electric & hybrid vehicle technology international

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January 2014

PORSCHE 918 SPYDER

Up close and personal with the Nürburgring lap time king, Porsche's record-breaking 918, a hypercar that changes the game

Range Rover HYBRIDS

13 countries, two continents, 16,000km and every type of extreme weather imaginable! ***E&H*** goes on the Silk Trail pilgrimage with **Land Rover** and the final verification testing of its first ever alternative powertrain models

January 2014

CHEMICAL ATTRACTION

What technologies will follow current lithium-ion solutions? Battery scientists and automotive R&D engineers have their say

ON A CHARGE

The key technological and political hurdles that wireless charging needs to overcome in the next five years

MATTER OF COURSE

With less than a year to go, manufacturers and authorities in the FIA Formula E program discuss the sport's wider implications

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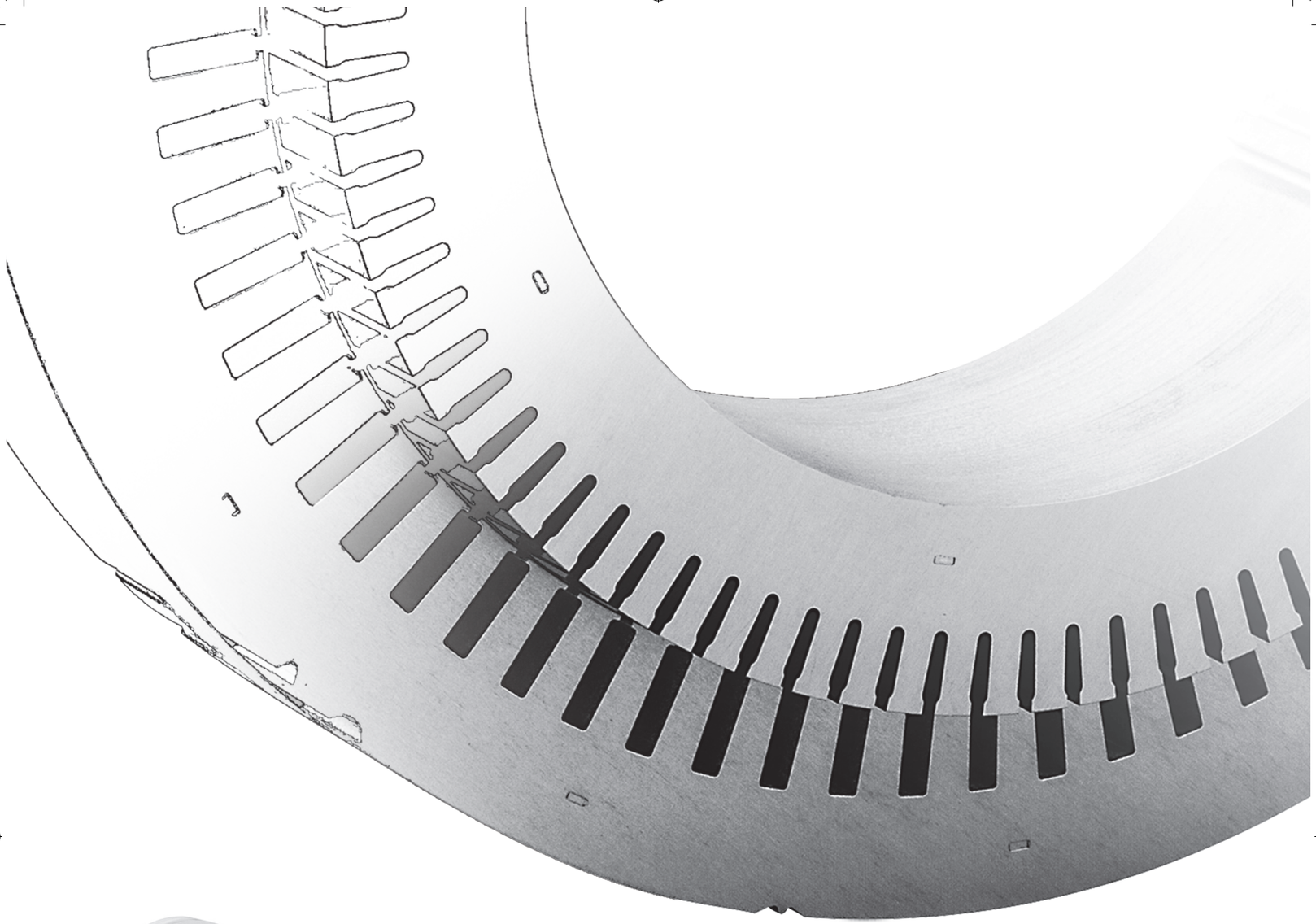

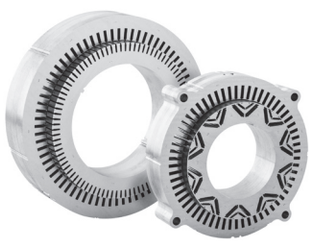

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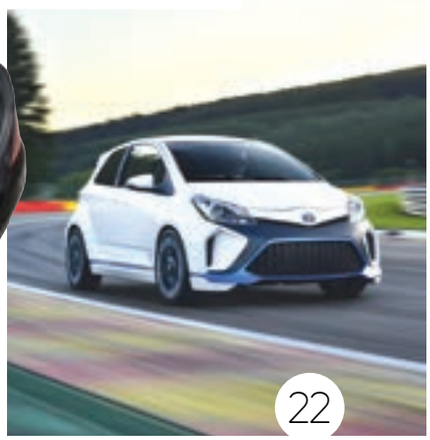

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EDITOR'S NOTE

During my 12 or so years as an automotive journalist, I've been fortunate enough to drive some truly wonderful and amazing vehicles that are – or at least were – exemplars of cutting-edge development.

I honestly thought I'd (more or less) driven all across the broad automotive spectrum, from lightweight supercars to the all-important mass-market family hatchbacks; pioneering prototypes, some of which never made it to production; as well as electrified vehicles that herald a new automotive age. And then in late October, Volkswagen called me to ask if I wanted to be one of the few UK journalists to get behind the wheel of the groundbreaking XL1.

Sometimes we – and when I say 'we', I mean car journalists and perhaps more so, the PR, comms and marketing teams for car makers – use words like 'groundbreaking' far too readily. But in the case of the XL1, groundbreaking doesn't even scratch the surface. Like the Audi A2 of yesteryear and the BMW i3 of today, the XL1 is a creation that's well and truly ahead of its time. So to spend 40 minutes driving one was an opportunity only a fool would turn down, especially as only 250 examples will be built.

Every part, every surface, every subsystem of the XL1 is pioneering in every respect. Forget the Bugatti Veyron, which some say is the automotive industry's 'Concorde' moment, the XL1 is a technology masterpiece and, in my opinion, far more relevant. Here's a car that's rated 0.9 liters/100km (313mpg), emits 21g/km of CO_2 and weighs just 795kg. Here's a car that features an advanced plug-in hybrid powertrain consisting of a two-cylinder diesel engine, an electric motor, seven-speed DSG and lithium-ion battery pack, all tipping the scales at a mere 227kg. Here's a car that's incredibly aerodynamic – Cd 0.189 – and is a showcase for exotic materials and intricate production processes. And here's a car that was 10-years in the making, with this, the third-generation iteration, being able to do 0-100km/h in 12.7 seconds before hitting a top speed of 160km/h thanks to the e-powertrain's combined 75ps and 260Nm of torque.

But as I prepared to sample the XL1 firsthand, I put aside all my positive preconceptions of the car, perhaps subconsciously thinking this revolutionary piece of design wouldn't live up to my lofty expectations.

How wrong I was. The XL1 is – and this is by no means a criticism – so easy to drive, it's unreal. Despite being so innovative, this truly remarkable development is an everyday vehicle and that feeling is heightened even more by it having similar interfaces and system layouts to, say, a VW Polo or Golf. Critics say there's no luggage space, it's expensive, it's not practical – but these people are not just missing the point, they are so wide of the mark that they're off the scale!

Most importantly, though, is this: prior to driving the XL1, I thought this creation was all about high-end technology and little else, but actually there's another, very important facet that probably only becomes apparent when you are behind the wheel of the vehicle. You see, the XL1 actually challenges the driver to drive intelligently, using different driving modes at different stages to optimize the journey. For example, as we approached a hill, I used the two-cylinder TDi to muster up enough speed to overcome the sharp incline, only to coast down it and enter a village at 48km/h (30mph), pass through the high street and stop at the lights without needing to accelerate, saving energy and allowing the battery to partly recharge. Now, add in the knowledge of your everyday commute, where you know every hill, decline, slow corner and fast straight, and you get where I'm coming from.

You see, the XL1 is not just a car rewriting automotive technology; it's a development that is helping to shape the automotive world as we know it.

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Brave new world

WORDS: MATT DAVIS

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1

Hot on the heels of the McLaren P1 and Ferrari LaFerrari is Porsche's 918 Spyder, proof that in a world of all-new advanced e-powertrains, hypercars will never be the same

If one were to put gradations of magnitude on the hottest powertrain developments in the automotive world at present, the two at the very tip of that hierarchical order could well be (at the time of writing, of course) the BMW i3 and the Porsche 918 Spyder. They are at very distinct ends of the alternative propulsion scheme spectrum, but each makes a valid proposal for ditching forever our traditional greasy ways of seeing the automobile powertrain, whether it be for city sessions or supercar hot laps.

So, having brought you the technology story behind the i3 a year ago, for this issue of *Electric & Hybrid Vehicle* we're at the supercar end of the EV agenda and the raconteur in great part is Porsche AG's technical master of all things 918, Frank Walliser, who was formerly the general manager of motorsports strategy for the hallowed Weissach skunkworks that we all routinely drool over.

To start with, Walliser is very quick to dive in with a history lesson, reminding us that Porsche has been revolutionizing things with carbon-fiber reinforced plastic (CFRP) for 15 years, beginning in 1998 with the supreme machine called GT1. This extensive experience and expertise in CFRP, says Walliser, is critical to the car maker's future projects, including the 918.

For the 1,640kg Spyder (that's weight without human flesh in the seats), Carbo Tech of Salzburg, Austria, has created, in the supercar's monocoque, the most complex piece of resin transfer molding (RTM) carbon compound structure ever designed. The Spyder chassis-with-body returns a 40,000Nm/d static torsion figure – and that amazing number comes from an open car. It would seem that the romantic days of autoclaving might be seriously numbered. "Lamborghini was at full capacity production anyway, so we couldn't just go to them," adds Walliser, somewhat tongue-in-cheek.

Beautiful 8,400rpm memory

After this re-education on Porsche's longtime relationship with CFRP chassis and body bits, Walliser happily jumps into responding nicely to our long list of questions about the engine and powertrain that drives this groundbreaking Porsche. It should be remembered that this is a longer than normal discussion, as the 918 has been a ground-up affair involving a new IC unit, new ECUs (and plenty of them; more on this later), playing extensively with an existing transmission, and then enhancing everything with a sometimes series, sometimes parallel, plug-in electric system. Then putting it all together in roughly three years with the Weissach package upgrade and lapping the Nürburgring Nordschleife in the hands of driver Marc Lieb in just 6 minutes 57 seconds. The Type 980 Carrera GT and its naturally aspirated 620ps 5.7-liter V10 powerplant has, with the dawning of the 918, become a beautiful and somewhat distant 8,400rpm memory.

1: Dr Frank Walliser, 918 Spyder project manager, says the M18 V8 owes nothing to the MR6 engine in the racing RS Spyder

2: Prototype testing of the 918 Spyder commences prior to final sign off. The development program spanned three years

3: Lavish use of CFRP and a complex piece of RTM carbon compound structure means that the Spyder weighs 1,640kg

3

1: The 918 Spyder complete with the Weissach package currently holds the lap record for road vehicles on the Nürburgring Nordschleife, with a time of 6.57 minutes

2: Manufacturing of the 918 Spyder and specifically the engine assembly line at Porsche's Stuttgart-Zuffenhausen plant

3: For thermal reasons the emission system of the 4.6-liter V8 is arranged inside the cylinder V with end pipes to the top

The direct-injected 616ps 4,593cc M18 beltless V8 in the 918 Spyder all on its lonesome is a whopping 40% more efficient and CO_2-clean than the Carrera GT's V10 screamer. Put it together with a 160ps electric motor on the rear axle and 130ps front e-motor, and the grand effective total power output of the 918 can arrive at well over 899ps. Torque figures in the maximus race hybrid mode (accessed via the red hot-lap button) reach just over 799Nm at the wheels between 800rpm and 5,000rpm of the 9,150rpm redline M18 unit, which may in part explain the noticeably slower acceleration times to 199km/h (125mph) and 299km/h (185mph) when compared with the McLaren P1 and Ferrari LaFerrari. Nürburgring Nordschleife super comparisons, however, should be thrilling to watch, especially as the 918 complete with the Weissach package currently holds the 'Ring lap record for road vehicles.

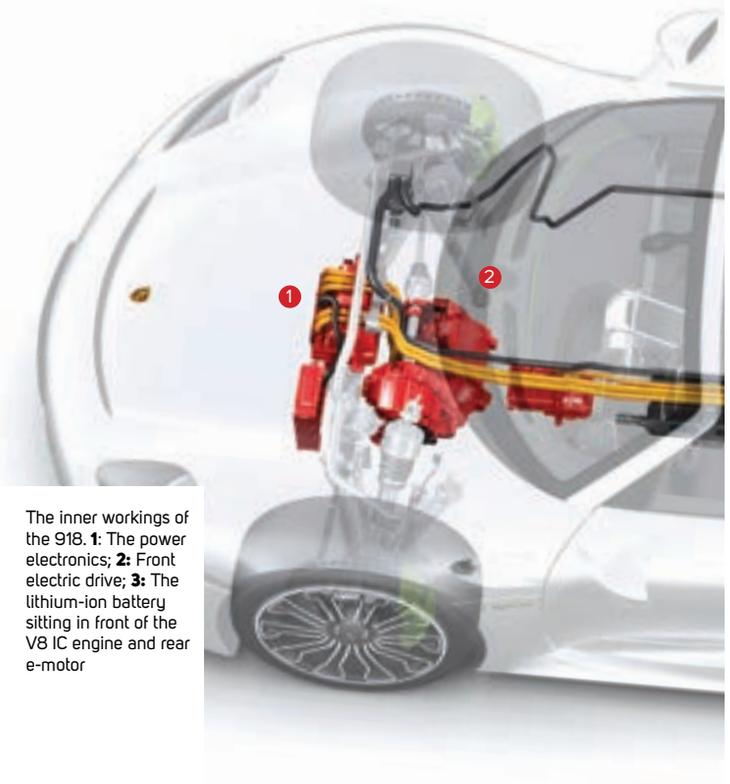
For the all-new dry sump 4.6-liter naturally aspirated M18 bolted down rear amidships, Porsche chose a 95mm bore and 81mm stroke to accommodate the pistons and titanium connecting rods of the 180° flat crankshaft. Many have been saying that this 4.6-liter mill owes an awful lot to the 3.4-liter MR6 V8 in the racing RS Spyder, but Walliser jumps all over that, stating that the M18 was designed from the start exclusively for the 918 Spyder and derives very little from any previous IC engine rolling out of Weissach. The main carry-over item is the actual engineering team in Weissach that designed and built the RS Spyder heart and then had full responsibility for the 918's motor.

A good part of the greater efficiency in this new V8 is achieved through the intensely precise and smaller spark in the cylinders, due to the reduced space between the valve openings in this design. This reduced space also requires a high central injection point that is, of course, likewise precise.

In a true fluke, Walliser says that the 312-cell lithium-ion battery stack riding low beneath the fuel tank weighs exactly the same as the CFRP monocoque, the M18 V8, and the specially adapted 911 Turbo seven-speed PDK gearbox that's been flipped over and spun 180°. For the record, each subsystem accounts for 138kgs. The housing on the gearbox is new, still in aluminum, and has four gears of a different ratio from the Turbo transmission, while three gears, the R series bearings, clutch and hydraulics are the same.

E for electric; H for hybrid

In the E (for electric) or H (for hybrid) setting on the steering wheel's right-hand dial, the 918 can leave the M18 unit out of the picture completely so long as the driver stays below 149km/h (93mph) or maintains the throttle pedal below 40% of its travel. Violate either of these parameters, and the 4.6-liter is compelled to kick in and liven up the party on wheels. Total range in EV mode is 30km



The inner workings of the 918. **1**: The power electronics; **2:** Front electric drive; **3:** The lithium-ion battery sitting in front of the V8 IC engine and rear e-motor

(19 miles) when driven gingerly, as supplied by the full 6.8kWh of lithium-ion energy. The simple front e-motor is always spinning to assist via front-axle traction, but at 235km/h (146mph) its dog-ring type clutch decouples entirely, leaving the 918 a rear-wheel-drive supercar.

It may feel as though the rear e-motor is going through some sort of shifting action with the IC engine and PDK, but that is only because it is mounted directly on the aggressive crankshaft; in fact, all the driver will feel (if anything at all) is a very enhanced shift moment. The difference between sport hybrid and race hybrid is also mainly this variation in shift feel, plus the e-motor boost effect fluctuates. Press the hot-lap button and the sequence of power actually reverses as the action is all undertaken through the V8 first and foremost. Then there is a kickdown feel from the e-boost effect, while the M18 is busily multitasking and making certain that the battery cells remain loaded with enough energy to pump more boost. But, unlike the McLaren and Ferrari hypercars, the 918 uses no formal KERS device, which could help explain why the acceleration numbers in straight-line dashes are less exciting to read than those for the Woking and Maranello beasts.

However, despite all this engineering greatness, possibly the most impressive of all the impressive facts on the operation of the 918 Spyder and its so-called 2007 Plus electronic architecture is that there are 57 onboard ECUs from Bosch managing the show, with 14 being uniquely developed for the 918 and 10 being dedicated exclusively to the powertrain. This latest generation of actuating ECUs is capable of transmitting no fewer than four million signals per minute, which does seem like plenty, and rather fitting for a millionaire's hypercar.

VITAL STATISTICS

Acceleration:
0-100km/h: 2.6 sec
0-200km/h: 7.7 sec
0-300km/h: 22.0 sec

Consumption (NEDC):
Total 3.3-3.0 liters/100km

CO_2 emissions:
Total 79-70g/km

Above and right: At the 2011 Detroit Motor Show, Porsche unveiled the RSR racing variant of the then 918 Spyder concept. Instead of using plug-in hybrid technology, power for the two electric motors is provided by a flywheel accumulator KERS system that sits beside the driver in the passenger compartment

TECH SPEC

Body: Two-seater Spyder; carbon fiber reinforced plastic monocoque interlocked with CFRP unit carrier; two-piece Targa roof design
Drivetrain: Parallel full hybrid; 4.6-liter V8 mid-engine with dry-sump lubrication; hybrid module with electric motor and decoupler; electric motor with decoupler and transmission on the front axle; auto stop/start function; electrical system recuperation; four cooling circuits for motors, transmission and battery; thermal management system
Displacement: 4,593cc V8
Engine power: 616ps at 8,700rpm (V8); 290ps at 6,500rpm (electric motors); over 899ps at 8,500rpm (combined e-motors and IC engine)
Torque: 917Nm to 1,280Nm depending on the gear
Maximum revs: 9,150/min
Power transmission: IC engine with hybrid module and transmission bolted together to form a single drive unit; seven-speed Porsche PDK; rear-wheel drive; front electric motor with transmission for driving the front wheels (decoupled from 235km/h); five pre-selectable operating modes for optimum coordination of all drive units
Weight: 1,634kg
Energy supply: Lithium-ion battery with 6.8kWh capacity; 220kW
Top speed: 345km/h
Purely electric: 150km/h

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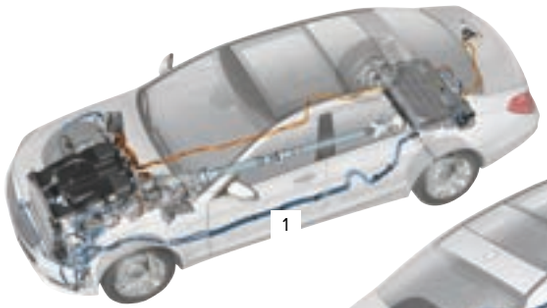
High-class hybrid

With a launch date scheduled for later this year, information about the greenest S-Class yet might be limited, but that didn't stop ***E&H*** finding out some key technical secrets

Bernhard Heil, Daimler's head of powertrain R&D, says future legislation, performance and driving range considerations all led to Mercedes' decision to opt for a plug-in hybrid solution for the new S-Class

Just a few years ago it would have been unthinkable for Mercedes-Benz's flagship luxury executive sedan, the S-Class, to be associated with the following ultra-green goodness: 69g/km of CO_2 and 3 liters/100km (94mpg) fuel consumption. But that's exactly what Daimler engineers have realized in the form of the all-new S 500 Plug-In Hybrid.

Under the skin of the eco-friendly S-Class is a second-generation hybrid drive system from Daimler comprising an 80kW electric synchronous motor and an externally rechargeable battery that allows for some 30km of emissions-free driving. Then, for those longer executive journeys, the S 500 Plug-In Hybrid calls upon a smooth 3-liter V6 turbocharged gasoline engine.



1. A 3-liter V6 turbocharged IC unit and 80kW electric synchronous motor combine for a top speed of 250km/h

2. An externally rechargeable battery pack results in around 30km of emissions-free driving

On the power front – and in addition to its 80kW output – the e-motor generates 340Nm of torque. The V6, meanwhile, brings 480Nm to the party, helping the S-Class to deliver a top speed of 250km/h and a 0-100km/h time of 5.5 seconds.

Shedding light

Yet with market launch of the greenest S-Class still some way off, only limited data was available (at the time of writing) relating to the intricate inner system workings of the S 500 Plug-In Hybrid. For example, Daimler says that the new high-voltage lithium-ion battery has 10 times the energy content of the batteries that graced the conventional S 400 and S 300 BlueTec Hybrids of yesteryear. And that the S 500 Plug-In Hybrid offers four hybrid modes of driving: hybrid; e-mode (electric power only); e-save (when the fully charged battery is reserved to be able to drive on electric power alone at a later stage in the journey); and charge (when the battery is being charged during driving). Finally, and this really is about it for now when it comes to official Daimler released technical information: the S 500 Plug-In Hybrid is the first vehicle to make use of a high-tech second-generation recuperative braking system that ensures an unnoticeable overlapping of the conventional mechanical brakes and the electric braking performance of the e-motor in alternator mode.

And yet, while technical data might generally be limited, in an exclusive interview with Daimler's head of powertrain R&D, Bernhard Heil, *E&H* can shed a little more light on the thinking behind the S 500 Plug-In Hybrid. For starters, the battery and e-motor have both been developed in-house, as part of Daimler's EM-motive joint venture with Bosch.

Also, according to Heil, a raft of powertrain designs were looked at for the new S-Class before Daimler engineering chiefs opted for a plug-in hybrid solution. "We thought about a pure electric powertrain for the new S-Class but it was very quickly ruled out," he adds.

"Creating a vehicle with a driving range of 500km or 600km is not possible for a full battery concept, especially when you factor in weight, space and cost. It became quite clear early on that we shouldn't follow that path, so we thought about what could be done. The best solution, for our customers, which really gives them no limitation compared with today's full electric powertrain, is a plug-in hybrid system."

Heil also says the PHEV architecture was chosen with one eye on tomorrow's world when it comes to urban mobility and evolving legislation: "I think the combination of a combustion engine and an e-motor is a good solution, because looking into the future, we think there might be certain areas, like city centers, where vehicles won't be able to travel using a combustion engine. This flexibility is something we wanted to have for our new S-Class."

While pure electric propulsion was quickly ruled out due to driving range limitations, Heil and his team also looked at the possibility of a range-extender setup over a PHEV system, only to reject the idea for very different reasons: "It's an interesting technology, but for a high-end luxury car it does not give our customers the ability to drive in the way they want. There is a performance issue when it comes to range-extenders because you're fully depending on the capability of the e-motors. Basically, even if you have an empty battery in a car like the S-Class, the driver still has the capability of a V6 turbo engine for performance – and a V6 turbo is not too bad!"

From scratch

Daimler's head of powertrain R&D says that starting development work from a clean sheet – essentially allowing his engineers to incorporate a PHEV's weighty subsystems early in the development process – helped his team when it came to packaging together the plug-in hybrid parts of the powertain and the 3-liter turbocharged V6 engine. "If we can make those decisions at the same time we're making decisions about a new vehicle, then for sure it's a great help. From the very beginning, when we were forming the new S-Class architecture, we always had in mind this technology, so we were able to plan ahead and think where we needed space for specific systems."

Having shown a plug-in hybrid tech demonstrator four years ago in an S-Class body, an S-Class PHEV model has been in the pipeline for sometime at Daimler. Now the world waits for the full launch of the S 500 Plug-In Hybrid, a development that promises to rewrite the upmarket executive sedan segment.

The S 500 Plug-In Hybrid emits just 69g/km of CO_2 and does 3 liters/100km

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All-wheel star

Representing several engineering firsts means that **Mitsubishi's Outlander** PHEV development is important on many levels

As part of a new forward-looking business model that will target 20% of its vehicle range to be either fully electric or plug-in hybrid by 2020, Mitsubishi has launched its Outlander PHEV in key global markets, including Japan and Europe.

The Japanese car maker is keen to underscore the important fact that its first plug-in hybrid product has been designed from the very beginning to incorporate e-powertrain componentry, as opposed to being an IC-engined vehicle re-engineered into an EV as a result of evolving market trends. It's a point worth making, especially when taking into account that the interior and cargo space of the Outlander PHEV has decreased by only 14 liters compared with the IC engined petrol and diesel derivatives.

Admittedly, much of that functionality is down the Outlander's development program having been geared toward a PHEV model from the very start, but clever packaging of the e-powertrain subsystems also plays a critical role. The clean-sheet architecture sees a 2-liter 87kW IC engine, a 60kW electric motor plus inverter developing 137Nm of torque, and a 70kW generator all placed at the front of the Outlander. In the middle of the vehicle and under the floor is a 12kWh lithium-ion battery pack with 80 cells. And under the floor at the rear of the eco-friendly SUV is a second 60kW e-motor and inverter generating an additional 195Nm of torque.

The result is a vehicle weighing in excess of 1,810kg – and with 1,500kg towing capacity – rated at 44g/km of CO_2 and 1.9 liters/100km (149mpg) fuel consumption. The Outlander PHEV has an all-electric range of 52km and can hit speeds of up to 120km/h when being powered by the e-motors alone. With the IC engine included, a total driving range of 897km is possible.

But there's much more to the Outlander PHEV than impressive eco-friendly stats. According to Mitsubishi, this is the industry's first permanent four-wheel-drive electric passenger car in series production from a mainstream manufacturer, fusing Mitsubishi's engineering leadership in SUV development with EV-based R&D that dates back to 1966. In this particular driving mode of the Outlander – branded twin-motor 4WD– each e-motor drives its own axle independently for optimum front/rear torque split. Mitsubishi says that such a setup gives more precise driving control, as well as doing away with heavy subsystems such as the propeller shaft, hydraulic system and clutch plate that's used to connect the front and rear axles in conventional four-wheel layouts. If that's not impressive enough, Outlander PHEV's twin-motor four-wheel-drive system is also mated to Mitsubishi's Super All Wheel Control technology, which was developed and honed in the Lancer Evolution program, and integrates ADC and ABS within the four-wheel drive setup.

In addition to the twin-motor 4WD driving mode, Outlander PHEV can also be driven in a series hybrid mode, with the twin motors being supported by the generator unit, or in parallel hybrid mode, where the petrol IC engine drives the front wheels of the Mitsubishi SUV and is supported by the electric motors.

Series hybrid mode is engaged when the driver needs to go beyond the all-electric top speed of 120km/h or when certain power output is needed, such as sudden acceleration, or when the battery pack falls below 30% charge. For this driving mode to work, Mitsubishi's advanced PHEV system makes the IC engine kick in to power the generator, which recharges the traction battery, and then returns the SUV to pure EV mode, because the system naturally reverts to full electric driving as often as possible.

For the parallel hybrid driving mode, which comes into its own when on the open road and when doing miles on the autobahn, the IC engine drives the front wheels of the vehicle through a clutch, with the e-motors providing support to the front and rear. In this particular setup, Mitsubishi's PHEV technology allows for the generator to distribute additional torque, which serves to enhance the overall efficiency of the engine and saves battery power.

VITAL STATISTICS

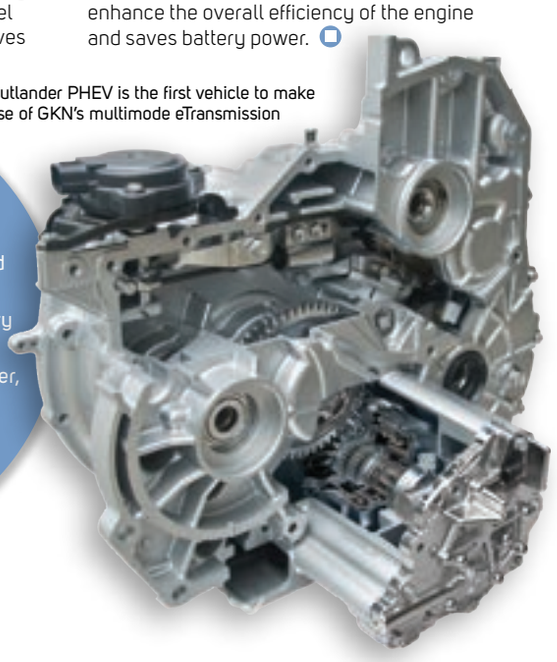
Front layout: IC petrol unit, 87kW; front e-motor and inverter, 60kW and 137Nm of torque; generator, 70kW

Mid layout: 300V 12kWh Li-ion battery pack with 80 cells

Rear layout: 60kW e-motor and inverter, 60kW and 195Nm of torque

Transmission: Permanent electric twin-motor 4WD

Driving range: 897km



Outlander PHEV is the first vehicle to make use of GKN's multimode eTransmission

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Electric appeal

From the very beginning, the seventh-generation Golf was designed to incorporate battery electric subsystems

Volkswagen engineers have finished work on the company's first battery-electric production vehicles – and they are no niche segment, test-the-water developments

Having toyed with concepts and technology demonstrators for a few years, Europe's largest car maker – and the world's third biggest OEM – has officially entered into the new era of production electric mobility. And Volkswagen is not undertaking such a transition by serving up a niche, top-end BEV product offering that will be available in limited numbers and only certain markets. No, instead, using the all-new MQB architecture, the German organization has transformed two of its most popular IC-powered people movers, Up and Golf, into all-electric forms.

Seven generations of Golf have sold more than 30 million units, so one can truly say that the e-Golf represents a new chapter for Europe's most popular car. The hatchback, which in addition to its mass appeal is renowned for emotive performance-oriented derivatives, such as the GTi, GTD and R models, is driven in electric form by a 115ps synchronous motor, code-named EEM 85, that has been designed to deliver 270Nm of torque. The 12,000rpm e-motor was developed in-house by VW engineers and so too was the e-Golf's EQ 270 single-speed gearbox with integrated differential.


1


2


3

1. When using fast charging, the e-Golf takes eight hours to fully replenish a completely flat battery

2. The e-Golf has a 190km range

3. Much of the e-Golf's powertrain was developed in-house at Wolfsburg, including the e-motor

MQB goes electric!

Key to the e-Golf seeing the light of day is the MQB architecture, with the seventh generation Golf being designed from the outset to be able to incorporate electric powertrain componentry. The upshot of this is that engineers were able to integrate a lithium-ion battery in a space-saving manner within a stabilizing frame in the vehicle floor, just under the front and rear seats and in the area of the center tunnel. Like the e-motor and gearbox, the battery was also designed and developed in-house by VW R&D teams.

The Wolfsburg-based car maker's first mass-production full EV weighs 1,510kg in total, which is around 300kg more than the TSI powered derivatives, a handy difference seeing that the battery pack itself weighs 318kg. The battery design comprises 264 individual cells, which are integrated into 27 modules, each with six or 12 cells. The cells add up to a nominal voltage of 323V while the battery's overall capacity is 24.2kWh. On one full charge, the pack will offer a driving range between 130km and 190km, depending on conditions and driving style.

Central to the drive system in the e-Golf is the power electronics module, which essentially acts as a link between the core electric powertrain subsystems, controlling the flow of high-voltage energy between the e-motor and the battery pack, and in the process converting DC into AC. As such, the power electronics in the e-Golf setup has four interfaces: traction circuit connection to the battery; three-phase connection to the e-motor; the plug connector from the DC/DC converter to the 12V power circuit; and a connection for the high-voltage power distributor.

Additional eco-friendly touches on the e-Golf include aerodynamic measures that reduce air drag by 10% and specially developed tires that improve rolling resistance by the same amount.

The conventional way of charging the e-Golf – through a 230V mains electrical socket at

a charge level of 2.3kW – takes 13 hours to transform the battery from flat to full. But as an optional extra, VW is offering a wall box charger for the garage or carport that charges at a level of 3.6kW and will replenish a completely flat battery in under eight hours.

Up and away

VW's electric roadmap will see the e-Golf launched in main European markets by the second quarter of 2014, but before that comes the e-Up, which has already been made available in Germany and will soon be rolled out to other European markets.

The e-Up shares many of the e-powertrain subsystems that drive the e-Golf, but tweaked and redesigned for a smaller package. For example, the compact electric motor has been reconfigured to offer 60kW and 210Nm of torque, which is channeled to the front wheels via the EQ 270 single-speed gearbox. Such power ensures that the electric Up can compete with its three-cylinder IC engine siblings, hitting 100km/h in 12.4 seconds before reaching a top speed of 130km/h. The most powerful IC-engined Up takes 0.8 seconds more to do the same sprint.

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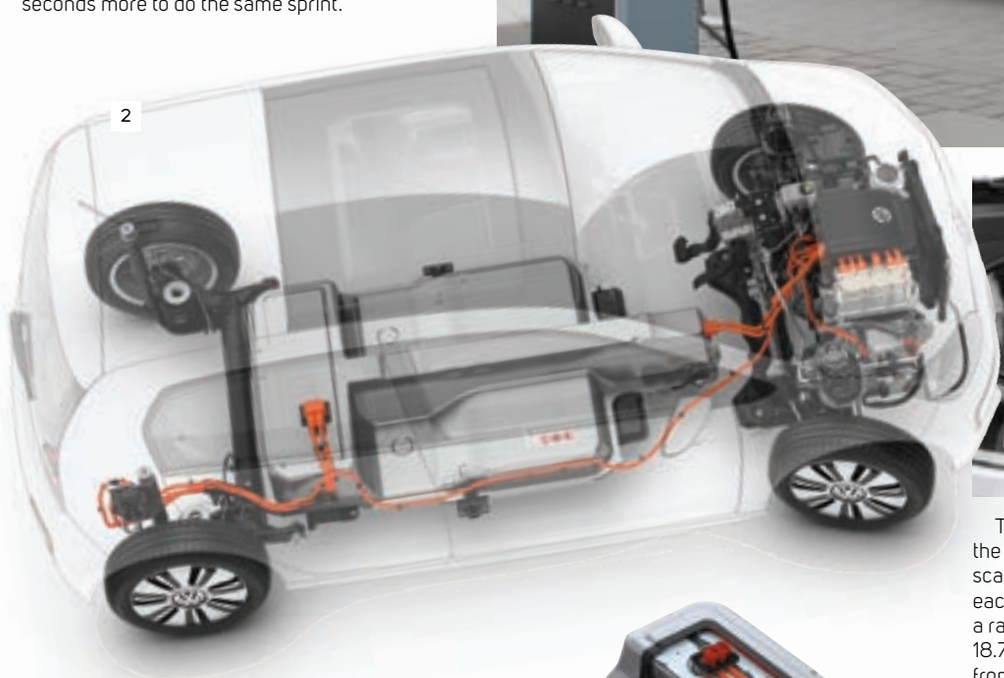
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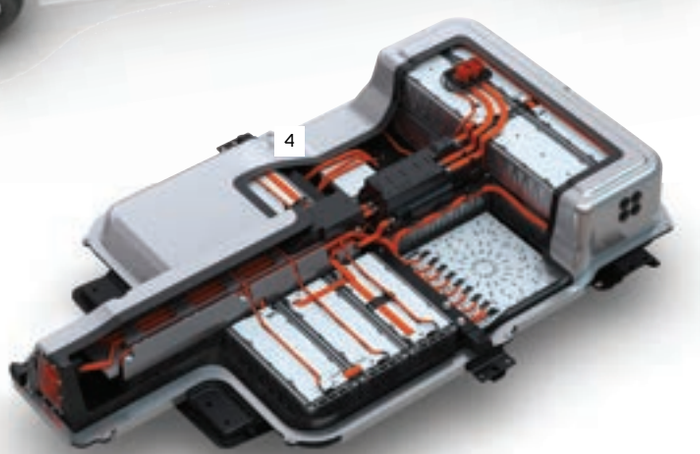
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1. Staying true to its city car roots, the e-Up has a 100km driving range when fully charged, which takes just six hours when using fast charging technology

2. The e-Up shares many electric powertrain systems that feature in the e-Golf, but modified for a smaller passenger car package

3. The powertrain in e-Up has been designed to offer 60kW and 210Nm of torque

4. The battery pack weighs 230kg and is made up of 17 modules, each with 12 cells

The battery, which has been integrated within the floor of the vehicle to save space, tips the scales at 230kg and is made up of 17 modules, each with 12 cells. These 204 cells add up to a rated voltage of 374V and rated power of 18.7kWh. An additional 10.5kg in weight comes from the e-Up's power electronics module, which links and manages power from the battery pack to the e-motor, mirroring the setup in the e-Golf. Staying true to its city car roots, e-Up offers a total driving range of 100km.

Fully recharging an e-Up flat battery via a 230V socket takes nine hours. The optional wall box takes just six hours to go from flat to full.

Next up for VW powertrain engineers is work on a plug-in hybrid powertrain that will be housed in a future Golf model, which will probably be unveiled at the Geneva Motor Show. *ETi* can reveal that the PHEV Golf will offer a 80km pure-electric driving range thanks to a better battery with greater capacity that can be charged from an external power source. It's all further proof – if any were needed – that e-powertrain technology is a growing in influence within VW circles.

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All for show

Bosch has teamed up with **Aston Martin** to develop a DB9 plug-in hybrid prototype to demonstrate how the technology can improve performance

Involving a team of 74 Bosch engineers and taking 13 months to develop, the plug-in hybrid DB9 is as much about emissions reduction as it is proving the performance worth of alternative powertrains

Hybridizing a high-performance vehicle is always going to raise eyebrows. Aside from the more obvious benefits of reducing CO_2 emissions and improving fuel consumption, it can sometimes be difficult, from a performance perspective at least, to see the bigger picture.

However, Bosch has produced a plug-in modular hybrid concept version of the iconic Aston Martin DB9 that aims to better the driving dynamics potential of hybrid sports cars.

Unveiled earlier this year at the Bosch proving ground in Boxberg, Germany, the technology demonstrator sees the DB9's original 6-liter V12 supplemented with a pair of 85kW electric motors that power the front wheels – making this the first four-wheel-drive Aston Martin – and a smaller 25kW electric motor positioned on the engine belt so that the power steering and other ancillaries can do their jobs even in all-electric mode. A 180kW lithium-ion battery sits just ahead of the rear axle, powering the motors to provide 25.7km of pure-electric range.

The inclusion of the hybrid system, which also features three inverters, a charger and a power distribution unit, adds 300kg to the car, increasing the overall weight to a whopping 2,085kg. However, according to Gabriele Pieraccini, Bosch project manager for hybrid systems, that doesn't stop the prototype from pushing out more than 750ps and 881Nm of torque – 233ps and 261Nm more than what the base DB9 is capable of. And not only is this car more powerful than its fossil fuel-powered counterpart, early simulations indicate it should cut the DB9's 0-100km/h sprint time from 4.6 seconds by 20% to 3.7 seconds.

"It's a fully functional concept vehicle," adds Pieraccini, who was also head of control strategies for F1 at Ferrari. "The task for us was, firstly, to show the potential of hybrid technology in sports cars – not only in terms of a reduction in CO_2 and fuel consumption, but also an improvement in performance.

VITAL STATISTICS

0-100km/h: 3.7 seconds
Power: 750ps
Torque: 881Nm
Battery: 180kW lithium-ion
Vehicle weight: 2,085kg

With all its e-powertrain systems fully integrated, the plug-in hybrid Aston Martin DB9 weighs more than 2,000kg, but it promises to be quicker in a straight line than its IC-engined stablemates

"Another issue we had was to determine the hybrid topology. Most sports cars are rear-wheel driven, so in this case we chose to electrify the front axle to get more acceleration performance."

Pieraccini also reveals that the decision to go with dual front-mounted electric motors was partly down to finding ways of improving the functionality of the hybrid's torque vectoring capability, while the position of the third motor helps to send recuperated energy back to the battery. Interestingly, the high-voltage battery pack is the only powertrain component not to be developed by Bosch. Pieraccini refuses to divulge the name of the external, UK-based supplier, but admits that its product was better suited to the restricted dimensions of the vehicle than Bosch's own energy-storage systems.

From a mechanical point-of-view, the biggest challenge faced by the 74 Bosch engineers involved in the 13-month-long project, which ran from April 2012 to May 2013, was the integration of the hybrid system's numerous components and subsystems in an existing layout.

As Pieraccini says, "There are a lot of devices that weren't originally in the car." One particularly taxing issue was the repositioning of the radiator. By moving it forward, Bosch engineers were able to incorporate the electric motors without any detrimental effects on the engine cooling air.

Though Aston Martin claims to have no plans to put the modular hybrid vehicle into series production, Bosch appears happy enough to have demonstrated what its technology, and specifically this powertrain architecture, can potentially do for existing performance cars.

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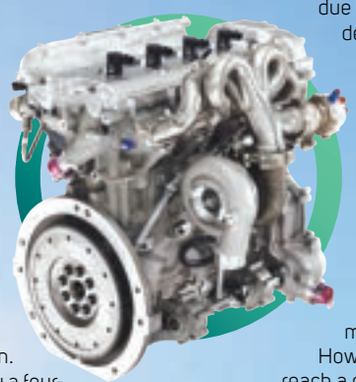
Pocket rocket

Combining the hybrid technology developed for its Le Mans prototype with a new IC engine designed for rally racing, **Toyota's** new Yaris Hybrid-R concept has given the subcompact class a jolt

At the Frankfurt Motor Show in September, Toyota unveiled the Yaris Hybrid-R, an all-wheel-drive supermini concept featuring a 1.6-liter turbo global race engine (GRE), supercapacitor and three electric motors. The car combines the technology of the Yaris Hybrid three-door with the engineering behind Toyota's racing prototype, the TS030 Hybrid, which participated at Le Mans and in the World Endurance Championship.



Each rear wheel is powered by the same two 60ps electric motors that are used in the standard Yaris Hybrid. The pair also work as electric generators during braking, and supplement the IC engine during acceleration.

The front wheels are driven by a four-cylinder 1.6-liter turbo gasoline engine developed by Toyota Motorsport (TMG), the company's Cologne-based subsidiary that is responsible for every Toyota rally car produced. A direct injection design with a power output of 300ps at 6,000rpm and 420Nm of torque, the turbo unit in combination with the hybrid powertrain produces maximum power of up to 420ps.

Much like the TS030 Hybrid, energy recovered under braking is stored in a supercapacitor under the rear seat of the Yaris. According to Toyota, the decision was made to go with a supercapacitor instead of a standard NiMH battery, due to the former's higher power density and a fast power charge/discharge speed, which leads to immediate bursts of power.

The Yaris Hybrid-R features two driving modes (track and road) and a boost function. When the vehicle is running in road mode, the supercapacitor releases energy for a maximum of 10 seconds per charge, and the total power of the two electric motors is reduced to 40ps. However, in track mode, the motors reach a combined maximum of 120ps for up to five seconds per charge.

Positioned between the IC engine and the six-speed sequential transmission is a third 60ps motor. It can also operate as a generator, during deceleration to feed power to the supercapacitor and during acceleration to power the rear electric motors. Toyota says the latter will only happen when engine power and torque exceed the grip potential of the front wheels. The generator behaves like an advanced traction-control system, redirecting torque as electrical energy to the rear wheels.

Meanwhile, the two rear electric motors can have a big influence on the Yaris Hybrid-R's handling when cornering, by altering the torque distribution between the rear wheels. Each unit can also be used independently as a generator or a motor to achieve the same effect as a torque-vectoring differential.

The 1.6-liter unit, which began its development program in early 2011 as a clean sheet design for use in the World Rally Championship, meets FIA regulations for a global motor, which means it can be used in a variety of motorsports. The powertrain has already undergone extensive performance and reliability testing on the dynamometers at TMG's tech center in Cologne.

"The technology we use does flow back into the development of road-car engines," adds Rob Leupen, director of business operations, TMG. "TMC is using us more and more in its prototype development, using the techniques we deploy on the development of GREs and other engines. Specific parts, or the whole engine, making it into a road car isn't to be expected, but the techniques and technologies will be exchanged with TMC in prototype development for future engines."

The Yaris Hybrid-R, which showcases several high-end technologies, is the result of Toyota's hybrid powertrain development expertise in combination with the Japanese company's rally and Le Mans motorsport activities

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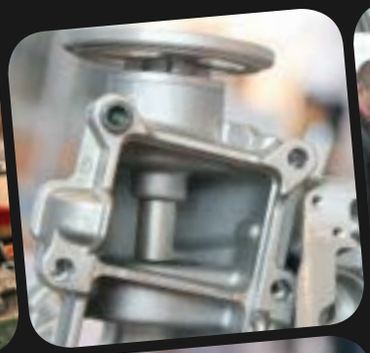



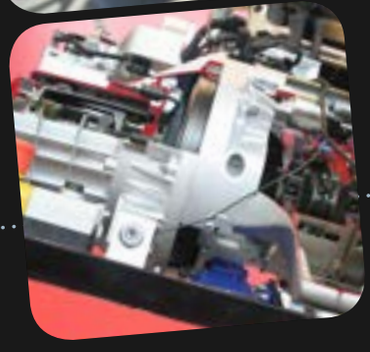

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Volkswagen XL1

Arguably the most advanced vehicle in the world right now, the XL1 is, in every respect, a technological showpiece from VW. With its layer-upon-layer of innovation (and we're not just talking about the high-tech powertrain here), this evergreen Wolfsburg creation is an engineering masterclass in how to do a hybrid, to the point that it probably reaches out the furthest of all recent eco-friendly efforts to that hallowed automotive ideology of sustainable transportation.

To start with, then, let's deal with what some critics had to say about the XL1: some said it's expensive, while others mentioned the lack of boot space and in-car practicality as well as storage areas. To these ill-informed detractors, we say you're missing the very point that underpins a daring conception such as this. Expensive it might be, but what does one expect from a truly pioneering vehicle like this, of which only 250 examples will ever be built. VW engineers should be celebrated for bringing this concept from out of the darkened R&D labs and onto our roads. We're not talking about Polo or Up production numbers and showroom sticker prices here people! As for the lack of functionality – really?! From initial design through to production, XL1 was not created to store the weekly shopping or one's golf clubs, but rather to house cutting-edge eco-friendly designs that will help VW and the wider automotive industry realize that sustainable transportation utopia.

So, what's it like to drive? Well, on the road, it behaves rather normally. Interfaces that we've grown familiar with on other VW best-sellers, like the Golf, make an appearance on the XL1, adding to the sense of normality when behind the wheel of VW's sleek, aerodynamic (Cd 0.189) two-seater green savior. In fact, XL1 mostly drives like any other PHEV, which is actually a complement given how truly groundbreaking this car is. And the 800cc IC unit is not half as rough as we expected a two-cylinder diesel to sound.

Yet the biggest thing we took away following our time with the XL1 is that it actually challenges how one drives, making the driver think about when to accelerate, when to coast, when to use the IC unit and when to rely on e-power. You see, XL1 doesn't just move the game on when it comes to technology, it marks the start in shaping how we use the car as we know it, taking into account our daily commute, external conditions and the road ahead.

Propulsion system: A 5.5kWh Li-ion battery pack at the front of the XL1 provides energy to the 27ps electric motor at the rear. The two-cylinder TDI engine is also located at the rear, with the DSG

Volvo V60

Prior to our time with the VW XL1, we here at *E&H* mostly agreed that following our week with Volvo's V60 Plug-in Hybrid, that this Swedish designed, developed and manufactured automotive product was probably the best hybrid we had driven.

Now, comparing V60 Plug-in Hybrid to the XL1 is probably like evaluating apples with pears, so we'll cast aside the absolutely pioneering VW creation for now. In fact, those critical of the XL1 (see opposite) should really spend some time with the V60 because, in essence, here's a brilliant, everyday PHEV in the here and now that's going to sell in far higher numbers, so will be far more affordable at showroom price level. And – here's the all-important point – the Volvo is very family-friendly too, with ample storage space and a boot that, despite being intruded somewhat by the battery, is of a decent size. Big enough to store the weekly shopping, suitcases and those golf clubs, at the very least!

So, why do we rate the V60 Plug-in Hybrid so highly? Because, in short, it works like it should. Drive it hurriedly, with the heated seats on, the A/C unit blasting cold air, and the radio on max, and the IC engine will not suddenly get the urge to cut in and take over from the e-motor, as is the case with many other hybrids. The V60 really is how a hybrid should be! In Pure mode, it is powered by the electric motor for up to 50km of emissions-free driving. In Hybrid mode, the IC unit and e-motor work together to achieve the best driving situation with regard to efficiency. Impressively, the V60 is rated at 48g/km of CO_2 and 1.8l/100km for fuel economy. And then, unlike many other hybrids, Power mode in the V60 really does mean that, with the two propulsion subsystems delivering 287ps and 600Nm of torque.

And this leads us nicely to the next point: Volvo's setup uses an in-line five-cylinder turbodiesel for its IC base. We here at *E&H* have a rather European perspective in that we really think that diesel-hybrids make a lot of sense on many levels, to the point that (XL1 not included) V60 would be the first hybrid car we'd consider buying!

Propulsion system: A 11.2kWh Li-ion battery pack installed under the floor of the boot of the V60 provides energy to a 69ps e-motor located at the rear axle. At the front is a 2.4-liter turbodiesel engine

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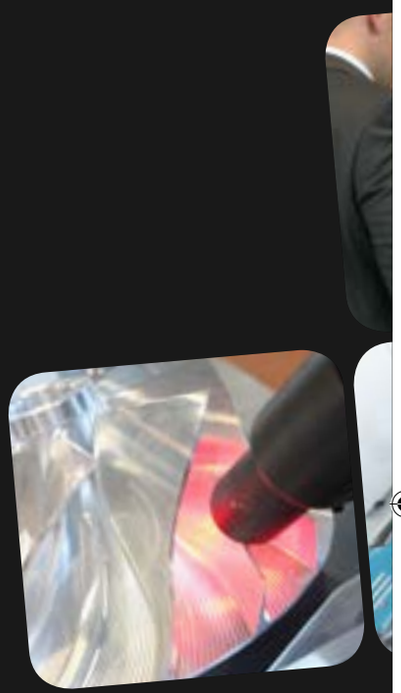

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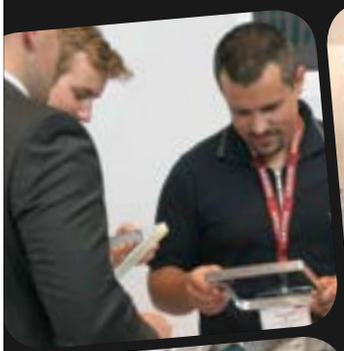


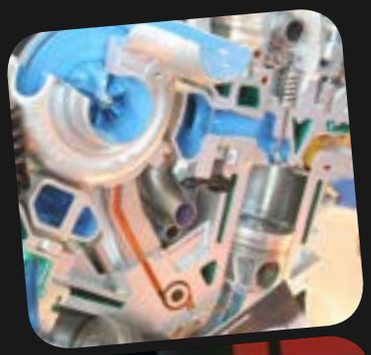
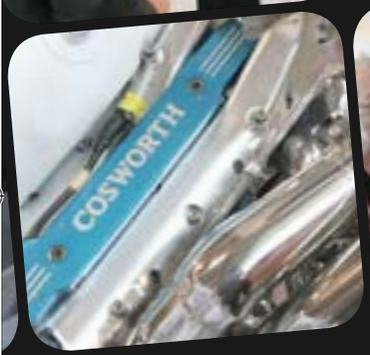


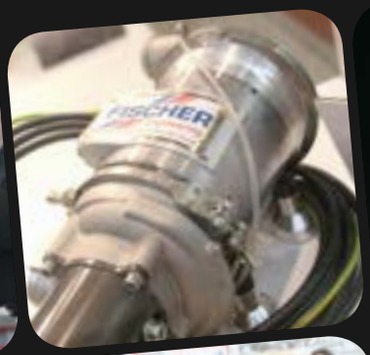



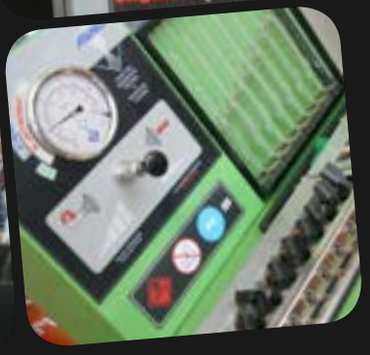
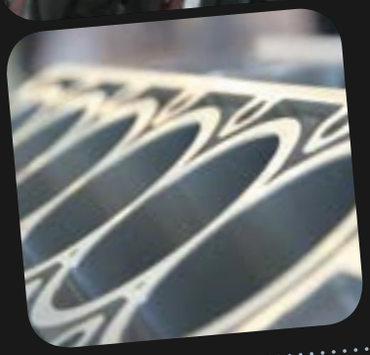

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Llewellyn

The Nissan Leaf was Norway's best selling car in October 2013, outselling IC-powered competitors

The thing I least expected when I first got into an all-electric car was how it would completely alter my relationship with these wondrous machines.

I was the sort of man who could walk along a city street chatting with an old friend about marriages, education and the stresses of fatherhood and I would hold my hand up mid-sentence so I could listen to the throaty warble of a Mercedes-AMG SLS 6.2-liter V8 as it rumbled past.

