in the UK and internationally. Launched in 2001, Consilium Group has over 10 years of dedicated HEV and EV experience, and as a result is now established as a leader on a global scale. Consilium Group's enviable database, and network of vacancies and candidates, provides an innovative ability to match technical roles with industry specialists.

Consilium Group was built by degree-qualified engineers with real-world industry experience. So whether the client is looking to fill a new role or find a new job, Consilium Group recruiters can talk technically, whatever the discipline.

Consilium Group
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ONLINE READER ENQUIRY NO. 542

Next-generation traction inverter

Arens Powerpac Traction Inverters provide OEMs with compact, high power reliability for truck, bus, agricultural and construction equipment applications. The Arens next-generation traction inverters are the result of nearly 10 years of production experience in the most demanding applications. With over 400 million vehicle miles undertaken, Arens traction inverters can provide customers with reliable operation for years to come.

Arens Powerpac inverters feature one the industry's highest power-density outputs; high-tech automotive-grade components; one of the industry's leading power cycle life offerings; a cast enclosure sealed to IP67/6K9K; intelligent thermal protection; and one of the smallest footprints available.

The standard Powerpac Traction Inverter is rated for 360VDC Input with peak power of 60kVA, however many variations. Arens can provide custom variations for specific vehicle and system requirements. Whether the customer requires a traction inverter, export power or power distribution, Arens has the capability to meet all needs relating to hybrid vehicle solutions.

Arens Controls Company
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ONLINE READER ENQUIRY NO. 543

The third Taiwan International Electric Vehicle Show

EV Taiwan is an industry-leading event that showcases global green motoring products. It is also the prime marketing hub of Taiwan's burgeoning electric vehicle market and the launching pad for high-quality electric components and batteries.

EV Taiwan builds on the stellar results from last year's event, which hosted 11,375 visitors including 1,095 foreign buyers from Japan, China, South Korea, the USA, Germany, Malaysia, Hong Kong, Indonesia, the Philippines and Singapore. And the 2013 event promises to be bigger and better with 250 exhibitors using 750 booths, as well as an expected 15,000 visitors.

The third Taiwan International Electric Vehicle Show unfolds at the TWTC Hall 1 from April 10 to 13, 2013, as part of a mega four-show event that aims to reshape modern motoring. The program will feature electric vehicles (e-cars, e-motorcycles, e-scooters and other e-vehicles); drive and motor systems; energy storage technology; energy and recharging; infrastructure; and test systems and services. The event has been created in conjunction with TAIPEI AMPA, Motorcycle Taiwan, and AutoTronics Taipei.

Spotlight activities of the event include an international EV technology industry forum and EV test rides.

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ONLINE READER ENQUIRY NO. 544

Reliable protection for the latest technologies

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. These same components must survive harsh automotive environments, including high temperatures, corrosive fluids and vapors, and prolonged UV exposure.

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.

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.

Specialty Coating Systems
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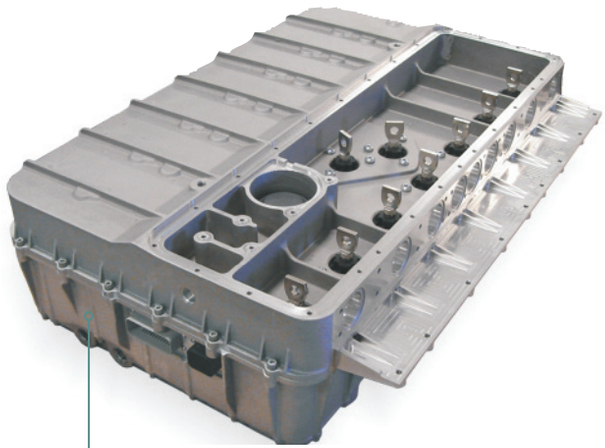
ONLINE READER ENQUIRY NO. 545



Rugged solutions for hybrid trucks and buses

Electric drive technology has been used in mining equipment and rail transportation for many years and is now finding its way into heavy construction machines, trucks and buses. Electric drive technology has penetrated automotive vehicle forms with a growing number of hybrid vehicles on the road. EDTA reports 2012 hybrid, PHEV, and BEV sales of 350,000 vehicles – a 3.26% US market share. As truck and bus fuel economy standards become law, commercial vehicle manufacturers will need to respond. These standards will add to the existing fuel economy-based market pull. Commercial vehicle manufacturers demand the ruggedization found in mining, but also seek the economies of scale from automotive.

Phoenix International fills this need with the Phoenix Drives product line of medium- to heavy-duty electric drives. Phoenix Drives incorporate robust design and test practices with product tooling and manufacturing setups that meet cost expectations. The Phoenix Drives PD300 is suited to full electric or parallel hybrid systems delivering 300A continuous current and up to 750VDC. The Phoenix Drives PD550 dual inverter is ideal for series-hybrid architectures with genset and traction control of up to 450A for each from a single physical unit.