All I hear now is a ridiculous waste of a non-renewable fuel in an absurdly expensive, oversized four-wheeled status symbol only a very 'special' type of person would have the desire to own, if you get my thinking.

Having driven well over 50,000 miles (80,000km) in electric cars, I've started to reconsider not only how transportation is powered and where the fuel actually comes from but also how these vehicles are built, where the materials come from to construct them and how long they will last.

I've started to consider the ridiculous and dated design restrictions of fitting an enormous IC engine, clutch, gearbox and exhaust system into a small metal box and the incredibly liberating and refreshing lack of such restrictions when it comes to electric car design. And as a society, we are just beginning to see the possibilities.

> "In the past two years, I have driven over 8,000 miles (13,000km) on solar power alone"

The knee jerk resistance to these innovations is also starting to wane – especially as more people are starting to think seriously about the realistic possibility of an electric car in their lives. Of course, there are still hundreds of hurdles to cross but if you have somewhere off the road to park an electric car and a roof that can support a few solar panels, it will become increasingly foolish not to have both.

In the past two years, I have driven over 8,000 miles (13,000km) on solar power alone. Okay, this is out of a total of 34,000 miles (54,000km) or so, and it's only in the summer months, and I only plug the car in during the day if it's sunny, but 8,000 miles at zero cost and zero CO_2 is a minor miracle.

An electric car really is fuel agnostic, it doesn't give a hoot where the electricity comes from and will still work. That's not something you can claim for a fossil burner.

A few years ago the hastily arrived at conclusion, based on our experiences with laptops and phones, that batteries would fail after a few thousand miles and electric car owners would have to fork out a fortune to replace them. The original battery, to quote a well-known TV car pundit, would of course be "plowed into land fill".

Now it is becoming clear that the battery will likely outlast the car, and only a fool would throw a car battery away as they're far too useful and valuable. As time passes and more electric car drivers cover more miles, the long-term economies of electric driving are nothing short of embarrassing.

After 40,000 miles (64,000km), my Nissan Leaf will have been cheaper than if I'd bought a bottom-of-the-line Ford Focus and driven the same distance and, more importantly, it will continue to get cheaper. No expensive servicing, no replacement timing belts, oil, oil filters, catalytic converter, the list goes on and on. The biggest expense I've had is a puncture. Oh, and screen wash – blimey that's expensive!

I live in the sticks and, according to numerous motoring pundits, am exactly not the sort of person to use an electric car. They are, so we are constantly told, for city driving and urban mobility, to use a marketing phrase. While this is true in that air pollution in cities would be immensely improved if the majority of vehicles were electric, I have found my EV completely usable in the countryside.

Everyone I have spoken to, argued against and debated the topic with agrees that there will come a point where the line on the graph depicting the cost of fossil fuel and the line depicting the cost of an electric car will cross, the only disagreement is when that will happen. Next year, five years' time, 10 years' time – does it really matter? Because it will happen. In fact, nobody argues that it won't. Electric cars are here to stay.

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PROFILE: MARK STANTON

Job title: Vehicle engineering director
Company: Jaguar Land Rover

What career did you want when you were growing up, and what was your first job?
I think the only job I remember wanting to have when I was young was to be a policeman. In truth, I've always had a love for cars, and what was drawing me to being a policeman back then was the fact I'd get to drive a car! My first job was actually in a bar, as a student. But my first proper job was with Ford, as I was a sponsored student through university, and I went on to work in the research department for chassis engineering and vehicle dynamics.

What was your career path to the position you currently hold?
The short answer is that I had a very long career path! As I mentioned, I left university and went to work for Ford. I progressed up the ranks in Ford UK, and after five years I moved to North America working with Ford on advanced vehicle and suspension concepts. I then came back to the UK after three years and worked on a special assignment for around 12 months. After that I worked in mainstream chassis engineering. From there, I moved further up the Ford chain, leading the chassis engineering project on the new global Mondeo program. After that I moved to Belgium for a couple of years, then back to America again for a year. From there, I moved to Dearborn to focus on some more advanced stuff. I then came back to the UK again to take up the role of vehicle-engineering manager on B-segment projects, working jointly with Mazda. I then became chief program engineer, a position that I stayed in for a few years. I was then asked to join JLR, as Ford owned us at the time, to do the job that I'm now doing, which was to create a vehicle engineering organization within JLR, as it really didn't exist at the time. When Ford sold JLR, I had the choice to stay on here or switch back to Ford. I thankfully made the choice to stay here – it's a better company car after all!

What are the best and worst elements of your job?
I'm a car nut and I always have been. I'm not one of those who will spend hours cleaning a car – I just love driving. So by far the best element for me is getting to drive and I take

> Everyone is trying to crack storage through different battery technologies, and Peugeot has even showcased the compressed air system it has created. Everyone is trying to find this panacea to the storage issue

a great deal of pride in seeing the cars I've worked on, out on the street! The worst element has to be being so busy and not being able to spend the time doing the things I love. Instead that time is taken up by meetings.

What car do you currently drive?
I've just traded in my Range Rover for a Jaguar XF Sportbrake. I'm lucky in that I get to change my car quite frequently, so I tend to use an SUV in the winter and something a bit sportier in the summer.

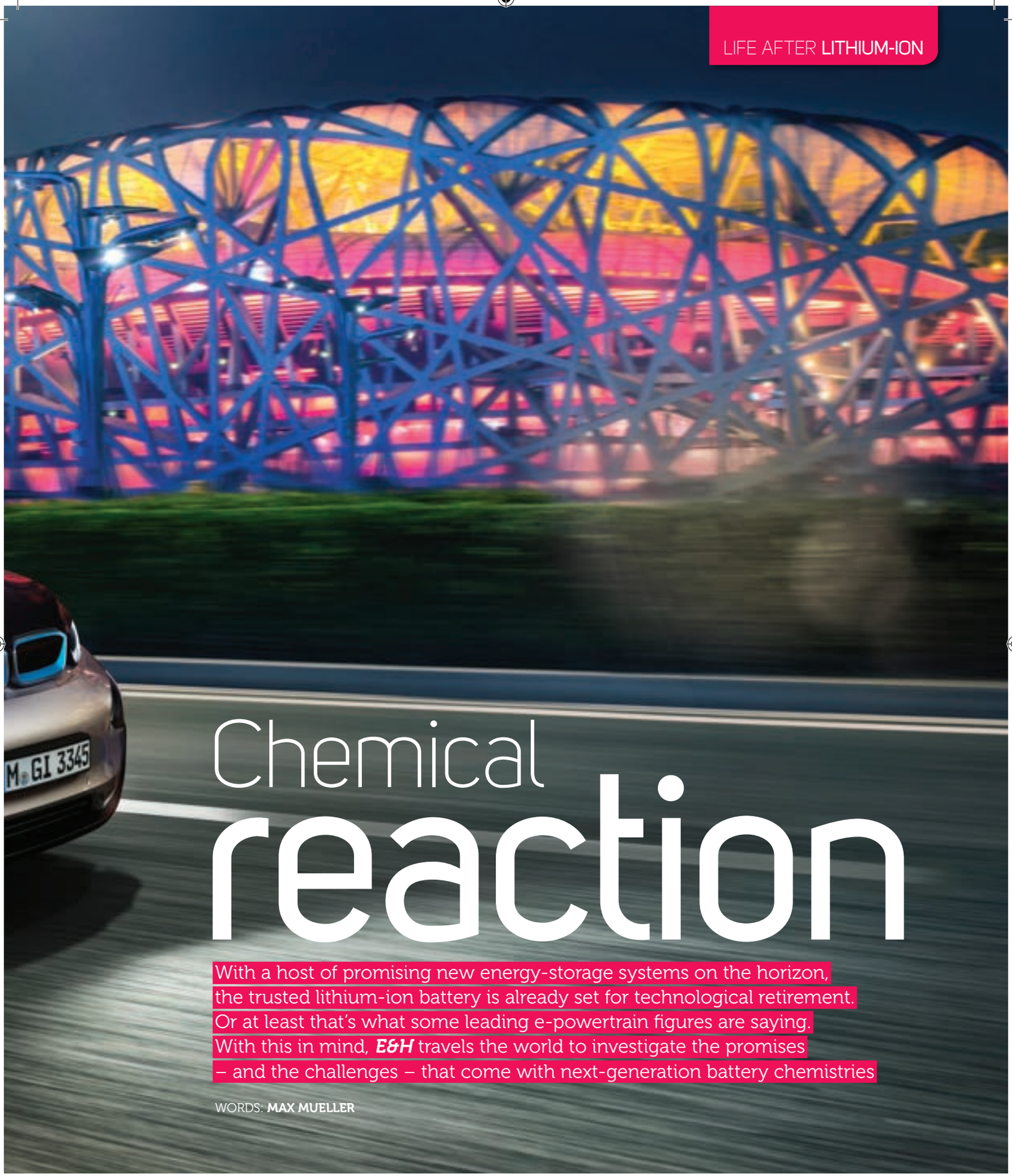
What would your dream engine specification be for today's eco-friendly world?
I think it's a very small, downsized engine. Depending on the size of the car, then a very small, turbocharged diesel is still the right way forward. Some of the analysis we've done shows that small turbocharged diesels are a better route than hybridization or other alternatives, and certainly better than BEVs.

Emissions legislation aside, what would be your dream engine specification?
I love driving the F-Type, and that's got a 5-liter supercharged V8 that's fantastic on those occasions when you can use all of it. The XF I have at the minute has the 3-liter diesel unit, and I can get 40mpg out of that while driving the hell out of it. That combination, across country, means it's probably just as quick as the XF-R. On a track, the more power the better, obviously. But in the real world? A decent diesel is my preference.

In your opinion, what is the greatest engine that has ever been produced?
The one engine that impresses me currently is the 1-liter EcoBoost from Ford. That is pretty good and I think it's rightly had a lot of credit. Is it the best ever produced? No, probably not, but sitting here today, it has to be that one.

In your opinion, what will be powering a typical family sedan in the year 2030?
The biggest challenge is the energy storage mechanism. If we can crack that, then it probably won't be an IC engine. But the way things lie today, the most efficient way of carrying energy about in a vehicle is in a fossil fuel because of its dense energy storage. Everyone is trying to crack storage through different battery technologies, and Peugeot has even showcased the compressed air system it has created. Everyone is trying to find this panacea to the storage issue. If we can't crack that, then we will still be driving around with IC engines – albeit in much more optimized, efficient and downsized forms.

The BMW i3's high-voltage lithium-ion battery pack delivers a pure-electric range of 130-160km, but what types of battery technologies will be powering future i EVs?



Chemical reaction

With a host of promising new energy-storage systems on the horizon, the trusted lithium-ion battery is already set for technological retirement. Or at least that's what some leading e-powertrain figures are saying. With this in mind, ***E&H*** travels the world to investigate the promises – and the challenges – that come with next-generation battery chemistries

WORDS: **MAX MUELLER**

No matter what one's position is on the electric powertrain revolution, most agree that there needs to be a real breakthrough in battery research and development if it is to achieve the power and energy densities needed for pure electric propulsion to rival or even supersede the IC engine in generations to come.

And that key engineering leap forward is unlikely to derive from lithium-ion, which, despite the best efforts of developers at both supplier and OE level, is set to be overtaken by a whole range of new technologies within the next two to three EV development cycles.

But just what are the advantages, disadvantages and challenges associated with these new pretenders to the battery EV crown, including lithium-air, lithium-sulfur, carbon-nanotube cells and lithium ultracapacitors? And perhaps even more pressingly, exactly when will EV makers implement these new battery solutions within their products?

Coming up for air

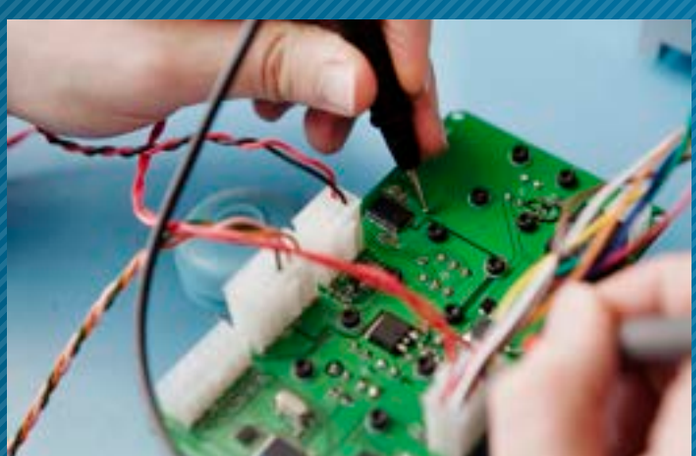
There's no denying that the technology most talked about at the moment is lithium-air. But the idea of using oxygen from the atmosphere instead of storing a regular oxidizer within the cell itself isn't exactly new. In fact, metal-air batteries were proposed as far back as the 1970s as possible power sources for electric vehicles. In net terms, zinc-air and lithium-air chemistries promise five to 10 times higher energy densities than current lithium-ion designs, and if that's not impressive enough, then try this next stat for size: lithium-air is even said to be able to eventually achieve the mythical Sakichi target of equaling gasoline, the energy density of which is 13kWh/kg, reduced to 1.7kWh/kg at the wheels after losses. The theoretical energy density of a lithium-air battery (excluding the oxygen mass) approaches 12kWh/kg, due partly to the higher efficiency of electric motors, which could translate to 1.7kWh/kg at the wheels even after losses from over-potentials, other cell components and battery-pack ancillaries. Currently, researchers across several industries are considering four different approaches to lithium-air

"Lithium-air technology has game-changing qualities. But the hurdles we need to overcome are significant"

Jeff Chamberlain, senior account manager for technology transfer, Argonne National Laboratory

UNDER NEW MANAGEMENT

Another critical part of the battery development process is the BMS, often overlooked, but a complex component that must interface with a vast array of on-board systems. Current setups already need to perform in the region of 20 essential functions in a typical EV or HEV, from maintaining cells within their operating limits, to applying the optimum charging algorithm and implementing an emergency limp-home mode in the event of cell failure. Is this complexity set to increase with advances in battery chemistry or is simplicity the key to success?

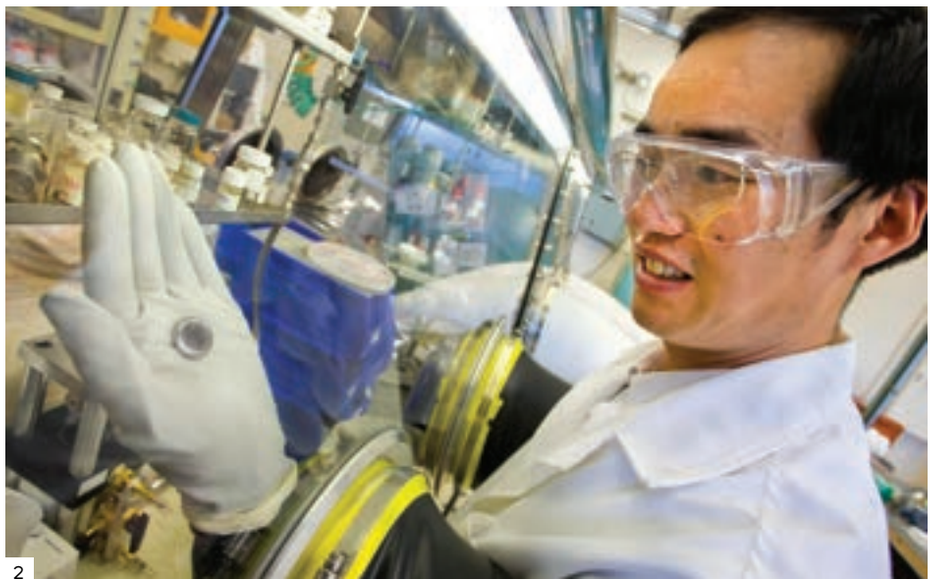


"Battery management is critical to maximizing performance and service life for any battery system, but the sophistication and operation of the BMS is very dependent on the particular battery chemistry," explains Thomas Apalenek, senior principal systems engineer for BAE Systems' HybriDrive Solutions. "Lithium-ion batteries require very close monitoring and balancing at individual cell level, to ensure a long service life and prevent failure during normal use. Nickel-metal hydride batteries tend to be self-balancing in large

1

1. Lawrence Berkeley National Laboratory scientist, Tommy Conry, loads a lithium coin cell sized battery for testing on a battery cycle. Image courtesy of Aragonne National Laboratory

2. Lawrence Berkeley National Laboratory scientist, Honghe Zheng, holds a coin cell sized battery that is used to evaluate high energy density electrode formulations. Image courtesy of Aragonne National Laboratory



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development: aprotic, aqueous, solid state and aqueous/aprotic.

As ever, the theory – usually based in an R&D lab – sounds extraordinary, but can the industry really expect a commercial application in the near future? Scientists at the US Department of Energy's Argonne National Laboratory (ANL) are cautiously optimistic: "Lithium-air technology has game-changing qualities," says an enthusiastic Jeff Chamberlain, senior account manager for technology transfer. "But the hurdles we need to overcome are significant. Any time you hear someone talk about solving the problems of lithium-air in a short amount of time, you should think twice about what that person is saying. It's going to be a difficult task – but not impossible. Our experience in lithium-ion has taught us a lot, both in how to develop the processes and materials and also, equally importantly, how to progress our relationship with industry so that the technology is adopted and commercialized."

Chamberlain's colleague, Michael Thackeray, senior scientist and distinguished fellow at ANL, says there are some fundamental technical challenges that first need to be overcome at R&D level before such applications are ready for the market: "On the scientific side, we're facing huge problems. In terms of the materials used, metallic lithium is particularly difficult – there are flammable electrolytes that have to be replaced – and there is also the issue of how to cope with what is essentially an air electrode and making sure that the oxygen makes contact with the components in the cell.

"The safety issues of lithium-ion and lithium-air are comparable. In fact, lithium-air might be worse if

strings and require fairly simple battery management at pack level. Any innovations in battery management will be directly tied to the requirements of whatever battery chemistry becomes dominant in the future."

Ralf Schmid, vice president for R&D at Continental's hybrid electric vehicle business unit, believes a simpler approach to BMS design is necessary, but there are other factors to take into account: "A reduction in the complexity of the BMS is needed and the safety of the cells must be improved. The question is: can we reach ASIL D compliance [as part of ISO 26262 'road vehicles – functional safety'] with the cell in the future? Also, active instead of passive cell balancing would generate more efficient systems – instead of burning the energy, we could shift it to other cells. This technology is still expensive, but I'm sure we'll find solutions."

Meanwhile, Stephen Irish, MD of Hyperdrive Innovation, says the BMS is an all-important part of the bigger battery picture: "For us, the real opportunities lie in battery management, the charging systems and providing an overall solution in the form of a battery pack. Our current BMS can be recalibrated to adapt to different chemistries. We've come up with a modular system that's flexible and can deal with an almost infinite number of cells – we can daisy-chain them so that they talk to each other across circuit boards, with one acting as the master and communicating with the others via CAN. The next version will offer more efficiency in balancing the cells. The next big step will be to greatly advance the quality of the circuits, improve the algorithms, and make the systems more compact and able to work at higher temperatures."

The final word goes to Tom Cleaver, Oxis Energy's project manager, who affirms the importance of BMS systems: "Current setups access between 60% and 80% of the energy stored in batteries in today's EVs. There is an aspiration to increase this to 95% in the next few years as, essentially, most EVs on the road today use only two-thirds of their batteries – the rest is dead weight!"

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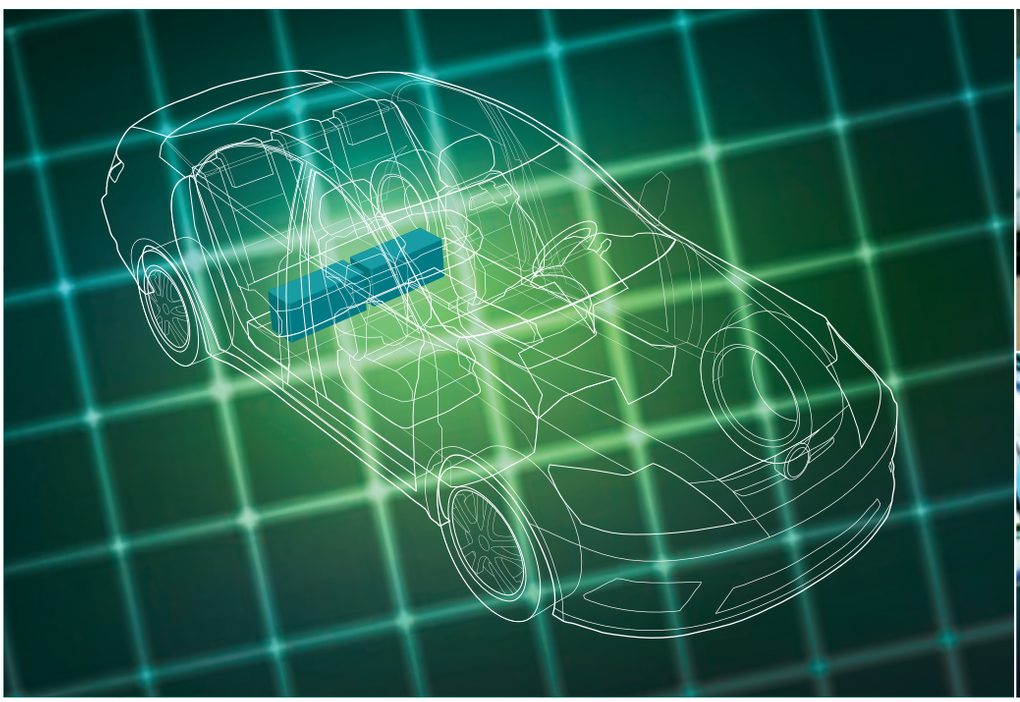

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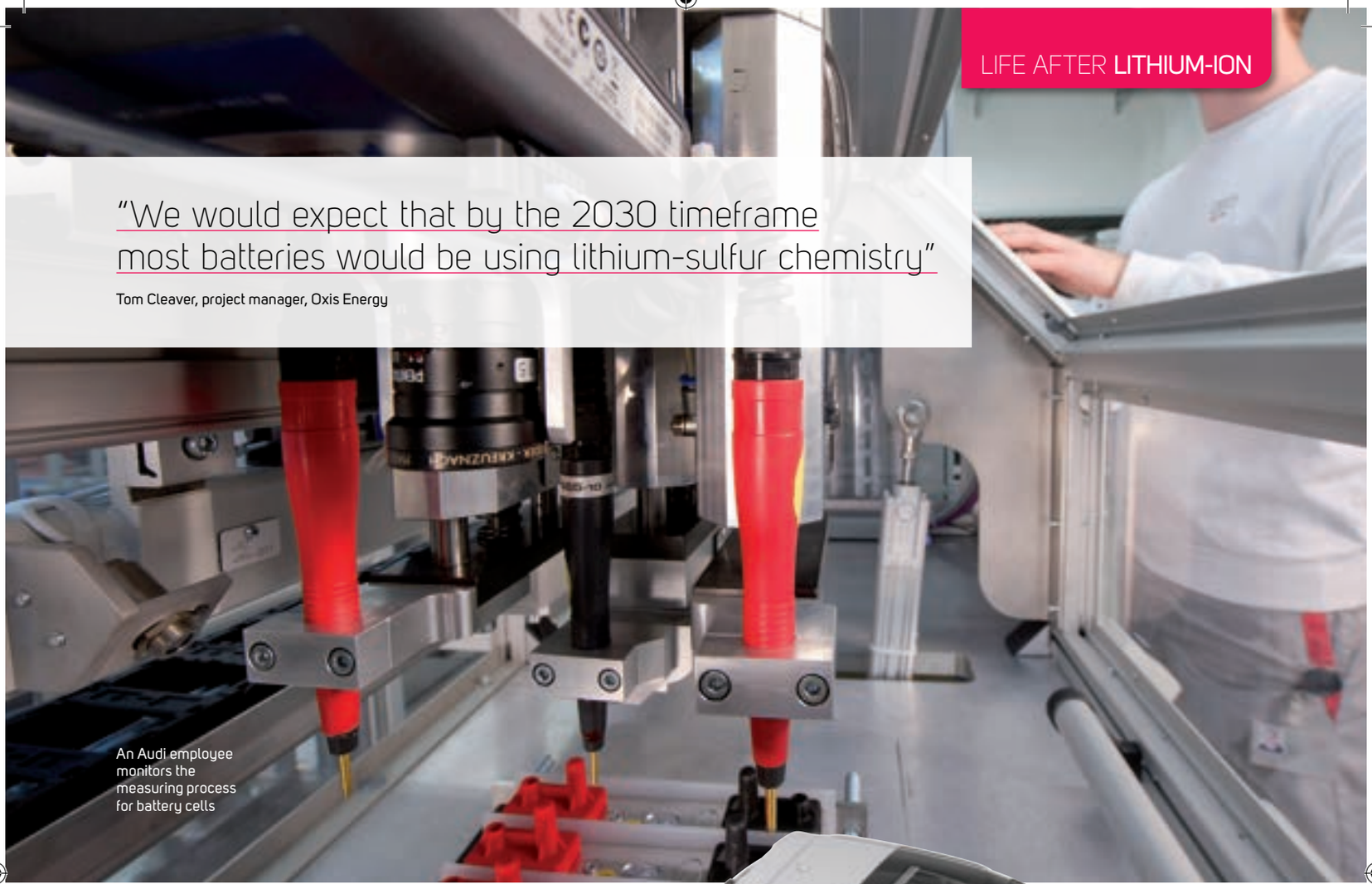
"We would expect that by the 2030 timeframe most batteries would be using lithium-sulfur chemistry"

Tom Cleaver, project manager, Oxis Energy



An Audi employee monitors the measuring process for battery cells

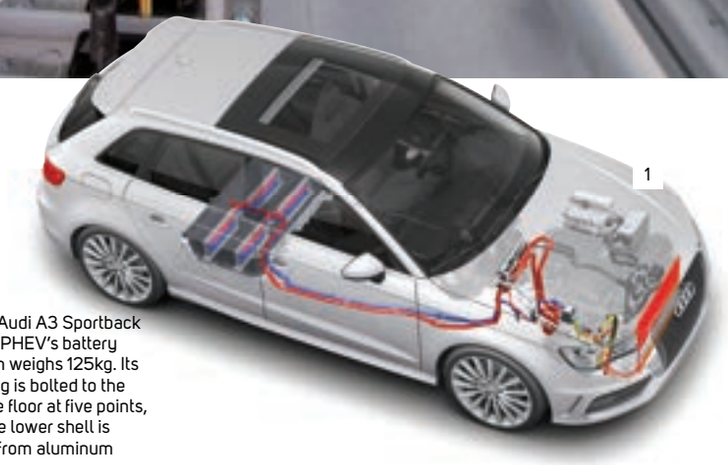
we cannot find a non-flammable electrolyte, as we know that if you recharge lithium electrodes they become highly reactive. So because of all the scientific and engineering problems it's going to be at least a decade or two before we get close to the market."

Super sulfur

Thackeray is not alone in urging caution over time-to-market predictions. "Lithium-air is a technology that has many challenging hurdles to overcome, so it is unlikely to be used in standard vehicles by 2030," estimates Tom Cleaver, project manager at Oxis Energy, based in Oxfordshire, UK. "Instead, we would expect that by the 2030 timeframe most batteries would be using lithium-sulfur chemistry." The pioneering supplier, which has made great inroads in the nine years since it has been formed, is currently working with researchers at Imperial College London, Lotus Engineering and Cranfield University to advance lithium-sulfur batteries for EVs with a control system that is claimed to use advanced modeling and algorithms to make use of 95% of the energy stored. Development work is expected to be completed around 2016.

Crucially, sulfur represents a natural cathode partner for metallic lithium. In contrast with conventional lithium-ion cells, the chemical processes involve dissolution from the anode surface during discharge and reverse lithium plating to the anode while charging. As a result, lithium-sulfur is claimed to deliver a theoretical specific energy in excess of 2.7kWh/kg, nearly five times higher than that of the current battery EV choice, lithium-ion. Oxis is aiming to substantially increase the energy density of its current batteries – 200Wh/kg has already been realized at cell level, 350Wh/kg has been demonstrated at effective material level in tests in 2013, and 400Wh/kg is said to be feasible within the next three years. Such progress means that Cleaver is optimistic about commercial applications. "Our Revolutionary Electric Vehicle Battery is a Technology Strategy Board-funded project to develop a lithium-sulfur battery that will achieve half the weight and price of the lithium-ion competition by 2016," adds the project manager.

Another area that excites developers is the use of nano materials. Carbon nanotubes are highly



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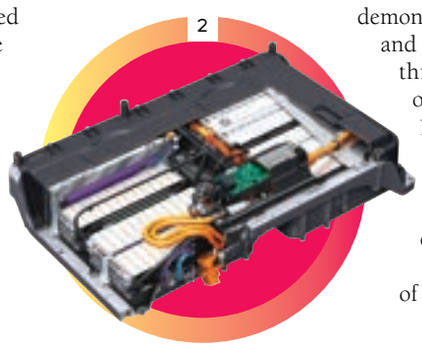
1. The Audi A3 Sportback e-tron PHEV's battery system weighs 125kg. Its housing is bolted to the vehicle floor at five points, and the lower shell is made from aluminum

2. The Sportback e-tron's battery module consists of 96 prismatic cells arranged into eight modules of 12 cells



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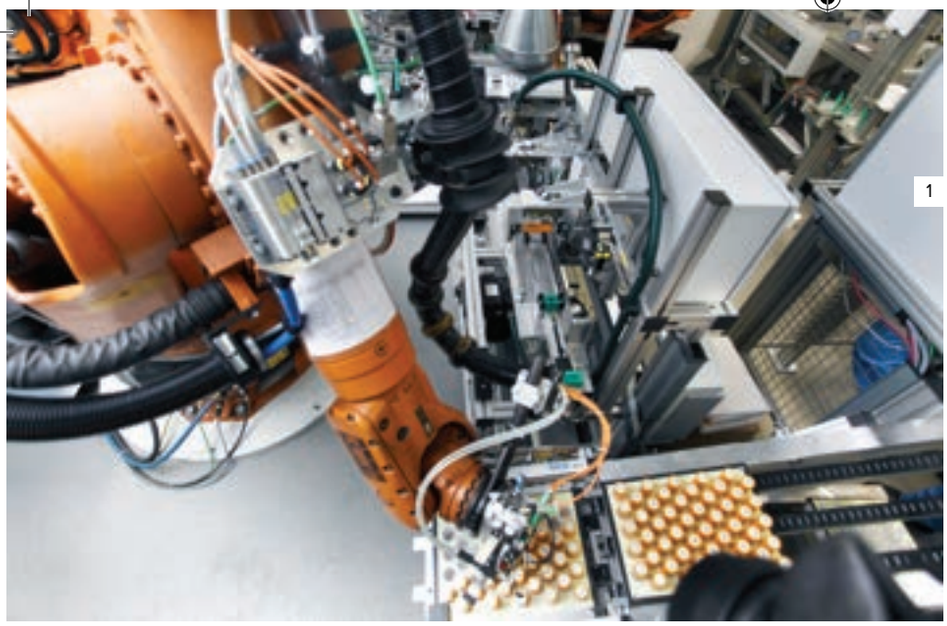

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1. BMW's Dingolfing plant is the location of the OEM's battery cell pre-assembly

2. BMW says that the intelligent heating/cooling system of the urban i3's high-voltage battery pack ensures that energy performance and total driving range are less affected by temperature fluctuations than is usual with batteries of this type

conductive and increase the surface area of anodes and cathodes considerably, thereby enhancing the overall energy density. Early trials with lead-acid cells claim a six-fold improvement over regular lead-acid batteries and up to twice the energy of conventional lithium-ion systems. Recent related research at Los Alamos National Laboratory has investigated a catalyst made from nitrogen-infused carbon nanotubes instead of platinum; it is believed to be capable of further

"Creating a battery with performance equivalent to gasoline is only a very small piece of the puzzle required for electric propulsion to replace today's combustion vehicles"

Thomas Apalenek, senior principal systems engineer for HybriDrive Solutions, BAE Systems

enhancing lithium-air cells. At BAE Systems, engineers are very aware of this technology's potential: "Most nano material research is in the area of new lithium-based battery types," confirms Thomas Apalenek, senior principal systems engineer for the company's HybriDrive Solutions business. "However, it is equally likely that the battery of 2030 will be based on some chemistry that none of us have thought of today. Regardless of the chemistry, it is almost certain that the battery of the future will be based on engineered nano materials and technology. That is the only way to get the surface areas high enough to achieve the energy and power density goals. The most likely engineering challenges will be finding ways to inexpensively and reliably produce large quantities of these highly engineered nano materials."

Apalenek recognizes that drastically increasing a battery's energy density is only part of the picture. "Creating a battery with performance equivalent to gasoline is only a very small piece of the puzzle required for electric propulsion to replace today's combustion vehicles," he outlines. "When you fill your car with gasoline, you are pumping energy into the tank at a rate that is roughly equivalent to a 4MW electrical outlet. So if everyone converts to electric cars, the recharging infrastructure and electrical grid requirements will be enormous. Yes, many people will charge their cars at home overnight, but generally people love to drive. When everyone wants to leave for a vacation after work on a Friday afternoon, there will need to be some way to charge all the vehicles. Every recharging station with eight 'pumps' would need a 32MW feed from the local power company to handle the Friday afternoon rush hour."

Caps off

Another new concept on the horizon involves the use of lithium ultracapacitors (LUCs), hybrid devices that combine the recharging mechanism of lithium batteries with the cathode capacitor that uses activated carbon material to store charge in an electric double layer design. The device's anode is produced from graphitic carbon

FURTHER DEVELOPMENT

During our battery-investigation travels, four other developments also caught our eye. The first, and perhaps most interesting, was in Sweden, where Volvo engineers have developed a revolutionary concept for lightweight structural energy storage components that could improve the energy usage of future electrified vehicles. The material, consisting of carbon fibers, nanostructured batteries and supercapacitors, offers lighter energy storage, which requires less space in the car, and is cost-effective.

In the USA, Daikin Industries is developing advanced high-performance electrolytes, based on fluorochemistries, that will enable lithium-ion batteries to operate at far higher voltages and temperatures.

In Japan, engineers from Denso are working with researchers at Nagoya University to create an in-vehicle battery-based energy-management system that can forecast models of household electricity demand and vehicle use to reduce overall electricity costs.

Finally, in the UK, and somewhat unconventionally, Dearman, Ricardo, E4tech and Mira are developing a novel, zero-emissions, piston engine that runs on liquid air or liquid nitrogen.

MATERIAL WORLD

Most industry analysts agree that substantial improvements in rechargeable lithium-ion batteries are required to meet the growing needs of EVs and PHEVs, yet major advances in battery performance have been slow to materialize.

Wildcat Discovery Technologies is working hard to shift this paradigm by applying the principles of combinatorial chemistry to the discovery of new battery materials. However, combinatorial chemistry itself isn't a new idea, having been pioneered in other industries particularly for the realization of new drugs and catalysts. Engineers at Wildcat, however, are the first to apply the technique to improving fuel cell batteries. Wildcat accomplished this feat by automating and parallelizing each step of the battery-discovery process, including synthesis, formulation, cell assembly, electrochemical testing and data analysis. The result of Wildcat's efforts is a high throughput battery workflow that enables its team to prepare and test thousands of new battery materials every week – far more than what's possible via conventional lab methods.

Wildcat's business model is to use its unique platform to accelerate battery discoveries for other organizations, and the high-tech company has been doing just that for over four years. The value of compressing the time-to-market for new battery technologies is huge, particularly when one considers the rapidly growing EV industry. Wildcat's high throughput approach is finding demand in the global race to develop advanced cell chemistries that will enable the widespread adoption of EVs.

Wildcat's customers include the global leaders throughout the battery supply chain, from chemical and material companies, to cell makers, electronics and automotive OEMs. Customer projects can target any component of the battery (including cathodes, anodes and electrolytes) and project goals range from quick, near-term cell optimization efforts to longer-term advanced materials projects that target truly breakthrough performance.

material, which is pre-doped with lithium-ions. This pre-doping lowers the anode potential and results in a high cell-output voltage, typically in the range of 3.8-4V. As a result, LUCs combine the higher energy density of a lithium battery with the power density of a capacitor – a win-win situation for many EV developers. Additional advantages are said to include high cell capacity, good reliability, a wide span of typical operating temperatures (-20°C to +70°C) and relatively low self-discharge, spanning from less than 5% voltage drop at 25°C over three months.

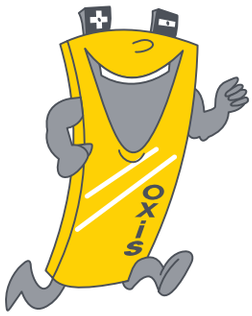
Battery development specialists at Goodwolfe Energy believe LUCs are an ideal candidate for bridging the gap between current lithium-ion technology and the advanced battery chemistries of the future. "The new lithium-ion capacitors are really interesting on many levels," states Ian Goodman, the company's founder and CEO. "They do hold a certain amount of energy and will hold it for three months. They have the millions of charging cycles you get with a capacitor and still deliver massive peak power. It's a really interesting transitional technology and we're working with a customer at the moment with a view to releasing a lithium-ion ultracapacitor system next year. It's ideal for OEMs who want the energy storage system to last the life of the vehicle. Testing shows 1.4 million cycles in the life of a typical hybrid vehicle application."

The Renault Zoe has a 22kWh lithium-ion battery that delivers a driving range of 210km under the NEDC cycle. But will this technology soon be surpassed by an advanced sulfur-based chemistry?

"It's a really interesting transitional technology and we're working with a customer at the moment with a view to releasing a lithium-ion ultracapacitor system next year"

Ian Goodman, founder and CEO, Goodwolfe Energy

However, when asked about the long-term outlook for battery systems, Goodman, a battery industry veteran, remains philosophical. "My gut feeling is that there will be an energy storage system that may not quite have the energy density of petrol or diesel but won't be far off, together with the necessary infrastructure," he concludes. "But I don't believe the technology we'll be using in 25 years' time will bear much resemblance to what we call a battery today."



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OXIS Energy (lead partner)
Imperial College London
Cranfield University
Lotus Engineering

The Project Targets
400Wh/kg
Half the weight of current Li-ion EV battery systems

The Final Deliverable
Li-S battery and powertrain, proven in Lotus EV simulator, delivery 2016

Crash test behavior

As the issue of battery safety remains an ongoing concern for electric and hybrid vehicle developers, researchers and academics are undertaking a range of tests to better understand the crash behavior of energy storage systems

WORDS: **RACHEL EVANS**

The batteries used in electric and hybrid vehicles can be severely hazardous in the event of an accident, when they can short-circuit and catch fire, or give off harmful gases. Their level of safety is therefore a primary concern.

Hazard damage depends on three main factors: battery cell chemistry and construction; battery pack and module design; and the integration of the battery pack into the vehicle.

Cooling helps to reduce the risk of overheating and work has been done to increase the protection of battery packs. In addition, researchers are developing tests to determine failure mechanisms and hazard levels with finite element models to validate these results. The underlying aim is to better understand the crash behavior of batteries and, as a result, improve their overall safety.

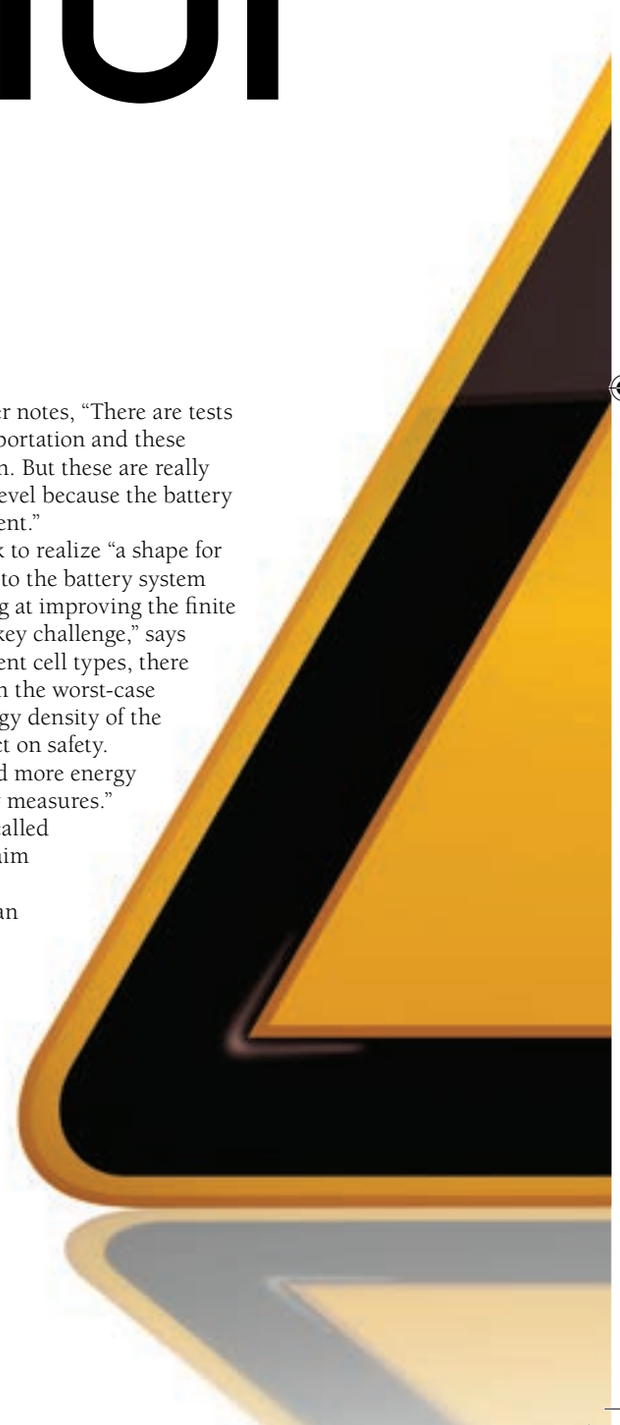
Hazard perception

There are currently no defined standards to specifically test the crashworthiness of a battery pack; however, there are some related industry norms. ECE-R100 has a requirement for the construction and functional safety of battery electric vehicles, while SAE J2464 addresses the safety and abuse testing of energy storage systems. In addition, FMVSS 305 has a requirement for electrolyte spillage and electrical shock protection.

At the Virtual Vehicle Research Center in Graz, Austria, Dr Alexander Thaler and Dr Gernot Trattnig have worked together on a battery safety project, to investigate further the issues involved with modeling the crash behavior of batteries. Thaler notes, "There are tests that have to be fulfilled for transportation and these procedures deal with deformation. But these are really standards only on a component level because the battery system in every car will be different."

The team has undertaken work to realize "a shape for deformation that isn't hazardous to the battery system after the crash", as well as looking at improving the finite element models for batteries. "A key challenge," says Trattnig, "is that for all the different cell types, there is a huge difference in behavior in the worst-case scenario. Unfortunately, the energy density of the battery system has a direct impact on safety. Having a better driving range and more energy usually requires additional safety measures."

A recent EU-funded program called SmartBatt was devised with the aim of developing a multifunctional, lightweight and safe concept for an electric energy storage system. With the input from industry experts including the Technical University of Graz (TU Graz, VSI), Fraunhofer, Ricardo, the Austrian Institute of Technology (Mobility, LKR), SP Technical Research Institute of Sweden, Impact Design Europe, Johnson Matthey Battery Systems and Volkswagen, the system was



"For all the different cell types, there is a huge difference in behavior in the worst-case scenario"

Gernot Trattnig, team leader of the material modeling group, Virtual Vehicle Research Center

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MODELING RESILIENCE

Tomasz Wierzbicki, director of the impact and crashworthiness laboratory at Massachusetts Institute of Technology, thinks batteries can be more resilient. He has studied the physical limitations of lithium-ion batteries, subjecting cells to forces aping frontal, rear and side impacts.

Using data from these experiments, he and his team developed virtual models that accurately simulate how a battery can deform and short-circuit under various crash scenarios.

The researchers found that a battery's shell casing may contribute differently to overall resilience, depending on the scenario. Making casings more ductile or flexible, the team believes, may help to improve the safety of lithium-ion batteries.

Wierzbicki says the team's model may be used to design new batteries, as well as to test existing ones. The model may also be incorporated into whole-vehicle simulations to predict a battery pack's risk of thermal runaway.

More information, including full results, can be found in volume 241, November 2013, p467-476 of *Journal of Power Sources*.

developed as an integrated structure for the body-in-white (BiW) of an IC car.

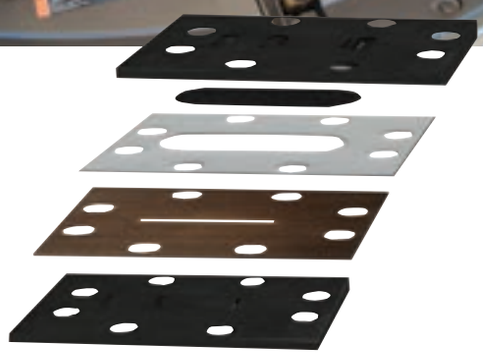
Most of the crash test work was carried out by an engineering team at Impact Design Europe and TU Graz. Peter Luttenberger, project manager at the Vehicle Safety Institute of TU Graz, says, "Building a safe housing for the battery with a novel mix of materials to ensure a lightweight design was a challenge and presented the need for additional FE-validation processes, which introduced the possibility of further problems."

The team's role at TU Graz was to perform all crash simulation and testing of the cells and of the pack, to define safe areas in which to place the battery in the vehicle, as well as to determine rescue guidelines and structural improvements.

During the project, Luttenberger explains, "Our focus was on deformation of the battery housing with the aim of achieving no deformation of the battery cells at all."

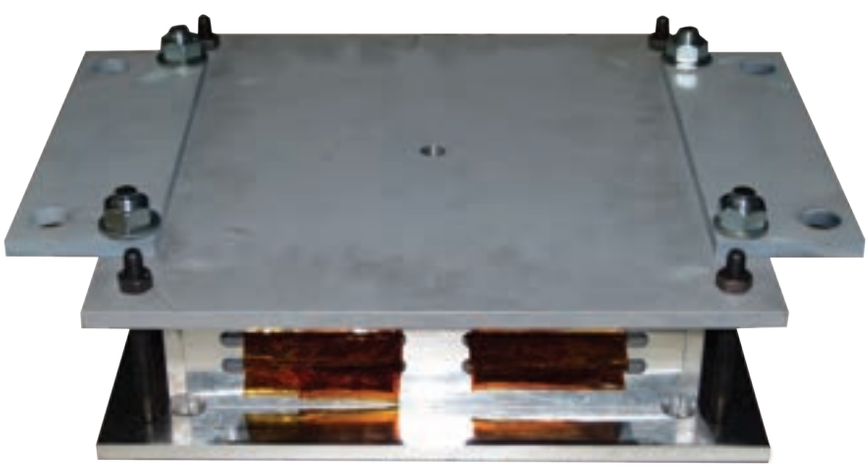
He describes the step-by-step process of the project: "To prove the crash safety of the battery, we ran full-vehicle crash simulations. The battery was integrated into a demonstrator FE model [of the BiW] and virtually evaluated according to different specifications including UNECE and FMVSS regulations, for frontal offset barrier crash, side pole impact, and rear and side barrier test."

He continues, "For the evaluation of safe locations, the FE model of the car was investigated in various crash scenarios considering the baseline conventional vehicle and a simple remodeled electric vehicle. In parallel, with the predefined requirements for weight, range and crash safety, a list of possible housing concepts were derived from the CAD-data of the BiW.



"There are only really standards on a component level because the battery system in every car will be different"

Dr Alexander Thaler, material modeling group, Virtual Vehicle Research Center



Below: Test bench module for pouch cells used in acceleration tests conducted as part of the SmartBatt program

"These results were the validation input for the ME [macro element] model, which was used for the battery integration process. For this purpose, the team performed a pre-evaluation of several battery positions/envelopes with the developed ME model, which minimized calculation time and therefore gave a view on a huge number of possible battery designs within the specified areas.

"The final FE model then considered only the best pack locations, fulfilling all the requirements."

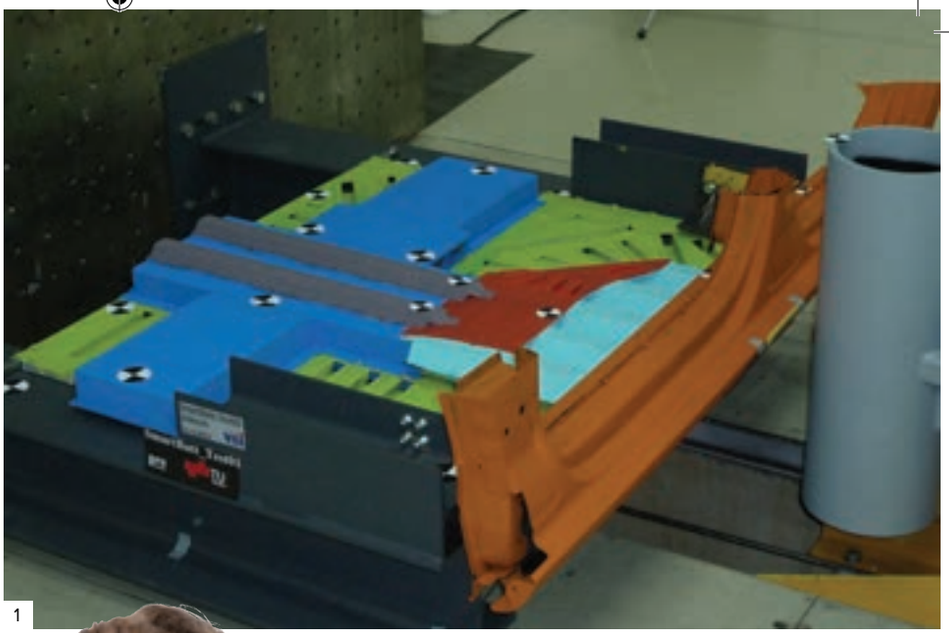
Product placement

As a result of space restrictions, the team was limited in terms of where it could place the battery pack. "We could not build a sandwich floor, for example, so we had to focus on placing the battery where there was space, so as not to influence the positions of the vehicle occupants."

As such, a detailed design plan of the floor panel with the battery housing incorporated into its structure was then derived.

One part of the battery was integrated below the front seat, with the other located below the rear seats. A tunnel combined both parts and was used for mounting electric devices. All original floor panel parts around the front and the rear pack were cut out of the simulation model and redesigned with a focus on creating better force distribution and floor-panel stiffness.

Next, physical crash tests were conducted with a battery pack containing real modules. Luttenberger and his team are yet to validate the results with simulation and integrate it into a demonstrator FE model. "We have not done that yet because there is no model of a used cell available. We did the test, but validation of the model of a real module has not been done. The virtual tests



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"We are still some way from defining hazard levels for crash testing and putting them into the FE model"

Peter Luttenberger, researcher, Technical University of Graz

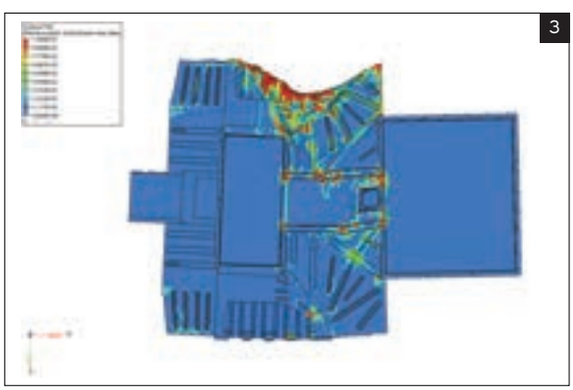
2

described were conducted with foam inside the pack, but with no real [cell] module structure."

The conducted analysis was a side pole impact test. "This is a crucial test when looking at deformation patterns of the vehicle that can be dangerous to the cells," continues Luttenberger.

Cost and time restrictions meant the team tested only half of the battery pack – specifically the front part – where higher deformations in the surrounding structure were expected: "We took only the battery pack with the side floor panel into account, and the rocker." The mounting points were designed to have the same boundaries as in the FE model of the full vehicle.

Luttenberger clarifies, "You would also check the rear, but only with full vehicle simulations. So it was more or less a validation process to show with a test, that the numerical model is correct and valid. Then you can validate a pole crash at the rear."



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1. TU Graz conducted side pole impact crash tests using a vehicle floor panel. The battery is shown in blue; there are 16 plastic modules containing cells. It has the same layout as the functional pack without the wiring between the modules

2. The Vehicle Safety Institute at the Technical University of Graz performs a variety of studies to aid its research into battery cell behavior during impact, such as compression tests

3. FE model, developed within the SmartBatt program, of the floor panel displaying the battery. The front and the rear pack have nearly no deformation, while the side absorber collapsed as planned

Unfortunately, time restrictions meant the team was unable to model battery cell behavior. With various cell chemistries reacting differently in an impact, this will be an important area for future research and development in the sector, although work is already underway with other research projects.

Cell shocked

Interestingly, additional testing with SmartBatt revealed that shock damage to cells during impact may not be as big a problem as expected. Luttenberger says, "We worked with a partner in Linz and single acceleration sled tests showed that this doesn't seem too much of a problem, at least on a cell level."

Further analysis could involve looking at correlations between levels of deformation and internal short circuits. "That would require testing of a large number of cells to prove the statistical behavior of all cells," explains Luttenberger. "We are still some way from defining hazard levels for crash testing and putting them into the FE model."

Within this particular project, Luttenberger says that, due to specified requirements, the optimum choice for the cell selection process was a small prismatic cell with a lithium manganese cobalt oxide cathode. Though for simulation purposes, only a solid foam structure inside the battery pack was modeled in order to measure deformations, instead of the original cell model. The next logical step is to finalize the numerical cell validation, and evaluate the virtual optimization process of the pack by integrating the numerical cell model instead of the solid foam.

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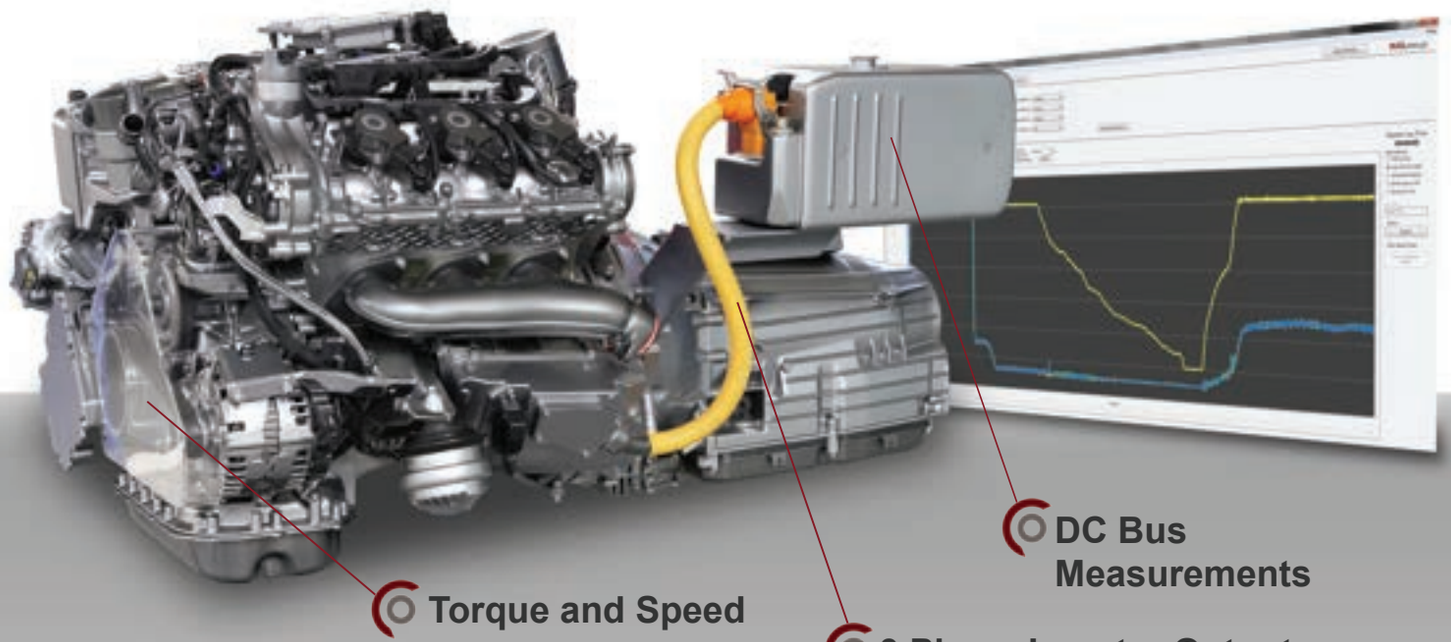

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Trail blazer

WORDS: **DEAN SLAVNICH**

To fully test and validate **Land Rover's** first ever production hybrid model, the company's engineering team undertook one of the most dangerous and challenging road journeys in the world: the Silk Trail

THE SILK TRAIL JOURNEY IN NUMBERS: 3 HYBRID RANGE ROVERS | 4 SUPPORT VEHICLES | 4 DAMAGED WHEELS | 4 CRACKED

WINDSCREENS | 13 COUNTRIES | 15 PUNCTURES | 53 DAYS | 300GB OF TECHNICAL DATA | 5,500M ABOVE SEA LEVEL | 16,843KM

The Silk Trail. Some say it's the most challenging journey in the world. A series of twisting roads, corridors and passages that date back to the 1st century, connecting East to West. It's a route steeped in history, tradition and danger, and where every possible type of terrain calls home, from roads slick due to ice sleet showers through to parched gritty sandy plains; deep sticky mud tracks, acute potholes and river crossings; extreme temperatures from -10°C to more than +45°C; and tight pathways that snake below, through, and cling to the side of mountains, reaching high into the sky at altitudes of 5,500m.

It's a journey that most IC-engined prototype vehicles would fear and ultimately fail. It's a journey that only one organization has dared to tackle with its first ever hybrid vehicles in what's being billed as the 'final extreme engineering sign-off test'. And it's a journey that, in this particular case, started in Solihull, UK, entailed 16,843km, lasted 53 days and passed through 13 countries and two continents. This was a pilgrimage where nerves were tested and engineering know-how was stretched to the limits, but not a single prototype hybrid engine failed.

"If I had known just how severe that drive on the Silk Trail was, I'd have been a bit worried about agreeing to it in the first place!" says Peter Richings, Jaguar Land Rover's (JLR) hybrids and electrification director, with a hint of irony. "But I'm bloody glad we did it because it's been such a fantastic test. We completed the 16,000km; we've been up to 5,500m in height, which is an altitude that we never engineered the vehicles for; and one of the cars went much deeper in water than it was meant to, but having done all those things, we've proved how capable the car is and we've come back not wanting to change anything. The result is great affirmation of what we set out to achieve.

"This is the way we do things on hand at Land Rover. When we started the hybrid project for Range Rover, it was always the case that we wanted to develop a Range Rover first, not a hybrid. It was absolutely essential that we create a fully capable all-terrain vehicle first and a hybrid second, not the other way around. So, when we started this project, we knew it was going to have to deliver that sort of performance and we designed it accordingly."

Having started their journey at JLR's home in Solihull, the Range Rover Hybrids blazed a trail through France, Belgium, Germany, Poland, Ukraine, Russia, Kazakhstan, Uzbekistan, Kyrgyzstan, China (including Tibet), Nepal and India, finishing in Mumbai, the home of Tata.

Yet it was where the north and south Silk Roads split, near the remote city of Kashgar, in northwestern China, that Richings says the expedition faced some of its greatest engineering challenges. Prior to the JLR party, this part of the mountainous route, called the Xinjiang-Tibet highway, was never previously completed by a vehicle from outside China. It was here where the three hybrid Range Rover vehicles, negotiating erratic traffic, reached heights of 5,500m above sea level. In fact, seven consecutive days were spent at altitudes between 3,500m and 5,370m, during which oxygen content in the air plummeted to just 10%, making life difficult for the base diesel engines but allowing the 35kW electric motors to come to the fore.

"The key thing we learned was how to 'guess calibrate' the car to operate at high altitude, because we

TECH SPEC

Range Rover Hybrid
Engine type: 3.0 SDV6
Power: 340ps at 4,000rpm
Torque: 700Nm at 1,500-3,000rpm
0-100km/h acceleration: 6.9 seconds
Top speed: 218km/h
CO_2: 169g/km
Fuel consumption: 44.1mpg
Weight: 2,394kg

With its parallel 3-liter SDV6 diesel engine and 35kW electric motor, the Range Rover Hybrid models have returned impressive fuel economy close to 40mpg on the waterlogged mud tracks of the Kalmykia grasslands in eastern Russia, and on asphalt highways and busy urban roads through Kazakhstan and Uzbekistan

hadn't engineered it to operate at over 3,000m and we were at 5,500m at some points in the journey," recalls the JLR director. "My engineer out there was having a bit of oxygen when he came up with a high-altitude calibration, which is fantastic because we will offer this car in the future in markets that have some high altitudes, and now we have a calibration that we can use. It was an added benefit from the expedition that we were really not expecting."

Throughout the journey, Land Rover engineers closely monitored dataloggers fitted to each of the three cars, sending back more than 300GB of detailed technical records to engineering teams at JLR's technical center in Gaydon, UK. The underlying purpose of the mission, says the British car maker, was not to test the reliability of the mechanical components, but rather to fine-tune the calibration of engine and transmission software in all terrains and at extreme temperatures and altitudes.

Three years in the making

Work started on the new Range Rover in 2009, and from the very beginning, says Richings, it was decided that there was going to be a hybrid model. "Certain things we package protected, such as the battery and power electronics, so we made sure that was designed-in and we allocated space for it and knew where they were going. But the real, in earnest, development work on the hybrid system started around three years ago."

Naturally, given that this is Land Rover's first ever production hybrid model, the development program took longer to complete than a standard IC engine project. The hybrid powertrain, which will be offered in both the Range Rover and Range Rover Sport models, offers three direct-selectable modes and combines Land Rover's 3-liter SDV6 diesel engine with an electric motor that is integrated with

an eight-speed transmission. The hybrid system, including the lithium-ion battery pack, inverter and e-motor, weighs less than 120kg – an impressive feat by anyone's standards.

The e-motor offers 170Nm of torque and acts as a generator, harvesting kinetic energy through regenerative braking, charging the battery when the vehicle is slowing. In pure electric mode, both Range Rover Hybrid offerings can travel at speeds of up to 48km/h for a range of up to 1.6km before the diesel unit cuts back in.

When combined with the V6, the powertrain provides 340ps at 4,000rpm and class-leading torque of 700Nm between 1,500rpm and 3,000rpm. The result of such power is a 100km/h sprint time from standstill in under seven seconds and a top speed of 218km/h. Perhaps more tellingly is that a CO_2 emissions reduction of 26% has been realized, meaning that in the real world, CO_2 is down to 169g/km, equivalent to 44.1mpg on combined mode.

Modularization and subsystem sharing is the key to the hybrid Range Rover models seeing the light of day. For example, the ZF hybridized eight-speed transmission has exactly the same external dimensions as the unit that features in the non-hybrid models. And working from a new, clean vehicle architecture was also a big plus point for Richings and his team: "Parts like the battery, battery power electronics and the cooling associated with those systems are the components you'd have a bit of fun with if you hadn't designed them into the layout in the first place. If you're designing a new vehicle to be a hybrid, you can accommodate these parts, but if you're taking an existing vehicle and turning that into a hybrid, then that's a much trickier task because the basic architecture wasn't designed for those specific components."

"We wanted to make the most fuel-efficient Range Rover we could and the diesel engine is inherently more efficient"

Peter Richings, hybrids and electrification director, Jaguar Land Rover

ELECTRIC EVOQUE

JLR's latest electrification program focuses on the Evoque, creating tech demonstrators that include a mild hybrid electric vehicle, a plug-in hybrid electric vehicle and a full battery electric vehicle. "The aim is to develop technology platforms that are configurable and compatible within the architecture of an existing production vehicle," says Richings. "The modular technologies include single- and multispeed axle drives; modular battery packs and integrated power electronics; multimachine, advanced control development; and torque vectoring."

Richings says some of the Evoque_e partners are the same ones that worked on the electric Defender, but new names include Zytek, GKN Driveline, Motor Design, AVL, Drive System Design, Williams Advanced Engineering, Delta Motorsport, Tata Steel, Bristol University, Cranfield University and Newcastle University.

"The research teams will look at how the speed of the e-motor can be increased to reduce its size, weight and cost while enhancing performance and durability. We will also look at the use of alternative materials to both reduce the use of rare earth materials and for system operation.

"The outcome of the Evoque_e project will be new technologies with the high potential for high-volume production that are capable of delivering benchmark performance in terms of cost, weight and sustainable use of materials."

A CO_2 emissions reduction of 26% was realized by the Range Rover Hybrid, resulting in a real-world figure of 169g/km, equivalent to 44.1mpg on combined mode

The last issue of *E&H* published the tech story of the electric Land Rover Defender project in which JLR partnered with a number of leading suppliers, but for the hybrid Range Rover program, the company worked with a different set of Tier 1 organizations: "The Defender was an interesting and fun project to do, but that was a research project and we made a few vehicles. When you're talking about a full-volume production vehicle, you begin to talk with different suppliers. The hybridized transmission is from ZF, so we worked with ZF right the way through the program, they were a key partner on that. The e-motor is part of the hybridized transmission, so that's from ZF Group too. The high-voltage battery is from Johnson Controls. The cells are made in the USA and the battery is made in Europe."

Not plugged in

Having taken the decision back in 2009 to develop a hybrid Range Rover, was it a brave decision to combine the electric componentry with a diesel IC engine, creating what some car makers call the most expensive powertrain setup? "I don't see it like that," replies Richings candidly. "For us, it was a pretty straightforward decision. We wanted to make the most fuel-efficient Range Rover we could and the diesel engine is inherently more efficient. Added to that is that the diesel has good acceptability in a lot of our key markets, specifically Europe. There was some discussion about it, of course, but we're pretty comfortable in having made

that decision and it's interesting now that one or two of our competitors are following us."

And being not only the company's first hybrid, but also the industry's first upmarket diesel hybrid all-terrain SUV meant that it was tough to benchmark the Range Rover derivative during development: "During the early stages, there were vehicles that we could look at in terms of benchmarks for the CO_2 number, but there were no benchmarks for most of the high-level vehicle attributes that we were aiming for because there were no other all-terrain hybrids out there at the time – and there still isn't now," reasons Richings. "I actually think we've made the benchmark for other people to look at."

Interestingly, and unlike Volvo's offering, which would be the most obvious comparison, the Range Rover diesel hybrid does not have plug-in capability, and there's good reason for that, says Richings: "We've done plug-in hybrid research programs, first with the Range_e project and then the XJ_e plug-in project. I think it's an open secret that we're working on plug-in technology, but we didn't look into it for this Range Rover hybrid program. The world's not ready for a plug-in yet – there are just not enough places to plug them in at the moment. You don't want a car that carries a heavy battery that's suitable for a plug-in if you can't plug it in regularly and recharge it, because it becomes quite inefficient. If you start driving a plug-in hybrid with a battery at a low state of charge, then it's running as a hybrid but with a much heavier battery than a conventional hybrid, so it becomes quite inefficient. We need to get to the point when you can plug in regularly and there's a good infrastructure. I'm a real fan of plug-in hybrids, but until we get to that [infrastructure] point, we're not quite ready for them yet." When asked if the current architecture can be modified to incorporate plug-in capability, Richings replies, "We'll have to see if and how we can engineer that option."

"I think it's an open secret that we're working on plug-in technology, but we didn't look into it for this Range Rover Hybrid program. The world's not ready for a plug-in yet – there are just not enough places to plug them in"

Peter Richings, hybrids and electrification director, Jaguar Land Rover

Facing extreme temperatures and altitudes, technical setbacks reflected the roughness of the road surfaces, with the expedition having to deal with 15 punctures, four wheels damaged by deep potholes, and four windscreens cracked by stones thrown up on loose surfaces

Growing influence

Having developed the Range_e, XJ_e and electric Defender PHEVs and full EV technology demonstrators, as well as being about to launch the Range Rover diesel hybrid production models and working on the Evoque_e R&D project (see *Electric Evoque*, previous page), there's no doubt that powertrain electrification is growing in importance within JLR. Richings' team, which is around 250 engineers strong, operates as a separate unit within the overall engineering department. "But we work extremely closely with other engineering teams," outlines Richings. "So, every project that we have running, we run it as a project team approach so that engineers from my team are working side-by-side with the guys from powertrain, body and chassis. It's an integrated organization." Richings' unit has come a long way from when he started the team five years ago with only 30 people. "We've grown significantly and we've worked really hard in recruiting the right people."

And the future looks even brighter: "In five years' time, the improvements that will be made [to battery technology and EVs] will be single- or low double-digit in terms of percentage. In terms of that big change, we're probably looking at a 10-year timeframe, but it will come. Electrified vehicles, in a generic sense, will become much more significant over that 10-year period."

But back to the present and basking in the Silk Trail glory. Is this Richings' greatest achievement? "It was an expedition that JLR put together as a team. I can't take credit for the whole thing, but my team and I can take credit and pleasure from how the vehicles performed. The Silk Trail has been a target that we had to achieve and we did it. The way the vehicles performed during this program – and it was honestly rather more severe than we expected – was so good that the hybrids came through with flying colors. The point is that our in-house testing that we do on all vehicles gave us a vehicle that could complete this journey. This expedition has validated the testing that we already do. We really proved our claim to develop the world's first all-terrain hybrid. I challenge anybody to tell me that their hybrid vehicle has done anything close to that sort of expedition."

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As a journalist, sometimes one really struggles for an opener when sitting down to write a feature. You know what I mean – a good hook with which to reel the reader in, packaging up exciting, new information but not revealing too much, all done in a concise and clever manner that will get you to commit to the piece after the first paragraph. And then there are other times, completely at the other end of the spectrum, when there's just so much on the plate that one really doesn't know where to start, because with every strand there's a great story to tell. This, dear reader, is one of those times!

All said, then (and if you're still with me), perhaps it's best to start at the beginning, and when I say beginning, I mean 50 years ago, when an iconic sports car was created that would go on to shape automotive development and engine design for the next half century: the birth of the Porsche 911.

Across the years and across the decades, few would have predicted back then at the 1963 IAA Frankfurt Motor Show just what impact the original 901 prototype and its subsequent production-ready successors, starting with the first 911 in 1964, would have on sports car engineering and powertrain R&D. Today, many even go as far as to say it was a landmark date not for just Porsche but for the wider automotive industry.

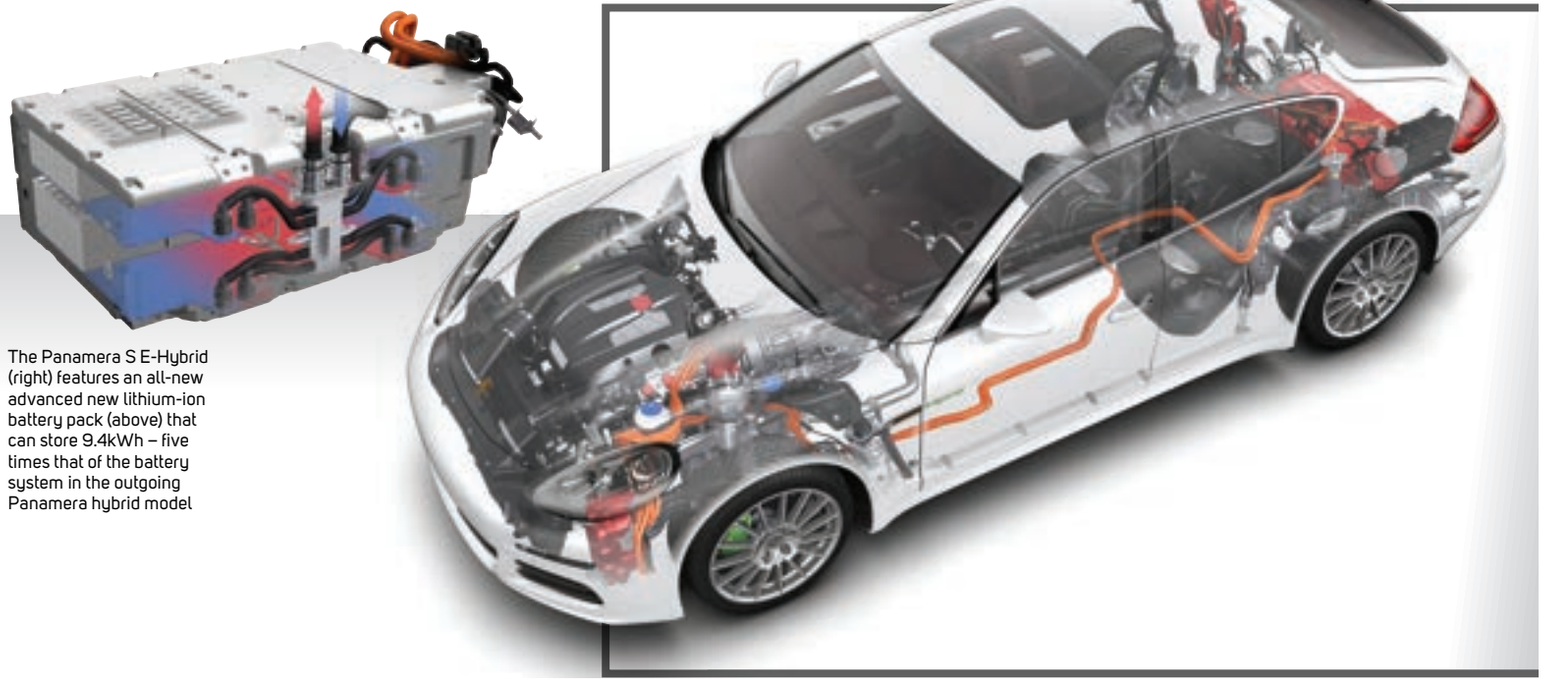
So, with so much to celebrate, 2013 was always going to be a special year for Porsche, but throwing a half centenary bash for the 911 was just the start. In June, Weissach's finest shocked most industry onlookers by winning one of the toughest categories at the 2013 International Engine of the Year Awards – the 2.5-liter to 3-liter class – with its compact but punchy 2.7-liter DI design in the new Boxster and Cayman, in the process ending eight years of successive victories by various turbocharged straight-six BMW powertrains.

Potential hybrid Carrera sports cars, new plug-in architecture, technology-sharing with VW Group members, the shortcomings of emissions legislation, record-breaking sales and – oh yes – the 911 turning 50 years old... Just some of the things Wolfgang Hatz, Porsche's head of research and development, wanted to discuss when *E&H* paid him a visit

WORDS: **DEAN SLAVNICH**

Future proof

Advanced hybrid plug-in systems, such as the ones featuring in the 918 Spyder (above) and the Panamera S E-Hybrid (right) are growing in importance at Porsche. The car maker's head of R&D, Wolfgang Hatz (left), is a big fan of the eco-friendly alternative powertrain technology



The Panamera S E-Hybrid (right) features an all-new advanced new lithium-ion battery pack (above) that can store 9.4kWh – five times that of the battery system in the outgoing Panamera hybrid model

On the product front, the car maker in the last 12 months has ushered out the new 911 to great acclaim – and especially the Turbo derivative; the Panamera S E-Hybrid – the first plug-in offering from the Stuttgart headquartered OEM; and the truly pioneering 918 Spyder. Work has finished on the Macan, which is due next year and will undoubtedly be just as good as its bigger SUV brother, the Cayenne.

The result of all this is that as a company, 2012 became Porsche's most successful year to date: 143,096 vehicles have been sold globally, an increase of 22% on the year before. Turnover is up by 27% to US$18.7 billion, of which operating profit is up to US$3.2 billion.

There's no doubting that much of Porsche's record-breaking year can be attributed to an expanded model line-up that encompasses rev happy flat-six sports car engines, smooth V6 powerplants, torquey diesel motors and hybrid electric designs too. But what of the future? "For the next decade, when it comes to alternative powertrains, I am convinced plug-ins are the right answer," states Wolfgang Hatz, the member of the Porsche board responsible for research and development. "You have to improve combustion engines – that's a given – but if you look at alternative engines, I really am a strong believer in plug-ins because I think it combines the best of both worlds, in the sense that a pure electric car struggles with driving range."

And when Hatz, who took on the R&D chief role at Porsche in 2011 and signed a new five-year contract earlier this year, says plug-in technology represents the future, he means just that: "I believe less in range-extenders. I believe that a strong combustion engine combined with a strong e-motor is the solution. A range-extender is just that: a range-extender. From an efficiency point-of-view, it's not really a solution. Let's say if you want to go from Germany to Italy by car, a range-extender is not really the solution you want."

The powertrain in the plug-in Panamera is a development that Hatz is particularly proud of. A synchronous e-motor is packaged with a 3-liter supercharged V6 engine, the drive of which is handled by a modified ZF eight-speed torque converter automatic unit

Integration with the family

The Panamera S E-Hybrid, with all-new plug-in hybrid architecture, is a development that Hatz is particularly proud of, especially as the powertrain was developed by Porsche's engineering team and not one that's borrowed or co-created with another Volkswagen Group member. "It's our plug-in hybrid system," he says firmly, putting an end to rumors that suggested Bentley also had technical input into the project. "I don't know what Bentley is doing on the plug-in side but what I do know is that we are first to market in our segment with this technology."

According to Hatz, work on the plug-in powertrain technology started three years ago and it was something that the 54-year-old German engineer personally "pushed very hard for". He continues, "The plug-in is based on our parallel hybrid system and what we've done here is to take it a step further. We put a lot of energy and power into this project."

PANAMERA S E-HYBRID TECH SPEC:

Drive system: Parallel full hybrid with plug-in technology, IC engine and hybrid module with electric motor and decoupling clutch
Power: 421ps at 5,500rpm
Torque: 590Nm from 1,250rpm to 4,000rpm
Maximum engine speed: 6,700rpm
Electric motor: Permanently excited synchronous motor
Electrical system: 12V vehicle electrical system; battery capacity 75Ah
Power transmission: Engine and transmission bolted to form one drive unit, rear-wheel drive via double-joint driveshafts; eight-speed automatic transmission with torque converter (Tiptronic S)
IC engine:
Bore: 84.5mm
Stroke: 89mm
Displacement: 2,995cc
Compression ratio: 10.5:1
Top speed: 270km/h
Electric top speed: 135km/h
0-100km/h acceleration: 5.5 sec
Fuel consumption: 3.1 liters/100km (combined)
CO_2 emissions: 71g/km (combined)
Electric driving range: Between 18 and 36km

Porsche's new plug-in hybrid architecture, which debuted in the Panamera, will find its way into the Cayenne next year. Pictured above is the Cayenne Hybrid S, which mates a six-cylinder engine developing 333ps with an e-motor that generates 47ps. Emissions are rated at 193g/km of CO_2, a figure that the new hybrid model will vastly improve upon

PORSCHE'S RECORD-BREAKING YEAR

Total sales: **143,096 (+22.3%)**
911: **26,203 (+48.8%)**
Boxster/Cayman: **11,740 (+4.1%)**
Cayenne: **77,822 (30%)**
Panamera: **27,331 (-3.1%)**

But talk of possible hybrid system sharing with Bentley gets Hatz a little unsettled. The former head of engine development at Audi checks his watch twice in less than half a minute before tackling my next question relating to closer engine development ties with the wider VW family. "It's very simple, really, in the Group there are three or four major concepts available. One is MQB, which is Volkswagen made, so all transfer systems are with them because they are the key developer. Then there's MLB, which is the longitudinal engines with front-wheel drive or all-wheel drive, a concept that Audi is using with the A4, A5, A6, A8 and so on. Maybe there will be other uses of MLB in the future. And then we have the rear-wheel drive platform where the responsibility lies with us. In addition, we also have a major role to play in the sports car concepts within the Group. I think it's very clear that the key R&D centers are in Audi, Volkswagen and Porsche, and then across the whole Group we can share certain concepts, which is a big advantage for us.

"Let's say there's a door ECU; it doesn't really matter from the customers' perspective if that ECU comes from Audi, Volkswagen or from us, but from an OEM perspective, it gives advantages in terms of higher volumes."

Such talk of technology sharing leads onto an obvious next question: does this mean Porsche will adopt the Group's blossoming strategy in making use of cylinder on demand (COD) technology? "I was in charge for many years of powertrain activities for the Group, so I know all about this concept. We are also thinking of such systems and perhaps in the future we'll even take responsibility of a new engine family for the Group." When pressed a little more on the possibility of Porsche using COD, Hatz replies: "Maybe, yes."

But back to the very heartbeat of Porsche: screaming, emotive and high-performance boxer designs that continue to raise the bar in engine development. "At the moment, we're investing a lot of money in our powertrain strategy," outlines Hatz when asked about the long-term future of flat-six engines. "This means we're developing completely new engine families for the next decade. We are also investing in a new engine plant, it's something that we have to do because we believe the flat-six engine, or just a flat engine design, has a future and we have to prepare this engine family for the next decade. Downsizing is a trend, for sure. I personally have done a lot with regards to engine downsizing and Porsche has always been downsizing.

"If you look at the 911 Turbo with a flat-six engine, for example, that's a downsizing concept in comparison to other models that in this segment use eight, 10 or even 12 cylinders. Downsizing is something that was always part of our history and will also be part of our future."

> "For the next decade, when it comes to alternative powertrains, I am convinced that plug-ins are the right answer"

The problem with legislation

Porsche's R&D man admits he has "no idea" what exactly future emissions legislation will entail but states, "If you look at SULEV legislation in the USA, cars have become cleaning machines!"

The groundbreaking 918 Spyder with the Weissach package currently holds the lap record for road vehicles on the Nürburgring Nordschleife, with a time of 6.57 minutes

"I think on the emissions side, we've achieved a certain level where it's difficult to say that we harm the environment now"

918 SPYDER TECH SPEC:

Drivetrain: Parallel full hybrid; 4.6-liter V8 mid-engine with dry-sump lubrication; hybrid module with electric motor and decoupler; electric motor with decoupler and transmission on front axle; stop/start function; electrical system recuperation; four cooling circuits for motors, transmission and battery; thermal management
Energy supply: Lithium-ion battery with 6.8kWh capacity (BOL nominal); 220kW
Displacement: 4,593cc V8
Engine power: 616ps at 8,700rpm (V8 engine); 290ps (electric motors); 906ps (combined)
Torque: 917Nm to 1,280Nm (depending on the gear)
Power transmission: IC engine with hybrid module and transmission bolted together to form a single drive unit; seven-speed PDK; rear-wheel drive; front electric motor with transmission for driving the front wheels (decoupled from 235km/h)
Top speed: 345km/h
Electric top speed: 150km/h
0-100km/h acceleration: 2.6 sec
Pure electric range: 16km to 31km
Consumption: 3.3 to 3 liters per 100km
CO_2 emissions: 79 to 70g/km

Developed in Weissach, the 918 Spyder will be assembled in limited numbers at Porsche's plant in Zuffenhausen

He continues, "I think on the emissions side, we've achieved a certain level where it's difficult to say that we harm the environment now. But for sure, legislation will always ask for more, so after Euro 6 there will be a Euro 7. Unfortunately, I think legislation will always continue to invent something new. I have nothing against more stringent emissions legislation, but my biggest wish is that we have a worldwide emissions standard because right now we have so many different regulations, but I think this situation will never happen. Having one worldwide emissions standard would help a lot and save resources to invest in new technologies because if you have to fulfill all the emissions levels around the world, then you spend money – and lots of it!"

If it's not possible for there to be one worldwide emissions regulatory body setting one standard for all markets – and its highly unlikely that Hatz's wish will ever come true – then the Porsche exec would like for more emissions legislation to mirror the laws in California, essentially giving car makers plenty of lead time to meet new regs. "In Europe, for example, there's a much shorter [turnaround] time," he explains.

"So, in 2014 there's a new homologation that we all have to meet but then in 2015 there's another new homologation, so if you're in production for an extra half a year, you can't actually sell the car, so in a short period of time you have to change volumes which is just a waste of money and doesn't help the environment because Euro 5

To celebrate 50 years of the 911, Porsche created a special anniversary edition. Hatz says it's possible that a future 911 will feature powertrain electrification

is not a dirty engine. So in that respect we need more flexibility – two, three or even four years to fulfill new emissions levels across the entire fleet, like the situation in the USA, which is a much more intelligent way of doing things."

Emissions legislation is clearly an issue that Hatz is not only passionate about, but wants to openly discuss. So, based on what he's just said, are legislators misguided? "You know, it's a fight," he says, having given the question some thought. "I also have big concerns about the environment and, in the end, we need a no impact product. This will be the future. But the wish for private and individual transportation will still exist in 50 years' time."

Having started the year celebrating 50 years of the iconic 911, it's apt that my time with the ever charismatic Porsche research and development chief finishes on a similar note, asking him just what type of powertrain will drive a typical 911 sports car in 2030? "Oh, now that's a good question," he says smiling, leaning back into his chair and taking a sip of water. "Ok, I don't think there will be just one engine – we will have different engines in it. I don't know if we'll have a hydrogen fuel cell in a 911, but most likely we will have some sort of electrification in that 911 because electric can be fun.

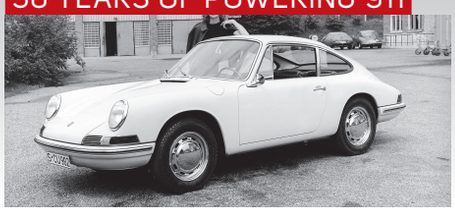
"We'll perhaps have a pure emotional 911 model with a combustion engine but which also has very low fuel consumption; it could be a four-cylinder 911, which is more than possible, and it will be a very efficient and clean powertrain." In a telling final remark, Hatz adds, "But I think it's most likely going to be a combustion engine combined with a strong e-motor."

DID YOU KNOW...

Porsche pioneered the dual-clutch transmission for racing in the 1980s, and in 2008, it was the first car maker to install such a technology in a production sports car – the 911 Carrera. Today, the 911 GT3 has the fastest and most powerful Porsche DCT, branded PKD, boasting a response time of less than 100 milliseconds

In 1972, Porsche launched the Carrera RS with a 2.7-liter engine. But will the 911 of 2030 be sporting a high-tech hybrid drivetrain with an efficient four-cylinder IC design?

50 YEARS OF POWERING 911



1964: The first-ever 911 hits the market, sporting an air-cooled six-cylinder boxer delivering 131ps

1966: The 911 S is presented to the world, featuring an up-rated six-cylinder unit developing 162ps

1972: The 911's displacement increases to 2.7-liters for the Carrera RS, with 213ps being generated

1973: The second-generation 911, known as the G-Series, is unveiled to the world. A year later, the first 911 Turbo hits the market with a 3-liter, 263ps unit

1977: The next major performance jump for the 911 is realized as the 911 Turbo gets a 3.3-liter intercooled engine generating 304ps

1983: A naturally aspirated 911 Carrera is developed, featuring a 3.2-liter engine that's good for 234ps

1988: The 911 (964) generation is released, starting with an air-cooled 3.6-liter engine delivering 250ps

1990: The 911 (964) Turbo is launched to great critical acclaim, initially powered by a 3.3-liter engine

1997: The 996 generation is the first 911 to be driven by a water-cooled boxer engine. Thanks to its four-valve cylinder heads, it churned out 304ps, but also set new benchmarks in its class for economy and emissions

2004: The 997 911 comes to the fore with a 3.6-liter boxer offering 329ps. This generation was also the first 911 to get a turbo with VTG, direct fuel injection and a DCT

2011: The latest 911 family – the 991 – is developed, sporting a smaller 3.4-liter unit but developing 350ps. A 911 991 with a 3.8-liter flat-six hits the market a year later offering 400ps. The Turbo S goes one better, generating 560ps

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What lies beneath

Some say that the long-term future of sustainable electric transportation is directly reliant on wireless charging, but there are many hurdles to overcome before such a utopia is achieved

WORDS: **SAUL WORDSWORTH**

Audi engineers are working on wireless charging systems for future electric vehicles. In this setup, the electricity flows to the vehicle without direct contact, realizing efficiency of around 90%

Conductix-Wampfler is leading the inductive charging cause for public transportation, having first worked on a bus project in Genoa back in 2002

If electric vehicles are the future, then wireless charging is surely the *pièce de résistance* in tomorrow's world of convenience. The possibility of powering EVs using a simple, wireless technology represents a major step toward improving the social acceptance of battery electric transportation, although, on many levels, there's still some way to go before such a dream even comes close to being a reality.

"There are barriers to the adoption of EVs," states Dr Anthony Thomson, VP of business development at Qualcomm. "The question is, how can these be overcome for EVs to go mass market? Inductive power transfer (IPT) principles remain seated in Ampère and Faraday's developments pre- the 1830s; it is the ability to charge wirelessly at high power and efficiency that is key."

For Johan De Backer, senior engineer at Toyota's drivetrain and hybrid division, the outstanding issues come down to three key strands: electromagnetic compatibility and interference with adjacent frequencies; interoperability between vehicle and charge stand, including standardization; and cost reduction to meet customers' expectations.

Conventional inductive charging or wireless power transfer is undertaken using the operating principle of a transformer consisting of magnetically connected coils. When transmitting a variable current through one of the coils – the primary coil – the arrangement will generate tension in the other, secondary coil. In an inductive charging system, one coil is suspended below the vehicle, while the other is installed in the road surface. The main engineering challenge is to control the magnetic field generated upon the transfer of energy in the free space between the two coils.

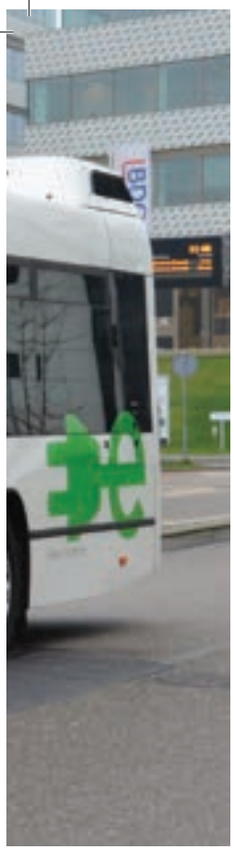
"From a Mercedes-Benz perspective, wireless charging is very interesting since it is a convenient solution for the customers. This technology is definitely the premium solution for the recharging of electric vehicles or plug-in hybrid vehicles"

Axel Willikens, senior manager for wiring harness components and charging, Daimler AG

The bus route

Given its inner system workings, then, it's no surprise that public transport has been an excellent starting point and a learning curve for inductive technology. Buses take the same route day in, day out and are continually stopping at designated points – an ideal opportunity for additional stationary charging. One of the first and most documented cases of vehicular inductive charging took place in Genoa, Italy, in 2002. Since then, there have been many other such projects on buses and trams.

The most recent – and arguably most advanced – example of inductive technology being successfully applied to public transportation is in South Korea, where municipality upon municipality are adopting the charging approach. During the third quarter of 2013, the city of Gumi launched a route between its train station and the In-Dong district for two induction-powered buses. The Korea Advanced Institute of Science and Technology developed the Online Electric Vehicle (OLEV) platform, which is already being used throughout Seoul. A similar system has been deployed in Utah, where the prototype Aggie Bus drives over the bus stop and therefore the charging plate.



1

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"Many drivers of plug-in hybrid cars appear to plug in their car only rarely or not at all. Here, as well, wireless charging may offer a good solution"

Renilde Craps, director, Flanders' Drive

The design is such that the bus can be misaligned by up to 150mm and still receive 25kW of power at 90% efficiency from the power grid to the battery pack.

But having proven itself in certain bus applications around the world, the race is now on to make such charging technology viable for electric passenger vehicles.

Passenger vehicle charging

"There are a huge variety of technical concepts regarding coil design and system operating frequency," explains Axel Willikens, senior manager for wiring harness components and charging, Daimler AG. "The main challenge is to find an appropriate solution that meets the automotive and safety requirements for reasonable costs and that enables interoperation between different supplier and OEM solutions. It is also important to [be in synch] with the standardization process, which is ongoing in national and international committees like VDE, IEC and SAE."

Daimler recently completed an inductive charging project sponsored by the German Federal Ministry of Environment using a technically modified Mercedes-Benz A-Class E-Cell. A charging coil was embedded in the carport of a house designed specifically to show the possibilities of sustainable living. A custom display was installed to maneuver the driver into the perfect position over the coil. The trial has already been deemed a success.

"We are currently evaluating different technical concepts to find a solution that meets our requirements best for series production," continues Willikens. "From a Mercedes-Benz perspective, wireless charging is very interesting since it is a convenient solution for the customers. This technology is definitely the premium solution for the recharging of electric vehicles or plug-in hybrid vehicles."

Conductix-Wampfler was responsible for the original Genoa bus project and also worked closely with Daimler on the Mercedes A-Class wireless charging program that Willikens is so proud of. Mathias Wechlin, project manager for inductive power and data transmission systems at the charging development supplier, says that while both technological ventures have been a real success, it's important to note key differences.

"Cars and public transportation are a very different thing," he states. "With buses, you have a tradition. So, today we sell modules of 60kW charging power for buses and the experience of the technology to date has been excellent. It is a great opportunity to genuinely compete on cost terms with diesel engines by reducing the number of batteries that need to be carried due to regular recharging opportunities at bus stops. By not going for big charging hubs, this positively influences the lifetime of the battery.

"Conductive charging will be an important lever for electric drive systems in public transportation. It will likely be very important for passenger cars too, and make them more attractive. Charging on the move may be another interesting opportunity, though technical challenges and huge investment must be faced first."

1. Daimler provided two electric vehicles as part of a recent e-mobility project in Germany. Participants had access to a modified Mercedes-Benz A-Class E-Cell with inductive charging technology and a second-generation Smart Fortwo electric drive model

2. A screen display inside the A-Class E-Cell helps the driver to position the EV directly above the loading coil for the charging inductive load

3. Using a Volvo C30 electric test vehicle, researchers at Flanders' Drive recently undertook a feasibility study into the wireless charging of EVs

3

"Inductive Power Transfer principles remain seated in Ampère and Faraday's developments pre-the 1830s; it is the ability to charge wirelessly at high power and efficiency that is key"

Dr Anthony Thomson, VP of business development, Qualcomm

COATED INSULATED WIRES

"The fact that there is no longer an issue regarding transfer efficiency is very exciting," states Qualcomm's Thomson. "There have been some significant changes in conductive technology in the past two years: from looking at the fundamentals of power electronics to how we get power across the pad gap efficiently, allowing for misalignment. In both cases this relates to resonant magnetic induction.

"Historically, magnetic architecture has been fairly basic. This has moved on through the use of different magnetic coil structures, as well as looking at different materials, especially coated insulated wire. When you bundle them together, you get hundreds of strands.

"This multistranded cabling prevents current loss and has an improved efficiency at higher frequencies. This has brought us to a position where we can transfer large amounts of power, up to tens of kilowatts, across big gaps – hundreds of millimeters – thereby opening up huge possibilities for automotive companies."

Above and left: The Qualcomm Halo wireless charging system helped Drayson Racing to break the world electric land speed record for sub-999kg cars earlier this year. Since then, Lord Drayson has gone on record, saying, "Drayson Racing is a laboratory for novel EV technology such as the high-power Qualcomm Halo wireless charging system, testing it to the most extreme level"

Below: Qualcomm is a founding technology partner in Formula E. The company will be wirelessly charging the safety cars in the first season and then will offer the WEVC technology to the teams in season two

A glimpse of the future

Leading Belgian research center Flanders' Drive recently presented the results of a collective feasibility study into the wireless charging of electric vehicles. Over the past 30 months, the research body cooperated closely with nine Flemish companies and two universities, focusing on the stationary and dynamic charging of vehicles. Its results confirmed that wireless charging is safe and efficient, both when static and on the move.

"In this collective research project, we've focused on technological aspects such as systems efficiency and the impact on energy supply and non-technological issues such as safety and social acceptance," says Renilde Craps, director at Flanders' Drive. "We studied the applications on a traffic lane of the N769 in Lommel, which served as test track, and in the Flanders' Drive research facilities."

Using a Volvo C30 electric test vehicle, the organization assessed a static inductive charging system of 3.6kW developed by Inverto. The system charges the car, with a battery of 24kW, in seven hours. The center also studied a 22kW charger from Bombardier, which was developed using the expertise gained from buses and charges the battery pack in just one hour. Regarding the positioning of the secondary coil in the car above the primary one in the road surface, the test results showed a lateral deviation tolerance of 30cm on a vertical distance of 10cm. Detailed electromagnetic field (EMF) tests showed that the construction of the car protects passengers during the energy transfer against the EMF according to ICNIRP standards.

"The average efficiency of the charging systems used in the study exceeds 90%, compared with 94% with a standard conductive charger," reveals Craps. "This is true both for stationary and dynamic charging at speeds of up to 70km/h. It also appears that the integration of charging technology in asphalt and concrete is equivalent in quality, but that prefabricated modules can offer a higher uniformity and that their implementation can be done more efficiently."

MORE THAN A MANHOLE

Electric vehicle charging stations that resemble manhole covers may be coming to New York City as early as 2014.

The innovative technology, developed by HEVO Power, uses a charging receiver on the bottom of a vehicle to sync wirelessly with the cords and cables under the cover in the ground. It takes one to two hours for a compact car to fully charge, which, according to the company, is up to three times faster than other wireless charging systems.

"It works in the way a tuning fork would work," explains HEVO Power's CEO and founder, Jeremy McCool. "The charge consists of two coils: one connected to the grid in the manhole cover and the other on the electric vehicle. When the car runs over the manhole, the coils conduct a 'handshake' and the manhole delivers a charge on that frequency to the car."

The manhole cover design was chosen to help the station blend in with an urban environment and make it easier for people to recharge their vehicles' batteries.

Depending on the success of the pilot project, future customers will be able to download an app that will show them available charging stations, which could even extend to highways. McCool says the price will be comparable to that of current plug-in stations, which range from US$2 to US$5 an hour.

The company is also working to create green loading zones for electric trucks at curbside locations in urban areas, where they can charge as the driver offloads goods to shops and depots.

While many see wireless charging as being the ultimate solution for electric vehicles, those pioneering more conventional charging systems, including fast charge posts, say their technology will continue to play a critical role in years to come, especially as they are far easier and cheaper to install, with a network that's already growing fast

While most automotive analysts appreciate that the time-to-market for new technology is sluggish at best, the majority of industry experts estimate that inductive charging for EVs will enter the mainstream within five years. Support of such a forecasted timeframe comes in the form of Toyota, which is starting verification testing of the technology next year in Europe, the USA and Japan.

"The first commercial applications for cars can be expected from 2015, possibly as an optional feature, with home and work as the main charging stations," confirms Craps. "Many drivers of plug-in hybrid cars appear to plug in their car only rarely or not at all. Here, as well, wireless charging may offer a good solution. For public transport buses, we consider static charging at one or more stops on their route as a first step. This may be combined with short inductive strips on steep inclines, with the absorbed energy being immediately deployed for driving the vehicle. From an economic point-of-view, it would obviously be interesting to install charging points at stops where several bus lines come together."

Qualcomm's Thomson shares such a vision: "My estimation is that wireless charging will appear in the more exclusive models in around three years' time," he says. "The development of wireless charging will help change the landscape, making EV charging simpler. In the future, I see interoperable technology. The car will be able to tell the infrastructure how much power it needs, for instance 3kW over seven hours at home, or 20kW over 60 minutes at the supermarket.

"Nirvana for us is where vehicles pick up power driving at highway speeds – charging on the move, dynamically. That's when you will see electric vehicles becoming what they truly could be: lightweight batteries and no need for huge storage since they can charge on the go and reduce manufacturing costs."

Ride the lightning

Less than a year away from the first FIA Formula E race, manufacturers and authorities involved in the venture discuss the sport's technological potential and its wider implications for e-mobility

WORDS: **MATT YOUSON**

The Spark-Renault SRT_01E tested for the first time in November 2013 at La Ferté Gaucher racetrack in France

The birth of Formula E is perhaps this century's least surprising development in motorsport. While hybrid technologies have been the darlings of the top echelon, around the fringes electric racing technology has been steadily making progress. That a senior international series would spring forth seemed almost inevitable. And so, in August 2012 when the FIA licensed an electric series to be known as Formula E, the news was greeted with little fanfare. A year on, however, Formula E is a big very deal.

Less than 12 months away from its first race, the nascent formula has a proto-calendar scheduled to tear through some of the world's greatest cities, with bespoke circuits on streets that would never shut down for conventional racing. Furthermore, a consortium of engineering big hitters has committed its resources to the design of the first Formula E car to launch. The norm for a new series is to wobble into being on a wing and a prayer, but Formula E is doing rather better than that.

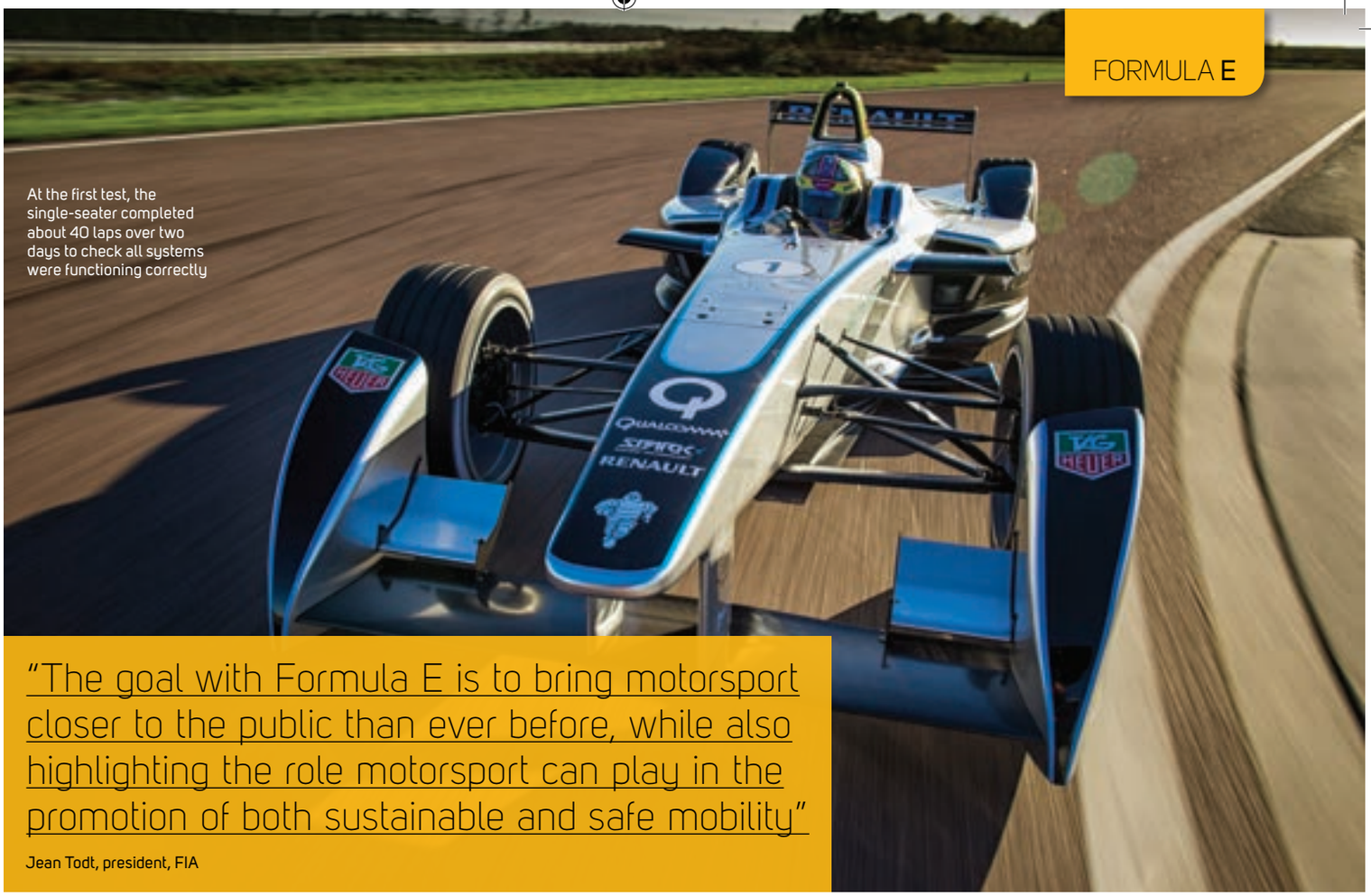
This is not intended to be a one-make series. Indeed with one of the goals being the development of new EV technologies, such a situation would not be conducive to achieving its aims. That said, the inaugural season may be contested solely with the Spark-Renault SRT_01E, the car unveiled at the 2013 IAA.

Forty-two of the cars are to be built by Spark Racing Technology, a new concern created for Formula E and headed by ART's Frédéric Vasseur. Behind Spark is a who's-who of motorsport. Dallara will produce a carbon fiber and aluminum monocoque. McLaren Electronic Systems (MES) is to supply the electric powertrain and ECU, while Williams is responsible for battery technologies. Paddleshift sequential gearboxes will come from Hewland; Michelin is the official tire supplier; and Renault Sport Technologies will have an oversight role, one function of which is to ensure that the cars meet the same crashworthiness standards as a Formula 1 car.

Full backing

The FIA has been the major cheerleader for Formula E. The new series slots neatly into the agenda it has rolled out with the intention of giving motorsport a sheen of environmental responsibility, while also making its championships socially relevant and maneuvering technical regulations to put the FIA formulas some way down development paths that match those of the automotive industry.

"The goal with Formula E is to bring motorsport closer to the public than ever before, while also highlighting the role motorsport can play in the promotion of both sustainable and safe mobility," explains FIA president Jean Todt. "The FIA



At the first test, the single-seater completed about 40 laps over two days to check all systems were functioning correctly

"The goal with Formula E is to bring motorsport closer to the public than ever before, while also highlighting the role motorsport can play in the promotion of both sustainable and safe mobility"

Jean Todt, president, FIA

has a proud heritage as a leading promoter of innovation, technology and performance, and Formula E fits perfectly into that story, making sure motorsport is up to speed to meet tomorrow's challenges."

Ultimately, Formula E is designed to appeal to an urban audience rather than one with a natural affinity for motorsport. It promises a truncated schedule and hints at packaging races with concerts and other events. Running on city streets naturally brings the race to the audience rather than demanding that the audience go to the race. While many of the Spark consortium are viewing the series as an opportunity to develop their technologies, it also presents an intriguing proposition for OEMs and sponsors keen to market themselves to a different demographic.

"It's one of the main aspects of our participation," reflects François Champod, motorsport technical manager at Renault Sport Technologies and Formula E coordinator for the French manufacturer. "Having races in the heart of big cities all around the world is really interesting for us in terms of marketing and global exposure. We're convinced the audience will be different from the F1 fan, and this is important.

"EVs don't tend to be about top speed but more about acceleration and handling, so city streets are definitely the best place to play with these cars. Renault is a world leader in electric vehicles, and through Formula E we can develop the brand image, but also prove to the public that electric vehicles have performance with reliability and safety. This is very attractive to us."

Uncharted potential

Champod is also confident that Formula E will provide opportunities for technology transfer, although he refuses to speculate on where these might arise. In many ways this is part of the allure: the initial specification has been codified, but no one is sure where the technology will go in the future.

It's a view echoed by Paul Newsome, chief technical officer, Williams Advanced Engineering. "Fundamentally one of the reasons Williams was keen to be involved in this program is not just the supply of batteries for the race series; it's the development of the technology for the future of the entire automotive industry.

"We see ourselves as taking the learning and improvements in efficiency from motorsport and providing them with a commercial opportunity. There is a very large difference in performance efficiency between EV and hybrid systems in motorsport and those in current automotive use. Translating what we're learning from motorsport into something that's useful for the hybrid cars, bikes and commercial vehicles of the future is an important part of our plan for this business. Formula E suits that very well."

1. The test car's battery had 50kW – a quarter of the final car's maximum power

2. Multifunctional steering wheel with capacity gauge

1

2

Seven of the 10 teams have already been confirmed. ABT Sportsline will have Audi backing and Super Aguri has close historical links to Honda

In recent years Williams has perhaps been better known for its work with flywheels, notably the systems used by Audi at Le Mans, in GT racing with Porsche, and in the various commercial vehicle programs it is involved with. The company has, however, also invested heavily in more conventional energy-storage options.