Phoenix Drives are used on John Deere construction vehicles, Oshkosh's L-ATV, MAN's Metropolis refuse truck, Odyne hybrid work trucks, mining applications, and several other truck and bus vehicles not yet publicly released.

Phoenix International
W: www.phoeintl.com
ONLINE READER ENQUIRY NO. 546

Liquid-cooled resistors

Whether for the London Underground or a wind turbine, electrical systems must be designed to operate safely under overload and fault conditions – and to dissipate any unusable or surplus energy in a safe fashion. The most effective way of doing this is to turn the energy into heat in a resistor.

Resistors are still needed even when, as with a metro train or a hybrid electric vehicle, braking energy is used elsewhere on the network or for charging batteries or flywheels. This is because batteries and flywheels can't always be charged at the same rate as braking energy is created – or the unit itself may already be fully charged. Most vehicles are able to stop faster than they can accelerate: even an ordinary car can generate hundreds of kilowatts of braking power. The power that can't be stored must be dissipated, and that's why even the most efficient electric drive systems need resistors for safety.

Cressall has been designing brake, discharge and earthing resistors for trains, ships and buses for 70 years. In the past three years the company has invested in developing, patenting and bringing to market a range of advanced liquid-cooled resistors that are smaller and lighter than any others available. Using the latest materials and advances in heat-transfer technology, Cressall's 4EV2 resistor gives 100kW of continuous braking power for a weight of only 10.2kg.

Cressall
W: www.cressall.com

ONLINE READER ENQUIRY NO. 547

Motor performance evaluation time

pMOTION is a device that has a system embedded within it to evaluate motor performance in the process of preparation, measurement, computing and summarizing. As a result, this device makes possible a considerable reduction in time in all these fields.

An easy motor evaluation is made possible due to auto-measurement of parameters and an auto-tuning function. Such a setup means that the customer only needs to prepare the motor to be evaluated.

The technology is such that it enables the engineer to undertake repeated work of the sweep drive and pattern drive automatically. Furthermore, automatic segregation is possible when computing iron, cooper and mechanical losses. An automatic summary report is available for N-T/I-T characteristics, efficiency map and other measured results.

In the real-world business environment, where R&D activities are very time and cost sensitive, reducing the time it takes to realize development with a technology like the pMOTION device enables development costs to be minimized.

Myway Plus Corporation
T: +81 45 548 8831
W: www.myway.co.jp

ONLINE READER ENQUIRY NO. 548

Lithium-ion battery technology for motive power

The latest addition to the acclaimed Hawker XFC range from EnerSys is the company's first motive power design with advanced lithium-ion technology. The 24V Hawker XFC-Li with 38Ah capacity offers major benefits compared with conventional units including greater power density, longer pack life and excellent performance at low temperatures.

The unique properties of XFC technology, including low internal resistance, mean the battery can be opportunity charged during inactive periods, irrespective of state of discharge, without degrading its long-term performance or reliability. It is ideal for duty cycles lasting up to 45 minutes and where operators want to maintain equipment availability without the complexity and cost of additional infrastructure. This includes intermittent handling applications such as offloading delivery vehicles and replenishing displays in retail environments.

The onboard high-frequency charger promotes rapid, energy-efficient charging. The battery can be fully recharged in under an hour from 80% depth of discharge. Onboard battery management protects against over-temperature, over-charge, over-voltage, under-voltage and short circuits. An LED indicates charge state and an integrated CAN bus supports external links.

The battery is totally maintenance free and requires no topping-up with water, giving a low overall cost of ownership. Rugged casing and the integrated design allow OEMs to specify the battery for plug-and-play and power-on-demand applications.