"We're technology-agnostic regarding the different types of energy storage," adds Newsome. "Formula E requires the much greater energy capacity of a battery in order to achieve the performance it requires. This series falls somewhere between the work that we've done with our batteries for the KERS used in F1, and the work we did developing the battery system for Jaguar's C-X75 hybrid supercar. Obviously the motorsport environment is very high performance but the Jaguar project was a very large battery designed for a vehicle with an all-electric range of 60km. With Formula E we are looking for a battery that has considerably longer life than the ones for F1, because we're expecting the batteries to last the whole season and work in a variety of temperatures."

MES has also adapted hybrid supercar technology for use in Formula E, in its case the motor-generator unit of the McLaren P1. MES managing director Peter van Manen agrees that the technology – having passed through motorsport – will eventually return to the road.

"It's going to provide an incubation platform on which we can develop smaller and more powerful electric motors, plus better and longer-range batteries," he says. "Those will feed across into general automotive use, not as parts that we'll suddenly see on cars at home, but in the lessons that can be taken up in the wider automotive arena.

"Formula E is a serious proposition with very serious partners involved. Inevitably we will learn things as we start to race. We'll discover what's attractive about the racing and what can be improved from season to season, until things settle. The first year is going to be exciting and different, good for the spectator, and with the potential to showcase a lot of new technologies."

Formula E is a demanding technical exercise with a great deal at stake. And should the new electric formula deliver what it promises, there exists the potential for motorsport to change beyond all recognition.

THE CALENDAR

Formula E's first season will be contested between September 2014 and June 2015. A provisional calendar is awaiting FIA ratification and encompasses a range of climates. After the opening round in Beijing, the teams will remain in Asia for rounds two and three in Putrajaya, the federal administrative center of Malaysia, and Hong Kong. From here, the series heads to Punta del Este, Uruguay; Buenos Aires, Los Angeles, Miami, Monte Carlo, Berlin and the season climax in London on June 27, 2015.

"There will be an effect as batteries have quite a large variation in output over temperature," explains Paul Newsome at Williams. "Thermal management will be a quite sophisticated part of the process. We will have an optimum temperature for the battery to run at. For low-ambient circuits, we will have to raise the battery temperature to achieve that optimum; at the higher-ambient-condition events we will cool it. We're designing a thermal management system into the battery that can do both."

"It's going to provide an incubation platform on which we can develop smaller and more powerful electric motors, plus better and longer-range batteries"

Peter van Manen, MD, McLaren Electronic Systems

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Endurance breakthrough

Just 33 weeks after Nissan announced its intention to enter its new zero-emissions electric race car at next year's Le Mans 24 Hours, the stunning ZEOD RC stretched its legs for the first time at Fuji Speedway in Japan

WORDS: **GRAHAM HEEPS**

When Nissan's ZEOD RC prototype turned a wheel for the first time at Fuji, it represented a milestone for this 'Garage 56' project on the road to Le Mans in June 2014.

But this Zero Emissions On Demand (ZEOD) machine is far from the finished article. The short, low-speed run at Fuji was completed in pure-EV mode, but the final design will see a small-capacity, turbocharged IC engine incorporated into the car as a range extender. Without it, the ZEOD would need to pit to recharge the battery pack after every racing lap of the 13.6km Le Mans circuit.

"At Le Mans, the range required for a tire stint is such that there is no existing electric vehicle technology that can get us those 12 or so laps at competitive prototype speeds," explains Ben Bowlby, the former Ganassi and DeltaWing designer who is now heading up the design of the ZEOD RC as Nissan's director of motorsport innovation. "We looked at the best batteries available to us and we're using the Leaf's lithium-ion pouch-style battery technology. Basically, the amount of energy we can store in a battery at a viable racing weight gives us just one lap under electric power. That is a description of where electrical storage technology is today."

The ZEOD's battery pack will have some important differences from the road-going Leaf's, of course. Bowlby describes the cells as "looking at future technologies within the same family". The cooling system will also be different.

"Because of the rate at which we are putting electrical energy back into the battery under braking, and the rate at which we are going to draw the power to drive the car in pure-electric mode, we are going to stress the lithium-ion pouch technology in a very extreme way," he says. "Therefore we can't control the temperature with air cooling alone. We will be using a dielectric fluid and a heat exchanger to air, to manage the battery temperature during those events."

Bowlby and his colleagues have considered several configurations of electric and gasoline hybrid powertrains to complete the other 11 or so laps of each stint. The current favored option is to rely solely

on a small IC engine to recharge the battery pack under braking, bit by bit, until there is enough energy in the batteries for one zero-emissions lap per stint.

"We've got a lot of testing to do, to be convinced that this is the right way, but we think we will run the gasoline engine and recover what would be otherwise wasted energy during braking events, and store it for later use on demand. I suppose it could be used while the gasoline engine was also running, if that was what was decided," he says.

Access granted

Little is known about the precise specification of the electric motors at this early stage of the program, but details will most likely emerge in the coming months. The non-competitive nature of a Garage 56 project means that Nissan has felt able to offer an unusual level of access to the development via the ZEOD RC Facebook page. Images there show the car coming together in the workshops of RML in the UK, as well as detail shots of the suspension and a size comparison of a traction motor with a smartphone.

"It is a surprisingly difficult thing to do," says Bowlby, of the project. "It's important to show the successes and challenges on the way. Innovation hurts sometimes, and we are showing every step. No doubt there will be some missteps and there will be some creative solutions to solve those problems. That's why we are bothering to show everybody a lot of the process. At the moment it's at a fairly surface level, but as we get closer to Le Mans, there will be more in-depth detail of the whole project."

He does, however, reveal that the ZEOD will most likely not reuse the original DeltaWing's 1.6-liter, four-cylinder IC engine.

"We found that there is no reason why we wouldn't go for a smaller capacity and a smaller cylinder count, but still a direct-injection gasoline turbo technology," says Bowlby. "We will probably go down to three cylinders; that's what we are planning at the moment, and that's what we are developing."

Given that this diminutive unit could be the sole source of motive power for the bulk of the ZEOD's race laps, it's remarkable that the team is aiming "to be a bit faster than the LMP2s in 2014", according to Bowlby. How about in pure-EV mode? "This is where we are going to be at the absolute ragged edge of technology," he reflects. "We will go as fast as we possibly can on the electric drive. We don't know if it is going to be as fast as we can go on the gasoline. If everything works out, we will certainly be faster than the GTEs. That would be impressive.

"To do a 209km/h+ average lap around Le Mans, on electric only, is exceptionally difficult. This will be the first electric lap record for Le Mans, a landmark, and strangely it will be a long time, I think, before it gets broken. It is difficult to do and does not sit within the regulations very easily. The 2014/15/16 regulation package for hybridizing won't let a car carry enough stored electric energy to complete a lap, at speed anyway, on batteries alone."

Such an ambitious target means that reducing weight and drag will be key to the ZEOD RC's success. The all-up weight of the car, with fuel and a driver on board, will be around 700kg; at 120kg, the battery pack – including its encasement and cooling systems – constitutes a large percentage of the total.

1

1. Nissan director of motorsport innovation, Ben Bowlby, and Nismo president, Shoichi Miyatani, say the ZEOD RC utilizes the same technology as in the Nissan Leaf

2. An aircraft-type steering wheel and state-of-the-art instrumentation complement the glider-like experience of the zero-emissions prototype racer

2

3

"Every single element is going to be as extreme as we know how to make it. You've got to be pretty brave to go and do what Nissan is talking about. It's not Mickey Mouse; it's the real deal"

Ben Bowlby, director of motorsport innovation, Nissan

"As a Garage 56 the car is outside the standard regulations, so we can look at some materials that people wouldn't necessarily be able to use in other cars," Bowlby promises. "There are also some advances in the aerodynamic specification of the car that will be revealed at a later date. These will all be very important technologies for the future."

The car's unique architecture is also requiring close liaison with the ACO and FIA to satisfy all parties that it will be safe to run at Le Mans. The large battery pack is a particular focus for scrutiny.

"You have to crash-test with a battery," Bowlby confirms. "These are fascinating and difficult problems. We are going to pull 25g average on the battery during the standardized 14m/sec (50km/h) impact test for the vehicle. So the peak g that the battery will see might be a lot higher than that for a very short time. The battery has to be safely managed; we know from the road car world that this is a very challenging problem and something we are all having to face."

Way to connect

Battery technology is a key area of Nissan R&D's involvement in the ZEOD RC project, which involves intercontinental cooperation between Bowlby (based in Indianapolis), RML in the UK, Nissan in Japan and elsewhere, and the usual network of supplier partners. Bowlby says that many of the parties have worked together for months at a time without physically meeting thanks to modern communications technologies such as video conferencing and electronic data transfer: "You're not burning jet fuel to get things done," as Bowlby puts it.

He's naturally keen to stress Nissan's corporate enthusiasm for the project, and it's easy to see why the company would want to be associated with an experimental design that has more relevance to future road vehicles than is the case with most competition cars.

"The concept of the car is Nissan's, and Nissan has specified what it is that this car is going to achieve," Bowlby clarifies. "It has gone to suppliers and subcontractors within the industry to solve many of the challenges out there, and to create this dream of what we can show at Le Mans. Nissan is driving the project and setting the targets, and many suppliers are helping make it happen. Many people within Nissan are contributing either by solving problems or by suggesting technologies to solve them. I have been to Japan a lot to work with the R&D guys on elements of the suspension, aerodynamics, chassis and whatever else ZEOD can mean for Nissan.

"There is tremendous interest from many parts of Nissan in what this project might inspire, or what problems it might solve," he adds. "Take for example the solutions we come up with for blending the regenerative

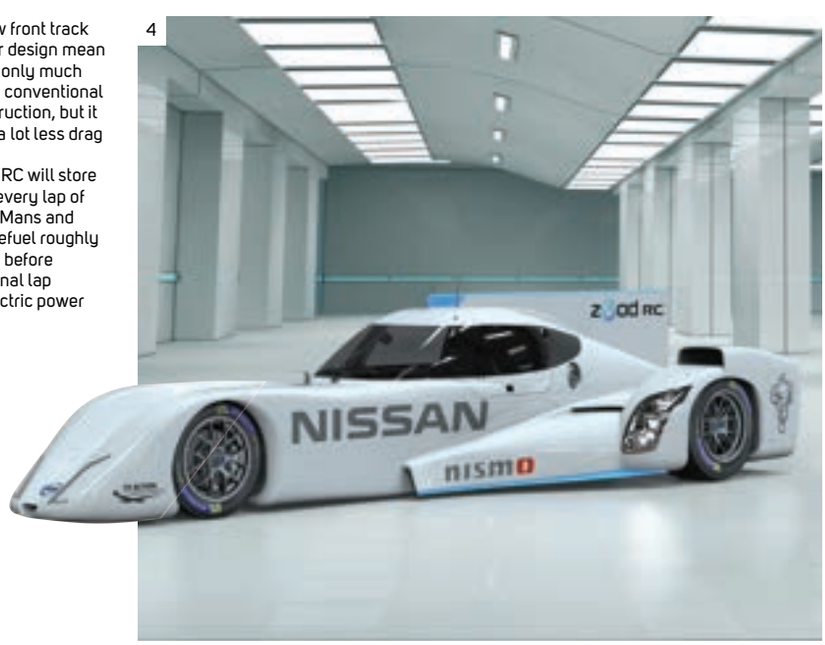
INNOVATION AT HEART

Ben Bowlby describes himself as an incorrigible innovator: "I love finding new and different ways to do something more efficiently or gain more performance from a package. I think one of the most interesting elements of racing is the innovation that comes from the heat of battle."

It's no surprise then, that as a child he was most drawn to motorsport by innovations like ground effects, turbo engines, active suspension and fan cars. "They are all really cool ways of going faster," he says. "No matter how you look at it, racing is always about efficiency. You are always looking for less weight, for greater stiffness, or less drag from more downforce, and so on. I love the innovation process and the challenge that being in competition brings from an engineering perspective – it's where our great strength lies. I passionately believe in racing as an innovation playground that captures people's imaginations and brings new technologies to people's awareness. That way, the auto industry can find great value in competing in the controlled environment of the racetrack, as well as competing for customers on the road, every day."

3. The narrow front track and wide rear design mean the car is not only much lighter than a conventional square construction, but it also creates a lot less drag

4. The ZEOD RC will store energy over every lap of its stint at Le Mans and will need to refuel roughly every 11 laps, before running the final lap purely on electric power



LESSONS LEARNED

Ben Bowlby has no doubts that the ZEOD RC project is highly relevant to the challenge facing road-car engineers in balancing the conflicting demands for low- or zero-emissions in urban areas and sufficient range in order to drive longer distances.

"There isn't yet a battery technology that can cope with great range in a viable way," he assesses. "You'd have to have a massive battery, but then you'd limit the performance of the vehicle. One solution is this combination of using liquid fuel for range and electric for urban duty. A gasoline engine is still an efficient, cost-effective and high-performance way of getting range.

"I think this is really a very public experiment that shows where battery and gasoline-engine technology is today. To take a new technology and show its worth relative to the refined technologies racing today, is a very valid exercise. I think it will be possible to see that electric traction motors have incredible performance."

Ben Bowlby says the ZEOD RC will most likely not reuse the original DeltaWing's 1.6-liter, four-cylinder IC engine. Instead, the engineering chief and his R&D team will probably opt for a three-cylinder, direct-injection turbocharged unit

braking: can they be more cost-effective than the systems that are currently in road use? We are going to extract as much energy as we possibly can from the braking events; we're trying to waste nothing, because we simply cannot afford to waste anything.

"I think the fact that we're pushing the boundaries of what is possible makes it very relevant to future road cars. The aerodynamics, tire technology and lightweighting structures all become relevant, for example."

The interim ZEOD RC completed its demonstration at Fuji barely eight months after Nissan stated its intention to run under electric power at Le Mans in 2014.

"If you were going to race the car for outright victory in Le Mans, then you would probably spend a lot more time on the detailed design," he acknowledges. "We've got a testbed up and running to learn about the technologies. It's much more important that we have the capability to practically test the simulated performance. In particular with the batteries and the super-lightweight, super-powerful electric motors, we need to spend time running them, learning about how to manage those kinds of systems in a race vehicle. There is a lot to it and our objective has been to get a car running, and then go through the iterations of powertrain testing and solutions for how we manage energy for the entire 24 hours."

A line in the sand

In the longer term, the learnings from the ZEOD RC will be applied to Nissan's future LMP1 program, which will be going for the outright win at Le Mans in years to come.

"Sometimes you want to show your customers exactly what is possible, what is new and around the corner, and why your brand has so much value," Bowlby observes. "The ZEOD RC will be a line in the sand: this is where electric vehicles stand; this is the level of efficiency that we can pull from a tiny, three-cylinder, turbocharged internal-combustion engine; this is how light we can make a car; this is how much energy we can store in this weight of battery today. Every single element is going to be as extreme as we know how to make it. You've got to be pretty brave to go and do what Nissan is talking about. It's not Mickey Mouse; it's the real deal."

SEEING DOUBLE?

A report in Autoweek in September indicated that DeltaWing owner Don Panoz was investigating whether the ZEOD RC infringed DeltaWing patents. Although he's no longer involved with the project, Ben Bowlby was the originator of the DeltaWing concept, so it's no surprise that the configuration of the two vehicles is similar.

"Of course I read these statements in the press," he says, "but without the paint schemes it would be very difficult even for a quite experienced race fan to tell the difference between an Audi LMP1 and a Toyota. And of course a Toyota Camry and a Nissan Altima, without the badges, are very similar-size cars, and have a lot of similar qualities and features. The Nissan ZEOD has a completely new set of surfaces and it's a completely new project, with no carry-over from the previous one. I have no comment beyond that."

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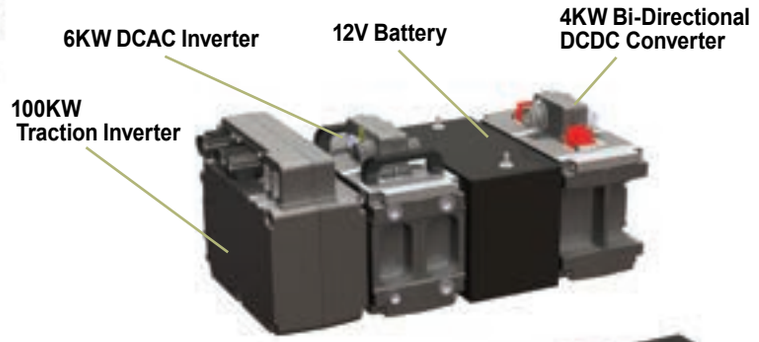

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Run to

the hills

A revamped version of **Toyota's** all-electric EV P002 race car returned to Colorado's Rocky Mountains hoping to achieve a second consecutive class victory at the annual Pikes Peak International Hill Climb

WORDS: **RACHEL EVANS**

On the back of its EV record-setting success at the 2012 Pikes Peak International Hill Climb, Toyota decided to enter the 2013 competition with a revised version of its all-electric race car. A six-week program to update the EV P002 was carried out by Toyota Motorsport (TMG) in Cologne, Germany, and Toyota Racing Development (TRD) in Concord, North Carolina.

TMG concentrated on upgrading the powertrain, which delivers 543ps and 1,200Nm of torque, while four engineers from TRD were responsible for aerodynamic upgrades and testing. TRD's technical director, Steve Wickham, says, "Most of our time is spent working on NASCAR, so this was a bit of a side project for us!"

Changes to the car included a new aerodynamic package, revised brakes and more power. The driver's position was modified and a bigger steering wheel was fitted.

Claudia Brasse, TMG's executive coordinator of strategic electric vehicle development, said that while improvements to the powertrain should confirm the EV P002 as the standard for electric race cars, much of TMG's engineering efforts focused on innovating its charging infrastructure.

For the hill climb, TMG used its offboard battery-to-battery charging technology, including a Schneider Electric EVlink DC charger, to power the TMG EV P002 from the mountainside, where there is no reliable connection to the power grid.

"In the real world you have to deal with varying levels of infrastructure and uncertainty regarding the power grid," adds Brasse. "The potential for offboard battery-to-battery charging technology is great. We have a flexible solution that can be adapted for different types of races and passenger cars."

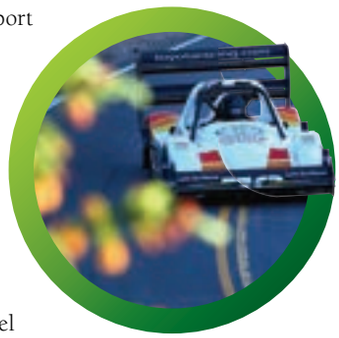
Mounted in the rear of a Toyota Hiace, it includes a 42kWh lithium-ion battery, which can be charged directly from the AC power grid, and after an overnight

charge can quickly deliver high levels of power to a battery-based electric car without additional installation or infrastructure. With varying current and voltage output, the TMG DC Quick Charger becomes an independent source of power for rapid recharging in any location.

Refreshed design

To increase performance, Wickham and his team rebuilt the electric motors and changed the specification to increase rpm. They also changed the gearing to make it more suitable for the hill climb, where top speed is only in the region of 225km/h, not the Nürburgring-spec maximum of 257km/h.

The vehicle's components were manufactured by DJ Cars from the UK, under design direction from TRD, which also was also responsible for the mountings. Wickham says, "A lot of load was put into the car, so we changed the structure underneath the skin from the standard radical-based structure to support the additional loads at the front and rear."



The car has a 60:40 weight distribution front to rear and produces 817kg of downforce at 160km/h. Wickham adds, "Extensions were placed around the wheel arches to encourage air out from underneath the vehicle, creating low pressure."

The new structure at the rear included a new cooling system, while the radiator was moved into a vertical arrangement with bigger fans to extract the heat.

TRD moved the driver to the middle of the car, which produced better performance by increasing the airflow to the rear wing and improving weight distribution. This change also enabled the squad to put in a bigger steering wheel.

With just six weeks to prepare, there was little time for testing, though Wickham managed to persuade the manager of Windshear's wind tunnel to let his team have a day in the rolling-road facility on a 12-hour shift testing the front and rear wings. "We ran through all the aerodynamics and all the sweeps of the positions of the wings, so we knew what we had in terms of an aero map," he explains. "This meant that on the mountain we could adjust the front and rear synchronization without having to guess."

Ain't no mountain high enough

There was no time for pre-event testing at altitude, but the team performed two shakedown tests in the Charlotte area, close to its base, at about 220m above sea level – a world away from Pikes Peak, which reaches 4,302m. These early tests allowed driver Rod Millen to familiarize himself with the car and to conduct system checks before it was packed up and shipped off to Pikes Peak.

At the event in Colorado, teams were given only limited track time before the actual race – just one or two runs a day, and never the complete course. TRD performed three days of tire testing before the main race week.

Initial testing revealed the need for almost no changes to the vehicle. The capacity of the power electronics cooling system was increased with what was essentially a dry ice bucket in front of the radiator. "At that altitude, the air is 30-40% less dense, so although you don't need the air for the engine, it is needed for the cooling system," Wickham explains. "Your cooling needs to be 40% more efficient than at sea level."

Come race day on June 30, 2013, bad weather prevented the team from improving on its 2012 record – however, it finished 16th overall and fourth in class. For Wickham, the exercise was about more than the result.

"One of the main reasons I pushed for this program was to give our engineers a different way of looking at things," he explains. "For many years, they've been working with a NASCAR frame of mind, but being able to work on this car with a limited budget and very few rules was a breath of fresh air."

1. The development of the EV P002 was split between TMG, who were tasked with upgrading the vehicle's powertrain, and TRD, who took care of aerodynamic upgrades

2. Prior to the 2013 Pikes Peak Hill Climb, the TMG EV P002 spent 12 hours at Windshear's 290km/h rolling-road wind tunnel in North Carolina, testing the front and rear wings

3. Featuring two axial flux electric motors and a 42kWh lithium-ceramic battery, the TMG EV P002 tops out at 230km/h, with a maximum power output of 543ps at 6,000rpm and 1,200Nm of peak torque

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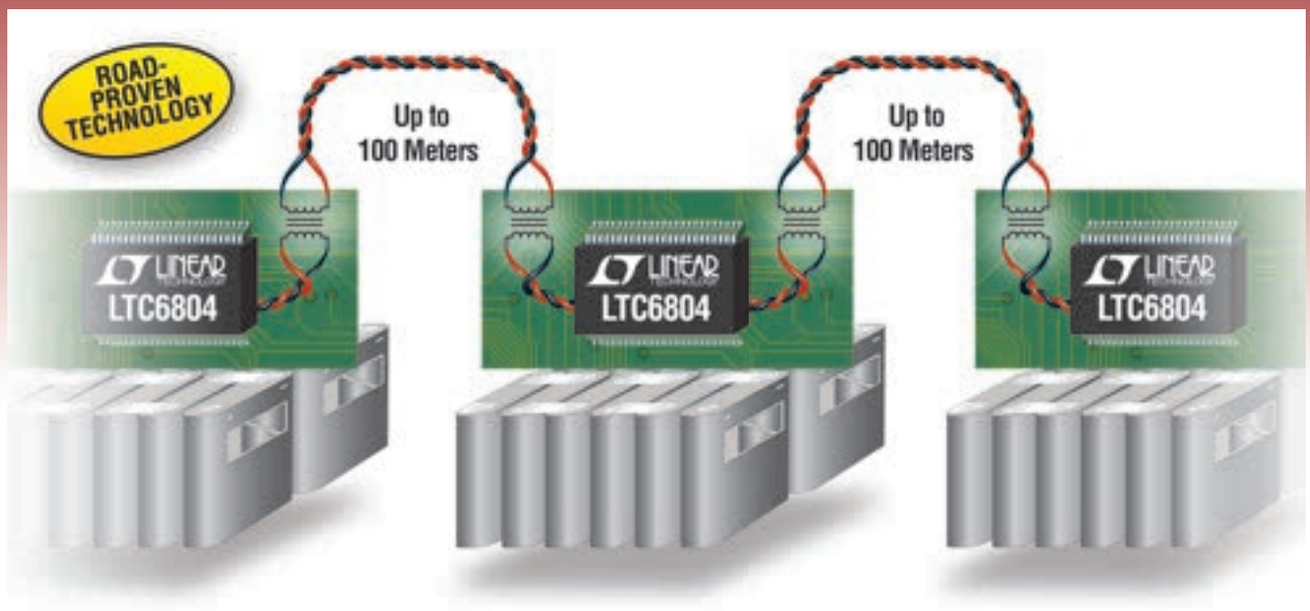

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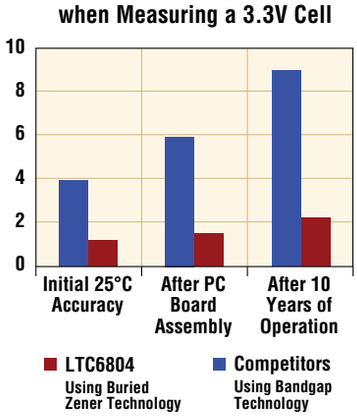

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Small car; huge ramifications

The 500e is just the start of **Chrysler Group's** entry into the world of electric vehicles

WORDS: **JIM McCRAW**

Having survived the global 2008 financial meltdown and the subsequent North American automotive industry crisis, Chrysler, first under part ownership by the Obama administration and now mainly under the guidance of Fiat Group, has come back stronger, leaner and fitter, allowing the organization to compete against GM and Ford, as well as European and Asian OEMs, in its home market.

And now, the next battleground for the Michigan-headquartered company is the EV arena, a growing slice of the automotive market in the USA that Detroit neighbors Ford and GM have prioritized in recent years, but one that Chrysler Group is yet to formally enter. Until now. Welcome, then, the Fiat 500e, a cute-looking car that has serious e-powertrain ramifications for Chrysler as a company.

Although 500e sales will be restricted to California for the time being, the tiny Fiat city car marks the beginning of a nationwide push for electric and hybrid vehicles under a capable, experienced new leader, Mike Duhaime.

In many ways, the 500e is a landmark in international cooperation, with the project featuring engineering development input from Fiat in Italy, Chrysler in Michigan, Bosch in Germany, Samsung in Japan, and final assembly in Toluca, Mexico.

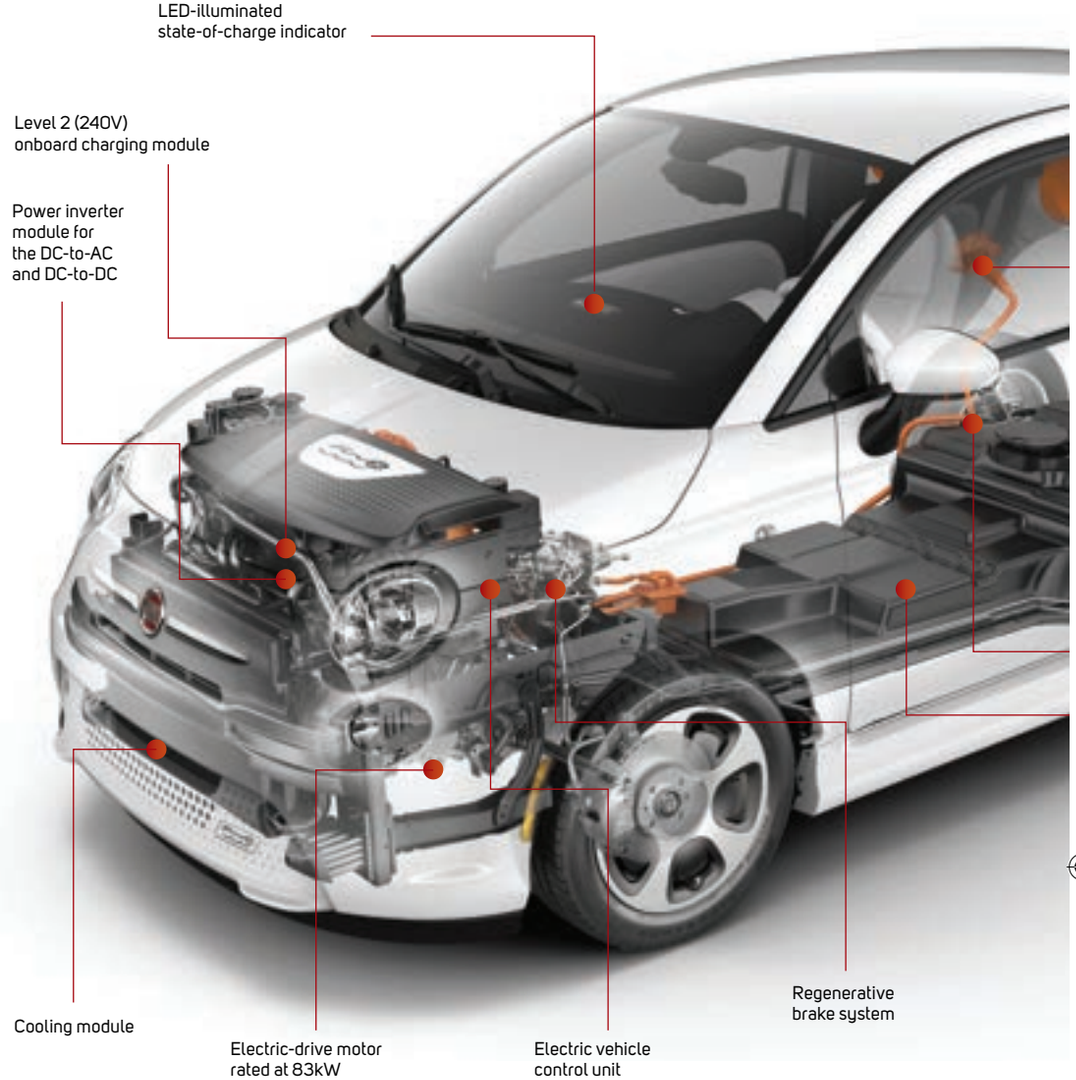
From GM Volt to 500e

Duhaime is a native Detroiter, a third-generation auto-industry veteran who launched the Chevrolet Volt at General Motors and then came to Chrysler Group in 2012 as global director of electrified propulsion engineering. He says building up in-house EV know-how while working with suppliers was the key to realizing the 500e: "As with any vehicle program, we rely on our own internal designs and a lot of external suppliers to create components for us.

"So we took the base Fiat 500 vehicle and electrified it over here. We took out the base vehicle components, designed the shape and form factors for the battery, and designed the power limits we wanted for the drive unit and the inverter. We did a lot of work on balancing the vehicle, keeping the mass distribution correct, and we made some aerodynamic changes to help with some of those efficiencies."

Chrysler worked closely with Bosch to develop the components of the entire drivetrain of the 500e. "For the batteries, we contracted Bosch, using Samsung battery cells. For the drive unit, we ended up specifying what we wanted the drive unit to be, and then we contracted Bosch to be the final assembler of the motor and gearbox. We specified the power electronics and Bosch did those for us too. We did a lot of the engineering of the controls and the vehicle management on the Chrysler side.

"At the same time, we wanted to keep the Italian flair and fun-to-drive character of the base car as a theme, and from there we specified the design of the components and how we wanted it to operate from an efficiency standpoint, with best-in-class highway mileage and the best range for that type of vehicle."



PICKUPS THAT PLUG-IN

In 2012, Chrysler launched a test fleet of PHEVs across the USA, made up of 109 pickup trucks and 23 minivans, that accumulated more than 1.3 million miles of service in various conditions, from high-altitude running in Colorado to Arizona's 130°C dry desert heat.

The PHEVs were evaluated for durability and other attributes by 16 partner organizations – mainly municipalities and utility companies across 20 states.

A primary objective of the program was to determine how reverse power flow might reduce the operating costs of commercial fleets. Some of the fleet's plug-in pickups are capable of transferring power from their batteries back to the grid, which could in turn generate revenue for fleet operators. The trucks also are able to link with each other to form independent mini-grids. They were the first factory-built vehicles to feature this technology.

If that's not impressive enough, the pickups are also the first factory-assembled advanced technology partial zero-emissions vehicles to pair PHEV technology with V8 engines.

During testing, the pickup trucks recorded a peak average fuel economy of 7.55 liters/100km (37.4mpg), while the minivans delivered 5.1 liters/100km (55mpg).

Running parallel to the PHEV pickup program, Chrysler Group has partnered with NextEnergy, a non-profit energy-technology and business accelerator, to evaluate vehicle-to-grid (V2G) technology using four all-electric minivans. The thinking is that if the electric minivans prove to be viable storehouses of electricity, they could provide energy savings by sending surplus power to

Smartphone apps have been developed to help with the everyday running of the 500e, as well as storing vital information when it comes to battery status, driving data and nearest charge points

"A lot of work was done in our aero labs to develop the right aerodynamics and balance for the car"

As such, the 500e's 83kW three-phase AC synchronous electric motor generates 112.5ps and 200Nm of torque, which means that it serves up some 10ps and 66Nm more than the MultiAir gasoline unit in the IC-engined 500.

A 291kg liquid-cooled and heated 24kWh, 97-cell lithium-ion battery stack is placed under the floor for best center of gravity location and handling performance. The battery unit runs from under the front seats almost to the rear bumper.

Duhaime, who started his automotive engineering career with GM back in 1979, calls the 500e's braking system fully blended, with a fairly complex control scheme so that, when the car is coasting or braking, the motor recovers power to the battery stack. At a speed of 12km/h or slower, the system reverts to conventional friction braking. The regenerative braking setup also shuts off during ABS emergency braking.

"It's a complex control scheme that tries to balance how much the motor wants to slow the vehicle down. The handoff between the brakes and the motor gets fairly complex to ensure that we do that seamlessly, so the customer doesn't realize that, for example, one time the vehicle has stopped on the friction brakes and the time before it slowed on the machine."

Having had full design responsibility for four-wheel drive hybrid models, range-extender propulsion technology, plug-in hybrids and battery electric vehicles at the General, Duhaime says that the Fiat 500e was subjected to vast numbers of computer simulations and validations in Auburn Hills to get aspects such as the power requirements, battery sizing, motor selection, electronics packaging, weight distribution, vehicle dynamics and crash attributes properly balanced and optimized.

the grid. The battery-powered minivans are connected to a charging module that, thanks to unique NextEnergy technology, can simulate any electrical grid in the world.

Among the scenarios being examined at Chrysler is reduced reliance on spinning reserves – the expensive practice of having huge generators at the ready to balance spikes in energy demand. If EVs were linked together in sufficient numbers and their combined surplus power were sold to utility companies, they could conceivably offset demand surges. The expectation is that tapping such a reservoir would reduce costs for utility companies, while also putting money into the pockets of electric vehicle owners.

Similarly, a mini-grid composed of electric vehicles would enable peak-shaving, which would see EV owners draw from their own power reserves during those hours when demand for electricity – along with its price – is highest.

The V2G project also considers the impact of cloudy days on solar-panel function, with electric vehicles providing a ray of sunshine in the form of supplemental power – a process known as generation-firming.

The two-year Chrysler-NextEnergy venture was launched in 2012 and has been gathering data from four Town & Country applications equipped with all-electric powertrains. Each is powered by a 24kWh battery modified to accommodate bidirectional charging.

In addition to studying vehicle design elements such as battery size, engineers are also investigating how electric vehicles with reverse power-flow might affect grids known as independent system operators (ISO), which buy, sell and transmit electricity. Project engineers are collecting real-time pricing data from ISOs and weighing it against projected battery performance to help define revenue expectations.

VITAL STATISTICS

E-motor: Permanent magnetic electric traction; 83kW; 200Nm

Battery: 24kWh liquid cooled/ heated lithium-ion type

Capacity/cells: 364V; 97 lithium-ion cells from Samsung

Thermal management: Four-mode system – thermal equalization; passive cooling; active cooling and active heating

Weighing 1,355kg, the 500e is the result of international cooperation between Fiat, Chrysler, Bosch and Samsung. The EV also features Dana lightweight aluminum cold plates that aid battery pack optimization

Flexible assembly line

In production, the 500e goes down the same assembly line in Toluca as the conventional 500, with some new body parts to accommodate aerodynamics and battery cooling and an entirely new platform to accommodate the battery, drivetrain and electric braking. Other alterations include a reinforced body structure that is 10% more rigid, stiffer suspension springs and a heavy-duty rear axle shared with the 500 Abarth performance version.

The 500e has some additional noise seals, noise insulators and supplementary insulating pads on the floor, as well as further acoustic padding behind the rear seats and in the wheel wells to keep it as quiet as possible. It rides on special 15in Firestone low-rolling-resistance tires to add to mileage and range performance. The vehicle realizes a drag coefficient of 0.311.

With battery, motor, cooling and control electronics in place, the 500e's load distribution is 57% front and 43% rear – much improved over the gasoline version.

"There are several design treatments on the vehicle to accommodate the battery electric version," adds the Chrysler director.

"For example, if you look at the nose, there are some unique cooling pieces there for the battery and the electronics. A lot of work was done in our aero labs to develop the right aerodynamics and balance for the car. In addition to this, the rear treatment has been changed for cooling and aero as well."

1. A key factor underpinning the development program of the 500e was retaining the behind-the-wheel fun-to-drive factor of the IC-engined city car. As such, the Li-ion battery stack is placed under the floor for best center of gravity location and handling performance

2. When fully charged, the 500e has a great city car range of 160km. The EV also serves up more power and torque than the MultiAir 500 model

"As we look at our electrification portfolio, we're actively engaged in several areas, and with several supply communities as well"

The Fiat 500e has posted an EPA mileage rating of 122mpge in the city, 108mpge on the highway, and 116mpge combined with an 160km (100 mile) range. Charging times vary, from about four hours with a 240V charger to almost 24 hours with a standard home-style 110V wall socket.

There's no doubt that the Fiat 500e marks the start of some major electric vehicle activity for Chrysler Group as whole, as Duhaime is keen to reiterate: "As we look at our electrification portfolio, we're actively engaged in several areas, and with several supply communities as well.

"We have ongoing discussions with them, and a lot of the pieces we've done were done by specification, and even as we go deeper into the specification, I'm very comfortable with the way we are doing our future programs."

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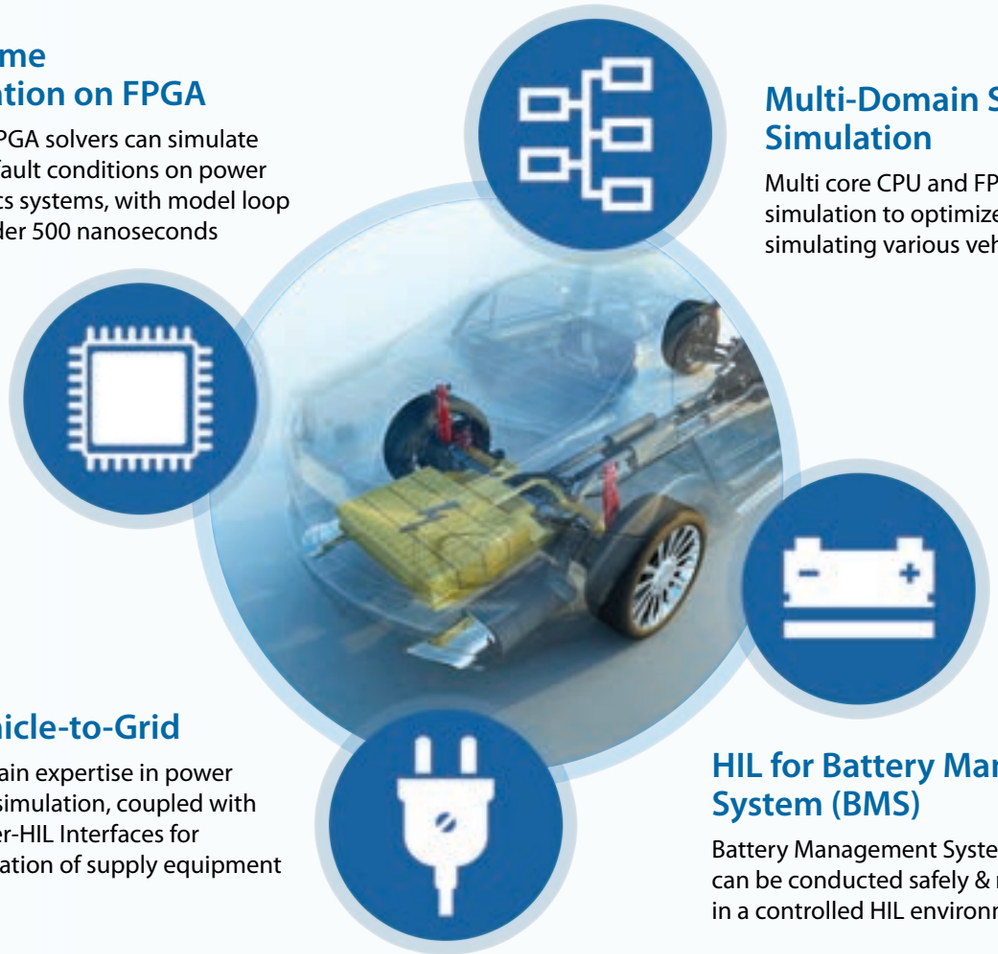

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Charged with progress

The fuel cell and battery research group at Imperial College London is earning a solid international reputation for its pioneering work in combining the science and engineering of electrochemical devices in real-world applications

WORDS: **GREG OFFER**

With a systems engineering approach combined with a strong foundation in the fundamental science, a team of electrochemists, materials scientists, and chemical, electrical and mechanical engineers – led by Professor Nigel Brandon, Professor Ricardo Martinez-Botas and Dr Gregory Offer – are working to solve some of the biggest challenges in the area of energy storage and conversion. The academic team works on both grid-scale storage and automotive applications, and its activities encompass any application that involves the use of fuel cells, batteries or supercapacitors. Specifically for vehicles, their work covers electrical supercharging, hybrids, full battery electric and fuel cell vehicles, and even fuel production via electrolysis.

One of the main challenges for lithium-ion batteries is to be able to predict performance and degradation in real-world applications. In this respect, the team is developing analysis and experimental approaches to parameterize and validate its models, alongside developing in-situ characterization methods so as to be able to deliver solutions to diagnose and prognose performance during operation. Such systems and models are necessary to be able to safely push battery technologies to their limits.

Communication breakdown

In the past there has been a large gap between cell development and the manufacturing industry, with developers in the lab being reluctant to divulge data because design information is highly confidential. On the other hand, systems engineers rarely have the complete picture describing the fundamental science of the component, and there is a gap in the engineering science around the integration and understanding of

"The models need to be simple, but creating them is not, and this is one of the key targets of the group"

A 75-cell fuel cell stack being showcased at Queens Tower, London

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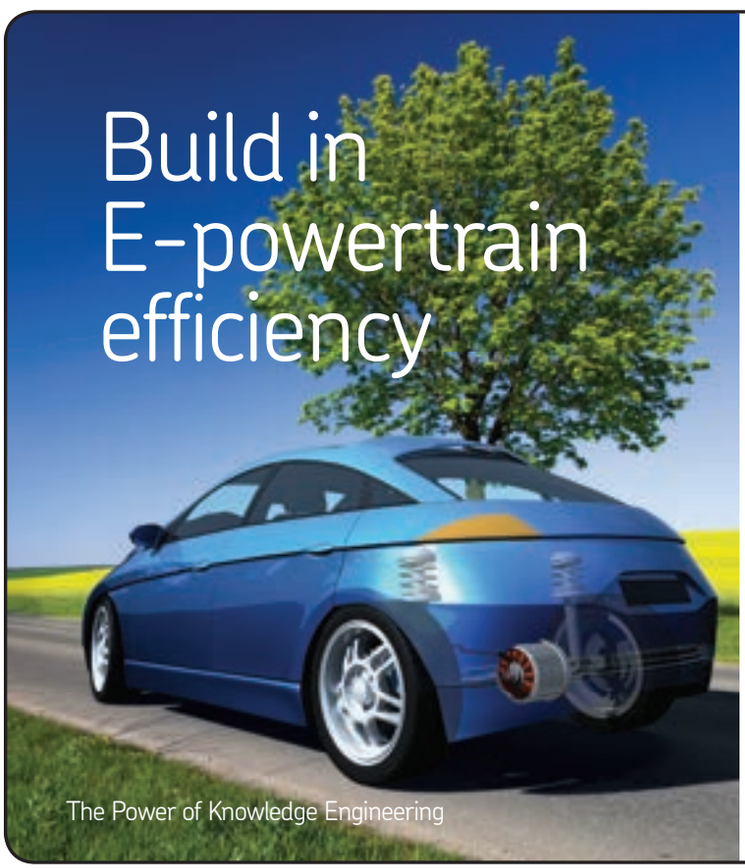

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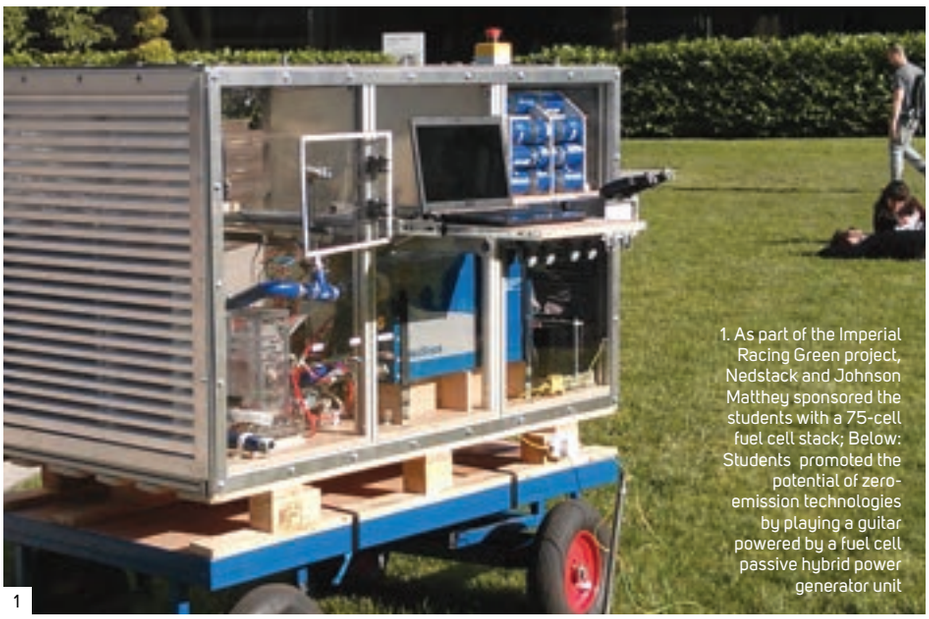
these components in an automotive environment. Many design models are developed for single cells, but the problems are non-linear and it is not possible to simply extrapolate performance or models based on a single cell to a system. This is particularly true when it comes to the understanding of degradation and failure, and models that are capable of both diagnosis and prognosis, as well as models that are capable of running in situ on a vehicle.

In the lab, a model-led approach based on an understanding of the underlying science has been shown to have a dramatic positive impact elsewhere in the automotive industry, for example in the area of design for crashworthiness. It works by speeding design iterations and problem-solving cycles while reducing the total amount of time and money spent on R&D. It is cheaper to explore problems in a simulation model, which means that the expensive physical development can then be targeted toward the improvements the model predicts are most likely to succeed.

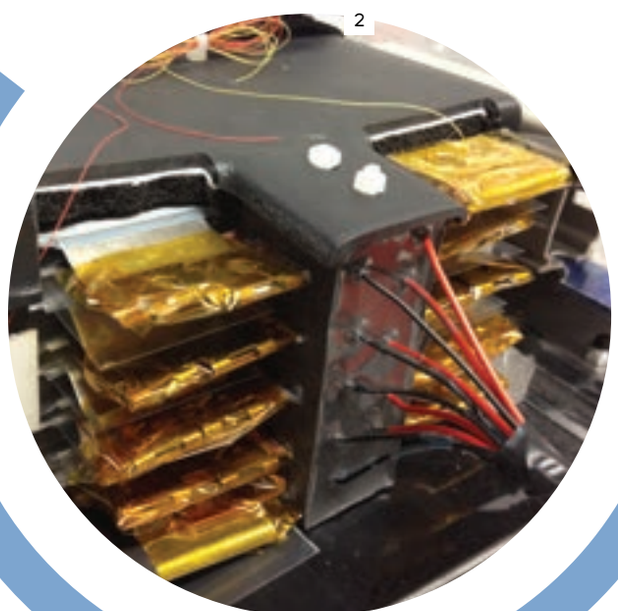
On the vehicle, reduced order models capable of monitoring the state of the batteries and predicting internal states from a limited number of in-situ measurements are required to maximize performance and guarantee safety. The models need to be simple, but creating them is not, and this is one of the key targets of the group. To correctly identify and model all the critical degradation mechanisms and failure modes; to model and understand the fundamental physics; to couple all the models and understand how they interact; and then create simplified versions capable of being run on-board a vehicle, is a big challenge. But doing so will have a major industrial impact and is therefore very worth doing.



1. As part of the Imperial Racing Green project, Nedstack and Johnson Matthey sponsored the students with a 75-cell fuel cell stack; Below: Students promoted the potential of zero-emission technologies by playing a guitar powered by a fuel cell passive hybrid power generator unit

1

2. A nine-cell 20Ah module designed by students at Imperial College London for their 2014 Formula Student vehicle, as part of the team's entry into the engineering competition, which won the design prize this year



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Pioneering methods

To create advanced models that represent the physical reality of lithium-ion cells, the group has had to pioneer the development of a suite of advanced characterization methods. Techniques such as high-resolution synchrotron nano-CT are used to produce 3D tomography datasets of typical lithium-ion battery materials down to voxel sizes of 16nm. The data can be used to quantify surface area, volume, connectivity and tortuosity factors, which are all essential parameters for accurate models, and are important to understanding localized inhomogeneities in current density distribution during operation.

The team has developed a novel low-cost characterization method for advanced battery management systems based upon in-situ impedance measurements that, combined with advanced parameter estimation techniques and models, could enable more accurate predictions of state-of-charge and the ability to estimate internal parameters such as temperature under dynamic operating conditions.

An investment in the laboratories of US$1.6m has also benefited the team, providing state-of-the-art facilities

PASSIVE HYBRID POWER GENERATION

Imperial Racing Green is an undergraduate teaching project at Imperial College London that trains the next generation of engineers to become leaders in battery, fuel cell and electric vehicle technologies. As part of the project, roughly 100 students from multiple engineering departments design, make and race zero-emission race vehicles.

Barriers to the mainstream adoption of fuel cells include cost and durability. To address this issue, Imperial College students have been developing a fuel cell passive hybrid power generator to promote zero-emission technologies at events such as music festivals, where diesel generators are typically used. Active hybrid systems have the advantage of decoupling power and energy requirements to enable downsizing of components and therefore save costs. The drawback is the additional need for power electronics such as DC-DC converters, which adds cost and extra levels of power conversion. Passive hybrid systems, where devices are directly coupled to each other, afford the same benefits as active hybrid systems, but without the need for additional DC-DC converters. Though active power regulation is lost with passive systems, with appropriate system design, the benefits can outweigh the disadvantages.

Johnson Matthey Fuel Cells and Nedstack sponsored the team with a 75-cell fuel cell stack and membrane electrode assemblies to give a gross electrical power output of 9.5kW. This is directly coupled to 33 1,500F Maxwell supercapacitors in series to give a peak power output of more than 30kW. The setup was shown in a BBC broadcast, powering an electric guitar. In this configuration the supercapacitors, due to their low impedance, act as a low pass filter to the fuel cells. This minimizes two of the main automotive modes of fuel cell degradation – zero load idling and rapid power cycling. Systems therefore offer the potential to reduce fuel cell powertrain costs through component reduction.


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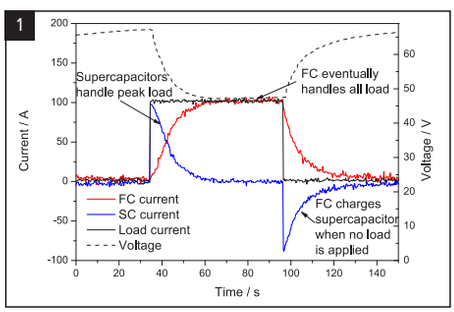

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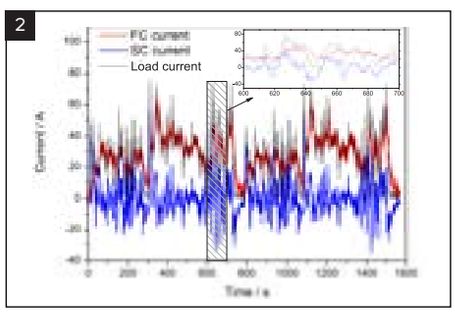

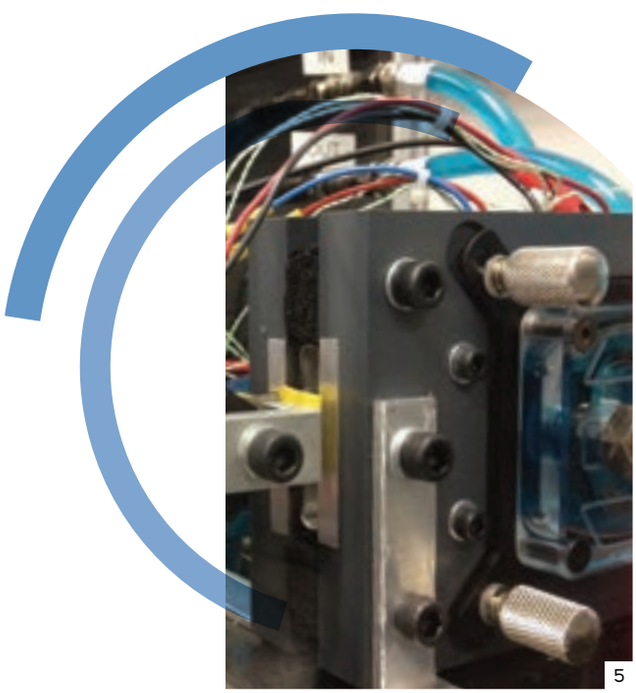
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1. The passive hybrid system responding to a large instantaneous load increase showing how the supercapacitors give the fuel cell time to respond

2. The system being tested against a HWFET drive cycle demonstrating how the load the fuel cell experiences is smoothed by the supercapacitors

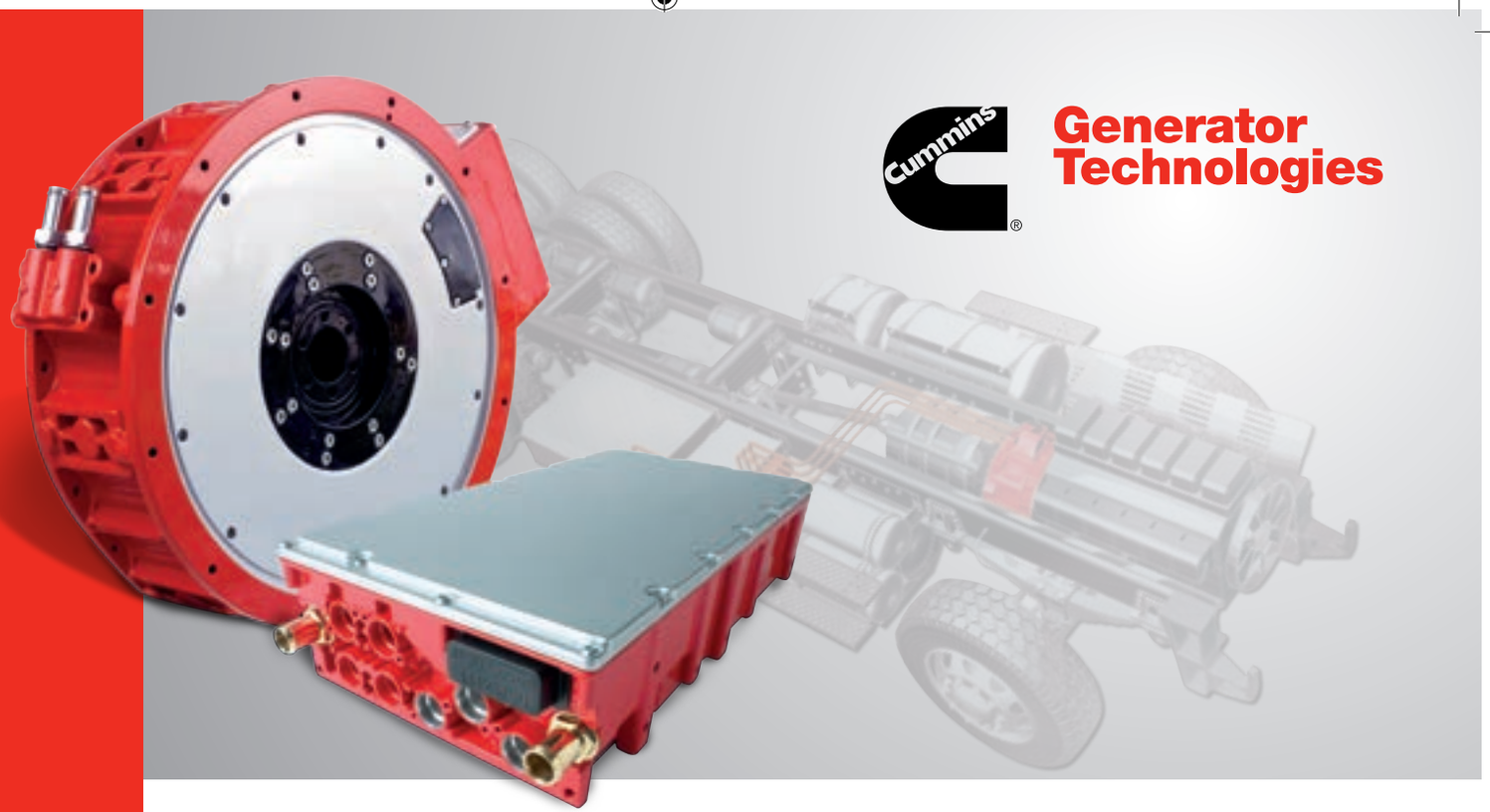
3 and 4. The IC+ electric motorbike raced at the 2013 TT Zero on the Isle of Man and finished seventh with an average speed of 115km/h

5. A thermal management rig has been built to help lessen the cost of exploring the effect of different thermal boundary conditions on cell performance

for the testing and characterization of electrochemical devices under extreme conditions. The new facilities enable experiments to be undertaken safely that push batteries into regions where they might fail (high charge rates, and very high or low temperatures), which are necessary to parameterize and validate models for batteries operating at the limits of operation.

Also, methods have been developed to artificially induce and maintain thermal boundary conditions experimentally during operation, which can reproduce the conditions across a single cell that it might experience within a large battery pack and could previously only be explored in models or by building a large battery pack. This new development could greatly reduce the cost of exploring the effect of different thermal boundary conditions on cell performance.

The characterization methods, combined with improved models for operation and degradation, and the ability to model and predict performance, should all enable future systems engineers to be able to design cheaper products around existing lithium-ion battery technologies through a better understanding of the fundamental physics.



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Sun seekers

A team of Cambridge University students took to the Australian outback earlier this year in a newly designed all-electric, solar-powered car in a bid to win the annual World Solar Challenge

WORDS: **RACHEL EVANS**

1

The World Solar Challenge provides a platform for students to enhance their skills while pushing energy-efficient technology to its very boundaries. This annual Australian competition attracts teams from all over the world, attempting to make the 3,000km trip from Darwin to Adelaide in an all-electric vehicle powered by solar energy.

This year the organizers altered the rules so that the entrants are now allowed to enter only a four-wheeled application. Using no more than 6m² of solar panels, cars are allowed 5kWh of stored energy. All other energy must come from the sun or be recovered from the kinetic energy of the vehicle.

University challenge

A team of students from Cambridge University, consisting of members from several academic disciplines including engineering, physics, business and media, created Resolution, an all-new solar car, specifically for the 2013 competition.

Instead of the typical table-top design, whereby the driver is fitted in between a silicon solar panel, the Cambridge University Eco Racing (CUER) team opted to use a tracking plate, which follows the sun to gather as much energy as possible. The team also used gallium-arsenide solar panels, which offer around 36% efficiency as part of the assembled array, compared with the silicon equivalent of between 22 and 24% efficiency.

Coupled with this, a carbon-fiber monocoque made in the style of an F1 car was built in collaboration with the UK's National Composites Centre.

Resolution is driven by an in-hub permanent magnet motor housed in the left rear wheel. It was produced to bespoke measurements by Australian supplier CSIRO, which designs them specifically for solar cars. The wheel had to be specially designed to house the motor, as Oliver Armitage, head of testing, explains: "We had to put a tower on the outside of the wheel rim and then inside design it to hold those magnets and the associated load. The magnets are pulled together with a force of 1.2 tons.

"We designed a dish with the tire on the outside, into which is bolted a ring of high-strength neodymium magnets. A second ring of magnets is located in a cap that is lowered onto the main dish by a special rig. This allows the two magnet rings to be brought together in a controlled way despite the extremely strong forces of attraction between them. There are coils of wire in the gap between these two magnet rings."

Matchtech, a leading engineering recruitment agency, optimized this proposed wheel design by using finite element modeling to make it thinner and lighter.

Another part of the vehicle that has been redesigned is the battery. In the 2012 race, during a stoppage, one of the

1. Designed and built in under six months, Resolution's aerodynamic shape breaks away from the 'table top' design seen in most World Solar Challenge entrants

2. The 97% efficient motor is mounted in the hub of one of the rear wheels to avoid using inefficient gears or chains

3. After catching fire at the 2012 World Solar Challenge, CUER reconfigured the car battery, opting for a fan-cooled design

2

3

cars' batteries caught fire. To ensure this didn't happen to Resolution, CUER made this year's battery fan-cooled and the motor air-cooled. "Part of the design of the motor casing is to have the components that get hot thermally connected to the outside walls so that they can conduct the heat out," explains Armitage.

To design the car, CUER students first drew it in SolidWorks, a 3D mechanical CAD program, then put the design into ANSA CAE software. Armitage says of the design, "The rules state the driver has to sit with a certain back angle and their heels below their behind! They also state that in the event of a crash, they have to be able to swing forward.

"We designed the aerodynamic package around that volume of space. We took the curve and projected it forward to get the front shape of the car, which is a teardrop. It's the most aerodynamic tail you can put on that and it is designed for the minimum coefficient of drag."

CUER received sponsorship for the project in various forms from more than 25 parties, including well-known suppliers such as SKF, Ansys, Millbrook Proving Ground and the National Composites Centre. Cambridge Precision and Jaguar Land Rover produced most of the parts.

Testing times

At the beginning of the solar car program, the team identified specific areas to test. Armitage reports, "There are several requirements, for example, we had to be able to a maneuver at a certain speed, and we had to be able to change lane and go back again in a certain time, at a certain speed." Initial test runs covered just a mile or so.

Many teams that have previously won the World Solar Challenge, Armitage notes, have benefited from access to a full-size wind tunnel. At only a slight disadvantage, CUER did some wind tunnel testing with a quarter-scale model in the facilities at Cambridge. Models were also run through CFD in Ansys Fluent software.

The team aimed to ensure that all the drivers had spent at least a race day's time in the car before the actual race. "We put the car on a constant circuit around the high-speed bowl at Millbrook. We constantly logged power, speed and all the temperatures of the car," says Armitage. "If we knew that when we went above a certain speed, certain parts of the car might overheat, we would be prepared."

CUER also built the battery, loaded it and then discharged it through a resistor. During testing, the battery induced a voltage in the battery box that resonated back into the motor box and caused the motor to cut out. This problem was quickly fixed with capacitors, which were fitted to the motor. Armitage notes, "Rarely do individual components fail. It's usually the interfaces between them."

1

"I would like to see some variation of this design run in a future solar car race"

Oliver Armitage, head of testing, CUER

1. Resolution was put through its paces at Millbrook's testing ground. The car was put on a constant circuit while power, speed and vehicle temperatures were logged

2. CUER designed a suspension system that features double-wishbones with a pushrod shock at the front and swing arms, one for each wheel, with a big anti-roll bar positioned between the two rear wheels

3. The tracking plate keeps the solar cells pointing at the sun, using software that triangulates the vehicle's GPS position and direction of travel with the time of day

2

3

As part of its goal to promote young engineering talent, JLR lent its environmental test chamber to the team. This enabled CUER to run the car, with the driver inside, at full speed in temperatures of about 40°C and windspeeds of 80km/h or greater, on a rolling-road with temperature-representative heat loading. "This allowed us to monitor the driver's temperature and the car's technical components that are heat sensitive, such as the battery and solar cells," adds Armitage.

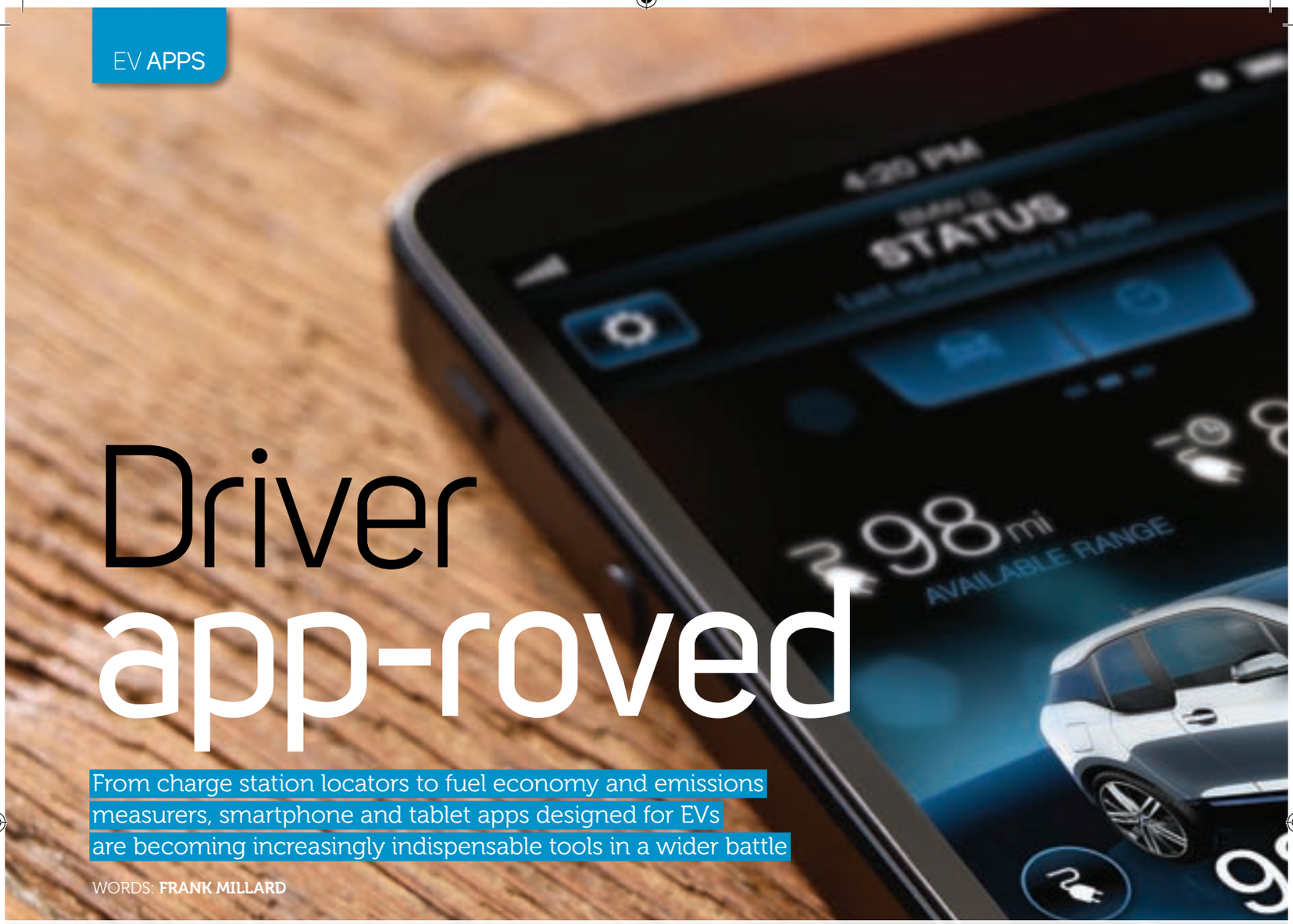
Next, CUER used the test track at JLR to constantly run the car and perform reliability testing. Armitage explains, "This was similar to what we had done at Millbrook, but we used the JLR track as it was next door to where the components were being made, so the car as a whole could be tested with new components as they were put on."

Back to the drawing board

Unfortunately, during last-minute testing on a specifically designated road in Australia in October, the car had an accident and rolled onto its side. Further tests carried out in controlled conditions revealed new dynamic instabilities that the team were unable to fix. As a result, Resolution was forced to retire.

Despite the fact that CUER was unable to compete this year, the team gained several positives from the experience. "The car's crash structure performed as designed in the event of an accident," comments Keno Mario-Ghae, team manager. "Also, Resolution produced its best-ever results while testing in Australia, indicating that CUER would have been on target to be competitive."

Future plans have yet to be agreed; however, Armitage comments, "We believe the design principles embodied in Resolution are sound. I would like to see some variation of this design run in a future solar car race, whether it is in the World Solar Challenge or otherwise."



Driver app-roved

From charge station locators to fuel economy and emissions measurers, smartphone and tablet apps designed for EVs are becoming increasingly indispensable tools in a wider battle

WORDS: **FRANK MILLARD**

The ubiquity of apps is a given in the modern world. In fact, in 2010, the term 'app' was voted the American Dialect Society's word of the year. And although apps are driven too often by modern desire, entertainment and social interaction rather than actual need, they can certainly be useful to the EV/hybrid owner – to the point that their importance is growing in stature on a weekly basis.

So, it's clear that apps have a critical role to play in the marketing of electric vehicles. But more so, if apps specific to EVs can answer questions relating to the ongoing problem of range anxiety, then more drivers might see electric motoring as a viable alternative to an otherwise more convenient IC engine norm. One such growing use of apps is in the anonymous exchange of information by EV drivers regarding charge station use and availability, in the process building online EV driver communities and vital data exchange hubs.

Growing in confidence

For the present, the chief areas that EV apps address are confidence, particularly associated with charging, range and convenience.

"The main objective of these mobile apps is to popularize the advantages of EVs and reduce the limitations associated with them," underlines Frost & Sullivan's information technologies research analyst, Shuba Ramkumar.

Addressing this very point, Continental has developed an intelligent charge-control system called AutoLinQ, using telematics as a portal between driver, vehicle and service providers. The system determines when energy is fed to the batteries and the level to which they are recharged. In addition, the driver can use a smartphone or PC to access services even when not in the vehicle.

In turn, says Herbert Halamek, key project manager for e-mobility solutions at Continental's interior division, third-party suppliers such as vehicle manufacturers, car-sharing organizations, insurance companies and energy providers can use the data from the vehicle to individually customize their user offerings, such as the optimization of charging and network management.

California-headquartered ChargePoint offers apps for iOS and Android platforms in the Australian and New Zealand markets. The apps are fully integrated with the ChargePoint NOS (network operating system) and services. Lance Douglass, ChargePoint's networks and technology manager, says, "The apps fit with the overall strategy of providing EV drivers with the tools they need to find charging stations, plan their trips and even reserve

a charging station for when they arrive. These tools empower the EV driver to stay in control and eliminate range anxiety."

GM's OnStar's Remote Link app was launched in 2010 and was originally created for the Chevrolet Volt. It allows the user to see state of charge, overall range (for both gasoline and electric), get alerts (charge full, charge interrupted and charge reminder) and change charge modes in the range-extender vehicle. It also has a Nav Tab that enables a driver to search for charge stations and enter those locations into the vehicle's navigation system. An additional enhancement of the app can be used with the Chevrolet Spark EV and tells drivers whether charge stations are along their route, where to find them and how long they will need to be parked to get to the next station. The trip is therefore optimized based on charge station data.

Toyota's advanced technology national manager of engineering and PMO, Brian Inouye, is enthusiastic about the company's development of several EV apps – specifically for its Rav4 EV and Prius plug-in hybrid. The charge station finder and map functions access the company's charge station database from its Entune smartphone app or the car's onboard navigation system. Inouye says the car maker not only geo-codes the station location but also adds logic to the onboard navigation so that the system knows which side of a shopping mall or parking garage to enter: "Our system shows the actual location of the station," he adds.

EV developers are increasingly investing in smartphone and tablet apps for their new electric vehicles, allowing drivers to access critical data, like charge station location as well as having the option to control comfort functions such as climate control from afar. Pictured above is the BMW i app for the new i3, while on the right is Chrysler's EV app in the USA for the Fiat 500e

"We take detailed notes on the facility and standardize the information, including hours of operation, charge type, station operator website and voltage type."

Users are able to see their vehicle's driving range and battery charge level through their smartphone via charge management. Once their vehicle is plugged in, the user can either use their app to begin charging immediately or program it to charge during off-peak hours. Remote climate can be used to turn on the car's HVAC while they are away from their vehicle, but this can only happen if the car is charging or if the charge is above a factory preset level. Vehicle finder assists easy location when drivers want to return to their vehicle once charging is complete. Injecting a bit of fun into EV driving, the Eco Dashboard app allows the user to see how well they drive against other EV and PHEV drivers, earning Eco trophies and sharing driving scores with friends and family.

Toyota says its apps for the Rav4 EV and Prius plug-in hybrid models empower the EV driver and help to eliminate range anxiety

Can't stop progress

But apps are an evolving technology and these companies are not relying on their existing offerings. Toyota has new apps planned, which are mostly centered on data coming from the vehicle and have increased elements of vehicle customization. ChargePoint is looking at further integration of its networked services, such as in the social, lifestyle, retail and financial domains. A pilot OnStar app, EcoHub, currently being tested in Austin, Texas, will enable home owners to see their EV charging data together with their whole home electricity use, with some comparisons provided.

Halamek at Conti says functionality is evolving: "Examples are the remote control of interior heating and cooling of the EV, to get more reliable range prediction and to access more comfort services. Its main focus, however, is to connect the application to the smart electric power grid."

But the future of the apps will include connectivity well beyond the vehicle and its thirst for fuel. The future direction of apps will enable users to tailor the interface to present exactly what they need to know. Through a series of opt-in and configurable choices, users will have the opportunity to create a unique portal view of their world.

FIRST RESPONDERS

Michael Smyth, assistant director for training and curriculum development at the National Alternative Fuels Training Consortium at West Virginia University, says its apps include a quick reference guide for identifying and securing alternative fuel vehicles at an accident scene.

The app, he says, is used almost exclusively by first responders such as firefighters, police officers, emergency medical services and other professionals who would deal with this new technology at an accident scene. "We are getting great feedback, because although there are fees involved with our traditional courses and manuals (unless we have a grant to support its use), our phone app is available at no charge," says Smyth

For the future, the company wants to develop a parallel app that would assist tow drivers and storage and wrecking yard facilities in safely moving and storing these vehicles.

Smyth says the company's main challenge is to keep the app current by adding new alternative fuel vehicles as they appear on the market: "We will be doing a major update in the next few months, bringing the new 2013 vehicles into the materials."

He believes the industry needs to remain flexible and prepared for potential changes in the future. "Right now, battery power and ethanol are by far the most prevalent alternative fuels on the highway. CNG, propane and biofuels could very well surpass electric drive down the road. No one can predict what the future of vehicle fuels will entail, but we need to be prepared to train and educate the public, technicians and the people that keep us safe on the highway on whatever fuels are leading the pack."

Above: Researchers at West Virginia University have created an app that allows emergency services to secure an alternative fuel vehicle at an accident scene

Below: The future of EV apps will go beyond basic charging point data, as Conti's schematic outlines

Yet although the technology has undoubted potential, bringing these apps to market has had its hurdles.

"The biggest challenge has been the speed of adoption of utilities for these types of new capabilities," says Paul Pebbles, global manager for smart grid and emerging services at GM, while Toyota's Inouye says charge station databases are maturing as more users provide input to each of the suppliers: "As you can imagine, a Toyota exclusive database taxes resources to manage/maintain/operate. Toyota is working with station providers and other OEMs to determine how best to manage costs and still provide highly accurate information."

Meanwhile, Continental is convinced that vehicle applications and services will play a major role in the near future in all fields of the automotive world.

"They will help to make EVs more attractive for drivers, because they will enable more spontaneous use and greater flexibility," says Halamek. "There will of course be important standalone apps that enhance the comfort of mobility. Examples could be apps that reserve parking spaces or let disabled people call for help at a station in advance. But painting a more general picture, we have to widen our scope to what could be called the internet of everything. The more things that get connected, the more intelligent we can make transport and mobility. Vehicle-2-X communication is a very important development that will enable a huge variety of services and applications, from comfort and safety to saving emissions and lowering traffic congestion."

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Opportunity knocks

1

In 47 years, Linamar Corporation has grown from a DIY operation into one of Canada's biggest manufacturers and suppliers of precision metallic automotive parts

WORDS: **JOHN THORNTON**

From a single lathe made partly with washing machine parts in one man's basement, to a multibillion-dollar global manufacturing company with nearly 18,000 employees and 42 manufacturing facilities around the world. This is the extraordinary transformation made by Linamar Corporation, a precision machining specialist for powertrain systems, since chairman Frank Hasenfratz founded the company in 1966.

Named after Hasenfratz's late wife Margaret and their two daughters, Linda and Nancy, Linamar is headquartered in Guelph, Ontario, Canada, and comprises four key divisions: driveline, industrial commercial energy (ICE), manufacturing and skyjack. The driveline and manufacturing divisions focus specifically on the development of precision metallic components and driveline systems for light passenger vehicles and heavy-duty commercial trucks.

With plants located in Canada, Mexico, the USA, France, Germany, Hungary, China and a new facility launching in India, the publicly owned company produces everything from cylinder blocks, cylinder heads, connecting rods and camshafts, to fuel rails, balance shafts and modules for engines; differentials, clutch modules, shafts and shells, as well as carriers and housing for transmissions; not to mention power transfer units (PTUs), rear-drive units/modules (RDUs/RDMs) and engineered gears for the vehicle driveline.

From strength to strength

Linamar is one of the few Tier 1 companies to have prospered since the global economic slowdown in 2008, posting impressive revenues of US$2.23bn for 2010, US$2.86bn for 2011, and US$3.22bn for 2012. Scott Maxwell, general manager, McLaren Performance, and director business development driveline and ICE groups, says,

2

1. Linamar's hybrid power unit can be integrated with virtually any existing standard two-wheel drive powertrain design to achieve an all-wheel drive hybrid system

2. Linamar acquired McLaren Performance Technologies in 2003. It provides engineering, testing and prototyping capabilities for product and manufacturing requirements

"The past three years have been extraordinary. Linamar came out of the downturn strong and has not looked back"

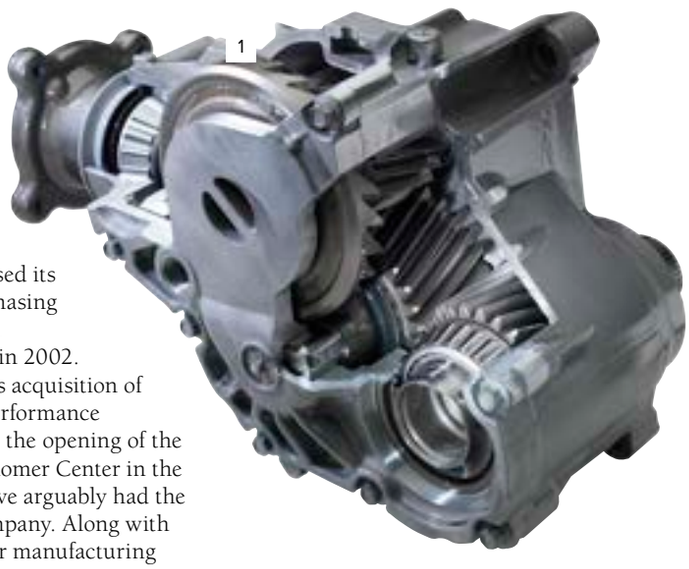
Scott Maxwell, general manager, McLaren Performance, and director business development driveline and ICE

"The past three years have been extraordinary. Linamar came out of the downturn strong and has not looked back. We have grown immensely through our takeover work, general market growth and regional expansion."

This expansion includes opening the Linamar Powertrain facility in Crimmitschau, Germany, in 2011, and, more recently, acquiring German auto supplier Mubea's camshaft business unit in October 2013. Linamar's overall track record for market growth and business acquisitions has remained strong since the late 1990s, when the company built Linamar de Mexico in 1998 to supply General Motors with transmission components. That same year Linamar acquired a 55% share of Industrias de Linamar, a diesel engine plant building complete engines for Renault. Four years

"The engine and transmission as we know them today are not going away in any large measure but will see significant incremental innovations over the next several years"

Scott Maxwell, general manager, McLaren Performance, and director business development driveline and ICE



later, the company increased its presence in Mexico, purchasing Federal-Mogul's camshaft manufacturing operation in 2002.

However, it is Linamar's acquisition of Detroit-based McLaren Performance Technologies in 2003 and the opening of the Linamar Automotive Customer Center in the same city in 2006 that have arguably had the biggest impact on the company. Along with its Ontario HQ's center for manufacturing excellence, much of Linamar's system R&D activity takes place in the USA's Motor City.

One of the most recent developments to come out of the Linamar labs – and one that could be a game-changer for future alternative propulsion systems – is the Linamar hybrid power unit (HPU). Launched in April 2013 and described by Maxwell as "a rear axle with two electric motors that combines all-wheel drive (AWD) and hybrid functions in one modular and scalable unit", the innovative HPU includes the two 75kW permanent magnet electric motors, two motor inverters, planetary reduction gearboxes for each motor to drive the wheels, disconnect feature, fluid pumps for actuation and lubrication, as well as integrated coolant, power and control connections.

According to Maxwell, the Linamar HPU, which can be used in micro-hybrids, PHEVs and full EVs, offers up to 80% fuel economy improvement in city driving when used as a plug-in hybrid, as well as AWD function equal to or better than any current mechanical system. It also has the ability to improve acceleration and offers active torque vectoring. A 330V 9kWh lithium-ion battery with battery management system (BMS) powers the unit, which sends a maximum of 1,500Nm of torque to each wheel and results in a pure electric range of 30km and top speed of 130km/h.

1. Linamar's power transfer unit (PTU) is available in one-, two- and three-axes setups. It is designed for optimal packaging and has a high torque density

2. Features of Linamar's rear drive unit (RDU) include integrated output shafts, mechanical and electronic LSD and integrated oil cooler pump

The technology was recently demonstrated in a Cadillac SRX and is fully integrated, modular and scalable, allowing for what Linamar describes as "bolt-on" installation between the vehicle's suspension components. "We appreciate that customers are keenly aware of axle and vehicle development costs, so we designed the axle to be scalable and simple so that variants did not require a complete new engineering effort for each vehicle," adds Maxwell.

Challenge accepted

Although he remains tight-lipped as to future developments over the next 12 to 24 months, Maxwell says that, thanks to the CAFE 2025 and EU equivalent emissions regulations, Linamar's powertrain work will be influenced "by mass reduction, efficiency and new technology introduction".

And in an effort to help OEMs overcome ever-stringent emissions legislation, Linamar is focusing on improving and optimizing the efficiency of their PTU and RDU gearboxes for AWD systems.

"In the next few years, we expect to see what are termed AWD disconnect systems where the moving parts within the gearboxes and the propshaft are disconnected and prevented from turning during normal driving," says Maxwell. "Today, most AWD systems have PTUs and RDUs that are always in motion. To achieve AWD mode in most current systems, the torque to the rear axle is controlled via a coupler that proportions torque to the axle as traction is required. However, all of the rotating parts in the system are rotating regardless. In a disconnecting AWD system, there is an actuator in both the front PTU and the RDU that will disengage the mechanicals inside the gearboxes to stop the rotating parts from moving, thereby saving the parasitic losses and hence fuel economy improvement."

Further ahead, Maxwell says Linamar is ready to meet the challenges presented by future vehicle electrification. "Our hybrid power unit can be used in the AWD area, but is easily adapted to EVs should that type of vehicle become more mainstream in the future. The engine and transmission as we know them today are not going away in any large measure but will see significant incremental innovations over the next several years. We are already well positioned for this change with our current capabilities."

Advanced Battery Testing

Illustration: Dean Armstrong/NREL

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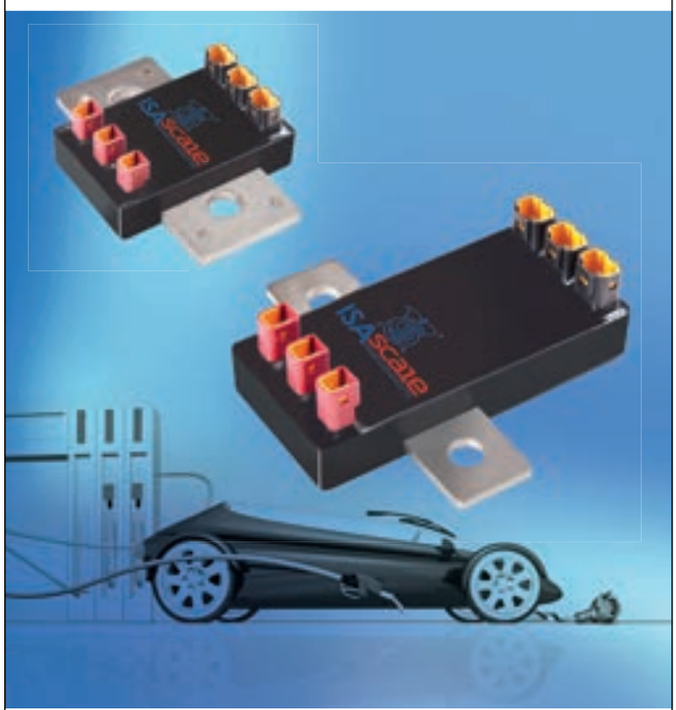

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Gear change

Dealing with the industry's ever-evolving transmission needs while offering services from initial concept through to product realization is the ethos underpinning growth for one pioneering supplier

WORDS: **KARL VADASZFFY**

Founded in 2007, Drive System Design (DSD) is an engineering consultancy that specializes in the design, simulation, control and development of mechanical transmission systems and drivelines. The British company provides full product design and development services, including the complete turnkey design of a product, and sourcing and building prototypes. Most of this work takes place at a build facility and R&D workshop in Warwickshire, UK, where DSD also offers functional testing, including assessment of hydraulic systems, component-led analysis and environmental validation. And if that's not impressive enough, DSD's staff of more than 30 engineers create bespoke control systems for customers and can write their own control algorithms and calibration.

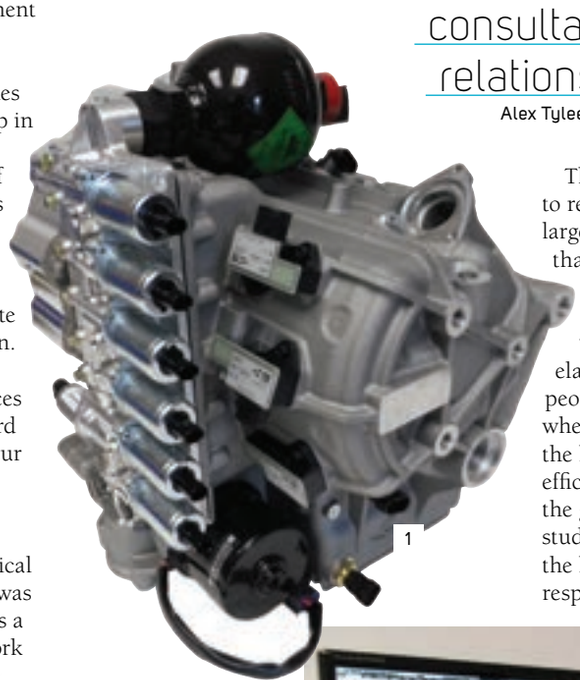
Such a combination of in-house engineering expertise and advanced services and technologies has allowed DSD to record year-on-year growth of 50% for the past four years – and this includes the financial downturn of 2009.

Alex Tylee-Birdsall, the company's technical director, says such growth is typical of DSD, given how and why the company was formed: "Many consultancies are viewed as a necessary evil rather than a pleasure to work with, so we saw an important opportunity to be a consultancy that builds stellar relationships with its customers. We work on the values of integrity and a fair price for a fair piece of work."

Different point of view

Much of the consultancy's initial electric vehicle work focused on gear noise issues. According to Tylee-Birdsall, the DSD engineering team took a radically different approach when exploring such problems, looking at the gear design in terms of tooth form from an engineer's perspective, whereas "most people design the tooth form for durability and then attempt to correct it for noise in the finishing process with micro-geometry corrections".

> "Many consultancies are viewed as a necessary evil rather than a pleasure to work with, so we saw an opportunity to be a consultancy that builds stellar relationships with customers"
>
> Alex Tylee-Birdsall, technical director, Drive System Design



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The DSD team was given just six weeks to resolve the gearbox noise problem for a large European manufacturer – a project that Tylee-Birdsall says was challenging but one that the company embraced.

"There's a certain type of specific teeth form that's important," he elaborates. "It's probably counterintuitive to people who design gears for normal vehicles where they're just looking for durability, but the key is to balance durability, NVH and efficiency in the tooth form. We improved the gear tooth design and did a full vibration study that resulted in us adding two ribs to the housing, which changed the way it responded to the excitation."

2

1: The development of the multispeed traction system (MSYS) was part financed by a grant from the Technology Strategy Board, Yasa Motors, MIRA and Jaguar Land Rover

2: DSD's 30-strong engineering staff write their own control algorithms in order to create advanced bespoke control systems

The end result of the project was more than impressive: a reduction in housing vibration by 45 times.

At present, DSD is busily involved in the UK government's Technology Strategy Board's (TSB) US$26m, two-year Range Rover Evoque_e R&D program (more details of which are in our Range Rover feature on page 48). Due for completion in 2015, it will evaluate electric and hybrid vehicle development by applying the widest range of components and technologies possible to three Evoque tech demonstrators, comprising a mild hybrid, a plug-in electric hybrid and a pure battery EV.

MSYS breakthrough

Yet not too long ago, some industry commentators were suggesting that the dawn of the EV era would signal an end to transmissions. But as e-powertrains are evolving, so too are the gearboxes that started life as basic one-speed designs to today's more complex and performance-orientated multispeed creations. It's now accepted that an advanced transmission is essential to operating an electric engine within its most efficient range. In response, and to demonstrate the company's versatility and capabilities, DSD has recently launched an internal project to develop a three-speed powertrain offering.

With a grant from the TSB and in partnership with Yasa Motors, MIRA and Jaguar Land Rover, the multispeed traction system (MSYS) was born.

Suitable for small A-segment vehicles through to much larger C-segment applications, MSYS is made up of an integrated design of an axial flux Yasa motor and multispeed transmission. Weighing only 55kg, the system supplies a peak power of 100kW with 55kW of continuous power, with more than 2,000Nm of torque at the wheels, in an extremely compact package of approximately 300 x 300 x 400mm. DSD claims MSYS provides a 40% weight saving and 10-15% lower vehicle energy consumption compared with current single-speed powertrains on the market.

"In 2010, we looked at the market and saw that everyone seemed to be doing single-speed transmissions with high-speed electric motors," explains Tylee-Birdsall, when asked about how MSYS came about. "We thought that didn't make a lot of sense from an efficiency perspective. People were particularly concerned about range anxiety, so it made sense to have the most efficient powertrain possible."

The DSD technical director says that increasing efficiency meant overcoming losses and discomfort: "We looked at what was the most efficient way of transmitting torque. Within a manual transmission, you're not running more than 7,000-8,000rpm, so with that as a starting point, we said that if we use a multispeed transmission, we could use a smaller motor, which means fewer rare earth metals, and we can also run it at lower speed and have no field weakening, which is a huge efficiency drain on the power electronics.

"Experience shows that AMT transmissions in small vehicles have not been very successful because people complain of poor shift quality. We do not want people to feel the power shift when using the transmission. So we have developed a power shifting system that doesn't require a lot of energy. Our shift system uses no power once the gear selection has completed – no power is needed to hold it in gear, unlike AT or DCT systems."

Looking further ahead, Tylee-Birdsall is expecting to see growth in the premium electric vehicle segment, and that's across Europe, Asia and North America. And in most markets, government-backed subsidiaries of up to US$10,000 are fueling further EV growth, albeit meaning that most battery-powered EVs and plug-in hybrids remain more expensive to purchase at showroom level than equivalent diesel- and gasoline-powered models.

However, Tylee-Birdsall cites the BMW i3 as a possible game changer: "It is the same price as offerings from other manufacturers, but it is a BMW, so suddenly the price does not seem such an issue because it is a desirable product from an attractive brand. BMW has stirred up the market and I'd even say caused fear in its rivals. What happens with the i3 will help determine how the market will go from here."

> "BMW has stirred up the market and I'd even say caused fear in its rivals. What happens with the i3 will help determine how the market will go from here"
>
> Alex Tylee-Birdsall, technical director, Drive System Design

1: DSD offers functional testing, including assessment of hydraulic systems, component-led analysis and environmental validation at a build facility and R&D workshop in Warwickshire, UK

2: DSD's MSYS features an axial flux Yasa motor and multispeed transmission, weighs just 55kg, and has a peak power of 100kW and 2,000Nm or torque

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Testbed measurements

Analysis of the longitudinal dynamics of electric and hybrid vehicles at the testbed using one measurement system is now possible thanks to a new modular data acquisition concept

Testing of a vehicle during the development phase usually requires more than one single measurement result. Parameters such as power, rpm, battery temperature, vibrations at the engine shaft or noises in the inside of the vehicle provide important data significant to the development of electric and hybrid vehicles. As such, the challenge is to find a way to acquire and analyze this information synchronously.

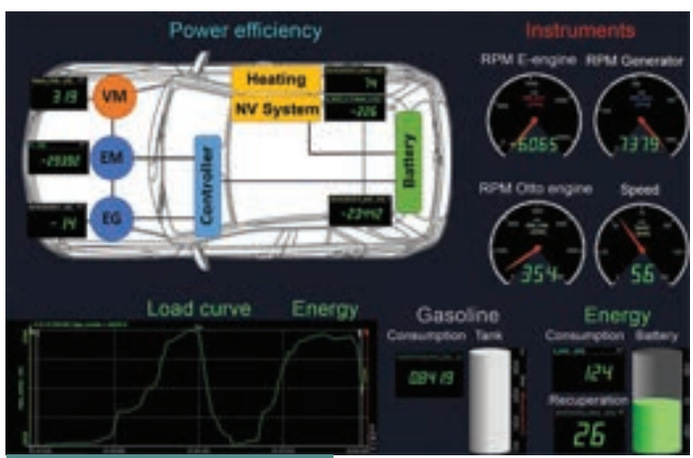
The Institute for Powertrains and Automotive Technology at the Technical University Vienna (TU Vienna) has met this challenge, having recently commissioned a measurement system for the analysis of the longitudinal dynamics of hybrid and electric vehicles. A Dewetron measurement system was chosen for this project because of its modular system architecture, which enables the synchronous acquisition of different input types.

The heart of the testbed consists of two DEWE-2600-E-Mobile measurement systems. Together, they are able to measure and store synchronously more than 100 signals with different sampling rates. The input signals comprise, among others, voltage, current, rpm, torque as well as noise, vibration and consumption and emissions data. Additional data of the testbed and the control unit of the vehicle can be imported into the software via a special interface.

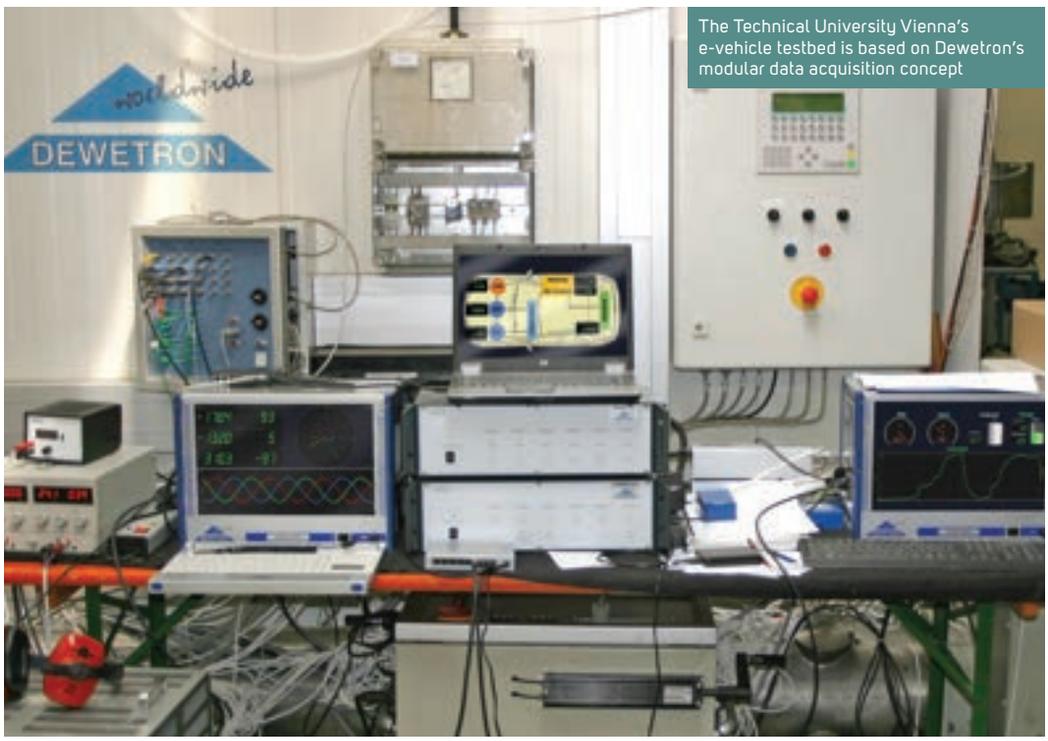
A comprehensive mathematic library for processing the input signals is included in the measurement software and is easy to operate. The library includes functions such as filters, counters, mathematical and logical operations, spectrum analyses and statistical reports that enable it to work with different signals and signal forms. For its comprehensive longitudinal dynamic analysis, TU Vienna used the mathematic library for calculating more than 200 parameters from the input signals.

One of the university's objectives was to determine the efficiency of the electrical powertrain. With Dewetron's measurement software, it is possible to create several power modules to calculate the power at different frequencies for several direct, alternating and three-phase current systems at the same time. In this way, it is possible to acquire currents and voltages at 14 different measuring points at the testbed synchronously. Among others, they acquire engine, generator, heating, air-conditioning and low-voltage systems to create an entire power

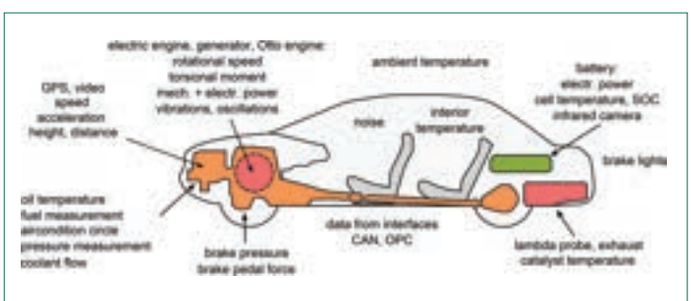
The testbed consists of two DEWE-2600-E-Mobile measurement systems able to measure and store synchronously more than 100 signals with different sampling rates



The processing of raw data, including statistical reports and route profiles, can be converted into different types of parameters for easier analysis



The Technical University Vienna's e-vehicle testbed is based on Dewetron's modular data acquisition concept



A singular measurement on one point in a vehicle results in limited knowledge. The synchronous use of hundreds of parameters makes the processes in a car much clearer

balance. To guarantee the highest quality of power measurement, the sampling rate and the analog bandwidth are vitally important.

Modern frequency converters for electric vehicles work with a pulse frequency up to 30kHz. To acquire these signals for precise power measuring, it is necessary to choose a high sampling rate to guarantee an analog bandwidth up to 600kHz. Dewetron's galvanic isolated amplifiers with a bandwidth up to 2MHz ensure this.

The battery is the central element in the electrical powertrain and strongly influences the performance and range of electric vehicles. As such, the lifetime of the battery is a problem. Therefore, TU Vienna also analyzed the cell characteristics, aging, as well as warming and temperature dispersion to evaluate the long-term performance of the battery. To this end, it analyzed more than 40 measuring points in the battery system.

The performance balance of the entire powertrain is determined directly in the measurement software. Hence, it is possible to identify the recuperation energy, energy consumption, efficiency factor, and so on, during the tests. The analysis can also be performed in the post-processing phase. Additionally, the software offers an export function for the most common data formats, such as Excel, MATLAB, FlexPro and Famos.

All measurement data can be embedded in testbeds again, with drivers for Labview and DASYLab developed for this task. Furthermore, special interfaces such as DCOM and OPC guarantee a universal and flexible integration of the measurement system.

Using the same Dewetron measurement system, it is even possible to measure during real driving conditions. The DEWE-2600-E-Mobile measurement system has two battery packs that supply the sensors as well as the system with enough power to guarantee a reliable measurement. For measurements during driving, further sensors such as GPS or video can be connected to the system. Such tests were executed by TU Vienna.

The university has already tested electric and hybrid vehicles from five manufacturers using the Dewetron testbed. The academics have come to interesting conclusions and found potential for improvement and research. Utilizing their practical expertise, they have developed longitudinal dynamic models to improve the powertrain efficiency of electric and hybrid vehicles.

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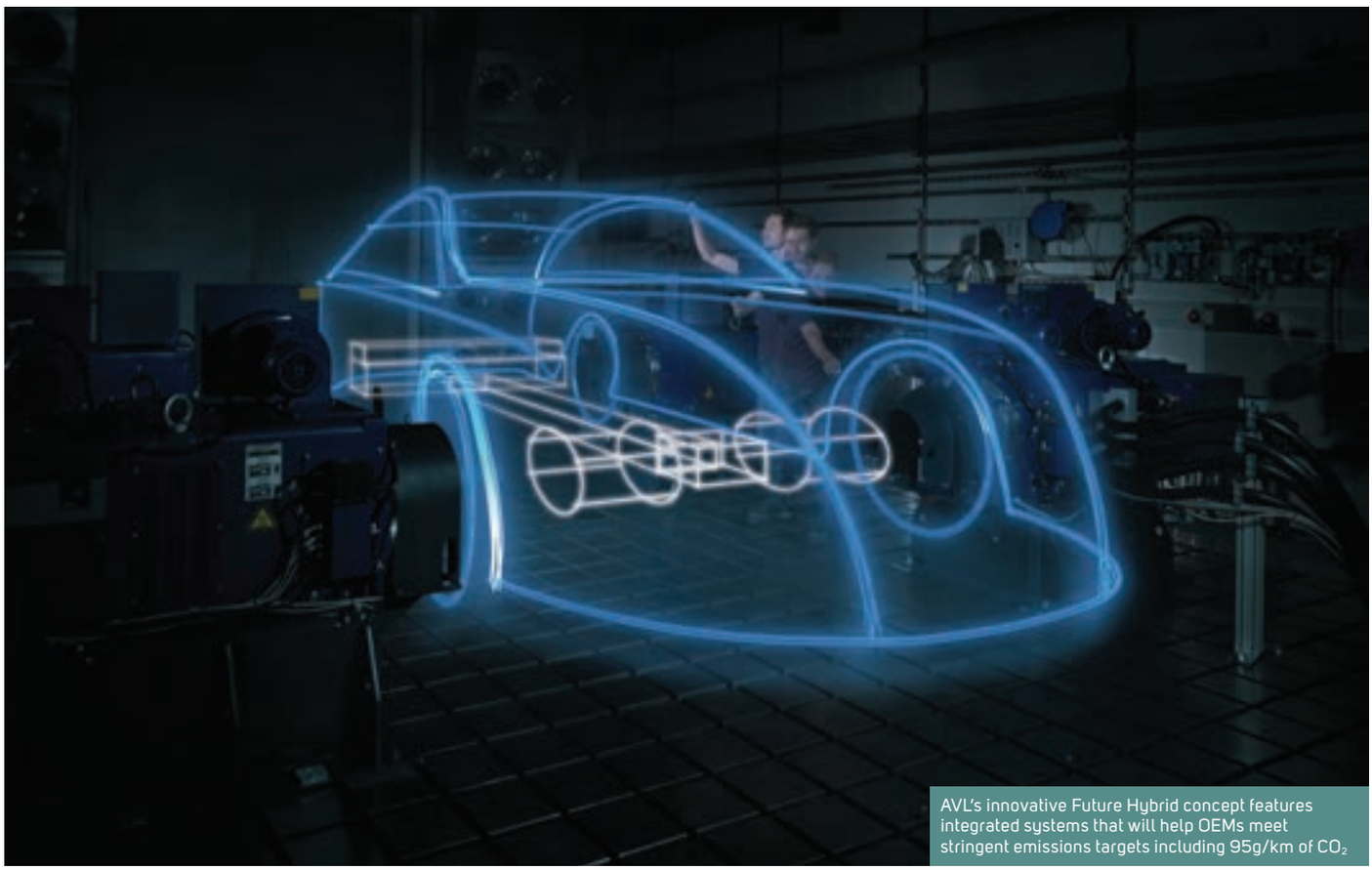
ONLINE READER ENQUIRY NO. 501

Plug-in hybrid advances

Designed to reduce hardware complexity and utilize efficiency synergies, a new PHEV drivetrain concept is aiming to reinvigorate interest in future hybrid mobility



AVL's innovative Future Hybrid concept features integrated systems that will help OEMs meet stringent emissions targets including 95g/km of CO_2

PHEV drivetrain design relies on a holistic approach to development. AVL's Future Hybrid concept is designed to significantly advance plug-in-hybrid-technology. The development target is a PHEV drivetrain solution that covers the everyday needs of AVL's customers, while putting best-in-class CO_2 emissions and low-product-cost designs into practice.

Starting with a holistic international market analysis, qualitative customer needs assessment, future legislation requirements and ideas from AVL's experienced practitioners have been condensed into the Future Hybrid concept.

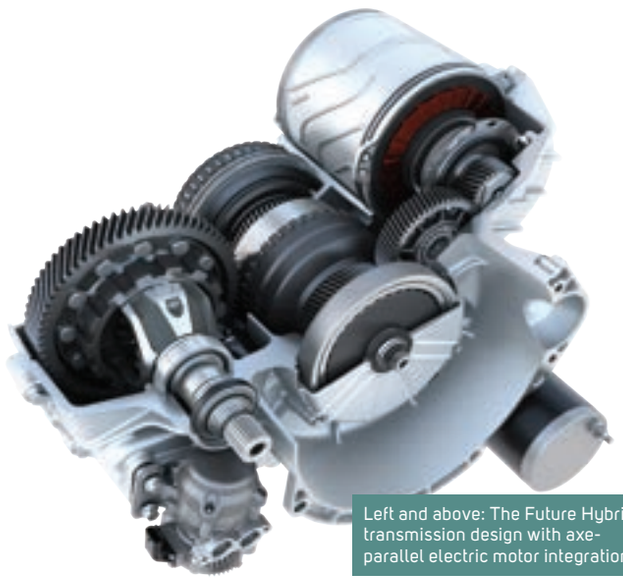
Frank Beste, senior program manager at AVL and program manager of the Future Hybrid concept, explains, "One of the reasons why the vehicle electrification hype from 2011 has turned into disillusionment and reduced customer attention is that very central customer questions have not been answered. These include significantly higher product costs versus perceived customer benefit, the limited range of battery electric vehicles and the limited availability of charging infrastructure."

Emissions legislation requires a fleet average of 95g/km of CO_2 by 2020, which translates to a further CO_2 reduction by about one-third from the current status.

"The consideration of drivetrain electrification in innovative and cost-efficient solutions will be mandatory for target fulfillment within the next two to three years," continues Beste.

Its phased introduction must be pulled by technical necessity and accompanied by tangible customer benefits. The requirements for plug-in drivetrain hybridization are immense: lowest CO_2 emissions in the NEDC certification, in customer cycles and at traveling speed. Designs for low product cost and further boundary conditions such as driver comfort, an all-electric range (AER) of more than 25km and functional safety are obvious.

For an OEM to achieve fleet CO_2 emissions targets, cost-efficient CO_2 emissions reduction in its mass products is essential. Therefore, AVL intends to demonstrate Future Hybrid's capability in the passenger



Left and above: The Future Hybrid transmission design with axe-parallel electric motor integration

car C-segment, which dominates the overall market volume. The demonstrator specification includes an AER of 30km (NEDC), an acceleration of 0-100km/h in 10 seconds and certified CO_2 emissions of 35g_2/km.