EnerSys
W: www.enersys.com

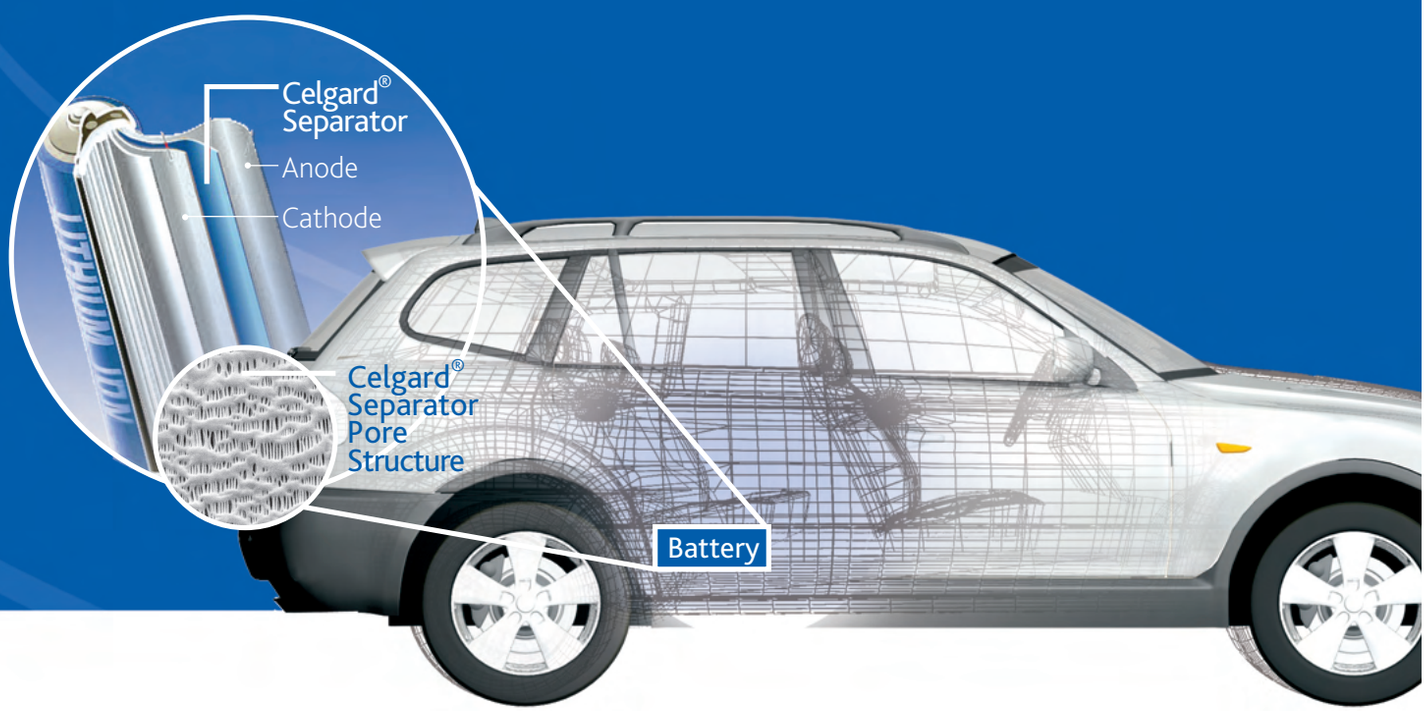
ONLINE READER ENQUIRY NO. 549

DID YOU KNOW?

Renault announces wireless charging plans

Renault has confirmed that it will participate at the Wireless Electric Vehicle Charging (WEVC) London trial, and at the same time the French car maker also announced that it is to start preliminary R&D studies focusing on the integration of Qualcomm Halo WEVC technology into some of its vehicles.

The Future Is Here



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Making micro hybrids more efficient with ultracapcitors

Due in part to federal regulations on vehicle fuel efficiency and carbon emissions, automotive manufacturers are paying more attention to energy-storage technologies. For example, manufacturers strive to improve stop/start technology, which enables micro hybrid vehicles to shut off the engine while stopped in traffic in order to save fuel and reduce emissions. However, in stop/start applications, running loads during stop/start events consumes a lot of energy, requiring frequent recharge of the energy storage system. With successive stop/start events, lead-acid batteries fall short due to their poor charge acceptance and need for continuous charging over a long period of time rather than short bursts of charging. This does not allow fuel cut-off or energy recovery. Successful stop/start and mild hybrid applications require faster-charging energy-storage systems.

Micro hybrids are a growing market for ultracapacitors, which do not have the same shortcomings as lead-acid batteries. Ultracapacitors recharge quickly and have a high cycle life, making them a prime technology for providing a quick burst of power to launch a vehicle for acceleration.

loxus
E: chall@ioxus.com
W: www.ioxus.com

ONLINE READER ENQUIRY NO. 550

Extensive experience in polycarbonate glazing

Weight saving is a crucial point in the development of both sports cars and electric cars. In the search for lighter construction, today's developers apply a range of high-tech materials to the end application, such as exotic alloys, reinforced polymers and smart hydride composites. However, a well-established solution that sometimes receives less attention in this area is lightweight, transparent polycarbonate (PC) for automotive glazing, such as KASIGLAS mar-protect.

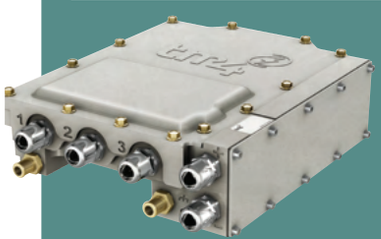
There might still be valid reasons for banning the use of PC in automotive windshields, but for other applications this technology can offer numerous benefits, especially as most technical challenges previously preventing PC-glazing in cars have for many years been overcome.