"The fulfillment of certified CO_2 emissions is dominated by the AER capabilities of the car," says Beste. "AVL's engineering task is driven by challenging component efficiency targets and intelligent operation strategies to achieve best CO_2 emission results in the charge-sustaining mode. In this mode, the battery state of charge (SOC) needs to be sustained to fulfill the target CO_2 limits of 79g/km. This is the benchmark to be achieved and is directly relevant for the customer perception of the vehicles' efficiency advantages in real-world customer drive cycles."

The targets require a holistic perspective of the drivetrain and vehicle integration along the AVL hybrid development process by an optimum balancing of key drivetrain components. This balancing allows the exploitation of new efficiency potentials that emerge only by the functional integration of a purpose adapted combustion engine, a new innovative transmission with an integrated electric motor (EM), the high voltage (HV) battery and an intelligent system control and operation strategy.

An example of such an advantageous synergetic approach is the integration of the EM in the transmission. By this, the three-cylinder TGDI IC engine can utilize the specific fuel consumption reduction of the Miller cycle combustion technology. Disadvantages in IC engine transient behavior and top-performance density are balanced out by the availability of dynamic EM torque. At the same time, the combination of the IC engine with the EM reduces the technical requirements and accordingly the overall costs for the electric propulsion system.

Reduced hardware complexity, compact transmission length and new transmission functionalities have been the guidelines for AVL's pioneering Future Hybrid transmission development.

"The transmission design at AVL started with a white sheet of paper," recalls Beste. "The transmission functionality had to guarantee the vehicle's mobility at any HV battery SOC to avoid the need for battery energy reserves. These would limit AER and increase both battery size and overall cost."

Therefore, for the worst-case scenario of an empty battery in stop-and-go traffic conditions, the transmission must allow for launch capability by the IC engine only and to operate the integrated EM in generator mode to provide sufficient electric energy for auxiliaries, air conditioning or cabin heating of at least 3.5kW. The vehicle launch feature is achieved with the introduction of an eCVT mode by a torque-split unit. At medium or high battery SOC, vehicle launch and typical city driving are performed in a pure electric mode.

In summary, the transmission design supports all operation modes shown, including the eCVT mode, to operate the combustion engine at minimum vehicle speed and provide charging power for the electric system; two electric gears for reduced e-motor torque demand and improved efficiency; and three combustion engine gears.

The compact transmission length of 350mm and a total transmission system weight of about 90kg including the EM support the compact drivetrain integration philosophy.

AVL's Future Hybrid transmission team has now completed the detailed design phase. The next steps include the build-up and testing of prototype systems on AVL's highly dynamic powertrain testbeds. Following this, the application of a C-segment demonstrator vehicle is planned to be completed.

The work is part of the VECEPT project, funded by Austrian company Klima- und Energiefonds. Magna Steyr Battery Systems, AIT, Verbund AG, IESTA and the Virtual Vehicle are also working on packages designed to create a lighthouse of future mobility.

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ONLINE READER ENQUIRY NO. 502

BMS developments

As electrified powertrains become increasingly complex, the burden placed on battery management systems to perform a greater number of functions is larger than ever

From a simple charge controller to a complex control unit, the demands being made of battery management systems (BMS) have increased rapidly – particularly for electric cars. As well as classical charge status monitoring, a BMS must also comply with increasingly strict safety regulations, look after control and standby functions, thermal management and cryptography algorithms to protect the original OEM battery (Figure 1). Even parts and functions of the vehicle control unit (VCU) could be relocated to the BMS in future.

Within the scope of the ISO 26262 safety standard, certain E/E systems, such as the BMS, will be classified in upper safety categories ASIL C to ASIL D. This corresponds to a fault detection rate of at least 97% to 99%. The most dangerous fault sources in battery systems are danger from undetected erroneous high voltage at the vehicle chassis and danger from fire or explosion of the high-voltage battery.

With regard to safety, the main switch (main relay) plays an important part in avoiding high-voltage related accidents and ensuring that the BMS electronics have an adequate fault reaction. In the event of a fault, the switch should be opened by the BMS module within an appropriate fault reaction time (for example, <10ms). The non-critical fail-safe condition is always characterized by the fact that if the BMS microcontroller (MCU) fails, the independent external safety element (such as a window watchdog) ensures that the main switch relay also reliably opens both high-voltage contacts to the inverter (plus/minus), even if the controller logic fails completely. There are other safety functions integrated in a BMS system, including leakage current monitoring and main switch relay monitoring.

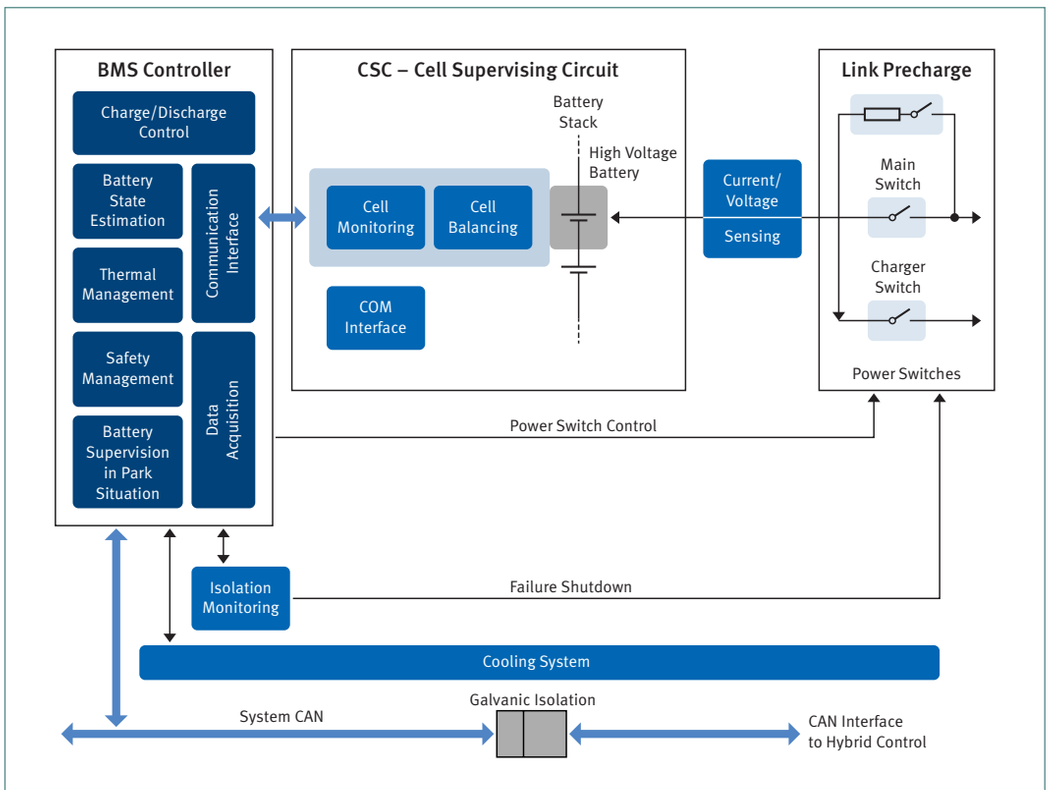

Figure 1: The battery management system of an electric vehicle with all of the relevant components

Other BMS functions include monitoring, care and maintenance of the expensive high-voltage battery in the electric vehicle. The BMS takes controls and monitors the electronic balancing slaves that are installed in the battery stacks. These balancing ICs act as an electronic front end of the individual high-voltage battery cells that are galvanically decoupled from the BMS, and take over the typical balancing of the individual cell stacks and also precise sensing of the singular cell voltages. A balancing IC usually looks after a cluster of up to 12 individual battery cells. The relevant quantity of clusters connected in series then produces the high intermediate circuit voltage of up to several hundred volts of the inverter control that is required for the inverter e-drive in the electric vehicle.

Synchronous measurement of the total current of all high-voltage battery cells by the main switch and simultaneous cell-accurate monitoring of all individual cell voltages via the slave IC allows the BMS to evaluate a battery's parameters, such as state of health and state of charge using specific algorithms (for example, on the basis of battery chemistry Matlab and Simulink models).

Due to the increasing complexity of the battery-specific chemical/electrical algorithms, microcontrollers, such as Aurix with 2.5 to 4MB of Flash memory and powerful multicore processor architecture, are being predicted for use in the BMS. This combination guarantees that there is enough memory for comprehensive calibration parameters and that sufficient computing power is being provided (Figure 2).

Manufacturers of electric cars prefer to monitor the charge status of the battery and the individual cells at regular intervals. Therefore, the BMS must provide special low power-based standby functions that only require extremely small MCU power consumption in the µA range and can also briefly wake up the system using a timer, for example, to record specific individual battery cell data in BMS active mode via balancing ICs. To carry out cyclic wake-ups for the BMS using a wake-up timer, an 8-bit standby MCU is monolithically integrated (on the same silicon) in a separate low-power domain in some variants of the Aurix microcontroller.

For design reasons, the high voltage battery modules often contain active thermal management, such as for a heater for winter or a cooling system for summer. These can be based on air- or water-cooling. In both cases the BMS is used to sense the relevant temperature data of the battery and actively actuate and control the actuators (for example, fan motors or water pumps). Thanks to built-in digital/analog converters and a multitude of timer functions, Aurix microcontrollers can take care of this task.

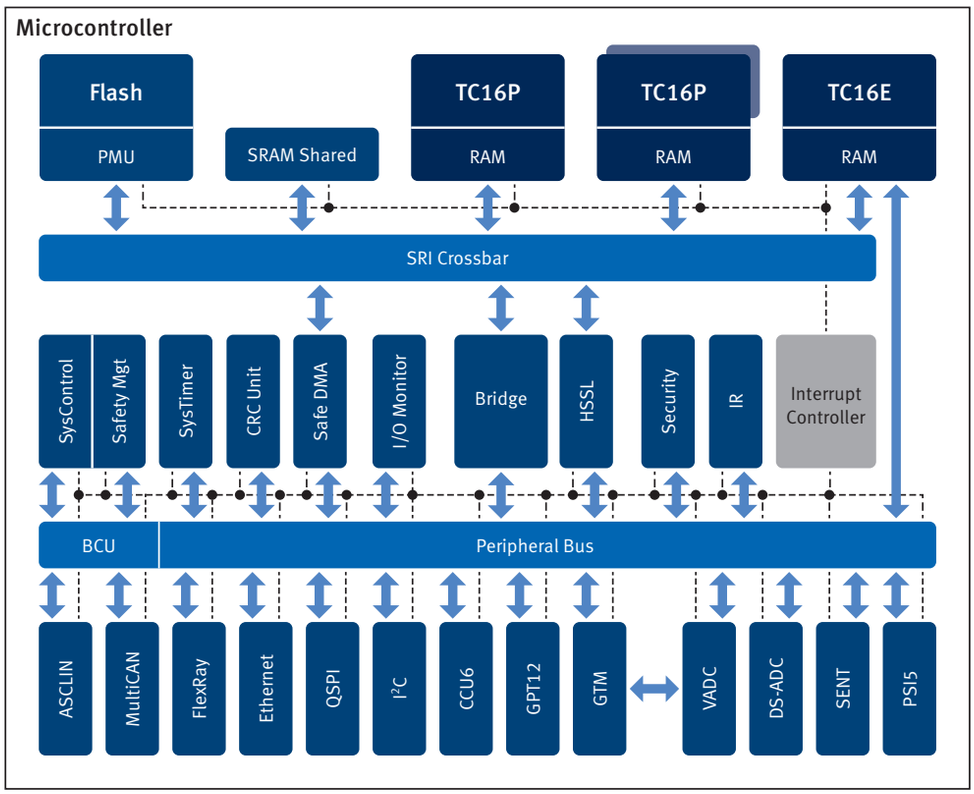

Figure 2: A block diagram of Aurix microcontrollers with 2.5 to 4MB of Flash memory and TriCore multicore architecture

The original OEM battery in electric vehicles should be protected from unauthorized intervention by third parties. The battery manufacturer's warranty period can only be guaranteed if manipulation by aftermarket providers, for example, can be ruled out. Replacing individual cells in the battery cluster or assembling used batteries from cannibalized individual parts conceals a latent risk of safety-related faults or even explosions or fires. Appropriate protection modules, such as Infineon's Origa chip, can be directly installed in the individual cell clusters. However, logical protection of battery individual data in the form of a hardware security module (HSM) integrated in the MCU could be used as a low-cost alternative.

In this case, the HSM in the Aurix can make an effective contribution toward detecting the above-mentioned battery individual parameters as the battery master and storing them in a secure HSM protected data memory. For example, the status of the individual battery cells is stored for the service life thereof as an AES-encrypted profile in this way, so that unauthorized replacement of individual cells would be detected on the basis of this data. It can be assumed that a typical battery cluster profile is similar to a fingerprint, making it so individual that a replaced cluster would be easy to recognize. Another application area for cryptography algorithms is charge monitoring and comparing the amount of charge that has been billed by the external provider with the amount of charge that has been actually measured by the BMS.

Depending on the choice of manufacturer-specific electronic topology in the electric vehicle, systems already exist that install both an inverter control unit and a separate control unit for the higher-order driving strategies, the VCU. As well as the entire torque control system, these also contain other advanced functions, such as an intelligent energy manager. Taking the planned car route into consideration (via the integrated navigation unit), an energy manager can optimize the entire energy system in a route-specific way and therefore help to increase the driving distance range of the battery.

Individual OEMs are now considering distributing all parts of the former VCU to the BMS and the inverter control unit to reduce the overall costs of the electronics in the electric vehicle. A prerequisite for VCU removal is ultimately the possibility of depicting microcontroller-specific parameters in the BMS, such as performance, amounts of Flash and SRAM, independence of the individual control unit functions with regard to real-time capability, and seamless integration of safety-related software functions (from QM to ASIL D) on a shared multiprocessor architecture in a scalable way. In this particular case, Infineon provides a facility for the integration of all of these requirements in future BMS customer developments within the controller hardware in the form of its TriCore-based Aurix multicore architecture.

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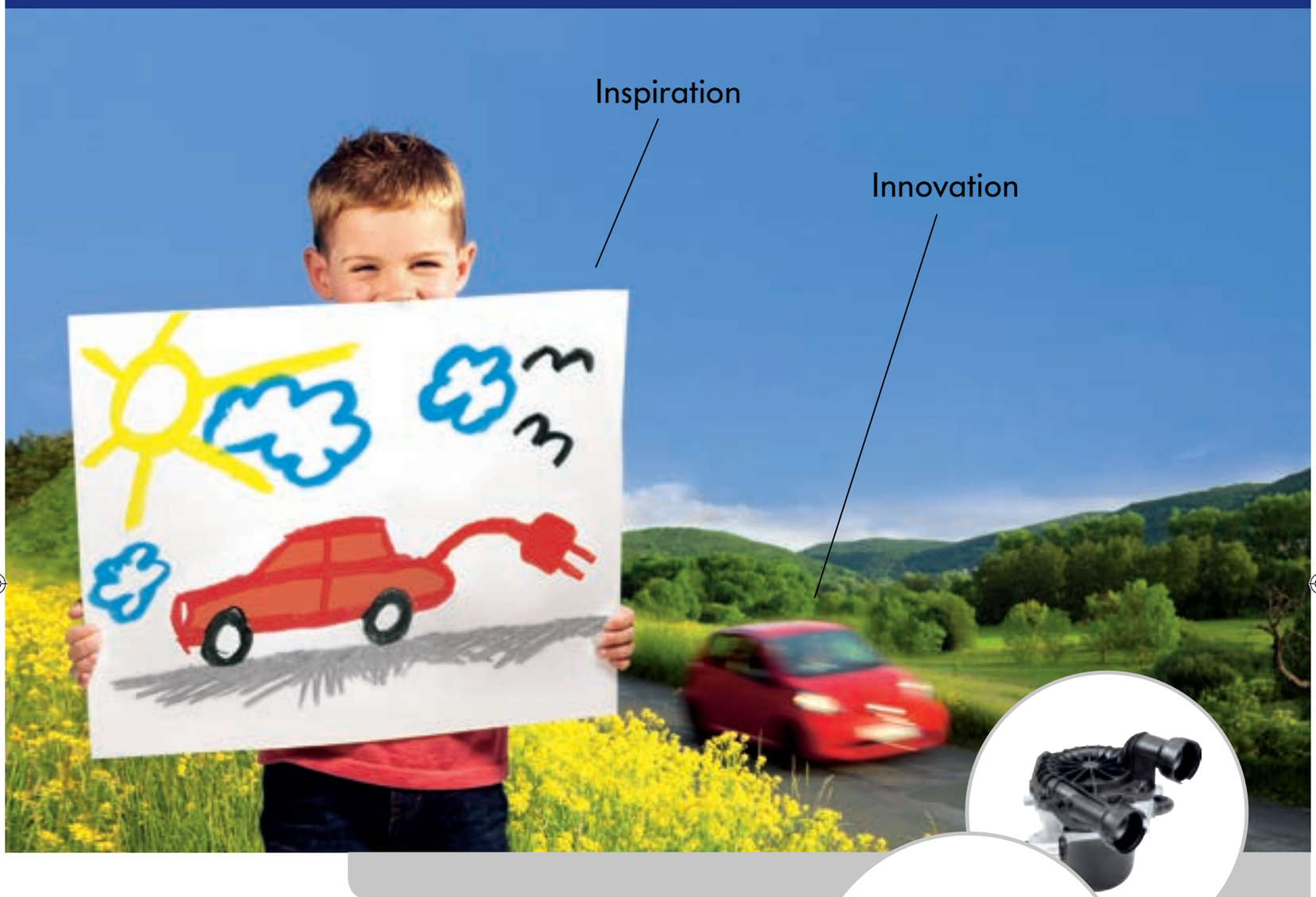

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Systems-level simulation

A physics-based approach to multidisciplinary and multiscale systems-level simulation is enabling a shift in its use, from an analysis tool to an integral part of the design flow

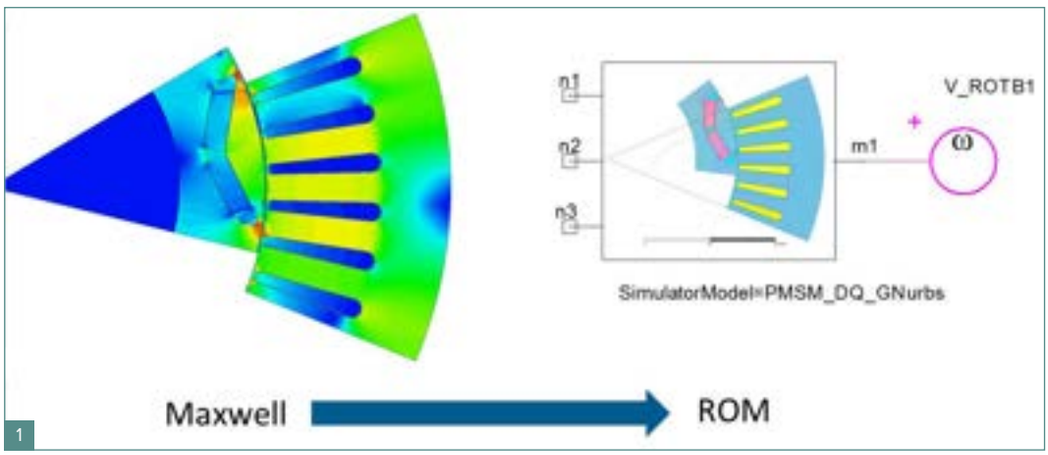
Rising fuels costs, new regulatory frameworks and geopolitical drivers are reshaping the automotive market. Automotive companies develop key business initiatives to reduce vehicle cost, improve fuel efficiency, improve safety and incorporate nice-to-have features in the most cost-effective way. To realize these key business initiatives in an ever-shorter development cycle, simulation plays a vital role.

Systems simulation provides engineers insight into the interoperability of individual components. For example, the team responsible for development of a traction motor for an electric or hybrid electric vehicle knows that this component does not work in isolation – it needs to work with the power electronics inverter as a single subsystem. This subsystem, in turn, is controlled entirely by embedded software.

Design engineers working on this system would employ dedicated tools customized for each component: for example, finite element method for electric machine design, circuit simulator for power electronics and control system software with C code generation capabilities for embedded software.

System engineers typically use a signal flow simulation tool and try to capture the behavior of the electric machine and power electronics as best they can by using textbook equations or extracting lookup tables from physical testing.

Ansys has developed a design environment that allows system engineers to simulate their designs with physics-based reduced-order models (ROMs) that are obtained from finite element, finite volume or other numerical method solvers. This allows for a much higher degree of fidelity and accuracy in the systems-level simulation. The system engineer no longer needs to know the governing equations of an electric motor. The design engineer of the electric motor can utilize Ansys' electromagnetic finite element simulation software to automatically create a non-linear ROM that can be sent to the system engineer (Figure 1). Thus, for the system engineer, this ROM can be added to his model library and used just like any other model. They do not need to be an expert in electric machine design, however, the system simulation is more accurate due to the physics-based ROM received from the electric machine design engineer.



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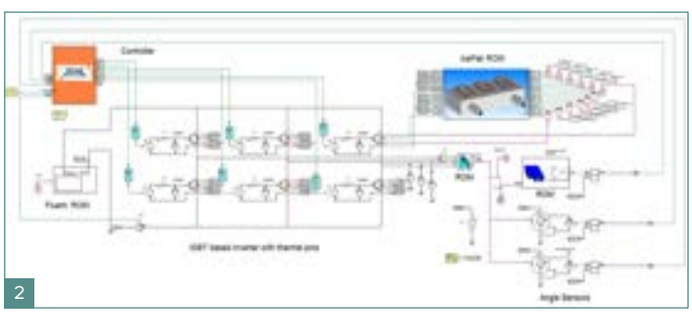

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Figure 1: Electric motor design engineers can use electromagnetic finite element simulation software to automatically create a non-linear ROM that can be sent to the system engineer

Figure 2: An illustration of the system simulation path. The system engineer is responsible for ensuring that the inverter, electric machine and embedded software work as one unit

The same principle can be used for embedded software. Again, the system engineer is responsible for making sure that the inverter, electric machine and embedded software all work together as one unit – even though they may not develop the control code that gets compiled into C code.

The engineer responsible for the embedded software can use Ansys to model the control software and then automatically generate the C code that meets the automotive standard ISO 26262. Just as the physics-based ROM was brought into the system simulation environment as a model library component, the same can be done with embedded C code.

The Ansys system simulation environment enables automatic linking to the embedded C code, electric machine ROM and power electronics. This leads to a fundamental shift in the use of simulation, from an analysis tool to an integral part of the design flow, and results in simulation-driven product development.

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EV battery advancements

Thermal-management technology can improve the life and range of lithium-ion batteries and help meet EV fuel economy regulations via system weight and temperature reductions

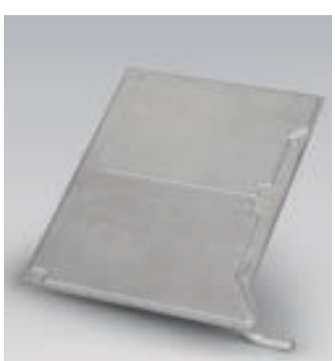
As fuel efficiency and emissions standards become more stringent and consumer concerns about the environmental impact of vehicles rise, auto makers are turning to hybrid and electric vehicles (EVs) as a way to meet demands. To help manufacturers reach the required corporate average fuel economy (CAFE) regulation of 5.183 liters/100km (54.5mpg) by 2025, suppliers are working with automakers to adapt existing technologies and develop new innovations that focus on improving battery life and range, regulating battery temperature, and boosting consumer confidence.

Dana's durable cold plates extract heat from lithium-ion hard can batteries in order to maximize the battery pack's performance

"Electric vehicles continue to evolve, and by developing highly effective technical advances in cooling systems, suppliers and automakers are able to support the mission to reduce environmental impact and develop the next generation of environmentally friendly cars," says Dwayne Matthews, president of Dana's Power Technologies Group.

Over the past few years, interest in EVs in the US auto industry has surged as manufacturers continue to introduce new generations. But one critical component of EVs, especially full-electrics, is the use of advanced lithium-ion batteries as the main power source. With this in mind, one way automakers and suppliers are driving innovations for battery life and range is through temperature regulation. The power electronics module, which is part of the electric system, controls the power flow to and from the motors and generators. As energy can be lost as heat, the module must be cooled. Most often with EVs, a liquid cooling system is integrated and used to cool multiple components of the power electronics.

The cold plates, with the aid of Dana's coolant chiller, stabilize battery temperature and enable a fast charge



Dana's aluminum cold plates are designed to be lightweight, while providing optimal structural support

Dana uses lightweight, aluminum cold plates and coolant chillers to provide a complete thermal-management system that works together to remove excess heat, extending driving ranges and lengthening the duration between charges for EVs. This combination helps to satisfy the needs of the consumer and the vehicle manufacturer. Featured on the 2013 Fiat 500e, the cold plates extract the heat from the lithium-ion battery cells and transfer it to Dana's coolant chiller for heat removal from the battery pack.

"Because of its unique ability to extend battery life and balance temperature, our technology allows consumers to drive for longer periods between charges – making the electric vehicle a more appealing option for the mainstream market," says Matthews. "By leveraging our long-standing manufacturing strengths, and delivering a complete thermal-management system, we balance temperature to optimize flow and uniformly transfer heat more efficiently and at a lower cost."

Another critical driver for battery systems is cost. Traditionally, cooling systems use more materials and ultimately increase weight, making them costly to operate. Yet, through Dana's 110 years of extensive expertise, this advanced technology improves cooling performance and power density, giving a material and weight reduction. Ultimately, Dana's thermal-management system provides a competitive solution that ensures consumer and automaker demands are met.

The world of automobiles is changing, and as regulations and customer demands drive the transformation of the industry, innovation remains the critical component in making progress happen. Through its commitment to innovation, Dana continues to move the EV market forward through its advances in battery technology.

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NVH countermeasures

Active noise control is being applied as an NVH optimization solution to enable CO_2 emissions reduction in electric and hybrid vehicles through improved driveline efficiency

An increasing automotive trend is to produce hybrid and electric vehicles as low-volume derivatives of conventional vehicle platforms. In these cases, a hybrid powertrain's requirements may have not been considered at concept and design phases (particularly in the case of older platforms), or may have been too expensive to compromise the main program.

To make these products commercially viable, substantial weight reductions may be required to offset increased weight from batteries and other additional electrical systems. NVH material not affecting structural integrity for crash or durability is an obvious target, but customers expect the same or higher levels of refinement in hybrid and electric vehicles than in the original IC vehicle. Therefore, as an effective and low-weight NVH countermeasure, active noise control (ANC) is of great value. Recent OEM interest has focused on applications to reduce CO_2 in two ways: by improving the efficiency of the driveline without compromising refinement, and by reducing body and trim weight while maintaining acceptable refinement.

Lotus Engineering has patented ANC technologies capable of reducing low-frequency cabin noise. In partnership with Harman, these technologies are now available for production under the Halosonic brand. The first of these technologies is engine order cancellation (EOC), which reduces dominant engine noise harmonics. This benefits both parallel and series hybrids, achieving acceptable NVH while enabling engine downspeeding strategies, including operating at lower speed and higher load; general engine downsizing (reduced engine cylinders and capacity with EV torque assist); low backpressure exhaust that's optimized for economy; and engine balancer shaft deletion.

The Lotus Evora 414E REEVolution hybrid vehicle

For range extended series hybrid applications, there is a further issue, since the engine operating speed is unrelated to road speed. In addition, electric mode and hybrid mode have very different NVH characteristics.

The Lotus Evora 414E REEVolution hybrid vehicle, running a three-cylinder 35kW range extender engine demonstrates the noise benefits of EOC.

To achieve similar levels of noise reduction with conventional methods would be next to impossible and could require a more substantial engine block (cast iron, not aluminum), more cylinders, additional NVH cladding/engine encapsulation, and strategies to run the engine at far lower load and efficiency.

Another advanced Halosonic technology is active road noise cancellation (RNC), which reduces low frequency broadband noise generated though the vehicle suspension. The potential for weight reduction comes from the idea that if the original noise level is acceptable and the RNC system can reduce noise significantly, then traditional NVH countermeasures can be deleted or reduced, thus increasing interior noise back to the initial levels while reducing weight. A specific example of this is shown in Figure 1.

During RNC development on a premium SUV, each rear suspension turret was found to have a large bolted-on mass, weighing over 3kg. These were removed and retested. The black line on Figure 2 shows the base car NVH levels. The blue line shows the increased noise with the turret masses removed. The red line shows the noise performance when RNC is implemented in this condition. This has achieved similar NVH to the added mass but has also shown key benefits through the rest of the frequency range, leaving the opportunity for deletion of other NVH components.

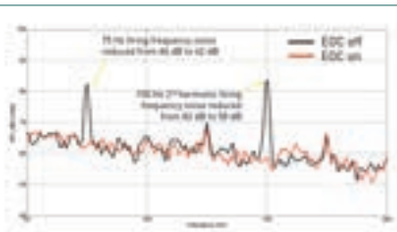

Figure 1: Outlining RNC benefits

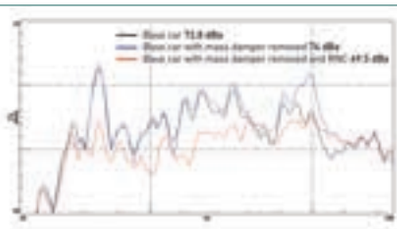

Figure 2: A comparison of RNC

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Gap Filler 1500LV is a low volatility, two-component, liquid-dispensable thermal interface material. This ultra conformable elastomer provides a thermal conductivity of 1.8 W/m-K. It offers the high temperature resistance and low modulus of a silicone material, with significantly lower levels of outgassing. At higher temperatures, volatiles from outgassing can create issues in enclosed fixtures such as lighting where the clarity is crucial. Gap Filler 1500LV is ideal for use in these lighting applications or other situations where fogging of lenses or optics is a potential consideration.

Low assembly stress on electronic components.

Gap Filler 1500LV is thixotropic and although it will remain in place after dispensing, the material will flow easily under minimal pressure resulting in little to no stress on fragile components during assembly.

Gap Filler 1500LV cures at room temperature – and the curing process can be accelerated with the addition of heat. When cured, this material provides a soft, thermally conductive, form-in-place elastomer that is ideal for filling unique and intricate air voids and gaps.

Another innovative thermal solution for optimized dispensing.

Gap Filler 1500LV is just one of an expanding line of liquid dispensed materials. Unlike precured gap filling materials, liquid dispensed materials offer infinite thickness options and eliminate the need for specific pad thicknesses or die-cut shapes for individual applications. Applying precise amounts of material directly to the target surface results in an effective use of material with minimal waste.

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Electromagnetic analysis

A new electromagnetic module has been launched to enhance the capabilities of a software package dedicated to the thermal analysis of electric motors and generators

The new Motor-CAD electromagnetic module (Motor-CAD EMag) provides fast and accurate performance calculations for electric machines. The electromagnetic module links with the thermal modules inside Motor-CAD to provide a complete multi-physics solution for machine design. Motor-CAD uses highly efficient methods to provide comprehensive design analysis.

The software automatically sets up the optimum winding for a particular slot pole combination, as shown in Figure 1. There is also the option to specify custom winding schemes. The harmonics, winding factors and phasor diagrams are automatically calculated.

Figure 2 shows one of the calculated performance curves for the various sine and square wave drives that can be modeled, which in this case is the back EMF curve. This is one of the many curves that can be calculated, including torque, cogging torque, drive currents, voltages and flux linkages.

The software uses fast and accurate methods to calculate the machine's magnetic performance. Figure 3 shows loss density shading. Motor-CAD has powerful loss calculation methods that enable the calculation of losses in conducting regions. Core losses are calculated with Steinmetz and Bertotti models. Magnet losses are calculated taking into account magnet segmentation. Motor-CAD includes a comprehensive material database for electric steels and magnets. It also provides harmonic analysis of waveforms.

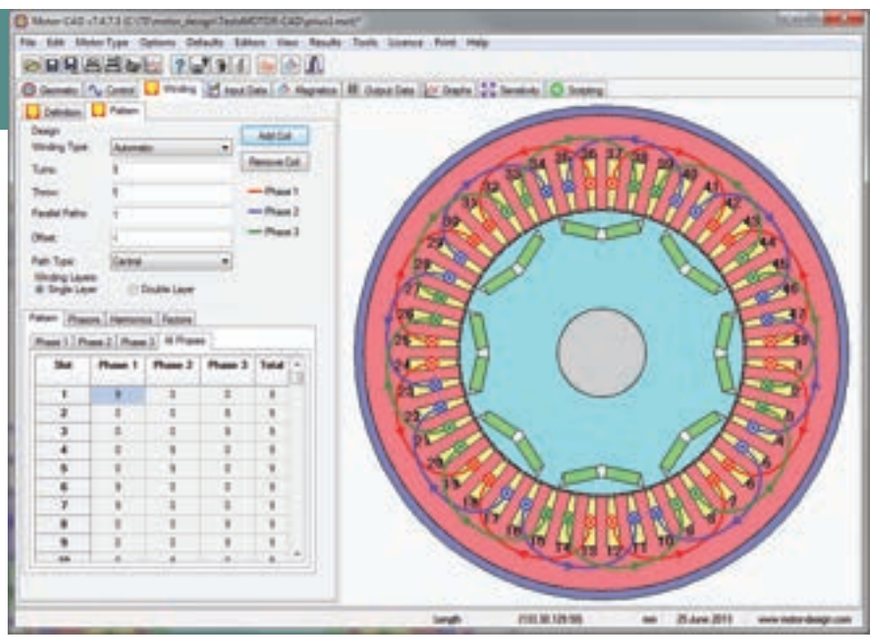

Figure 1: Optimum winding automatically set up for any slot pole combination

The Motor-CAD thermal analysis tool is an industry-leading piece of software designed by motor designers for motor designers. The new electromagnetic calculations in Motor-CAD have been developed by Motor Design Limited (MDL), which has once again brought its unrivalled experience to the table to ensure that the new module meets customers' needs. The new EMag module has been subjected to rigorous beta testing with a number of development partners during the past six months to ensure that the product has been fully validated.

MDL has been designing and developing electric motor simulation software since 1999. It is a world leader in the development of advanced software design tools for thermal analysis of electrical machines. It supplies software to most sectors designing electric motors and generators, including automotive, aerospace, servo, renewables and industrial. MDL's customers include many prestigious names such as ABB, Bosch, BMW, JLR, John Deere, Magneti Marelli, Mitsubishi, Nidec, Porsche and Seimens.

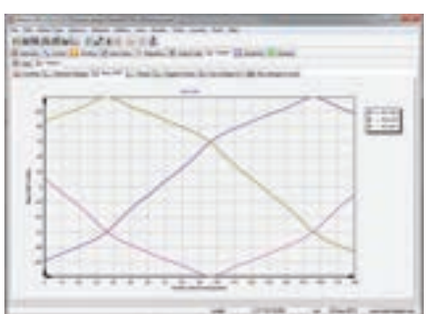

Figure 2: One calculated performance curve

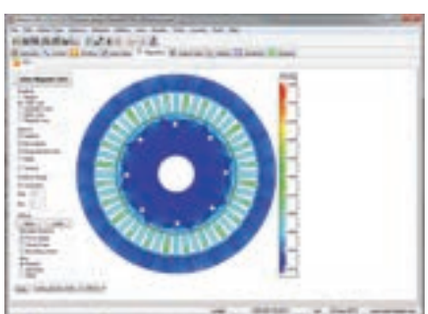

Figure 3: Loss density shading shown in software

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ENGINEERING

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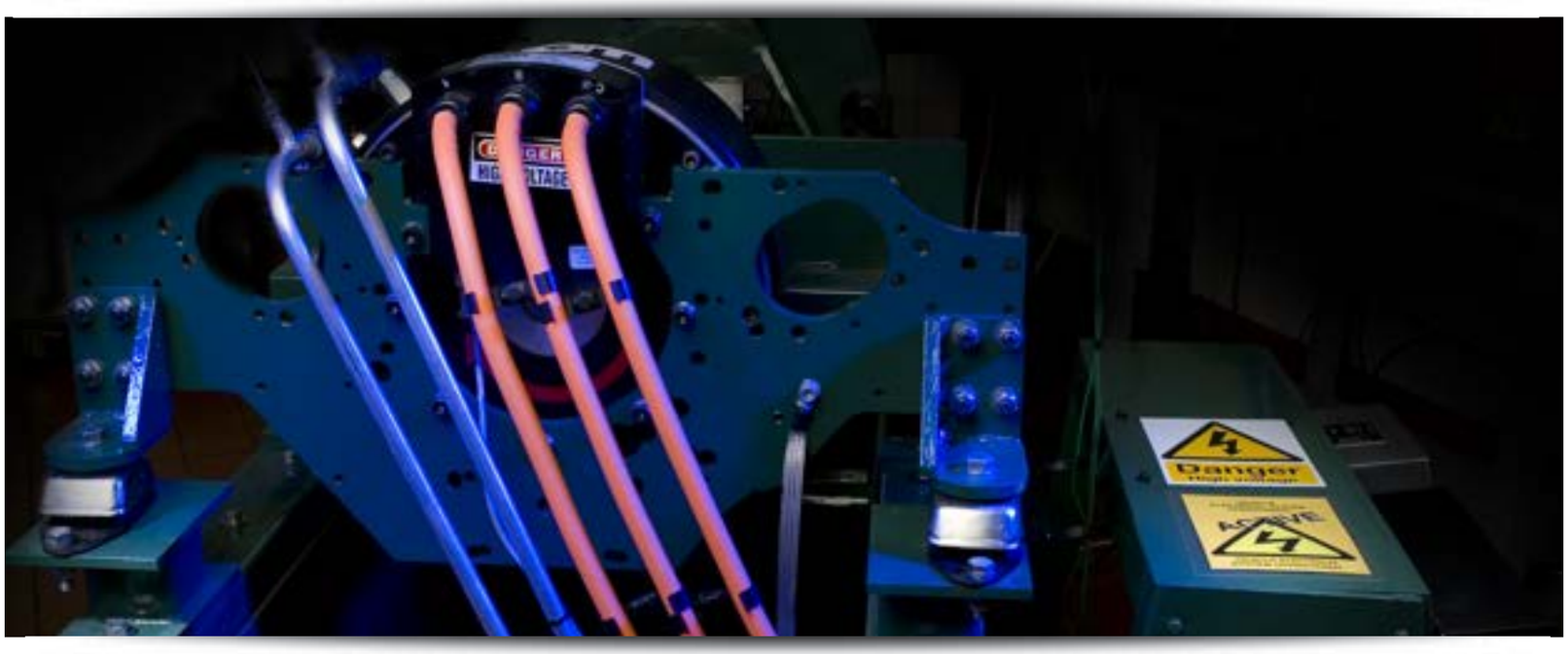

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Lotus Engineering is leading the way in the fast moving development of hybrid and electric vehicles, utilising a wide range of virtual and physical testing from component to the vehicle level, across the entire development process. Our extensive powertrain development facilities in Europe and North America are constantly expanding to meet the increasing demands of powertrain electrification.

We have over two decades of experience in building electric and hybrid vehicles. The challenges they pose are well-suited to the breadth of skills and expertise within Lotus Engineering. Our experience in control systems, electrical integration and engine design complements our '*whole vehicle*' knowledge that comes from being a car manufacturer. This means we can help create practical, efficient hybrids which are viable for production.

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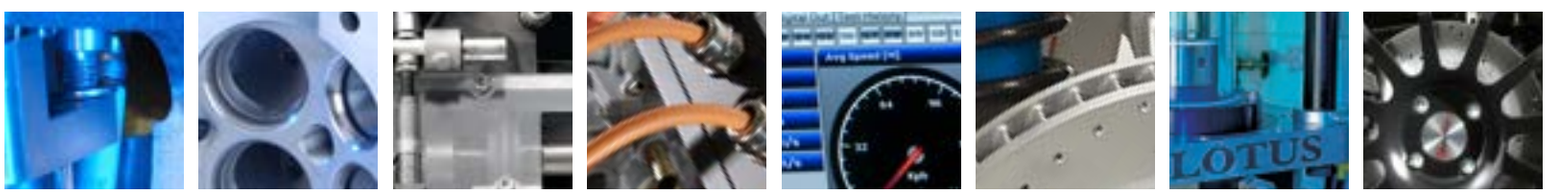

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High-speed breakthrough

Next-generation high-speed electric motors for traction and energy harvesting in premium hybrid powertrains are helping to meet the increasing demand for higher energy efficiency

Over the past few years, the increasing demand for energy efficiency in every area of human activity has led to the introduction of new concepts in the architecture of power systems. Among these innovations, the turbo-compound represents a very promising solution in the field of hybrid traction powertrains, as proved by the inclusion of such systems in the 2014 F1 World Championship. The result of this in the automotive world will see this technology first applied to high-end vehicles and then, in the medium-term, to be applied to mass-market applications.

The basic engineering principle of the turbo-compound architecture is the recovery of energy stored in the high-temperature combustion exhausts by means of a turbine that is directly connected to an electric drive and works as a generator for a large portion of its duty cycle and as a motor for keeping the turbine at high speed if required. The electric energy generated in this way can feed a second electric drive that contributes to the traction in conjunction with the combustion engine and can recover braking energy. An accumulator for storing the recovered energy not directly used by the traction motor completes the system.

The Mavel site in Aosta, Italy, where much of the supplier's R&D takes place

The electrical systems of the turbo-compound present very peculiar characteristics. The generator unit needs to be directly connected to the turbine, the rotational speed magnitude of which is in the range of 100,000rpm; the traction unit needs to have a high power/volume ratio and to provide high constant torques at low-speed regimes and lower torques at higher speed regimes. The solution to these extremely demanding requirements is the design of very high-speed electrical machines.

The challenges offered by the design and manufacturing of these machines is extraordinary. The high rotational speed and the consequent high commutation frequency imply severe requirements in terms of balancing and homogeneity of the rotating parts; structural resistance of the rotors; rotor loss minimization and heat management for motor and electronics; control software optimization; definition of production processes; and even development of adequate testing tools. The advantages of the high speed are numerous: high power density, high conversion and gravimetric efficiency, relative independency from rare earth magnets, and low trend costs.

In the last decade, Mavel has gathered extensive experience in the development of a high-speed powertrains in several successful projects. The company firmly believes in the potential of the turbo-compound hybrid systems and has developed its own solutions for turbo-compound powertrains.

The Mavel LF60 electric motor is a perfect candidate for the role of the turbo-generator. It is designed for a 120,000rpm rotational speed and a continuous output of 60kW. The motor case has a diameter of 100mm and a length of 150mm,

The Mavel LF60 high-speed motor, which offers 120,000rpm for direct connection with the turbo-compound turbine

and with the cooling system included, it weighs less than 5kg.

The Mavel LF100 electric motor is the machine developed for traction generation. It can provide 120kW and generate a maximum torque of 30Nm in a wide speed range (0-38,000rpm), after which the torque decreases proportionally to the increment of speed up to 60,000rpm. The active parts, as well as the cooling system, are contained in a 160mm x 160mm case. The LF100 electric motor weighs less than 9kg.

Rounding of the high-tech developments, the Mavel DC100 inverter controls the LF60 and LF100 electric motors. It is based on a modular IGBT architecture that is able to commute at 50kHz. The soft switching commutation, interleaved windings and modified vector modulation are the technological keys to achieving high efficiency and limited volume, making it ideal for numerous automotive applications.

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The world's leading thermal analysis tool now includes electromagnetic calculations

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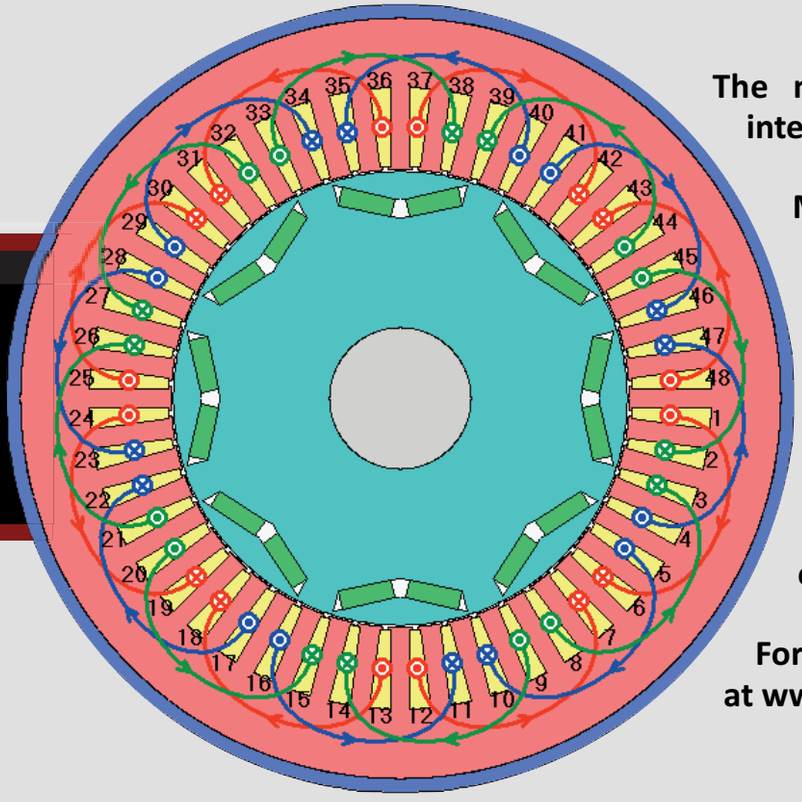

The new EMag module is now fully integrated into Motor-CAD

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Thermal analysis solution

Auto makers are using isothermal battery calorimeters to design thermal management systems capable of maintaining a battery pack within the desired temperature range

The success of electric-drive vehicles (EDVs) relies on lithium-ion battery technology. While the battery manufacturers strive to develop more compact and powerful battery packs for EDVs, thermal management continues to be a major challenge, with temperature critical to battery performance, life, and safety. Several high-profile accidents in recent years have exemplified this challenge, including the Boeing Dreamliner 787's battery problem.

Before the advent of the isothermal battery calorimeter (IBC) 284, these battery thermal management issues could not be handled effectively because there was no calorimeter that could measure heat generation from these large battery packs. The IBC 284 is the first commercial analytical tool to study high power and large battery packs for EDV applications. It was co-developed by the National Renewable Energy Laboratory (NREL) in Golden, Colorado, USA, a leading research organization in the development of analytical tools for designing optimized battery thermal management system, and thermal analysis experts Netzsch Instruments. It can measure heat generation during charging and discharging cycles with unprecedented accuracy. The IBC 284 received the 2013 R&D 100 Award due to its original design and its application to providing solutions to a major industrial issue

The IBC 284 has several unique, innovative and patent-pending features that allow it to be very accurate even with large batteries. The battery test chamber is completely submerged in an isothermal bath with very tight temperature control. Ambient temperatures do not influence the heat-flux measurements. Heat-flux gauges can measure small quantities of heat energy flowing to and from the isothermal bath surrounding the test chamber. The battery is connected to patent-pending copper busbars that route heat conducted from the battery to the inside chamber walls. The cables are routed through the isothermal bath before exiting to ambient air. These innovative design features prevent heat bypassing the heat-flux sensors. In case of battery thermal runaway, the burst disk will rupture and relieve the pressure inside the test chamber to maintain safety and protect the test chamber from damage. The IBC 284 operates from -30°C to +60°C, covering the battery-pack testing range for all climates in accordance with guideline set by the United States Advanced Battery Consortium (USABC).

The Netzsch isothermal battery calorimeter (IBC) 284 is the first commercial analytical tool to study high power and large battery packs for EDV applications

The IBC 284's accurate measurement of batteries' thermal performance under various electrical loads and boundary conditions makes it possible for battery engineers to design effective thermal management systems. For example, understanding how much heat is produced by a battery allows a vehicle manufacturer to design a cooling system that enables the battery to operate within a temperature range that optimizes its lifespan and operational safety. Heat generation is dependent on ambient temperature conditions and the magnitude of the current applied to the battery.

The information generated from the IBC 284 enables engineers to design advanced battery thermal management systems for maximum battery (and vehicle) performance, lifespan and safety in the early design stages, long before any accidents can happen and cause significant financial loss and potential casualties. The IBC 284 is a crucial tool in helping the automotive industry design better and safer battery packs for EDVs.

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THE ART OF CHARGING

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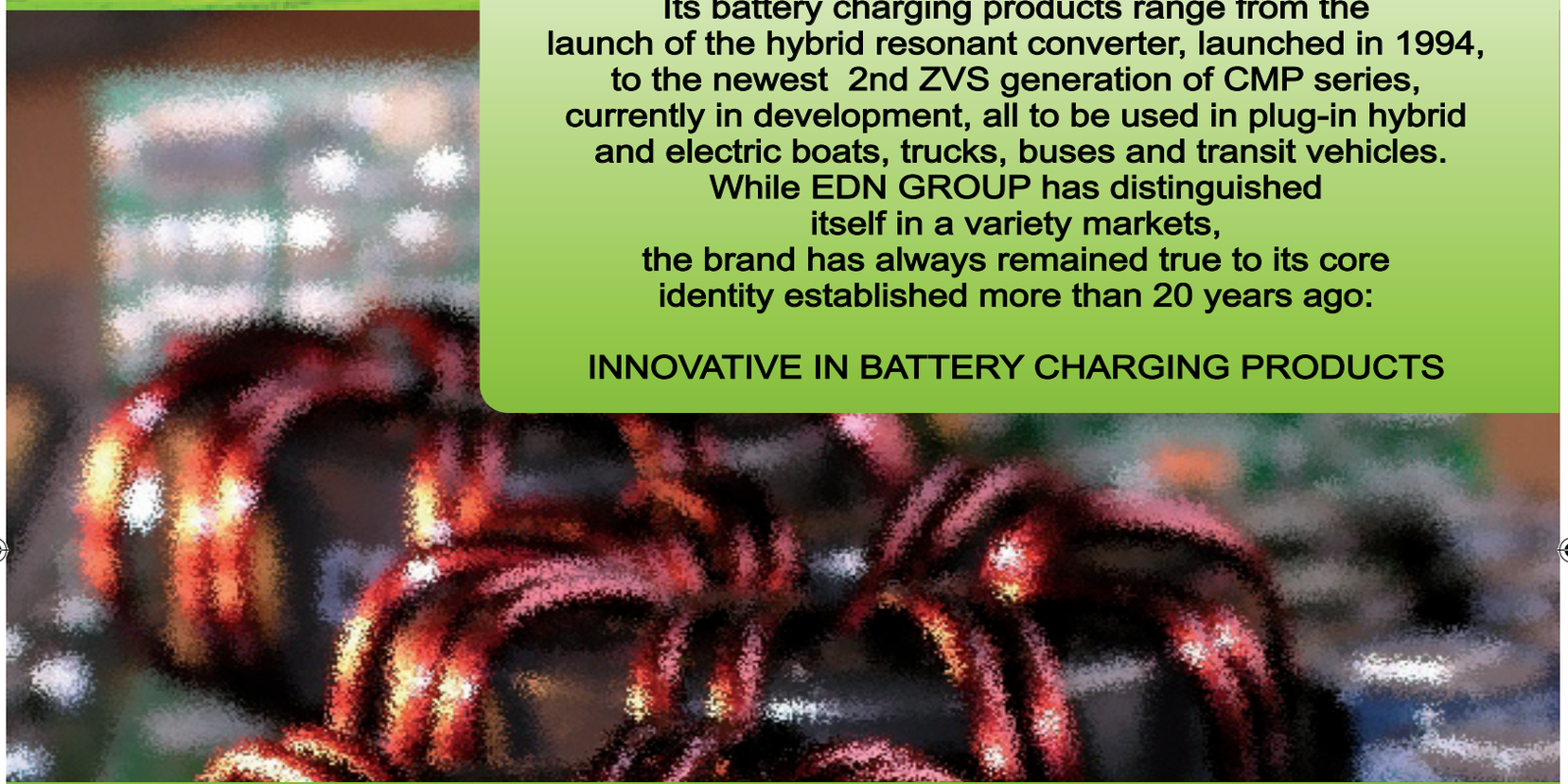

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HEV mobility solutions

A range of innovative solutions developed for hybrid and electric vehicle applications includes connectors, headers, touch-safe sockets and charging coupler cables

Following the announcement in the June 2013 issue of *Electric & Hybrid Vehicle Technology International* that components specialist Dalroad had been awarded Authorized Distributor status for TE Connectivity Hybrid & Electric Mobility Solutions (TE HEMS), this article takes a closer look at what the company has to offer to the electric and hybrid vehicle sector.

With 90,000 employees working in 50 countries, TE Connectivity is a global leader in connectivity solutions helping connect power, data and signal in everything from automotive and aerospace to broadband communications, consumer, energy and industrial applications. Importantly, drawing on over 50 years' experience in automotive connectivity systems, TE Connectivity has developed a comprehensive and flexible range of solutions specifically for hybrid and electric vehicle applications.

It is common knowledge that vehicles represent one of the world's most challenging engineering environments. Exposed to regular temperature fluctuations, continuous vibration and frequent neglect, they are still expected to operate flawlessly for years. In electric vehicles the challenges are even greater, with the imperative to improve the power-to-weight ratio and the necessity for effective and safe shielding of in-vehicle electronics and people from high-voltage electricity in the event of an emergency. TE HEMS aims to address these problems head on with an innovative and integrated range of solutions from the charging socket, to the battery, the motor and almost everywhere in between.

The AMP+ high-voltage contactor 500-500L offers 900V DC and 500A continuous current carrying capabilities

Except for the enclosure itself, TE Connectivity has everything it takes to create a charging station, with components designed to work seamlessly, safely and reliably together. These include Level 1 & 2 charging coupler cable assemblies, contactors/relays and inlets electricity to a battery; meters for measuring how much a vehicle consumes, for accurate billing; and touchscreens to make every transaction easy and intuitive.

Additional technologies include card reader connectors, grid connectors, base connectors, data and power connectivity, and powerline filters. Rated from 12V to 1,000V, in-vehicle solutions include connectors, relays, harnesses, contactors and disconnects to safely connect and protect the flow of data and power around a hybrid or electric vehicle. Outlined below are some proven and popular examples of TE HEMS products.

The HVA 280 connector system used in wire-to-device and wire-to-wire applications for individually shielded and multicore cables/high voltage accessory device interconnects

For high current distribution, there is the widely specified HVP800 range of connectors and headers; touch-safe 2-3 position with integrated HVIL and multiple routing options to AK 4.3.3, LV215-1. For low-medium current, there is the HVA 280 family of connectors and headers; touch-safe 2-3 position with over 3,000 combinations and not limited by the header on the device. The same interface is used for individually shielded wire and multicore wire. TE Connectivity's comprehensive range of contactors switch high-voltage power on and off, providing the capability of handling arc conditions. Hermetically sealed and safe, they are able to operate in a variety of harsh environments with no oxidation or contamination of coils or contacts – even during long periods of non-operation.

For servicing, or when things go wrong, TE Connectivity also offers various manual service disconnect solutions; touch-safe sockets and connectors for disconnecting internal HV battery packs for use by service technicians and emergency first responders; and high-voltage wiring harness assemblies.

The TE HEMS range is now available in the UK from Luton-based TE Connectivity Authorised Distributor, Dalroad. In addition to the auto industry, Dalroad provides electromechanical, automation and control components to the industrial, automation and electronics sectors.

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ADVANCE NOTICE

14th European Lead Battery Conference and Exhibition

Edinburgh | Scotland | September 2014

The International Lead Association is pleased to announce that the 14th European Lead Battery Conference (14ELBC) and Exhibition will be held at the Edinburgh International Conference Centre, Scotland on 9-12 September 2014.

14ELBC will provide an ideal opportunity for anybody involved with the global lead battery industry to review and discuss the most recent technical advances associated with lead-acid batteries, especially in the areas of emerging new automotive and renewable energy systems.

Dramatic improvements in the design of lead batteries, and in the materials used in their manufacture, have brought a range of new roles for them in automobiles, resulting in better energy efficiency and significant reductions in CO_2 emissions. The latest developments in stop-start technology, hybrid applications, "Super Hybrids" and 48V lead batteries will all be presented at the conference. Other papers will focus on market reviews, industrial battery applications and R&D. An extensive Exhibition – expected to involve over 100 exhibitors – by suppliers to the industry of equipment, materials and technology, will also take place.

Since the first meeting in Paris in 1988, the European Lead Battery Conferences have developed a reputation for high quality presentations on the design, manufacture, performance and use of lead-acid batteries. Over 600 delegates and 100 exhibitors attended 13ELBC in Paris in 2012, and similar numbers are confidently expected in Edinburgh.

14ELBC Conference Secretariat:

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Tel: +44 (0) 20 7833 8090 | Fax : +44 (0) 20 7833 1611 | E-mail: 14elbc@ila-lead.org

ila International Lead Association

Improved heat-flow density

The advent of dual-sided cooling of power semiconductors not only improves the transfer of heat in inverters but can also help to lower the cost of hybrid and electric vehicles

Hybrid and electric vehicles (HEVs) passed the tipping point a long time ago. The benefits of HEVs have been widely acknowledged and reflected in the growth of the number of vehicles sold. However, one of the biggest remaining obstacles hindering faster adoption is cost. Besides the battery, the second most expensive component is the traction inverter. A large part of its cost comes from the semiconductor power modules. In some estimates, this cost is as high as 25% to 30% of the inverter cost.

One major factor affecting the cost of power semiconductor switches is the physical size of the power switch die. Efforts to improve the performance and minimize the cost of semiconductor switches have resulted in smaller devices with every new generation. But with the power losses still relatively high, a new challenge has arisen: removing the heat from the semiconductor switches through the shrinking surface area. In short, the heat-flow density must be increased.

In conventional power modules, the top of the device is used only for electrical connections implemented with wire bonds, while the bottom, which is typically attached to a DBC substrate, is used for electrical connection and heat transfer. The conventional approach is limited to heat removal through one side of the semiconductor device and the heat transfer problem can be solved only by reducing the thermal resistance between the semiconductor and the coolant using materials with high thermal conductivity and with improved heatsinks. Improvement potential is limited and the cost goes up.

A breakthrough can be achieved by using both sides of the semiconductor to remove the heat. This is possible only by eliminating traditional wire bonds. The CooliR²DIE technology being developed by International Rectifier offers this capability.

With this technology, the heat transfer occurs through the bottom and top of the semiconductor switch. Theoretically, the thermal transfer capability is doubled and the thermal resistance between the device and the coolant can be reduced by 50%. Importantly, the two-times improvement can be achieved with the existing thermal transfer and cooling materials and technology – no other improvements are needed.

Cost optimization, mechanical constraints and other practical reasons may limit the performance of the top-side heat transfer path. The coolant flow, the heatsink size and the thickness of the thermal interface material on the top may be inferior when compared with the bottom. Luckily, as shown in Figure 3, the dual-sided cooling performance exhibits low sensitivity to the effectiveness of the additional cooling path. Even with the top-side thermal resistance being twice as high as at the bottom, the resulting dual-sided cooling thermal resistance is still approximately 35% lower than single-sided cooling.

Improved heat transfer with dual-sided cooling allows the semiconductor switches to work harder and conduct more current, while the current density of power semiconductor devices is greatly increased. It has been estimated that an increase in current density of about 50% can be achieved. This means devices that are 33% smaller can be used for the same current rating, or 50% more current can be handled at the same cost.

The consequences of this are lower cost of automotive power electronics, more HEV vehicles on the roads and a greener future.

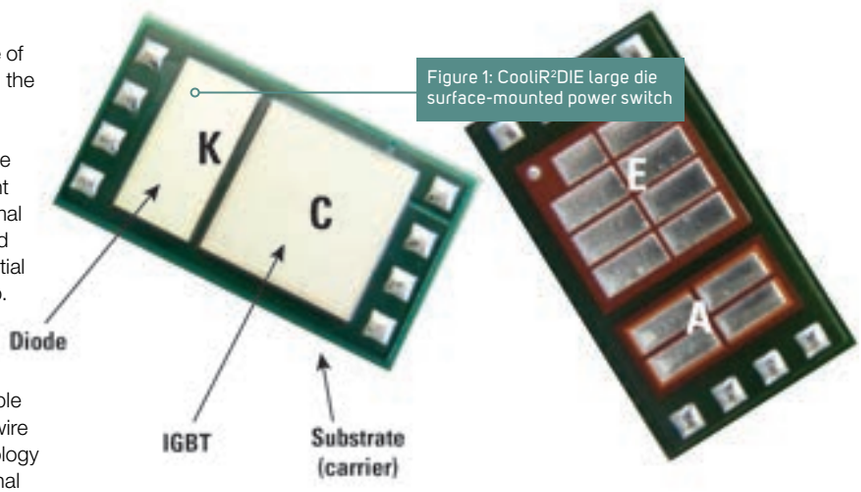


Figure 1: CooliR²DIE large die surface-mounted power switch

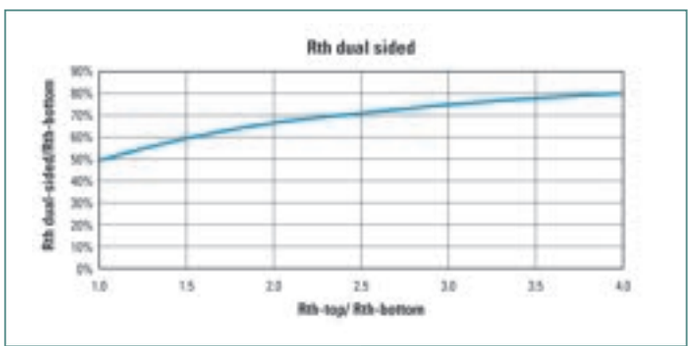
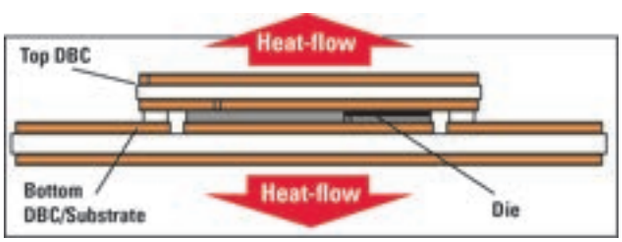


Figure 3: Dual-sided junction-coolant thermal resistance as a function of top-side cooling effectiveness

Figure 2: CooliR²DIE power switch cross-section and heat-flow paths



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Battery system alternative

A new lithium-sulfur battery being developed for EV applications could halve the weight and price of batteries compared with conventional lithium-ion energy storage systems

Revolutionary Electric Vehicle Battery (REVB) is a three-year project being undertaken by Oxis Energy, Imperial College London, Cranfield University and Lotus Engineering, and sponsored by the UK's innovation agency, the Technology Strategy Board. Oxis Energy is leading the team in the development of a lithium-sulfur (Li-S) EV battery that will have an energy density of 400Wh/kg at a cost of US$250/kWh.

The REVB project will develop an energy storage system coupled to a powertrain that will prove Li-S as the next generation of EV battery technology in a simulated environment by the end of 2016. To achieve this, the consortium will adopt a number of novel approaches to its development.

The Li-S chemistry will be improved by Oxis Energy and Imperial College London using simulation modeling of the electrochemistry to accelerate the R&D process. Oxis Energy will build the resulting improvements into cells for further testing and validation. This simulation development approach has been proven in fields such as aerodynamics, but has never before been adopted for developing battery electrochemistry.

Developing accurate simulation models of the chemistry's behavior will also allow Cranfield University and Lotus Engineering to develop an advanced energy system controller (ESC). The ESC allows up to 95% of the energy stored to be accessed by the vehicle, compared with the 60-80% seen today. This will be done by reducing the order of the high fidelity simulation models and deriving accurate control algorithms to control the Li-S cells.

The final deliverable for the project will be a Li-S based energy storage system integrated to a powertrain, equivalent to a system fitted to a battery electric vehicle. This system will be subjected to a variety of drive cycle and lifecycle testing in a simulation environment in the Lotus test facilities.

The resulting system will prove that a Li-S based energy storage system is not only lighter and cheaper than lithium-ion, but suitable for the strenuous demands of the EV market and capable of utilizing much more of its energy.

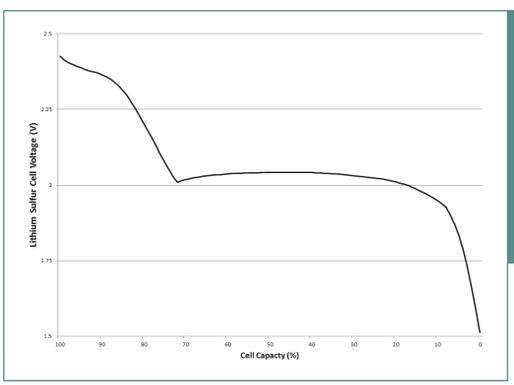
To make this technology available to the rest of the market, the consortium will be able to offer a variety of services.

Oxis Energy and Imperial College London will be able to offer a development team that can quickly design and build a tailored cell on demand to the specifications of vehicle developers. They will also be able to offer unparalleled cell characterization and simulation models to enable advanced system design and control.

Cranfield University will be able to develop those simulation models into precise control and optimization algorithms that can be integrated into the Lotus ESC. Lotus Engineering is well known for its vehicle design and consultancy services and can do anything from developing a Li-S battery pack to designing a full vehicle with REVB technology incorporated, depending on requirements.

The intended outcome of the REVB project is to prove both the Li-S chemistry and its control system in an automotive environment, ready for integration into vehicles for fleet trials. The next step is for the marketplace to decide whether or not it wants a lighter, cheaper and better battery for EVs.

The Oxis Energy lithium-sulfur pouch cell will have an energy density of 400Wh/kg in 2016



A lithium-sulfur discharge curve. The REVB simulation modeling will allow for advanced control of this in order to store and use much more energy than other modern systems

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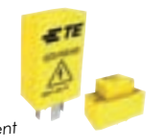
- AK 4.3.3, LV215-1
- Current rating up to 300A
- 2 position or 5 position

AMP+ EVC 500
- Voltage rating max 900VDC
- 135A continuous current
- 1250A max short circuit current
- 8kV of isolation between open contacts

AMP+ HVA 630
- Voltage rating up to 850V
- AK 4.3.3, LV215-1
- Current rating up to 40A at 140 C
- 2 position or 5 position

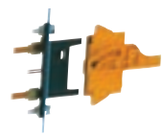
MSD
- Voltage rating up to 700VDC
- Fuse rating up to 350A
- Current rating determined by fuse selection

Mini K HV
- Voltage levels up to 450VDC
- Pre-charge current to 20A
- Limiting break currents up to 20A
- Form X (NO DM) contact arrangement



AMP+ HVP 800
- Voltage rating up to 1000V
- AK 4.3.3, LV215-1
- Current rating up to 250A
- 2 position or 3 position

SD125
- Up to 50 mating cycles
- No tool required to unmate
- Integrated fuse rated 125A
- Integrates internal HV



AMP+ EVC 135
- 2000A interrupt at 320VDC
- 500A continuous current rating
- Voltage rating (MSX.): 900VDC
- 12V coil version available

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Flywheel KERS scalability

From trains and buses to scooters, the alternative to battery hybrid systems will soon be available in small, medium and extra-large applications outside the automotive world

While hybrid systems are all the rage in the automotive world, and Flybrid Automotive's mechanical flywheel-based variety has been proved in several demonstrator road cars, the Silverstone-based company is keen to explore further applications for its low-cost, battery-free option.

With work on a flywheel hybrid city bus for Wright Group already well underway and due to see fleet tests in 2015, there is now strong evidence that the mechanical kinetic energy recovery system (KERS) is well-suited to more robust applications. Buses, for instance, offer a comparatively tough environment for hybrid systems to endure, being designed to cover up to one million kilometers in their working life, spanning 12 years and up to 42,000 operating hours. Compared with an average passenger car's 250,000km design life, running for only 5,000 hours, system durability presents a major challenge for bus hybridization.

Different sizes of flywheel are available for a wide variety of auto applications

Another key challenge is the frequent stopping pattern in bus duty cycles, with more than three times more braking events per kilometer than the average car, resulting in a quarter of the lifetime average speed. Constant deceleration and acceleration of a bus weighing up to 15 tons puts substantial torque demands on the engine and hybrid system. However, the Flybrid unit is designed to use the vehicle's weight and frequent braking patterns to its advantage, capturing and storing the considerable kinetic energy available under braking.

It is known that the add-on cost for battery hybrid systems on buses can be equal to the base vehicle cost, and can have payback periods longer than the service life of the vehicle. In addition, due to their severe duty cycle and high power demands, many battery-hybrid systems for buses will require replacement battery packs during their service life, at an additional cost to the operator. The flywheel-based system currently in development by Flybrid is expected to cope easily with the anticipated eight million charge and discharge cycles with relatively little maintenance, and have a payback period of less than five years.

This highly extended and often low-speed duty cycle, common to buses and many other commercial vehicles, is a far cry from the Formula One application for which Flybrid designed its first KERS. However, it is the characteristics that come from F1, such as the systems' resilience against vibration, extreme temperatures, debris and impacts, that make it so well suited to the harsh duty environments of larger vehicle applications.

Flybrid's hybrid bus system is put through its paces on the test rig

It is this aptitude that has led Flybrid to investigate applications even further afield from the wider automotive market. Small electrically powered local trains, for instance, which have a regular stop-start duty cycle, have been identified as suitable for mechanical KERS hybridization. The energy saving in this instance would enable the train to draw less electricity from cables or rails. By storing up to 20MJ of recovered kinetic energy in a series of flywheels on each axle of the train, Flybrid suggests an estimated energy saving of 35% is possible.

Also being investigated are possible applications for a scaled-down M-KERS unit. A micro M-KERS with only 10kW could be sufficiently compact to fit scooters or other small passenger vehicles, ideal for city transport. This large and growing market segment is more of a challenge to the electric hybrid, due to cost and the complexity of the electrical installation. Some of the largest markets for two-and three-wheeled passenger vehicles are also the most price-conscious, with India, China and ASEAN countries together accounting for 80% of global two-wheeled sales in 2012. However, in the absence of heavy and costly battery packs, and with the addition of a simplified control system, flywheel KERS may just offer a suitable and frugal alternative. Flybrid is hoping to investigate M-KERS downsizing for such applications with a brand new development project set to commence in 2014.

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Safety product development

Functional safety features form an integral part of every product development phase, and a new inverter designed for electric sports cars meets the ISO 26262 standard

Hofer Electric Drive Systems (Hofer EDS) has developed an inverter under the constraints of ISO 26262 to enter series production in an electric sports car. This development is a direct result of the cooperation between Semikron Automotive and Hofer EDS. The hardware consists of a proprietary Hofer control board and Semikron's SKAI2 platform, combining sophisticated functional safety with robust and compact inverter technology.

On the basis of this well-prepared hardware platform, and in combination with an established software development process, Hofer will achieve the ISO 26262 requirements for ASIL C.

The safety case for the Hofer inverter was based on a hazard analysis and risk assessment at vehicle level, conducted during the concept phase of the project. The outcome of this assessment indicated one central safety goal at component level (defined with ASIL C): prevention of unwanted actual torque. The main challenge with regard to safety during the development of the inverter was to prevent violation of this safety goal in any driving situation.

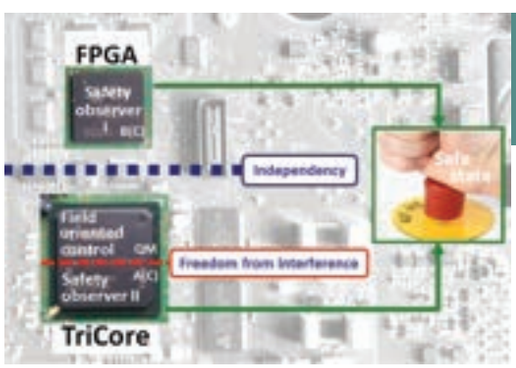
To achieve the target hardware metric values, decomposition was chosen to set up two redundant safety observers (torque and current monitoring) with ASIL A(C) and B(C).

The independency was proven through a detailed dependent failure analysis using fault tree analysis of the hardware and software functionalities. The freedom from interference has to be ensured by dedicated safety measures, such as memory protection, data flow and control flow monitoring within the TriCore processor.

There are five challenges relating to the safety management of the tailored Hofer inverter safety lifecycle. The first focuses on the partitioning and maintenance of proper interfaces within the product development, giving a clear understanding of the responsibilities of the development partners.

The second challenge centers upon the consistent requirements relating to engineering, which includes traceability from the technical safety requirements to the hardware, as well as the software safety requirements and even the corresponding test cases.

The third challenge is goal-oriented safety analysis via a failure modes effects and diagnostic analysis (FMEDA) to prove the effectiveness of the architecture to cope with random hardware failures as well as prevention of safety goal violations due to random hardware failures.



The architecture of the technical safety concept to prevent unwanted actual torque while driving

Hofer EDS's new inverter for electric sports cars combines advanced functional safety with a highly robust and compact exterior design

	ASIL C	hLE300TF
Single-point fault metric	≥ 97 %	99,1 %
Latent-fault metric	≥ 80 %	89,4 %
Probalistic metric for random hardware failures	< 5 x 10^{-8} 1/h	0,52 x 10^{-8} 1/h

The results for the hardware metrics of Hofer EDS's inverter following FMEDA testing

The fourth challenge relates to the adequate inverter hardware qualification, such as functional testing during typical operation; test of protective functions during emergency conditions; insulation tests; mechanical tests (vibration, shock, drop); resistance to climatic changes; pollution burden; lifetime tests; electromagnetic compatibility.

The final challenge concerns effective testing throughout the various integration levels (hardware, software units, hardware/software integration and system), including fault injection tests to prove the implemented hardware and software safety mechanisms.

During the FMEDA analysis, Hofer's choice of safety mechanisms focused on the trade-off between aspired safety and excessive complexity. In addition to this, assuming an operating time of 187 hours a year, which is typical for electric sports cars, the FMEDA analysis resulted in the metrics for Hofer's inverter.

To evaluate the appropriate suitability of all functional safety activities, a functional safety assessment is performed by TÜV NORD, which included audits and confirmation reviews to verify the effectiveness of the technical safety concept and the implementation of the required processes. As such, Hofer is looking forward to transferring this experience into further safety-related products.

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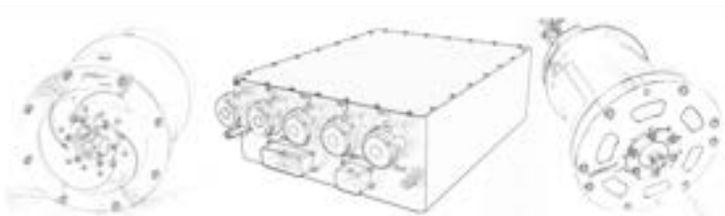

High-speed measurement

Modern variable speed drive applications require high-speed analysis and rapid frequency synchronization to accurately measure dynamic power conditions

The technical demands of accurate power measurement in variable speed motor drive (VSD) applications is well recognized and a number of measurement products are available that address the challenges presented by this particularly difficult measurement application. However, a rapid growth of VSD techniques into traditional variable speed motor applications and the development of high-speed drive applications have created a need for measurement speed that is not provided by most conventional instrumentation.

When considering variable speed motor applications, such as elevators, escalators, conveyors, washing machines, air-conditioning fans and so on, it is clear that the change in speed is relatively slow. The growing use of variable speed motors in new applications such as electric vehicles and high-speed machines, however, is creating a demand for accurate power measurement with a much faster response in order to accurately measure dynamic power conditions.

Since engineers need to observe power characteristics that change quickly over time as a motor accelerates or decelerates, high-speed gapless analysis that maintains synchronization with a changing frequency is required. It follows that data acquisition systems with a fixed time-base or event-activated triggering are unlikely to meet the demands of such an application.

Using a proprietary design that combines innovative analog hardware with a unique FPGA/DSP digital architecture, the PPA precision power analyzer range from N4L offers an attractive combination of wideband accuracy, dynamic range, noise rejection and speed that ideally meets the needs of this highly demanding measurement engineering challenge.

Figure 2: The PPA5500 power analyzer is available with 10Arms, 30Arms or 50Arms internal shunts. N4L offers external shunts of up to 500Arms

Unique technical features include a sample rate of 2.2Ms on all inputs that is maintained with fundamental frequencies down to 20mHz while remaining fully synchronized with the DUT frequency. Other features include no gaps between measurements, a leading CMRR of 150dB and a real-time datalog to standard PC software. Maintaining high sample rates while analyzing low fundamental frequencies, such as those seen during variable speed drive testing, is vitally important to wideband power and harmonic analysis. This is possible as a result of sophisticated processing and the use of high-speed modern processors in the PPA5500.

These features enable the engineer to characterize motor efficiency during rapid acceleration, deceleration and load change, the datalog plot in Figure 1 illustrates a real-life test of deceleration and acceleration of a motor drive. The motor was accelerated from 10Hz to 60Hz in less than a second while the N4L power analyzer synchronized to the changing fundamental frequency flawlessly, providing accurate measurements during dynamic conditions.

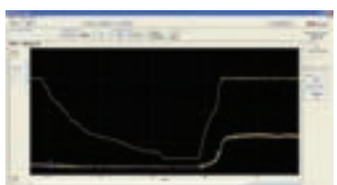

Figure 1: The datalog plot shows a real life test of deceleration and acceleration of a motor drive

No-gap analysis is an important performance characteristic to look for in a power analyzer, especially when analyzing dynamic waveforms. A product of the N4L analysis technique being no-gap is that efficiency measurements are synchronous from input to output and common windowing – a necessity in gapped measurement instrumentation – is no longer considered to be a restriction.

Featuring an intuitive and sophisticated PWM motor drive application mode, torque and speed inputs fitted as standard and market leading accuracy, the PPA5500 series of power analyzers are the natural choice for the PWM motor drive test and development engineer. N4L supply every power analyzer with a three-year warranty and a UKAS calibration certificate. The first power analyzer manufacturer to be accredited for UKAS certification of voltage, current, power, phase, harmonics and flicker, N4L are also the first power analyzer manufacturer to provide ISO 17025 calibration as standard.

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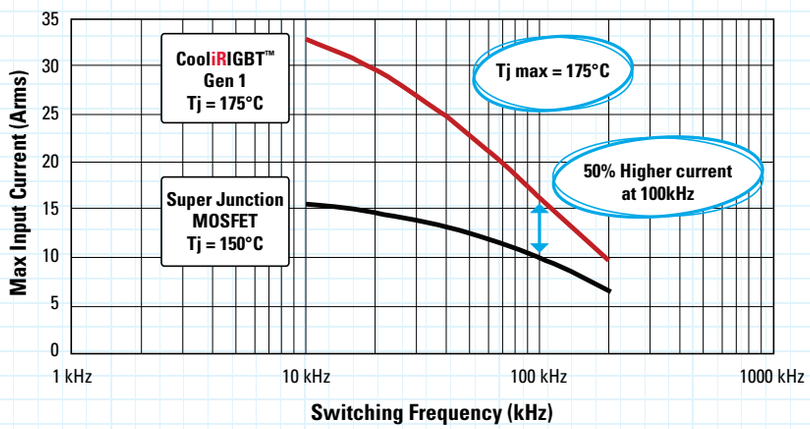

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Power safety certification

With the new UN38.3 regulations in force, it has never been more important for lithium battery pack manufacturers to ensure the production of safe, rigorously tested products

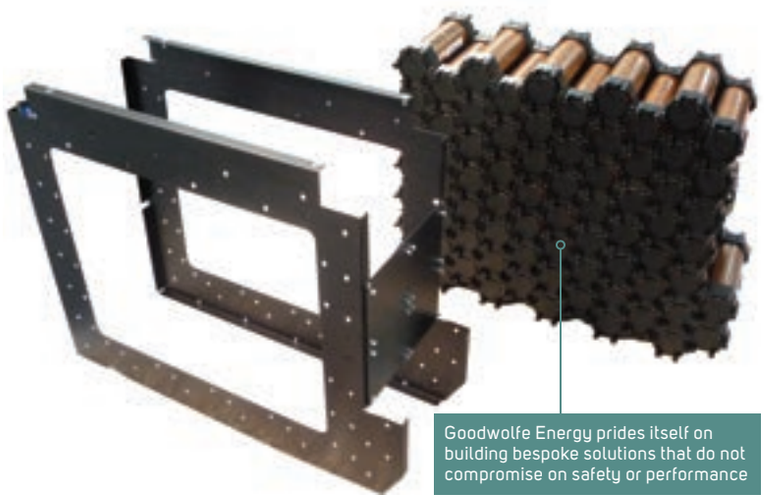
The latest revision of the UN38.3 regulations state that all lithium-ion batteries with greater than 100Wh of energy must be transported as Class 9 dangerous goods. As a consequence, they are subject to various transportation restrictions. Goodwolfe Energy has successfully achieved UN38.3 certification, meaning that its 2.5kWh modules are safe for road, air and sea transportation, which following the introduction of these regulations are proving to be a problem for many other lithium battery manufacturers.

Aided by its cage-like structure, Goodwolfe's 2.5kWh SPX battery module has endured highly demanding tests, with the pack's structure ensuring correct configuration at all times and preventing damage to both the cells and the cell management module (CMM). Larger batteries, including the 68kg 5kWh pack, were also tested and passed, meaning that Goodwolfe Energy can supply the automotive industry with solutions for far higher energy requirements.

In order to realize this certification, the battery systems were subjected to a series of tests including altitude simulation, thermal testing, vibration, shock, external short circuit, impact, overcharge and forced discharge. After being subjected to tests that involved the modules enduring temperatures ranging from -40°C to +72°C, as well as being subjected to *g*-forces, crushed under 13kN of pressure and charged at well over their recommended maximum current, the $LiFePO_4$ packs passed all the tests. And despite the rigorous tests, the Goodwolfe Energy batteries did not catch fire, rupture, leak, disassemble or overheat, and still maintained a voltage of over 90% both during and after the tests. Following recent concerns about lithium batteries, OEMs can be assured that Goodwolfe Energy is providing a fit-for-purpose and safe solution.

As well as being UN certified, these SPX modules can be uniquely configured to meet the power requirements of OEMS, and come with numerous advantages including weight and lifespan.

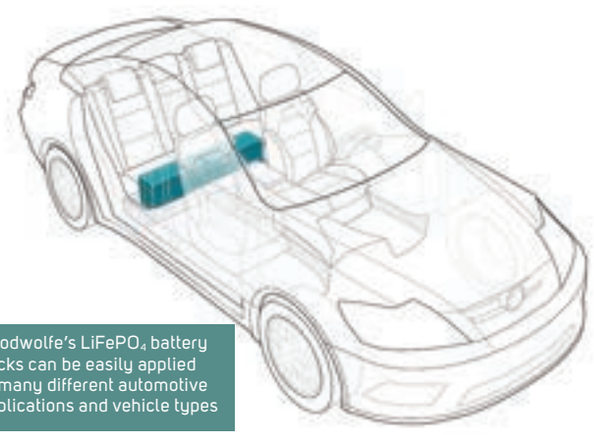
When partnered with its intelligent battery management system, Goodwolfe Energy's battery solution can solve the concerns of vehicle makers and is suitable for use in hybrid and electric drive systems in cars, buses, and automated and off-highway vehicles. By connecting these modules in either series or parallel, the engineers at Goodwolfe Energy can create packs of any size and capacity, while still complying with the UN38.3 regulations. The battery system construction allows Goodwolfe Energy to design and develop solutions in a relatively short time, which is ideal for prototype and development projects.



Goodwolfe Energy prides itself on building bespoke solutions that do not compromise on safety or performance

Bespoke build projects have also successfully passed these tests, highlighting not just how safe and reliable the battery systems are, but also how much care is taken during the development process. These projects require strict attention to detail as the cells are configured into special voltages and capacities, and also into unique shapes. The team at Goodwolfe Energy has succeeded in developing specialist housing and fitting battery packs into challenging layouts to ensure that no space is wasted on a vehicle. Despite the individuality and complexity of these projects, the team ensures that its standards in delivering a safe system are not jeopardized by constantly meeting the required power specifications or architecture. All lithium battery manufacturers should have UN38.3 certified products and Goodwolfe Energy is proud to announce that its technology has passed the rigorous testing process. Goodwolfe Energy prides itself on always meeting stringent safety criteria without compromising on performance.

Goodwolfe is one of the first battery developers to meet the new UN38.3 regulations in all their product ranges



Goodwolfe's $LiFePO_4$ battery packs can be easily applied to many different automotive applications and vehicle types

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Optimizing vehicle concepts

Virtual engineering simulation software is helping vehicle designers to develop low carbon electromechanical vehicle concepts that meet emissions reduction targets

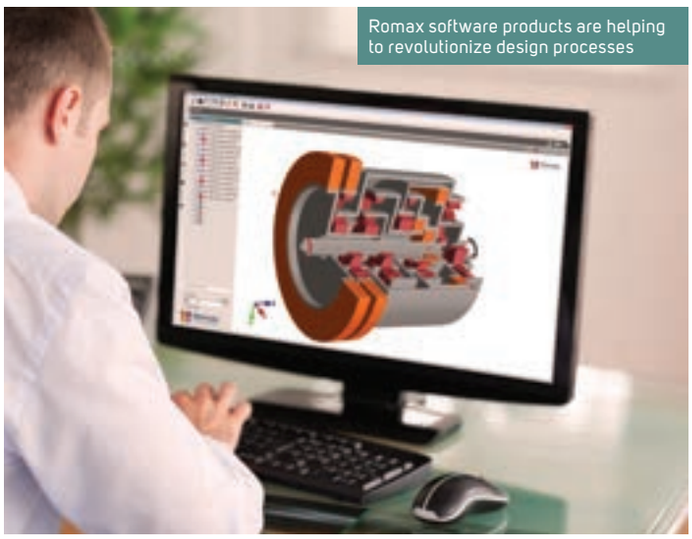
With growing industry interest in lower carbon emissions, many major OEMs have moved towards developing low carbon electromechanical drivelines and vehicle technologies.

According to the UK's SMMT New Car CO_2 report 2013, the UK average of new car CO_2 emissions dropped significantly from 181g/km in 2000 to 133.1g/km in 2012. As a result, the EU put in place a comprehensive legal framework to reduce CO_2 emissions from new light-duty vehicles to ensure it meets its greenhouse gas emissions reduction targets under the Kyoto Protocol and beyond. Car makers are obliged to ensure that 80% of their new passenger car fleet will meet a 95g/km of CO_2 target by 2020 and 100% of their respective fleets will have to meet this target by a 2024 timeframe.

The fallout of this has seen major OEMs actively developing all-new low carbon electromechanical drivelines and vehicle technologies to address consumer demands while meeting EU requirements.

Romax, an engineering and design specialist working across industries including automotive, aerospace, marine and off-highway, is helping manufacturers to drive this trend in the industry. The supplier does this by utilizing its virtual engineering simulation software, which allows vehicle designers to quickly create vehicle concept designs. In turn, this allows designers using the software to analyze vehicle performance, drivability, fuel consumption, CO_2 emissions and the impact of many other factors, including the overall fuel economy on the driveline.

As a result, Romax can provide customers with cost-effective solutions that allow the designer to reduce development time and cost during the vehicle development process while enhancing and optimizing design capability – all while ensuring the highest levels of design and quality in support of its mission to drive business sustainability. Such is Romax's experience and expertise in the automotive industry that it currently supplies simulation and analysis tools, as well as engineering services, to the top OEMs worldwide.



Romax software products are helping to revolutionize design processes

In order to continue its support of efficiency improvement programs for transmissions and drivelines, Romax works closely with a cross-section of carefully identified partners, including universities and leading authorities in engineering and design, to continually position itself at the forefront of technology.

Examples of this can be seen in Romax's work with the University of Nottingham to jointly develop vehicle simulation software that could improve NVH understanding. The result of this research has helped Romax develop a detailed understanding of the dynamics of the whole vehicle, not just transmissions engineering.

In another example, a Romax-sponsored PhD student at Loughborough University is carrying out a research project investigating energy use within the powertrain of a hybrid electric vehicle and a smart EV during real-world driving.

Most recently, Romax has been involved in a collaborative project alongside a number of automotive companies, aimed at looking at the simulation and optimization of a highly integrated EV drivetrain. The three-year project will look at innovating driveline components and the early analysis of efficiency, noise and vibration through whole-system simulation, amongst other focuses such as housing integration, cooling lubrication and power electronics.

By undertaking such projects, Romax can stress the need for whole-system rapid analysis of a large number of candidate concept designs earlier on in the development cycle, to free design engineers to investigate competing solutions at the very earliest stages. Changes at the concept design stage are easier to implement and less costly than later on in the design process, and allow the designers freedom for creativity within the design process.

Romax and Loughborough University hybrid electric vehicle collaboration

These examples demonstrate Romax's desire to drive next-generation technology development across the hybrid and full EV markets. In light of increased legislation and consumer demands, a greater emphasis is being placed on addressing efficiency across driveline technology. Romax is meeting these challenges by providing software and design methodologies to ensure the next generation of hybrids and EVs is as efficient and refined as their customers will surely expect.

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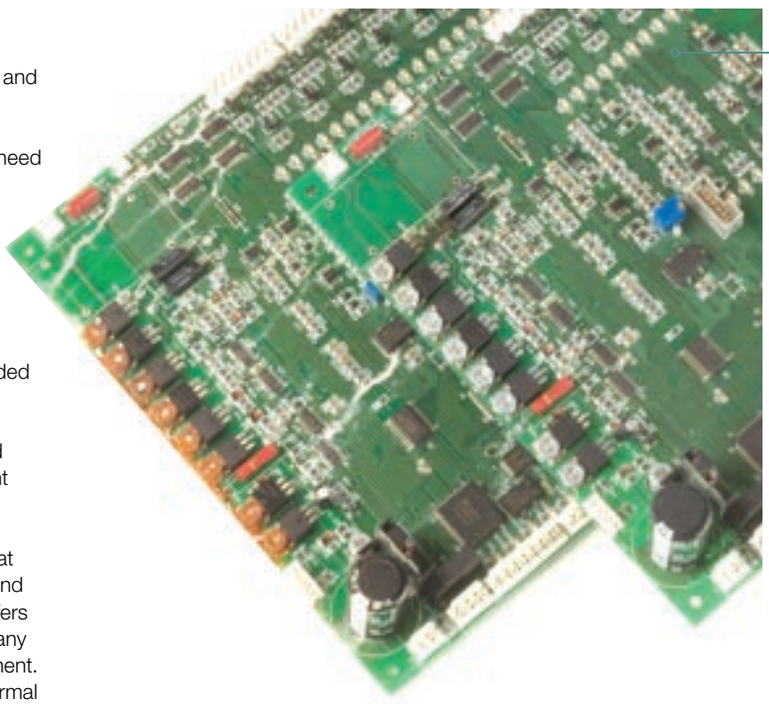
Electronics protection

Due to their increased barrier properties and reduced cost, Parylene conformal coatings are being used to protect numerous electronic components and subsystems in EV applications

Today's vehicles have an increasing number of electronic systems driving their design. The high-tech systems and controls that support them are smaller than ever, formatted in highly complex packages that need protection from the harsh environment and rugged use they face inside any vehicle.

Parylene conformal coatings are superior in protecting components and parts against various types of corrosion. The protection afforded by Parylene extends to many automotive parts, electronics, systems and subsystems, providing excellent dielectric barrier protection in addition to being a barrier to chemicals and any moisture that could affect the performance and life of the systems. Parylene offers this protection without adding any significant mass to the component.



Both Parylene C and Parylene HT are well suited to automotive applications because they can withstand harsh environments

The family of Parylene conformal coatings has been trusted as reliable protection for a wide range of harsh applications for more than 40 years. Both Parylene C and Parylene HT are well suited to automotive applications. Parylene C provides excellent moisture, chemical and dielectric barrier capabilities. Parylene HT is an excellent dielectric and moisture barrier, but also offers increased thermal and UV stability. Parylene coatings are also Restriction of Hazardous Substances (RoHS) and Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) compliant and have proved to provide metallic whisker mitigation in lead-free solder applications. Parylenes are ideal for protecting printed circuit boards (PCBs), sensors, micro-electromechanical systems (MEMS), elastomers and other surfaces and components that need reliable, long-life performance in harsh automotive environments.

Parylene coatings are applied using a vapor deposition process. Because there is no liquid phase in this process, there are no subsequent meniscus, pooling or bridging effects, thus dielectric properties are never compromised. The molecular growth of Parylene coatings also ensures not only an even, conformal coating at the thickness specified by the manufacturer, but because Parylene is formed from a gas, it also penetrates into every crevice, regardless of how seemingly inaccessible. This ensures complete encapsulation of the substrate without blocking small openings. Parylene is typically applied in thicknesses ranging from 50nm to 75µm, and is thus extremely lightweight – an essential factor for the automotive industry.

As far as key benefits are concerned, Parylene has an extremely low dielectric constant and dissipation factor, enabling it to provide small, tight packages with dielectric insulation via a thin coating. It has been demonstrated that the voltage breakdown per unit thickness increases with decreasing Parylene film thickness. Parylenes also offer excellent moisture and chemical barrier properties to a wide array of automotive components. SCS Parylene HT has been tested as an effective barrier against a wide array of automotive chemical and fluids, including antifreeze, engine oil, transmission fluid, brake fluid, power steering fluid, windshield washer fluid, unleaded gasoline and diesel fluids, in addition to automotive chemicals such as nitric and sulfuric acids.

Other benefits of Parylene HT include excellent thermal stability for harsh automotive environments, remaining stable in operating temperatures up to 350°C long term and withstanding short-term exposures to 450°C. All Parylenes offer extremely small molecular structures, allowing the coating to ingress deeper through open areas on the top or bottom of any package, regardless of the size or complexity of integrated devices. This provides complete protection of electronics.

Parylene coatings are able to protect a wide array of automotive applications and systems, including fuel systems, water pumps, steering systems, emissions systems, tire pressure monitoring systems, oil conditioning systems and diesel emission fluid (DEF) applications. The latest in electronic technologies, computerized communications and sensor systems monitoring/control makes all vehicles what they are today. And nothing protects electronic components, assemblies and miniaturized sub- and stacked electronic assemblies like Parylene technology.

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Cell finishing line advances

A recently validated and fully automated cell finishing line is making inroads in one of the most competitive electric vehicle markets in the world

Founded in 1984, Project Engineering and Contracting (PEC) is a leading manufacturer of lithium-ion cell formation lines and a supplier of battery testing and laboratory automation solutions. The company is now fulfilling its ambitions to become a major player in the automotive market in Japan – to date the leading country in the manufacture of advanced batteries and hybrid electric vehicles.

Since its establishment in 2010, PEC Japan has successfully implemented several projects, including battery testing labs and pilot production equipment with major Japanese cell manufacturers and OEMs. In the third quarter of 2013, PEC completed its first fully automated cell finishing line in Japan. The delivered system is equipped with formation towers, aging areas and peripheral equipment for the automated production of large format pouch type cells for the EV market.

PEC's innovative cell finishing process, with the availability of standard equipment and real-life experience, has resulted in validation of the equipment by a leading Japanese OEM and the decision to replace existing processes and tools previously embedded in Japan's lithium-ion industry since its formation.

PEC offers solutions and expertise in battery testing and laboratory automation in battery testing labs, as well as lithium-ion cell manufacturing

The PEC system offers substantial operational cost reductions through complete automation, simplification and integration of all processes after the electrolyte filling, including the electrical formation, aging, roll-pressing, degassing, grading and sorting of the cells. All operations are integrated in one turnkey production system, using a high-speed automated storage and retrieval system (ASRS) for the material handling of the cells. PEC's embedded MES software guarantees traceability at cell level, enforces the configured routings and grading rules, and provides the operators and management with real-time progress reports. The PEC system also results in substantially improved overall performance, as well as higher quality and consistency of the cells, by having a tighter control on the critical process parameters.

Due to using the standard building blocks approach, and the experience gained using the PEC pilot manufacturing equipment, a six-month very aggressive implementation time target was achieved, while risk was almost completely reduced.

With a completely modular standard design, the required engineering work is reduced to a strict minimum. Capacity extensions, resulting from continuously growing needs, can be realized within a minimal timeframe, without interfering with the ever-running production.

The PEC cell finishing lines are managed by an integrated manufacturing execution system, which controls all aspects, including flow control, quality control, material handling and even maintenance tasks. The software guarantees an embedded tracking of all cell movements, collected process data, capacity results and grades, with extensive reporting capabilities.

With the company's ability to win contracts in the ever-competitive Japanese domestic market, PEC has proven that it can bring substantial business value to customers by simply delivering a superior and more consistent cell at a much lower cost.

PEC designs, manufactures and supports its solutions to the market from several locations in Europe, the Americas and Asia Pacific. PEC is now headquartered in Leuven, Belgium, with R&D and project management groups in Belgium, Hungary, the United States, China and Japan.

PEC's cell finishing lines cover all process and testing operations from after the electrolyte filling and supply pack assembly with a flow of finished and sorted cells

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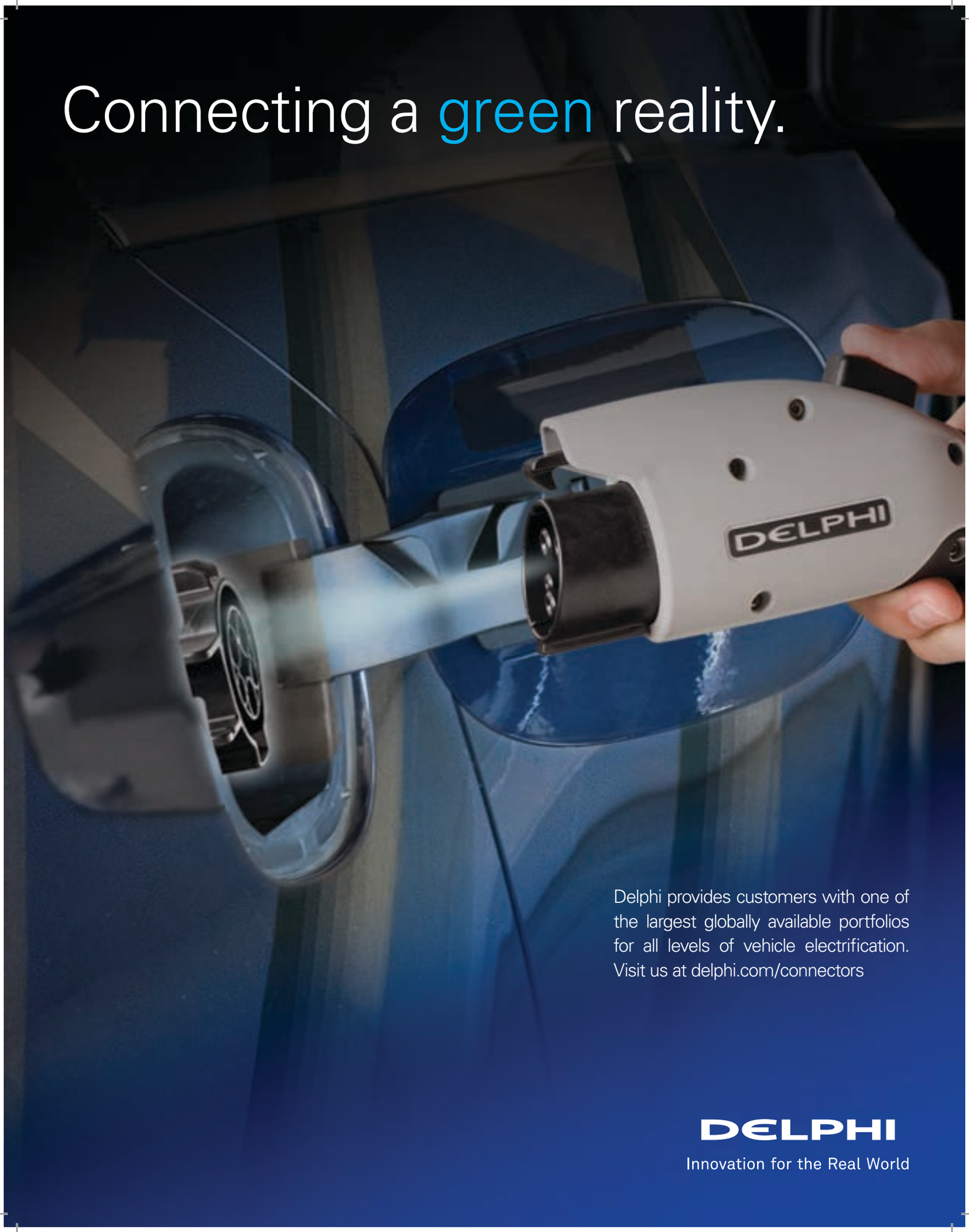
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EV powertrain testers

A new line of high precision lab testers for electric motors and inverters has been designed to support and enhance the capabilities for development, validation and end-of-line processes

D&V Electronics has added to its line of electric motor and drive testing products: the EPT tester range features full testing capabilities for e-motor, inverter and battery testing. Each group of testers has been designed to support and enhance the capabilities for applications, such as development, validation and end of line processes.

One recently completed EPT-150 tester will be deployed at the research laboratory of a major automotive Tier One in China to develop inverter/e-motor system technologies. Specifications for this tester have been tailored to handle high acceleration capabilities by encompassing both a low inertia driveline and significant power capabilities. This has been made possible through a new dual motor dynamometer configuration: two motors feed power to a single driveline through a belted transmission system. This allows significant power capabilities in a test system without having to procure long lead-time and prohibitively expensive motors.

The driveline and motors are highly balanced machines on a lowered testbed plate, which gives the test system a lower center of gravity. Thus, vibrations are minimized to provide cleaner torque measurements and safer operating conditions. Furthermore, the selected temperature measuring, thermal chamber and chiller system options provide customers with full-range testing capabilities for thermal characteristics analysis.

OEM customers will find the scope and recorder tools, which are made available out-of-the-box, useful. The fastest sampling parameters can be displayed on-screen much like a scope device while monitoring testing conditions and settings. These include position, torque, resolver z-pulse, phase voltage, phase currents and more. The scope can also be configured to provide plots for calculated values from a variety of measurements versus time, which include electrical/mechanical power measurements. For the D&V EPT-150 systems, all the parameters are sampled from measurement electronics receiving data from all channels at the same frequency. This is a synchronous feed of information that provides an accurate picture of each parameter in relation to extremely small time slices. This becomes a powerful tool for viewing current control dynamic performance and resolver dynamic performance all along the same synchronized timeline.

The EPT-150 is designed to be a high-accuracy development platform for e-motor, inverter and battery pack testing. The main vehicle driveline can largely be tested on the EPT-150 due to its highly modular capabilities

In addition to the scopes in this laboratory platform, the D&V EPT-150 tester software includes graphical display tools to present data in the form of a circular graph, spectrum plots or custom plots. For example, the user can custom plot the resolver error based on position of the rotor. This establishes a clear window on a product's rotor or resolver behavior in relation to angular position. If there is a problem here, it can be quantitatively displayed at the outset with a click of a button. This is just one example of a plot that can provide measured feedback into product improvement cycles.

The main vehicle drive components can be tested on the EPT-150 due to its highly modular capabilities and functional characteristics. Inverters can be controlled and tested in conjunction with selected motors optionally powered by a proprietary battery pack. Simulation features, vehicle network control and e-motor controller calibration options are available to provide a full testing suite. The EPT-150 is designed as a long-life, high-accuracy test platform for the e-motor, inverter and battery pack.

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Powertrain validation tools

The combination of co-simulation/virtual experimentation platforms and testbed automation systems is seamlessly merging simulation and real-world engine testing

To develop a new hybrid powertrain is to inaugurate new methods and new validation tools. The process of validation is no longer sequential as simulation, control systems and testing teams collaborate throughout a project. As such, the variety and complexity of interactions between the powertrain components require constant exchanges between the teams. This is a new way of working that D2T's tools enable and support.

These tools were implemented in Solaize, Lyon, on the new heavy-duty transient engine testbed of IFP Energies nouvelles, the parent company of D2T. The first milestone was the modeling of the entire testbed for a preliminary software-in-the-loop (SIL) validation, including a heavy-duty vehicle model, engine models, battery, electric motor, transmission, driver and the test bench itself, as well as the simulation of the vehicle CAN and UDP networks. All models are hosted inside xMOD, a co-simulation and virtual experimentation platform, and the ensemble is commanded via the Morphee 2 testbed automation system, with exchanges between the systems at 1kHz. Thanks to xMOD, numerous skills from varying sources can communicate with each other; it accommodates models derived from Simulink or AMESim just as well as models from GT suite and Dymola. "xMOD enables experts from various domains to collaborate around a singular simulation platform that is shared between office and testbed," says D2T product manager Hassen Hadj-Amor.

The second stage – the hardware-in-the-loop (HIL) phase – takes place on the engine testbed, enabling the final validation of the supervision strategies. And while a prototype and heavy-duty chassis dynamometer are expensive, the high-dynamic engine testbed eliminates the need for the former and can postpone the latter. However, certain conditions must be met in order to approach a real-world vehicle environment in a convincing fashion. This is achieved thanks to a highly dynamic D2T 530kW dynamometer controlled by the highly responsive D2T Drive Box. Then, Morphee 2 and xMOD, which were already used during the first phase, are copy-pasted onto the testbed, along with their models and ability to reproduce the dynamic behavior of the vehicle, driver and road testing.

The test cell of the D2T transient engine testbed for heavy-duty hybrid powertrains at IFP Energies Nouvelles in Lyon, France

As an output, the tests performed on the testbed enable the assessment of the emissions levels and fuel consumption of heavy-duty vehicle configurations and, in an iterative manner, the modification of the parameters of engine control and even the components, such as an overheating battery, an e-motor with insufficient efficiency, or a non-optimal torque-split strategy – until reaching a satisfactory result. From the virtual SIL testbed to the real HIL engine testbed, the process is continuous and the feedback immediate. The concrete impact on the vehicle, following the work done on the dimensioning of the battery cells/pack, e-motor and transmission, can be witnessed almost instantly.

Launched in 2011, the Citybrid project, led by Renault Trucks in partnership with IFP Energies nouvelles, Saft, Carrosserie Vincent, Frappa and G2ELab, best illustrates the full capabilities of D2T's tools. The objective was to evaluate the impact of hybridization on the pollutant and CO_2 emissions of a heavy-duty vehicle. The project was successfully completed and both D2T tools, xMOD and Morphee 2 were among the key elements.

Thanks to these tools, simulation and real-world validation are now firmly intertwined and every step of the development process is completely covered from beginning to end.

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Power delivery systems

From wire harnesses and smart junction boxes to terminals and connectors, electrical distribution systems can help to reduce drivetrain weight, complexity and material costs

The level of electrification in vehicles continues to increase, driven by strict mandates for fuel efficiency and emissions. To satisfy this demand, Lear, a global leader in automotive electrical distribution and seating, has gone to great lengths to bring innovative products to market for OEMs around the world. As a company, Lear has a full range of products in series production that include charging, energy management and power distribution systems.

In order to deliver power to the vehicle, Lear has a full range of cordsets and wall stations that are certified to meet all the necessary market standards and are delivered to OEMs in all major global regions. These products interface with another Lear subsystem, the vehicle receptacle. Lear is vertically integrated in terminal design and manufacture. As such, these critical parts were specifically designed to exceed 10,000 mating/unmating cycles to guarantee trouble-free lifetime for the end-consumer.

Lear has a huge amount of production experience with these new technologies, having already launched more than 20 production programs with global OEMs. By applying the latest technological innovations, Lear is continuously improving on the size, weight, efficiency and cost of its designs. The company is now in its fourth generation of onboard charger designs and anticipates launching a 7kW charger that is industry-leading in terms of size, weight and overall efficiency.

Beyond consistently looking to refine existing products, the Lear engineering team devotes significant resources to cutting-edge research. "We are always working diligently on new applications and anticipate discussing our future in the EV space in greater detail soon," said Steve Bull, Lear's UK-based European advanced sales manager for electrical distribution systems.

In addition to the more complex products, Lear also designs and manufactures a line of high voltage (HV) and high current terminal systems. The Lear 14.5mm female terminal is capable of an industry-leading 250A when used with 50mm^2 wire. The 6.35mm terminal is capable of 165A on 25mm^2 wire. As a result of this patented technology, regular 8mm terminals can be replaced with smaller, lighter, 6.35mm sizes, resulting in even higher current carrying capability. Due to superior performance, Lear's high power terminals are among the most desired by global OEMs for high power applications. The Tier 1 supplier has also adapted its terminal designs to use lighter aluminum instead of copper, achieving both cost and weight savings.