A leader in this demanding field is the KRD Group, located in Geesthacht, Germany. KRD's KASIGLAS – thermoformed PC sheets treated with polysiloxane coatings developed with almost two decades of premium formulation experience – combines high transparency with extremely low optical disturbance and excellent abrasion- and UV-resistance.

KRD Group
W: www.kasiglas.de

ONLINE READER ENQUIRY NO. 552

Power electronics innovations



TM4, a Canadian manufacturer of electric motors and power electronics, unveiled in 2012 a new generation of motor controllers equipped with its innovative Reflex gate driver technology. Combining many hardware and software improvements, the new CO150 controller uses the Reflex gate driver technology to anticipate a voltage peak on the IGBT, thus ensuring that it never reaches the voltage limit. TM4 also uses an Infineon HybridPACK2 but designs and manufactures its own gate drivers. Most companies using the same module limit the current to 450A, whereas TM4 limits it to 650A.

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, so it has no negative effect on efficiency and temperature.

TM4 is offering its CO150 motor controller as part of its MOTIVE B electric and hybrid powertrain system, but it has also been adapted to many third-party motors and generators. Used in several automotive, commercial vehicle and motorsport applications, the CO150 is a versatile and very powerful motor controller with an unmatched current density.

TM4 has a production capacity of up to 20,000 units per year and can supply OEMs and motor manufacturers with validated production units.

TM4
E: transport@tm4.com
W: www.tm4.com

ONLINE READER ENQUIRY NO. 551

Rotor-position sensor designed for HEV and EV needs

Optimized control of electric motors requires precise knowledge of the rotor position. Optoelectronic or magnetic incremental sensors, or inductive resolvers, are often used to measure the rotor position in industrial motors. However, synchronous motors for electric and hybrid vehicles have special needs that these traditional sensors cannot always meet.

For this reason EFI Automotive has developed an Electric Motor Position Sensor (EMPOS) based on eddy-current technology. Less than 10mm thick and weighing under 100g, the sensor can be easily integrated into HEV and EV applications. Its sealed package is designed to keep water, oil and pollution out. With no ferromagnetic parts, it is insensitive to EMI, vibrations and positioning errors. In addition the trigger wheel has been designed to keep production costs down.

The sensor delivers +/-1° accuracy (electrical) at speeds up to 200,000rpm electrical, more than enough for EV and HEV requirements. An ASIC handles the entire signal-treatment chain, including analog and digital processing. It includes diagnostic functions to avoid false position information in the event of any single failure.

The sensor sends position and diagnostic signals to the motor controller via either analog SIN/COS (modulated or not) or an SSI based digital serial interface. The digital interface eliminates accuracy losses due to analog/digital conversion, noise and EMI.

Standard prototypes for testing are available from EFI Automotive on request. Mass production is scheduled for 2015.

Electricfil Automotive
W: www.electricfil.com

ONLINE READER ENQUIRY NO. 553

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OpenECU at heart of electric Defender

Jaguar Land Rover chose Pi Innovo, the vehicle electronics innovators, for a fast track collaboration to create an eco-friendly electric variant of the Defender chassis. The challenge was to design and build, within six months, a quiet, eco-friendly electric vehicle for taking tourists on game viewing trips in South Africa's excellent reserves.

The key to minimizing cost and development time was to maximize the use of standard components and focus all drive control development on one central ECU. This supervisory ECU is connected to the inverter/motor, battery, driver controls, power steering rack and a standard instrument cluster with modified graphics.

An OpenECU M250 ECU from Pi Innovo had the right combination of robust construction and flexible development environment to enable control strategies developed in MATLAB/Simulink to be quickly deployed and modified in the field.

The Pi Innovo team was then able to use its expertise across a wide range of powertrain and chassis domains to implement the major functionality, including start up and shutdown sequencing, integration of all driver controls, calculation of torque set point, management of limp home functions and revised cluster functionality.

The Jaguar Land Rover and Pi Innovo collaboration delivered more than a fully functioning vehicle in time; it delivered a vehicle that potential customers agreed gave the driving experience to justify the Defender badge.

Pi Innovo
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W: www.pi-innovo.com
ONLINE READER ENQUIRY NO. 554

High-dynamic test-bench energy system

With its ERS series, Heinzinger offers bidirectional high-dynamic systems with active energy recovery. ERS units are available from 50kW up to 160kW as off-the shelf products and up to 300kW in customized version. Along with battery simulation and inverter validation, testing and verification of high-voltage batteries for EV and HEV systems is a typical application of these units.

The power supplies are liquid cooled and able to reproduce real-world conditions during a test cycle by using high-speed regulation and communication to reach continuous transitions between source and sink mode.

A few important features for the testing of HEV batteries are the cableless connection to the supply, the protection by setting of end-of-charge or end-of-discharge values for the voltage, as well as the control of current rise times along with the remote access to the internal insulation measurement.

Standard ERS units comply with these requirements and are available as single- or dual-channel units that offer a wide range of output configurations. Dual-channel units enable energy balancing between two output channels so that the energy consumption from the mains is reduced to the minimum. These units are much more cost-effective than two single units and an upgrade from a single to a dual unit is also possible at a later time.

Heinzinger
T: +49 8031 2458 61
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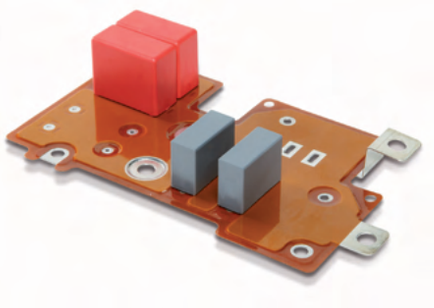
W: www.heinzinger.de
ONLINE READER ENQUIRY NO. 555

DID YOU KNOW?

Audi EV shatters Nürburgring record

In preparation for its production debut, the all-electric Audi R8 e-tron has set a world record for a production vehicle with an electric drive system on the Nürburgring Nordschleife. Racing driver Markus Winkelhock piloted the high-performance, all-electric sports car around the demanding 12.92-mile track in 8:09.099 minutes, which means that Audi has achieved yet another milestone in its history, following overall wins at the 24-hour races at the Nürburgring and Le Mans. The drive system of the Audi R8 e-tron that Winkelhock drove to the world record is identical to that of the road-going model that will enter production toward the end of the year. The car's electric motors generate a combined output of 280kW and 820Nm of torque; more than 4,900Nm is distributed to the rear wheels virtually from a standing start. The Audi R8 e-tron accelerates from zero to 62mph in just 4.6 seconds.

Power distribution systems for HEV and EV applications



Growing electrification in future cars will drive the need for reliable power distribution solutions in both powertrain and battery interconnection. The trend for higher power and improved energy storage results in the need for higher current and higher voltage capabilities and requires several electric functionalities within strict mechanical and thermal boundaries. Long-term reliability in harsh environmental conditions, vibration and crash resistance are increasingly essential.

Many applications in a EVs and HEVs 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, flexibility and ease of installation.

RO-LINX PowerCircuit busbars and RO-LINX Hybrid are two products in the RO-LINX family, custom designed to meet 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 hybrid and electric cars. Rogers has been developing and manufacturing laminated busbars for more than 40 years and can leverage its knowledge in electric propulsion drive technology for trains and off-road vehicles into HEV applications. Rogers has a worldwide presence and its manufacturing is ISO/TS 16949 certified for automotive projects.

Rogers Corporation
W: www.rogerscorp.com/pds

ONLINE READER ENQUIRY NO. 556

Smarter charging

Lear's Advanced Vehicle Smart Charging System builds further on Lear's long expertise in high-power electrical power management systems that provide many hybrid and electric vehicle solutions for leading OEMs. This next phase in Lear innovation enables smart and safe recharging of electric vehicles, including power line communication for smart grid functions to transmit crucial data for customers and enable flexible options for end consumers.

With an emphasis on performance, safety and ruggedness, Lear's energy management systems include standalone and complete integrated power modules for all types of hybrid and electric vehicles, designed to optimize packaging, efficiency and cost.

Lear's line-up of products also includes onboard battery chargers, travel charge cord set, wall-mounted fast-charge station and the charge receptacle and terminal and connector systems for its charging systems, including proprietary round pin terminals that are capable of high amperage and durability cycles but with low insertion force. Lear offers the most innovative high power distribution systems, which include terminals and connectors, high-voltage wire harnesses, manual service disconnects and high power distribution boxes.

Lear
W: www.lear.com

ONLINE READER ENQUIRY NO. 558

Sustainable cities and much more

The sixth edition of the Macao International Environmental Co-operation Forum & Exhibition (MIECF) will be held 21-23 March 2013. 2013MIECF will continue to serve as a high-powered platform to promote solutions for a low carbon future and sustainable city development. Initiated and actively led by the government of the Macao Special Administrative Region (Macao SAR), MIECF is strategically positioned to nurture business, technology and information exchange and cooperation between the Pan-Pearl River Delta Region in Southern China and the international markets.

Through a range of activities such as the Green Showcase and the Green Forum, 2013MIECF facilitates business exchange among southern China and international industry players. The event will feature green solutions from the region, including electric, hybrid and fuel cell vehicles, charging stations, battery and storage solutions and much, much more.

MIECF Secretariat
W: www.macaomiecf.com

ONLINE READER ENQUIRY NO. 557

High-tech traction-inverter solutions

Rinehart Motion Systems (RMS) offers some of the smallest, lightest, highest performance EV/HEV power-electronics and traction-inverter products available on the market today. RMS provides electronics to teams at the pinnacle of motorsports, including Formula 1 KERS controls for two cars in 2009 and six cars since 2011; Drayson Racing's EV LMP Prototype; Tajima Motor's Pike's Peak EV; and many other applications. Furthermore, RMS has more current first places and world records in electric motorcycle racing than any other supplier. The company also serves the highest performance on-road supercar development programs, including the new Lotus Evora 414e, the Infiniti EMERG-E and many other development projects that can't be revealed but would surprise most readers.

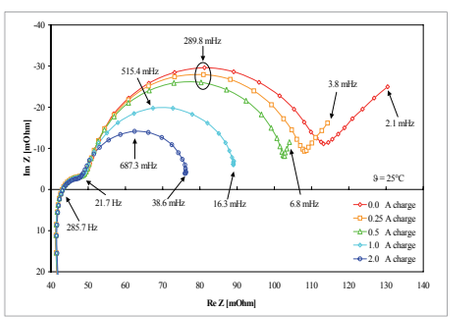
With one of the most experienced teams in the industry, RMS offers standard and bespoke products for military vehicles, on-road passenger cars, trucks, delivery vehicles and other demanding applications.

Rinehart Motion Systems
T: +1 503 344 5085
W: www.rinehartmotion.com

ONLINE READER ENQUIRY NO. 559

e-mobility Battery Safety Testing

A Lithium-Ion battery is a complex device that has to pass many demanding tests, just like any other component in a car. This is especially important as the battery is integrated with the car's chassis and thus becomes a vital part of the vehicle. Phoenix Testlab operates such a dedicated specialized laboratory in Blomberg, Germany, using Digatron Firing Circuits' test equipment.



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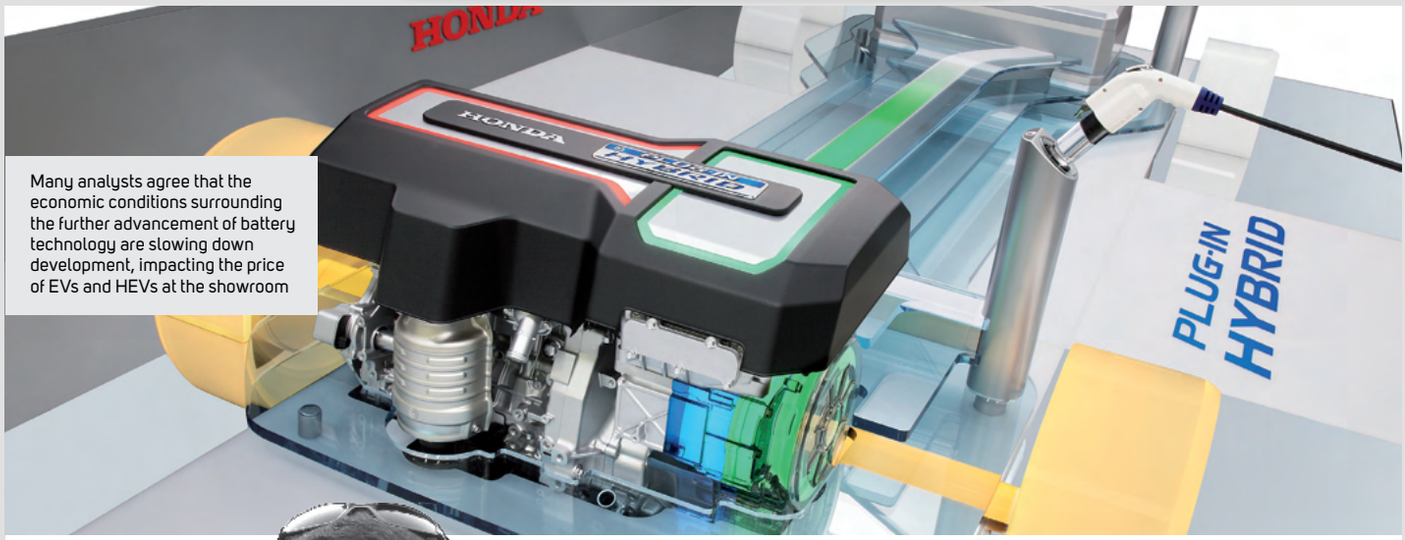
LAST **WORD**



Many analysts agree that the economic conditions surrounding the further advancement of battery technology are slowing down development, impacting the price of EVs and HEVs at the showroom

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

I had a discussion with someone recently about the economic viability of electric vehicles. They had calculated that the cost per cycle for a range of typical lithium-ion batteries, which is simply the cost per kWh divided by the number of rated cycles, and compared this figure to the cost of diesel, which stands at US$4 per gallon or roughly 10 cents per kWh. His opinion, therefore, was that until the cost per cycle of batteries is less than 10 cents per kWh, they are not economically viable – and that's before the cost of the electricity to recharge them is even considered.

For a simple approximation – and looking at current battery technologies – prices range between US$1,000 and US$2,000 per kWh for good quality battery packs that offer longer life cycles. The end result is a cost base of 25 cents per cycle. However, a low upfront cost isn't necessarily cheaper, as the cycle life is likely to be compromised, often making poor quality cells more expensive per cycle. Looking at industry projections, the crossover point could be around 2020 based on current trends. But with what is effectively a new technology for the automotive industry, until either the fundamental cost comes down to below five cents per cycle, or the cost of fossil fuels goes up considerably, it is going to be difficult to develop mass-market products based on these economics alone.

> "However, a low upfront cost isn't necessarily cheaper, as the cycle life is likely to be compromised"

Of course all this is based on a very simplistic set of assumptions and also serves to highlight problems with how we compare batteries. The number of full discharge cycles under continuous steady state charging and discharging currents often bears no relation to how the cells are used in the actual vehicles. This is a function of not just vehicle design, but how the customer uses the vehicle, and even where said vehicle lives. The other problem is that cells are very non-linear devices and operating them at extremes, close to 100% and 0% of charge, storing them at high temperatures, operating them at cold temperatures and subjecting them to high charging, will all cause faster degradation and greatly limit their cycle and shelf lives. Therefore we need to not only reduce the fundamental costs of the batteries, but also understand how to use them better.

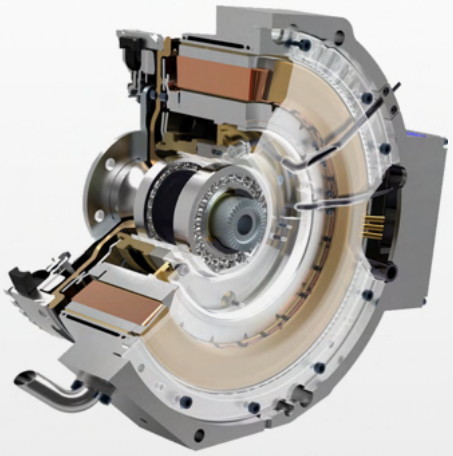
The calculations for hybrids are also different. The energy flowing into and out of the cell is smoothing a drive cycle in some way, and it is the amount of fuel that is saved that matters. Hybrid batteries are normally designed to be more durable but store less energy, and are operated across a narrower operating window where degradation is minimized. Therefore less capacity is used but the cells last longer. The same metric, cost per cycle, can still be used but is more complicated and often very specific to how the vehicle is used.

Ultimately we need to move toward targets for cell developers that take into account cost and reliability. Arbitrarily driving down cost per kWh doesn't help anyone. In the long run, what's important is that informed users of batteries will understand these complexities and the industry will only purchase cells that they know will meet their product specifications.

Technical excellence in electrical drive systems

hofer e-mobility

hofer powertrain was established in 1980 and is now a very strong and compact, full service engineering company for the automotive industry. The technical core skills of the hofer group are mechanic, electric and hydraulic components, modules and systems combined with a high level of expertise in software, testing, industrialization and series production for complete drivetrains.
hofer e-mobility utilizes the know-how of all hofer competence centers for the development of electric or electrified drivetrains. hofer e-mobility has more than 20 years expertise in development of electric powertrain systems and its components from the white sheet to series.



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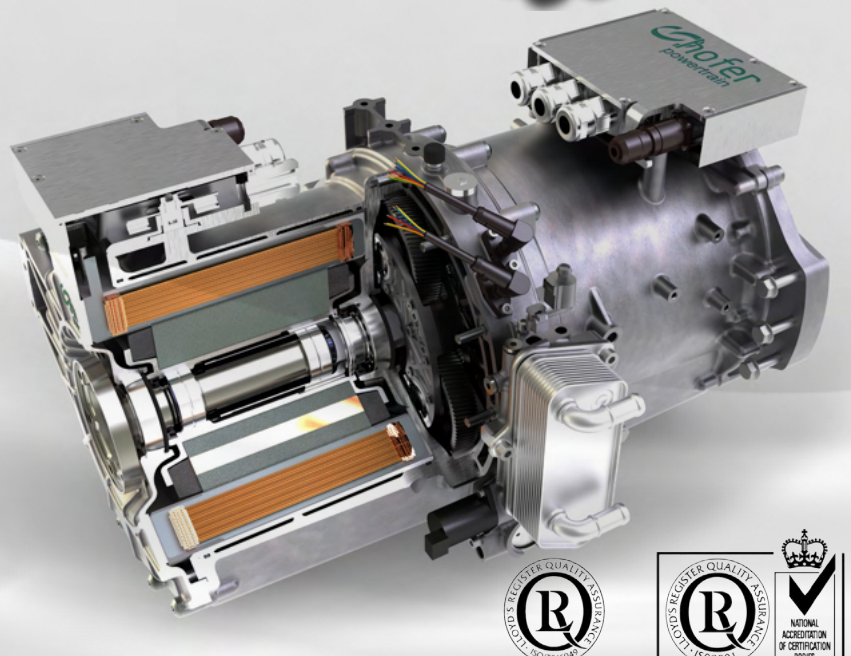

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Driving Innovation

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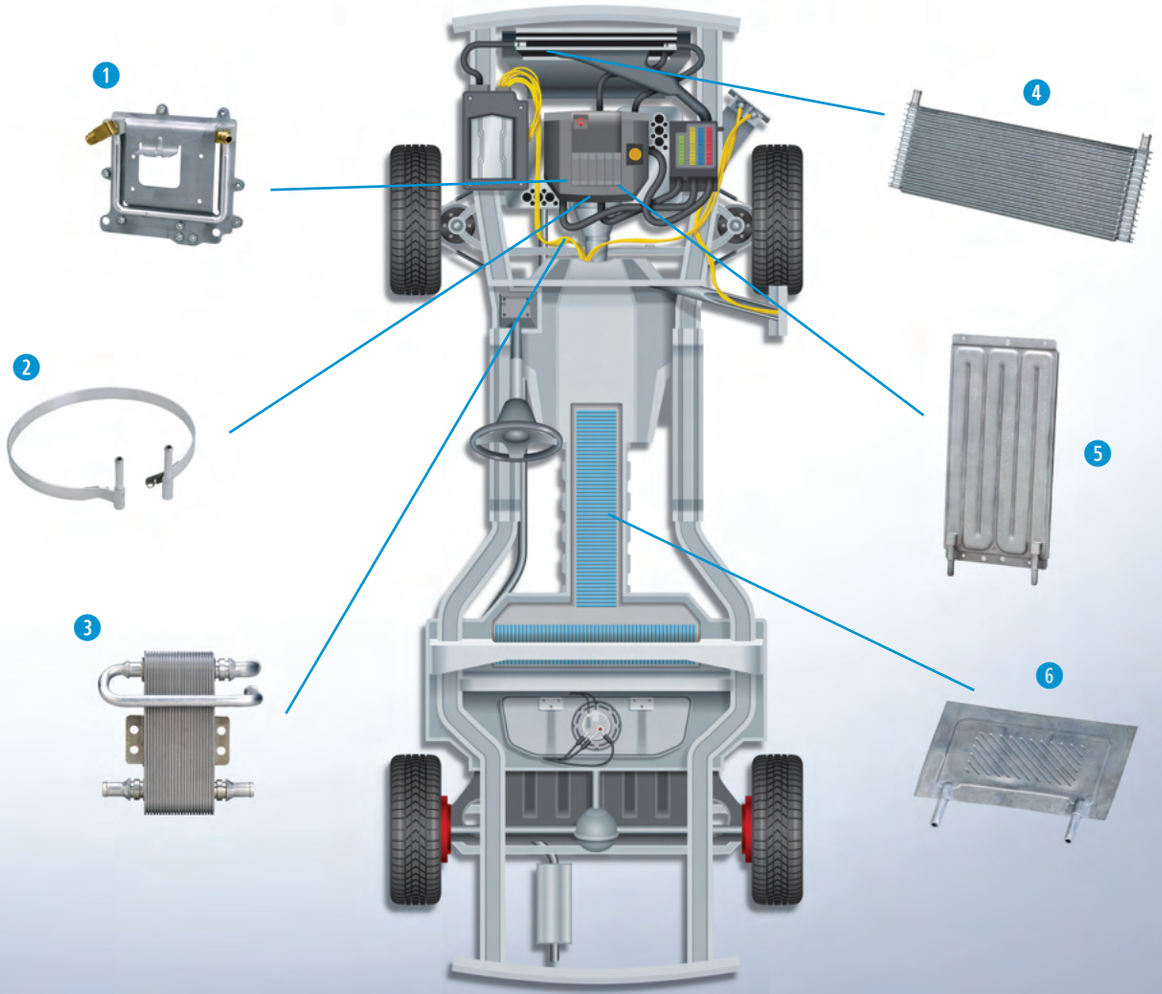

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