Lear also focuses on validation, which drives the team to go beyond OEM requirements for durability and reliability, with each product going through punishing electrical, mechanical, thermal and environmental tests before being declared ready for production. This close attention to detail ensures the long-term success of these new technologies in the marketplace.

Founded in Detroit in 1917, Lear has established a global footprint of 221 facilities in 36 countries on six continents, and provides electrical content and seating for every vehicle segment from compact cars to full-size sport utility vehicles. Serving all of the world's major OEMs, Lear is a Fortune 200 company headquartered in Southfield, Michigan, USA, and listed on the New York Stock Exchange.

The Lear cordset has been certified to meet all the international market standards

Lear's electrical systems are put through extensive testing, including environmental assessments, to ensure the long-term success of the technologies

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Weight: 0.4kg
Voltage: 12V
CCA: 85 A

Replace traditional AGM battery No.:
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12N5-3B,YT5AL-BS,YB5L-A, YB5L-B,YB5L-
B2,12N5.5-3b, 12N6-3B, YB6L-B,12N6.5-
3B,12N6.5C-3B,YT6.5L-BS,12N7A-3A,12N7B-
3A,12N7C-3D,YB7C-A,YTX7DL-BS

CMP-19F

Dimension:15 X 8.7 X 9.3 cm
Weight: 0.6kg
Voltage:12V
CCA: 105A

Replace traditional AGM battery
No.: 12N6.5B-4B, YTX7A-BS,YTX9-
BS, YTR9-BS

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Multimode battery tester

A new and powerful two-channel test system for energy storage applications has been engineered to provide greater flexibility and a wider range of operating specifications

Energy storage requirements have become increasingly diverse in recent years and continue to evolve rapidly. A challenge for researchers, battery manufacturers and OEMs is finding testing equipment that has the flexibility and wide operating parameters to support current and future energy storage testing needs. Likewise, many organizations will need to test a variety of different sized battery packs. The testing equipment used in these situations is a significant investment, and it is important they are configured with future growth and expansion in mind.

In response to this challenge, Arbin Instruments has developed the EVTS-X testing system (Figure 1) to meet the growing number of operating specifications. Building on Arbin's EVTS series, all of the EVTS-X systems use regenerative circuitry that discharges power back to the grid. Additionally, the EVTS-X boasts a hardware architecture that allows for four different operational modes of its two fully independent test channels. In addition to running each channel independently, the EVTS-X channels can be configured to operate in parallel, in series and in differential modes for reverse polarity testing. Figure 2 represents the operational range of an EVTS-X system with two 400V, 300A channels. This is only one example of a popular standard configuration.

Arbin Instruments was the first company to introduce channel paralleling, which is now a common feature of test systems throughout the industry. By paralleling channels, users can effectively double the current capacity (600A in this example), which offers a wider range of testing scenarios and provides the capability for overcharging and other unique charging applications.

Also, the EVTS-X series has the ability to configure channels into series and differential modes. Connecting the channels in a series doubles the overall voltage range of the test station (800V in this example). The increased range allows users to test an expanded range of battery packs with one piece of test equipment.

The differential mode reverses the polarity of one channel enabling an extreme negative voltage testing range. This mode provides a test channel with a full negative to positive voltage range (for example, -400V to 800V) for safety testing, such as over-discharge and reverse-charge, and other specialized R&D testing.

Figure 1: The EVTS-X multimode, two-channel tester offers a new discharge booster mode

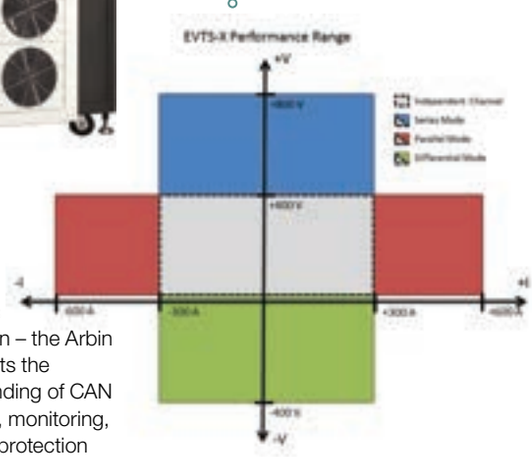

Figure 2: The EVTS-X system's operational range with two 400V, 300A channels

The EVTS-X includes CANBus communication – the Arbin CANBus device supports the reading, writing and sending of CAN messages, and logging, monitoring, setting, controlling and protection of the battery pack being tested. Figure 3 shows a graphical representation of CANBus communication within the system.

Other optional features include cell voltage monitoring, temperature monitoring, temperature chamber communication and digital or analog input/output channels. Most of these options can be added to a testing system at a later date, due to the modular and flexible design of Arbin's hardware.

The EVTS-X is designed to be a complete testing solution. From basic charge/discharge testing to complex drive cycle simulations, the system provides testing versatility. Arbin Instruments began producing EVTS-X systems in November 2012 and is now shipping them globally.

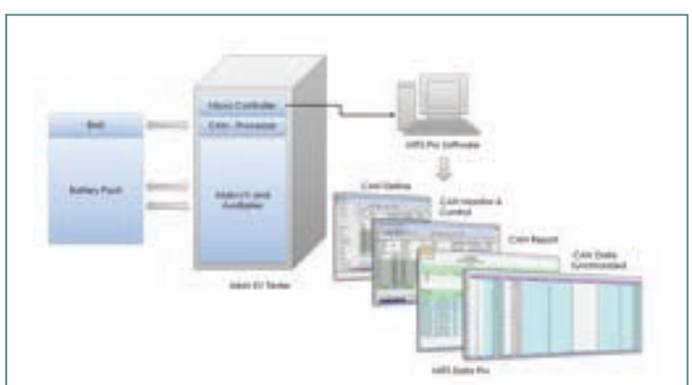

Figure 3: A graphical representation of CANBus communication within the EVTS-X

Industry specialists in EV, HEV, grid-storage and battery safety applications have come to rely on Arbin Instruments for battery testing solutions. The EVTS-X system complements the company's extensive product line of standard and custom engineered systems for testing single cells, modules and large-scale battery packs.

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ONLINE READER ENQUIRY NO. 523

Efficiency booster

Designed for medium- and heavy-duty commercial applications, a new direct-drive electric powertrain eschews a gearbox for higher system efficiency and reduced cost and complexity

Optimization is the key to a cost-effective electric powertrain solution. Launched in 2012, the Sumo powertrain line for commercial vehicles and buses offers a highly efficient direct-drive electric powertrain system, as opposed to the more common approach involving an electric motor coupled to a single or multiple ratio gearboxes. A wholly owned subsidiary of Hydro-Québec established in 1998, TM4 develops and delivers production-ready electric and hybrid powertrain systems for passenger cars up to commercial trucks and buses. Always focused on improving the products and technologies used in electric vehicles, TM4 has developed a solid expertise in permanent magnet motors, thermal management, coil winding, outer-rotor topology, and motor and inverter control algorithms.

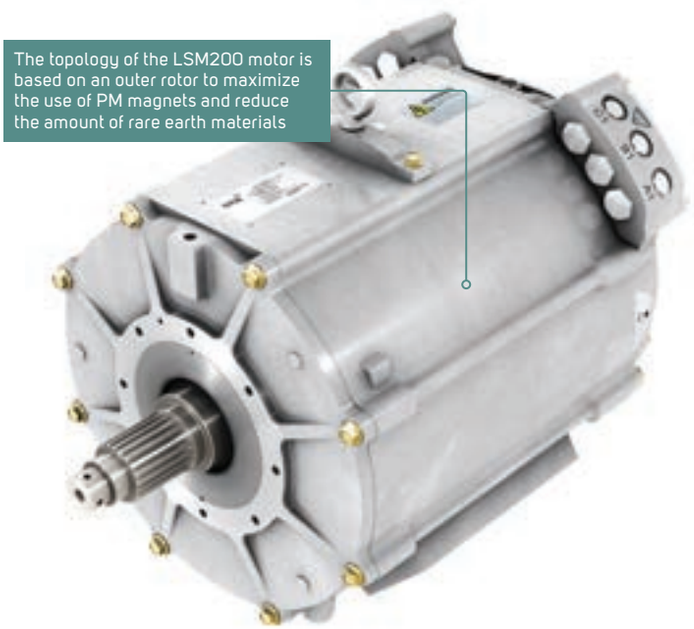
Developed for performance and durability, TM4 Sumo systems are designed exclusively for heavy- and medium-duty electric and hybrid vehicles. A direct-drive system yields over 10% efficiency gains throughout the driving cycle, representing an equivalent gain in the battery size, weight and cost. Removing the gearbox reduces the powertrain's complexity and cost, allowing for a simple, efficient and low-maintenance solution.

An external rotor and internal stator machine has a longer radius than other topologies, generating more torque while using less material

To meet the demands of the different types of commercial vehicles operated by fleets, TM4 developed its Sumo MD platform, covering the whole range of medium-duty commercial vehicle platforms. With power ranging between 100 and 200kW, and with a standard SAE 3 flange diameter, this new family of motors/generators is offered in five different lengths. The peak torque ratings start at 600Nm and go up to 2,080Nm. Some versions are offered with a double-ended shaft option, allowing for easy integration in hybrid-electric powertrain system architectures.

Moreover, the Sumo MD is offered in both 450V DC and 750V DC inverters to allow for easy integration in a greater number of vehicle platforms. TM4's inverters use the latest generation of insulated-gate bipolar transistors (IGBT) and TM4's proprietary Reflex gate drive technology to deliver high power and current densities in a very compact package. Across all platforms, TM4 uses automotive certified components that have cumulated millions of kilometers inside TM4's products.

The CO200HV controller utilizes automotive grade IGBTs and TM4's Reflex gate driver technology to deliver industry-leading high specific power and current densities



The topology of the LSM200 motor is based on an outer rotor to maximize the use of PM magnets and reduce the amount of rare earth materials

Since it develops its own electric motors and technologies, TM4 offers turnkey systems that are already tested, optimized and ready to be integrated inside a vehicle. Vehicle controller hardware and development service are also offered by TM4. Therefore, along with its integration and development partners, such as Rational Motion, TM4 is a true one-stop shop for electric mobility.

TM4 is currently working with different OEMs and technical centers in North America, Europe and Asia in order to test these powertrains in several types of electric and hybrid commercial vehicles. Production is undertaken at TM4's Canadian facility in Boucherville, as well as Prestolite E-Propulsion Systems in Beijing, China. These facilities are all equipped with high volume, flexible and automated production lines, as well as a large range of dynamometers and test cells in order to conduct full validation and certification of electric and hybrid powertrains, including electromagnetic interference/electromagnetic compatibility.

Other products offered by TM4 include its Motive series powertrains; and compact and high-power density electric and hybrid motor and controller systems for light-duty and automotive applications.

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EV motorsport advances

A customizable EV development program using F1 technology and based on off-the-shelf motors and inverters is furthering the development of on-road electric and hybrid projects

Toyota Motorsport (TMG) is celebrating five years at the cutting edge of hybrid and electric vehicle development by embracing new technologies for the road and track. True to its origins, TMG's journey began with development of KERS hybrid units for its Formula 1 team, beginning in 2007.

However, mirroring TMG's evolution into a multipurpose engineering supplier beyond motorsport, the EV Technology Center in Cologne, Germany, has embraced a wide range of applications for its increasingly diverse products. As well as maintaining its strong motorsport links through its hybrid-powered World Endurance Championship team and lap-record-setting EV racecar, TMG is also increasingly focused on road-going projects.

In 2009, TMG's EV Technology Center was founded to provide development and integration of electric powertrains for motorsport and road-going vehicles. Since then, the first EVs have rolled out of the TMG factory with an ongoing and continuous development of the services and technology offered at the EV Technology Center.

TMG's executive coordinator of strategic EV development, Claudia Brasse, said: "We are proud to celebrate five years of TMG's EV Technology Center, and we can look back with satisfaction on many successful projects. TMG sets out a holistic approach to EV technology, employing state-of-the-art technology to foster integrated solutions for sustainable mobility. This also includes infrastructure-related and enabling technologies, such as EV charging and on- and off-grid energy management. Now we look forward to many more years of innovation in the field of electric vehicles and beyond."

TMG specializes in the integration and development of EV powertrains, such as with this 400kW example

TMG utilizes its experience in EV motorsport in order to develop innovative charging technologies

Using technology derived from its time in Formula 1, TMG has established itself as a global leader in the EV field. TMG uses Toyota's corporate vision and mission as its guiding principles with effectiveness and customer satisfaction at the heart of its operation. Motor and inverter technology is developing continuously, presenting a risk that in-house development will soon be overtaken by commercially available solutions. So to stay flexible, TMG, in partnership with providers of best-in-class battery solutions, has created a comprehensive and customizable EV development program based on off-the-shelf motors and inverters.

The performance of these components is also entirely dependent on the respective management systems, so TMG has focused on developing unique expertise in this area. By developing its own hardware and software, TMG is pioneering new techniques and optimizing existing processes to deliver better performance, reliability and safety. A dedicated team of researchers has enhanced challenging techniques, such as torque vectoring and torque control, and close collaboration with the TÜV ensures the highest safety standards. TMG's extensive testing laboratory enables testing of EV components to complete the development cycle.

TMG's EV Technology Center in Cologne, Germany, was founded in 2009 and is located within the company's automotive engineering facilities

Vehicle integration and powertrain tuning to achieve the desired performance parameters are absolutely key to consistently delivering innovative and customer-satisfying EV solutions. TMG's background in F1 technology development and project dissemination, as well as Toyota's influence on quality and working spirit, results in a unique match of competencies in the quickly evolving field of EV technology.

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ONLINE READER ENQUIRY NO. 525

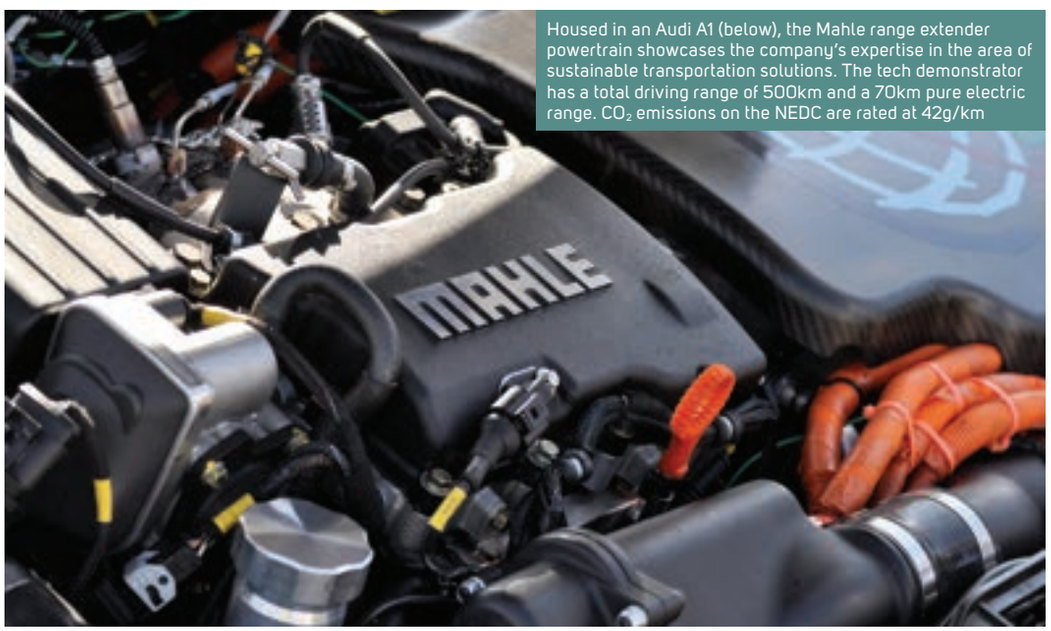
Range extender optimization

A dedicated range extender powertrain has been developed from a clean sheet and applied to a standard production vehicle in an effort to prove the technology's maturity and potential

Following the success of its advanced engine downsizing project, the engineers at Mahle Powertrain's Northampton, UK, headquarters have turned their attention to the growing vehicle hybridization trend. Recognizing the obvious technical and commercial limitations of battery electric propulsion, the decision was made to develop a bespoke, dedicated range extender engine targeted at light EV applications.

The prime objective of the project was to create an auxiliary power unit, comprising both IC engine and generator, in the smallest, lightest and most cost-effective package. Gasoline fueling was chosen at an early stage to reduce total engine weight and exhaust aftertreatment complexity as well as to enable a broader range of potential vehicle applications in all global regions.

With the engine driving only the generator, and no mechanical connection to the wheel, transient operation was minimal, thus permitting a low-cost approach to the engine's components and subsystems. A simple two valve per cylinder arrangement was adopted, with fixed timing and lift, and port fuel injection was employed in a 900cc, four-stroke, parallel-twin configuration. The overall package dimensions were minimized in the early design phase by incorporating specific design features, including an intake system feeding air into the combustion chambers from underneath the fire face, and directly mounting the generator rotor to the end of the crankshaft.



Housed in an Audi A1 (below), the Mahle range extender powertrain showcases the company's expertise in the area of sustainable transportation solutions. The tech demonstrator has a total driving range of 500km and a 70km pure electric range. CO_2 emissions on the NEDC are rated at 42g/km

To maximize installation flexibility and vehicle packaging options, the engine lubrication system was specifically designed with additional baffle plates and oil galleries to allow operation when mounted at any angle from vertical to horizontal. The latest Mahle component technology was incorporated within the engine, including a low-friction piston ring pack and polymer-coated main bearings, to ensure durability during the expected long periods of inactivity.

The optimization of the engine's NVH characteristics was another key consideration during the initial design process. Typically, twin cylinder engines display unfavorable NVH due to poor primary balance. This was directly addressed by adopting an uneven firing order with a crank configuration of 180° (one piston at TDC when the other is at BDC) to achieve primary balance. This approach results in a cyclic torque output due to the uneven ignition events/power strokes. However, this effect could be mitigated by synchronized switching of the generator load to provide full dynamic torque control.

Following further development work on the in-house transient dyno (complete with a high-voltage battery emulator), the engine was installed in the selected donor vehicle. The Audi A1 was chosen to clearly demonstrate that all necessary hardware could be successfully packaged in a compact-class vehicle without sacrificing passenger or luggage compartment space. The entire process of converting the vehicle to electric drive, including installation of the engine, generator, inverters, traction motor, gearbox, 14kWh battery pack and all associated control and cooling systems, was carried out at Mahle Powertrain's dedicated vehicle workshop facility. The project was an ideal showcase for the company's vehicle integration and control system development capabilities.

The Mahle RE-EV demonstrator vehicle is now fully operational and has already been driven at a number of OEM sites and industry events across Europe. The vehicle attracted great interest at the Frankfurt IAA motor show and went directly from there to participate in the Bertha Benz Challenge event.

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ONLINE READER ENQUIRY NO. 526

Complete turnkey solutions

From test cell upgrades to new installations, a wide range of engine and vehicle testing requirements can be met with highly flexible, customized software and hardware solutions

Thirty years of successfully meeting tough customer challenges has taught Sierra-CP that the one-solution-fits-all concept just doesn't work in the automotive testing industry. The company works hard to create an open atmosphere for client interaction that embraces the critical role that flexibility plays at every stage of design and development. This strategic approach to every project starts with a clear and thorough understanding of a client's requirements prior to making any potential recommendations.

Whether upgrading existing test cells or planning new installations, Sierra-CP works in partnership with global clients to develop custom products and systems or provide complete turnkey solutions. They also match the customer requirements of today with tomorrow's needs to guarantee a solution that can expand with the test of time.

Sierra-CP covers the complete range of automotive test applications, including engine, vehicle, powertrain, transmission, emissions, analytical and component testing. Their team of highly-skilled, experienced and professional engineers thrives on solving diverse and complex testing problems – typically to tight deadlines and budgets.

To help meet the challenges of a rapidly changing industry, Sierra-CP has developed advanced hardware and software solutions that cover the complete scope of test applications. An open design approach and a common, easy-to-use interface allow them to integrate seamlessly with existing instrumentation and other manufacturers' equipment, or build bespoke turnkey systems designed to specific requirements.

Sierra-CP covers the complete range of automotive test applications, including engine, powertrain, transmission, emissions and component testing

At the heart of the company's solutions is the proprietary Cadet V14 test automation software, which combines accurate multichannel control with high-speed data acquisition. Cadet V14 is the basic platform for all Sierra-CP's solutions because of its great application flexibility and scalability. As the software is developed in-house, Sierra-CP can do rapid customization for clients, no matter how complex the testing demands.

From upgrading existing facilities to custom end-to-end solutions, Sierra-CP provides the most advanced tools available for engine and vehicle testing. Applications include emissions, endurance, motorsport, performance development, climatic, calibration, NVH, production and quality audit.

With eddy-current and high-performance AC dynamometers, tests can be configured for steady-state, transient and dynamic operation. The company also manufactures specialized equipment to precisely control the engine's environmental conditions. Driven by the Cadet V14 CDS test automation software, the chassis dynamometers cover all certification, research and development requirements for cars, trucks, motorcycles, three-wheelers, off-road and treaded vehicles.

By combining Sierra-CP's design expertise with specialty products, they are able to deliver advanced solutions for powertrain and transmission testing applications suitable for conventional motive power units, e-motor and hybrid variations. Solutions include a wide range of applications from durability and key life testing to NVH and performance development.

Sierra-CP manufactures a wide variety of emissions measurement solutions to meet nearly any engine and vehicle testing application. They specialize in particulate matter (PM) partial flow dilution sampling with their BG3 technology, and offer seamless integration and control of devices, such as CVS and gaseous analysis via the Cadet V14 test automation software. Working in tandem with the BG3, the Soot-Trak instrumentation measures real-time engine soot particle mass emissions and performs characterization of average soot agglomerate particle size, number and surface area.

Sierra-CP designs, manufactures and supports all of its own solutions, with technical support centers in China, UK, USA, India and Malaysia. The company's client portfolio includes Honda F1/Mugen Euro, Foton, Protean, BP, Castrol, Caterpillar, Cummins, Delphi, Ford, JCB, John Deere, Mercedes AMG High Performance, MTU and many more.

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ONLINE READER ENQUIRY NO. 527

Voltage stabilization issues

Ultracapacitors are being used in voltage stabilization applications to help maintain high electrical power supply in vehicles during the engine start-up process

Electrical-driven machines require high power for start-up. The result of this current is often an unacceptable voltage drop due to impedance in the power supply network. This voltage drop may result in the malfunction of other equipment that is connected to the same power network.

Energy storage technologies, such as batteries, have been proposed to resolve these voltage stabilization issues. Although batteries can store and release a large amount of energy over extended time periods, they have difficulty in providing the short-term high-power levels required for voltage stabilization. In addition, batteries are slow to charge and in some applications their lifecycle is notoriously short, often less than a year or two. Moreover, batteries do not perform well in extreme and harsh conditions.

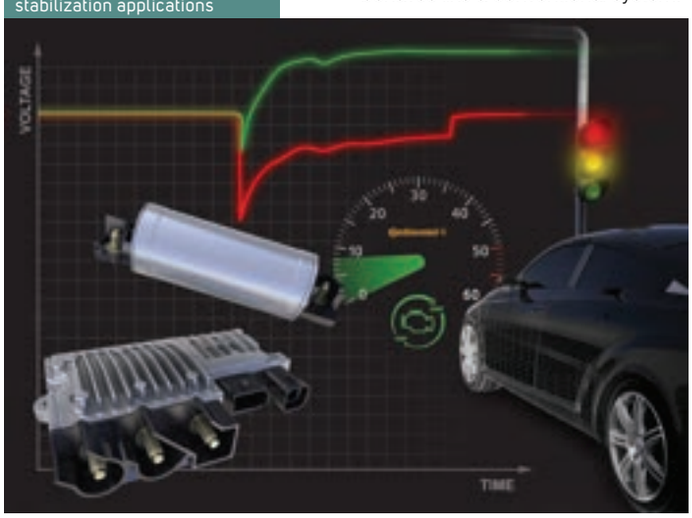
Maxwell's ultracapacitors have been successfully used in voltage stabilization applications in different industries, including automotive and large-scale industrial systems.

OEMs are striving to improve the fuel economy of their vehicles. One increasingly popular approach is the use of stop/start systems. This can reduce harmful exhaust emissions and improve fuel consumption, which also lowers CO_2 emissions. The best-performing systems today use a belt-driven starter/alternator to restart the engine quickly and quietly. However, the fast start of the engine means very high current is required from the onboard battery. In practice, the peak current can momentarily exceed 1,000A.

To avoid the voltage drop of the onboard power supply at every start, a voltage stabilization system (VSS) that adopts Maxwell's ultracapacitors as the energy storage device has been designed and implemented by Continental.

The VSS is a simple addition to the existing power network that's installed between the negative terminal of the battery and the chassis ground of the vehicle. While driving or when the vehicle is stationary, the electrical system behaves like a conventional system.

Advanced ultracapacitors from Maxwell have been successfully used in voltage stabilization applications



Automotive engineers at Continental have created a highly acclaimed energy storage device that makes use of Maxwell ultracapacitors

During a restart, the VSS will switch in when the system current exceeds a preset value. At this point, the charged ultracapacitors are placed in series with the battery, thereby raising the available voltage. This will then raise the voltage of the entire power network. The ultracapacitors supply the high power needed for the engine-starting event, which is usually less than one second.

In fact, when using Maxwell's ultracapacitors, the engine starts substantially faster than before. The onboard power supply sees a higher start current, but a much lower voltage drop. The application enables the starting performance to stay consistent even as the vehicle battery ages, therefore extending the useful life of the battery.

Since the ultracapacitors can be charged and discharged quickly (a complete charge takes less than one minute; a partial charge after a normal start takes only a few seconds), the VSS can effectively handle the frequent stop/start demands typical of heavy city traffic. Furthermore, Maxwell's ultracapacitors can operate over a wide temperature range of -40°C to 65°C. This makes the VSS highly suitable for operation in all climatic conditions.

The VSS includes two Maxwell 1200F ultracapacitor cells in series. In addition to meeting the power and energy demands of the engine starting process, the ultracapacitors are specifically designed by Maxwell to meet the stringent mechanical and environmental requirements of automotive components. These highly reliable devices are expected to operate for many years without maintenance or replacement.

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ONLINE READER ENQUIRY NO. 528

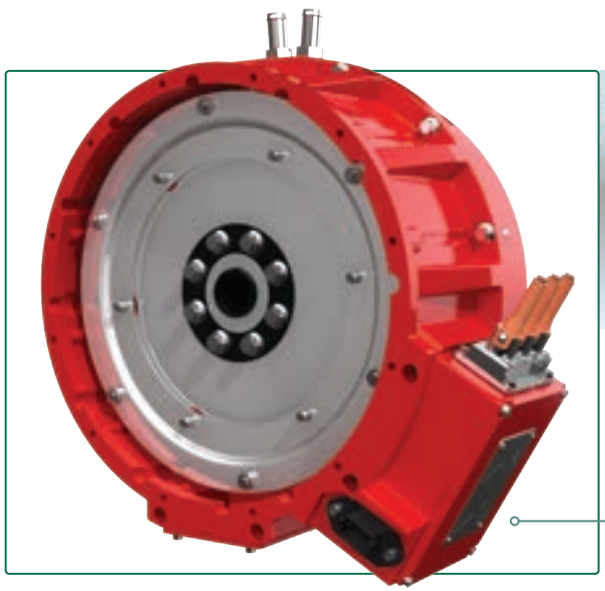
Stop/start efficiency gains

A new integrated starter generator could help lower fuel consumption and CO_2 emissions in heavy-duty vehicles, with minimum modification to existing diesel-engine drivetrains

With the launch of its first integrated starter generator (ISG), Cummins Generator Technologies has brought the prospect of the wider application of fuel-saving stop/start systems for trucks and buses with large-displacement diesel engines closer.

The ISG represents the next stage in Cummins Generator Technologies' CorePlus project (first reported in the January 2013 issue of *Electric & Hybrid Vehicle Technology International* and subsequently featured in the June 2013 edition), in particular building on its benefits of providing a high-efficiency electrical power source (typically 30kW versus 5kW from regular automotive alternators) for driving engine ancillaries as well as external equipment.

However, unlike its ongoing motor generator counterpart, which can be de-clutched from the primary diesel engine when used in a hybrid-drivetrain application, the ISG is permanently attached to the engine crankshaft, thereby acting as a high-torque starter motor, making it ideal for stop/start vehicle systems. The ISG could also provide an additional power boost to a vehicle, such as when hill-climbing, enabling truck and bus OEMs to downsize by fitting a smaller-displacement diesel engine.



Cummins' CorePlus controls software, embedded in the power electronics, uses the latest solderless IGBT transistor technology for extended life

Cummins' CorePlus integrated starter generator achieves 660Nm peak torque, 90kW peak power and efficiencies of up to 95%

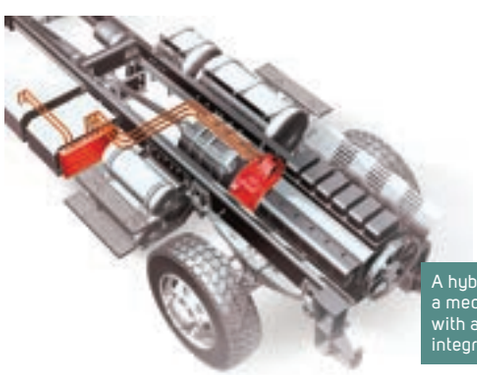
Commenting on the ISG, Nicolas Bertrand, Cummins Generator Technologies' general manager of CorePlus Technology, says: "We've given it many differentiations, not only in the fact that we can provide it with CorePlus power electronics, but also with its high torque and efficiency, and high integration level with an engine manufacturer."

The stop/start capability of the ISG is expected to create strong interest among city bus operators. "This is leading-edge technology. We can put into place a stop/start system specifically for the bus market – it's something customers are demanding, rather than just asking for," notes Bertrand. The ISG's high torque and efficiency delivers reduced engine cranking times and a smoother start-up, which could prove attractive to vehicle manufacturers looking to upscale their stop/start engine systems for delivery trucks and city buses with diesel engines, where an engine could require as many as 30 starts an hour.

Equally important, the ISG clearly has the ability to satisfy the growing demand from end users for more electrical power on vehicles – for example, for additional air-conditioning and full wi-fi communications in a bus or coach, and in specialist military vehicles. "We've identified the markets that are most power hungry," adds Bertrand, who also confirms that further ISG power applications could include refrigerated trucks and concrete mixers.

By being an integral component of a mild hybrid system, the ISG can also provide power back to the hybrid vehicle's storage batteries through regenerative braking. The prototype version of the ISG, which was unveiled at the recent Electric Vehicle Symposium in Barcelona, currently extends the overall drivetrain length by 168mm. However, ongoing development work will see that figure reduced on production versions. The additional weight of the ISG is a modest 113kg.

As truck and bus operators, as well as legislators, increasingly look to tackle the challenge of reducing fuel consumption and CO_2 emissions (with the latter expected to be the focus in the next-round of EC emissions legislation), Cummins Generator Technologies' integrated starter generator offers a clear opportunity to hit both targets with minimum modification to existing diesel engine drivetrains.



A hybrid propulsion system in a medium-duty truck chassis with a Cummins CorePlus integrated starter generator

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ONLINE READER ENQUIRY NO. 529

Signal and power cables

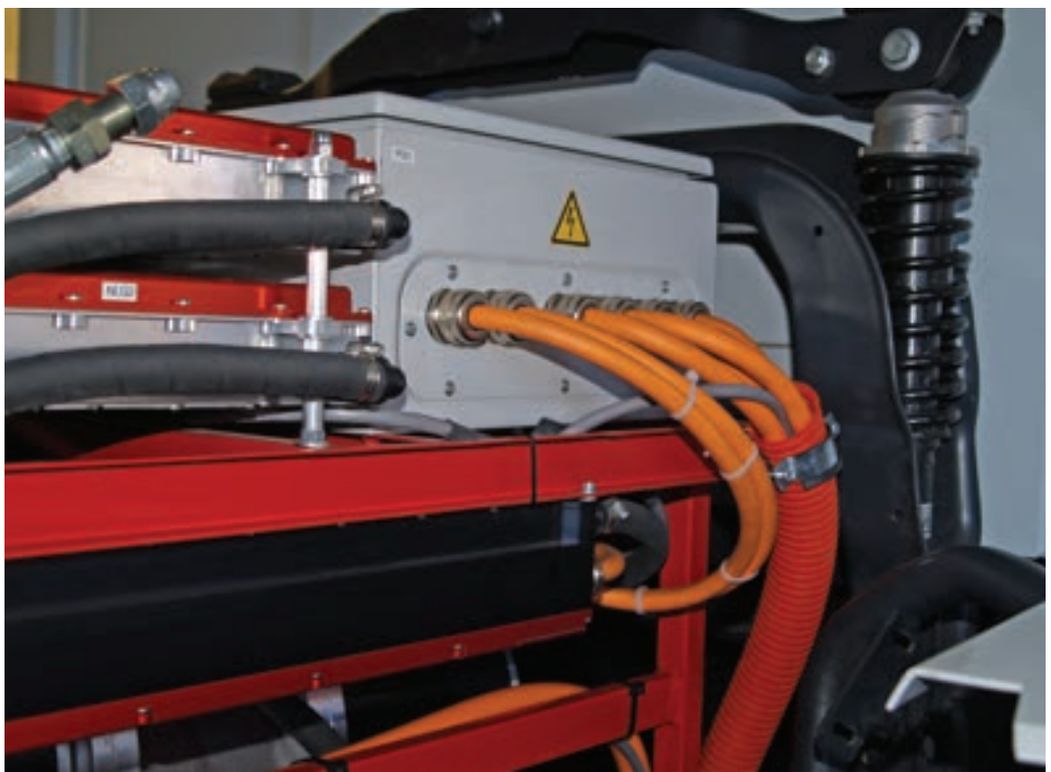
The addition of high-voltage cables in the engine compartment of the world's first electrically powered 18-ton truck played a pivotal role in the success of the project

A 30km range, 240kWh battery capacity and 413ps. These are the impressive vital statistics of the world's first electrically powered 18-ton truck, which was created in Fehraltorf, Switzerland, on behalf of E-Force One. And Radox cables by Huber & Suhner helped make the reliable construction of the high-voltage electrical system possible.

Smaller models had been built previously, but so far no one had dared to build an electrically powered 18-ton truck. Designwerk, an engineering company based in Fehraltorf, made it possible and developed the E-Force. To this end, an Iveco truck was equipped with two electric motors and two lithium battery units. With a range of 30km, the prototype hit the road for test purposes in September for the Feldschlösschen brewery in Rheinfelden. In October, retailer Coop also subjected the vehicle to long-term tests.

Following a detailed planning phase, the diesel vehicle was converted into an electric truck within just six months. "The main challenge was efficient packaging and the enormous battery output of 240kWh," says Marc-André Beck, development engineer at Designwerk. "We were able to draw on our experience from previous projects and rely on experienced project partners."

To construct the high-voltage electrical system, Designwerk relied on connection solutions by Huber & Suhner. "We were familiar with the company's Radox cables from other projects," says Beck. "They are robust, reliable and perfectly suited for use in the engine compartment." Huber & Suhner supplied the orange-colored Radox high-voltage cables for the high-voltage connections. The cables connect the high-voltage power distribution unit (PDU) with all other electrical system components. Two 1.3-ton lithium batteries supply energy. It is routed by Radox battery cables through the PDU to two inverters, where it is converted into three-phase AC, and then fed to two electric motors. With their total capacity of 300kW (413ps), the motors can pull a payload of 10 tons at speeds of up to 90km/h. During braking, 40% of lost energy is recovered and fed to the batteries through the same circuit. High-voltage products by Huber & Suhner connect the PDU with other system components and ensure a reliable flow of current. The heating system, two chargers and a DC/DC converter for the alternator are connected to the PDU with the aid of Radox cables.



Huber & Suhner's Radox power cables were chosen for inclusion in the truck's high-voltage electrical system due to their high heat resistance and current capacity, robust composition, compact design, flexibility and long service life

In 2014, E-Force One wants to purchase another 100 trucks for conversion to an electric drivetrain. The engineers at Designwerk will provide more support for this project. "The main thing now for series production is to create modules that are as compact as possible and can be installed simply and efficiently as an assembly kit," states Beck. This is why the company is in talks with Huber & Suhner. The cable manufacturer already has experience in designing and manufacturing complete electrical systems. On customer request, Huber & Suhner supplies high-voltage distribution units complete with the entire wiring. There is every possibility it will be doing the same for the world's largest electric truck.

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ONLINE READER ENQUIRY NO. 530

AC motor controllers

Designed for drivetrains using three-phase asynchronous induction or PMAC motors, a new range of AC motor controllers could benefit small and mid-sized EV manufacturers

Small and mid-sized EV manufacturers face limited choices when designing vehicle drivetrains, often being forced to adopt expensive systems intended for voltages of 300V or higher. This paradigm has finally changed with the introduction of the 60-144V DC Curtis Model 1239E AC motor controllers, which are uniquely well suited for designers of low-volume, specialized niche electric vehicles.

The Curtis Model 1239E delivers a highly cost-effective combination of power, practicality and functionality. It is intended for drivetrain systems using three-phase asynchronous induction or PMAC motors, and a nominal voltage of up to 144V DC for traction motor power. A separate, isolated 12V DC source is used for logic and I/O. It features a powerful dual-microprocessor logic architecture to provide improved performance and enable compliance with international functional safety requirements. The Curtis Model 1239E is available in several versions for 60-144V nominal system voltages, suitable for use on EV drivetrains requiring up to 70kW peak power.

With more than 50 years of experience, Curtis Instruments is a global EV technology leader with millions of controllers installed in all types of electric vehicles, including fork lift and warehouse trucks, airport ground-support equipment, mobile elevating work platforms, as well as light on-road and recreational vehicles.

With 15 locations on three continents, including sales, service, R&D and manufacturing facilities, Curtis Instruments has set the standard for motor-speed controller technology, vehicle instrumentation and related componentry.

For example, the range of Curtis enGage color LCD vehicle instruments is fully CAN compatible for vehicle integration, environmentally hardened and available in various sizes to allow integration into dashboards of all vehicle types. These highly configurable instruments provide a wealth of information such as battery status, speedometer, tachometer, odometer, temperature, status and diagnostic message centers in a single display, enabling OEMs to easily create a custom LCD instrument cluster optimized for their application.

One of the growing applications for Curtis EV technology is urban delivery vehicles. As trends in consumer shopping behavior have shifted to online buying, the need for doorstep delivery has increased greatly. The companies providing these services are under increasing pressure to reduce the carbon footprint and environmental impact of their fleets. Clean and green electric vehicles are the answer, providing high productivity while satisfying stricter environmental restrictions on noise pollution, particles and CO_2 emissions.

The new 1239E 144 Vdc Curtis AC controller features a powerful dual-microprocessor logic architecture to provide optimal performance

The Kyburz DXP tricycle postal delivery vehicle has helped to revolutionize clean and green mail delivery

The Swiss electric vehicle manufacturer Kyburz, for example, has successfully optimized the postal delivery vehicle. The DXP tricycle, as used by Swiss Post, uses the Curtis Model 1234 AC motor-speed controller for traction power, together with an enGage display. The excellent power efficiency, using a 2.4KW induction motor and lithium-iron phosphate ($LiFePO_4$) batteries, provides a delivery range of 50km with more than 500 starts and stops, and a top speed of 45km/h, given a starting load of up to 270kg of mail when combined with the purpose-built trailer.

These same benefits of electrification apply to all local utility vehicles, examples of which are the G3 and G5 vehicles manufactured by Goupil Industrie, France. These versatile vehicles use Curtis enGage displays and asynchronous traction motors driven by the Curtis Model 1236AC controller, at 48V for the G3 and 72V for the larger G5 vehicle. Custom application software was quickly developed using Curtis's proprietary vehicle control language (VCL), to meet Goupil's needs.

These are just a few examples of Curtis technology on the move. With the introduction of the 144V Curtis Model 1239E controller, even more small and mid-sized vehicle OEMs will benefit from high performance at an affordable cost.

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ONLINE READER ENQUIRY NO. 531

Optimal power handling

The 48V voltage level finds its way into vehicle applications at the low-power end of vehicle electrification. But it is low power that's provided at high levels of reliability and availability

In high-power applications, the decision to introduce a standardized voltage level in electric cars and trucks is still pending. However, for low-power requirements, the outlook is clearer, with the 48V voltage level being seen as the smart balance between power capability, safety needs and overall cost.

But what does this low-power level mean for electrical vehicle applications and what are the reliability requirements? AC drive systems based on 24V to 80V battery systems have a strong track record in the materials handling industry, with power levels ranging from 5kW to 40kW for drive and pump units requiring an operating lifetime exceeding 20,000 hours.

Taking into account the 48V systems in electrical vehicles today, the arrangement includes not only the drive application but also the auxiliary drives (including the air-conditioning unit), the generator and the starter generator. It is important to note that the starter-generator unit for bus and truck applications is the most demanding of these subsystems. With vehicle lifetimes of more than 12 years and operating lifetimes of more than 45,000 hours, these specific requirements exceed those known from the materials handling sector.

Long operating lifetimes are always a challenge, even when power demand is only at 5kW continuous, as is found in bus and truck generators. Thermally driven aging of components, such as electrolytic capacitors, limits the overall operating lifetime. One measure to overcome this is a lower temperature; however, sufficient cooling is typically not available.

Yet it is not only the long operating lifetime that is a challenge for the inverter. Assuming one start/stop operation per minute, the system needs to support about 2.7 million start/stop operations, with very high peak currents of up to 900A for intervals of less than one second. This pulsing load puts high thermal stress on the interconnect technology of the power part.

The approach to handle these requirements in Semikron's SKAI2 LV inverters is to combine its windmill-proven SkiiP technology with the lowest ohmic switches for minimal heat generation. By reducing the resistance to 0.3mΩ per switch in 48V systems, the temperature levels could be lowered significantly.

Start/stop starter-generator systems are ideal for bus and truck applications

The SKAI2 low-voltage single inverter system 72V DC (48V nominal) with 0.3mΩ per switch

SkiiP technology not only delivers a highly reliable interconnect system, but also allows for the assembly of power switches in a dense configuration, which is mandatory for precise control and high switching frequencies. This combination opens up the opportunity to build air-cooled systems without separate fans, where otherwise forced air would be required via forced air-cooled systems. Water-cooled systems would also be needed.

The SKAI2 inverter hardware and the Quasar motor control software are a tested bundle. The rugged and compact design of the inverter together with the accurate control provided by the Quasar software make this package ideal for vehicle designs that require high reliability and precise control.

But the SKAI2 inverter is not just a component; it represents a network of partners: Semikron as the inverter manufacturer; SKAltek as the software provider; and Drivetek for engineering services. When combined, these three partners and the SKA12 technology realize optimal real-world solutions for the customer and allow for the full implementation of customer-specific solutions to meet specific application requirements.

The SKAI2 LV product family supports battery-powered drives with an extensive range of robust inverters, each fitted with a wide set of freely programmable additional functions in addition to the main inverter. Developed for batteries from 48V to 120V and supported by air or liquid cooling, the systems come with an IP67-rated enclosure that can sustain vibration amplitudes of up to 10G_{rms}. The systems can comprise single inverters but are also available as dual inverters to operate two individual motors completely independently.

The SKAI2 LV family fits into many applications, such as auxiliary drives or the powertrains of materials handling machinery, generator and starter-generator systems, as well as small off-road vehicles.

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ONLINE READER ENQUIRY NO. 532

Wireless charging solution

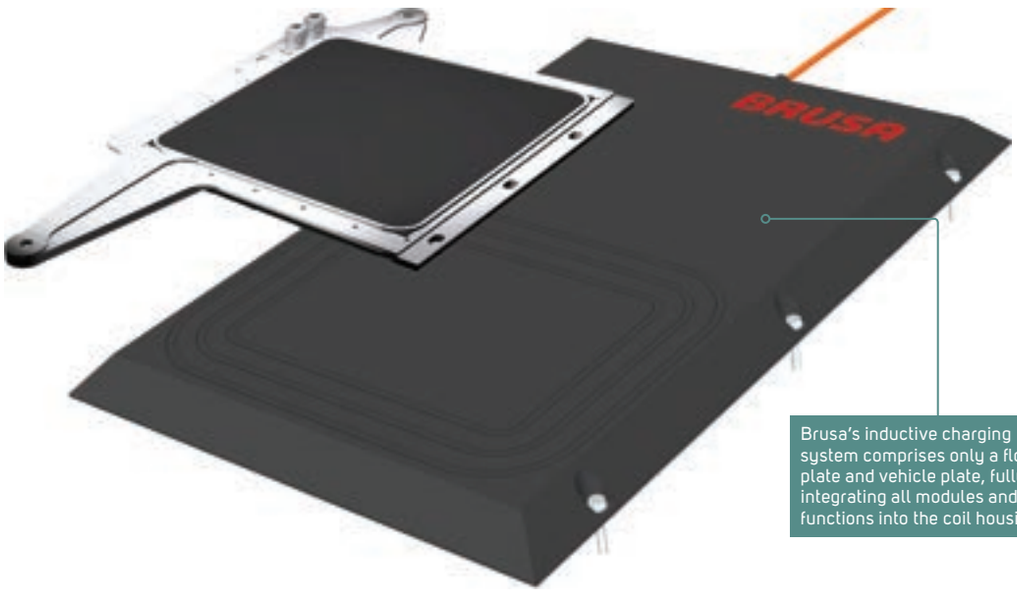
With fewer components and integrated power electronics, advances in inductive charging systems are helping to improve wireless charging capabilities in electric and hybrid vehicles

Brusa Elektronik concurs with the view of experts that in the future it will become increasingly commonplace for electric vehicles to be charged wirelessly – and that this increase in convenience will lead to a further reduction in the obstacles to e-mobility.

This trend has also been identified by other manufacturers, who are already developing inductive charging systems (ICS). Existing implementations of inductive charging systems comprise two current coils: a primary coil located on the floor or, for instance, embedded in the road; and a secondary coil on the underside of the vehicle. The primary side includes a wall box that contains the power electronics and supplies the primary coil.

Other functions are also required, for example, for foreign-object and living-object detection. On the vehicle side, besides the secondary coil, a further module is needed, containing a power control unit, AC/DC converter and other communication components.

However, Brusa has adopted a different approach with its ICS. Instead of utilizing multiple separate components, it has succeeded in integrating all the modules and functions into the coil housings. This means the ICS comprises only the floor plate and vehicle plate.



Brusa's inductive charging system comprises only a floor plate and vehicle plate, fully integrating all modules and functions into the coil housing

Brusa's ICS is designed for everyday use. It incorporates a host of safety features, including foreign-object and living-object detection. The charging system activates automatically as soon as the vehicle is in the correct position, with the vehicle and floor plate communicating via the wireless LAN standard 802.11p. The floor plate offers advanced connectivity via a power line communication (PLC).

In addition to space and cost savings, the Brusa ICS offers other benefits such as a vast improvement in electromagnetic compatibility because there is no longer any need for meters of HF cabling between the wall box and primary coil. Installation of the floor plate in the end customer's garage is easy because it can simply be connected to the home's consumer unit (230V/16A).

Moreover, because the entire floor plate weighs less than 20kg, the customer can handle it with ease. OEMs also benefit from shorter production and vehicle integration times because they have to install only one component: the fully integrated vehicle plate.

The overall system also boasts an efficiency rating of approximately 92%, making it just as efficient as conductive charging systems. Indeed, the ICS recently won the Energy, Infrastructure, Connection Technology category at the eCarTec Awards 2013.

Since 1985, Brusa Elektronik has focused exclusively on developing and manufacturing powerful and highly efficient electronic components and drives for electric vehicles. In the area of charging technology, in particular, the company has made a name for itself with its versatile chargers: Brusa chargers have been a standard component in thousands of electric vehicles around the world for more than 10 years. With the ICS, Brusa Elektronik is helping to drive forward future developments in the area of wireless charging.

Brusa's ICS won the Energy, Infrastructure, Connection Technology category at the eCarTec Awards 2013

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ONLINE READER ENQUIRY NO. 533

Vibration test uptime

One supplier is offering complete vibration testing solutions for the accelerated lifetime testing of components and batteries, and takes care of all maintenance and servicing requirements

Vibration testing faithfully condenses the stresses and hazards that components, batteries and sub-assemblies will endure over a lifetime on the road. With vibration testing, innovators can fully test the durability of all new vehicle components over a full projected lifecycle, but in a much shorter time.

Over 10,000 red LDS shakers are used around the world today for accelerated lifetime simulation of components and sub-assemblies, squeak and rattle testing, modal test excitation and more. Versions are available to suit any test object imaginable, and range from hand-sized modal exciters with 9N of force, through rugged, air-cooled electronic component testers, right up to 400kN water-cooled behemoths for precisely shaking the life out of electric truck batteries.

As standard, there are three dedicated hybrid/electric battery test systems available, and each can comfortably operate with off-center loads, such as irregular battery shapes. This is thanks to large guided-head expanders for holding large loads during vertical-axis testing, and slip tables for horizontal testing. The actual electro-dynamic shaker unit connects to both of these test platforms when needed, and can quickly rotate to power whichever surface is required. These three turnkey systems suit 500kg, 750kg and 1,500kg batteries respectively, and come complete with controllers, amplifiers, training and the option of a maintenance and servicing agreement.

For specific requirements, such as simulating cycles between cold and heat extremes of -40°C to +140°C, shakers need special interfaces to environmental chambers. A host of tailored options are available, such as custom cooling arrangements for noise limitations or cleanrooms, combinations of shakers for large or irregular objects, and bespoke mounting fittings to secure specific components. In fact, the majority of Brüel & Kjær's LDS customers specify a project-based installation.

Brüel & Kjær's LDS vibration test solutions cover everything from hand-sized shakers up to monsters like this, and include controllers, amplifiers, maintenance agreements and training

Road-induced vibration and shock affect the performance of all vehicle and powertrain components, so vibration control software precisely emulates these factors with high acceleration levels and random bumps. Modern Brüel & Kjær kurtosis control software improves on traditional gaussian random signals, to more accurately represent the peaky vibration signals seen in the real-life use of many products, especially over condensed timeframes. Consequently, the test object spends a more realistic amount of time at very high acceleration levels.

In such intense test schedules, vibration test systems need to be tough on a level that far surpasses most of the components they test. Destroying objects with precise force time and again, day in and day out, means they must be designed, built and – crucially – maintained to demanding specifications. One LDS shaker at Valeo, France, has run for over 74,131 hours since 1999 – that's more than 16 hours a day for 14 years! And the only reason it is still testing alternators as dependably as when it was new is thanks to a regular maintenance plan from Brüel & Kjær. Under that agreement, major maintenance is carried out every three years, and minor maintenance every other year.

Service agreements keep downtime to an absolute minimum, through scheduled maintenance that allows customers to plan their test schedules in advance. They entitle holders to fast advice and help, and quick access to local inventories of OEM-produced spare parts. After calling the global customer service organization with a query, customers are directed to the appropriate sales, support or field service specialists, so they quickly get people with the skills they need, from the largest service team in the industry. Service and maintenance agreements complete the solution available from Brüel & Kjær, so customers can focus on their business while their test systems enjoy maximum uptime.

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ONLINE READER ENQUIRY NO. 534

EV drivetrain economics

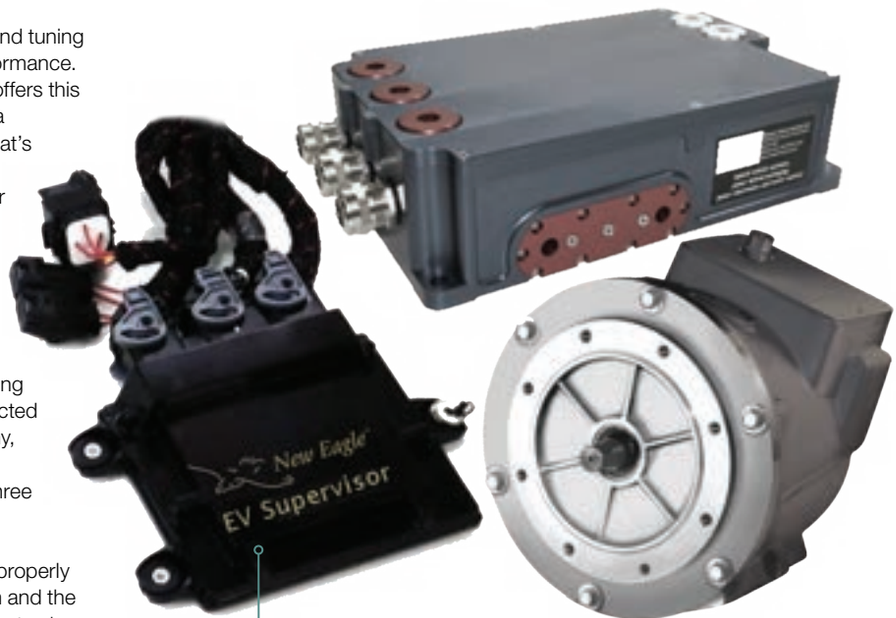
Built on proven supervisor software and automotive production hardware and components, a new EV drivetrain already designed and validated reduces vehicle build time and total cost

Historically, the creation of an electric or hybrid vehicle requires considerable development time and money. This is due to the complexity of the vehicle technology and the associated component cost. New Eagle provides an alternative to this strategy with a complete EV drivetrain system that has already been designed and validated. This system leverages proven supervisory software and electrical design coupled with automotive grade components all created to work together. Collectively, this greatly reduces vehicle build time and total cost. The drivetrain can be used in fleet vehicle conversions, new OEM vehicles, aftermarket kits and many other applications. This approach reshapes the economics of building an electric or hybrid vehicle and enables this technology to be newly accessible to many vehicle markets and customers.

The most crucial aspect of New Eagle's electric and hybrid drivetrain is the supervisor software. This software serves as the total vehicle control, by making decisions to ensure proper commands and vehicle operation. Some features of this offering include an HV startup and shutdown sequence, torque security, power management, component interfaces and tuning for driveability and performance. In addition, New Eagle offers this proprietary software in a pre-flashed controller that's designed to work with many inverter and motor combinations right out of the box.

New Eagle builds electric and hybrid systems around the best available components by leveraging relationships with respected suppliers including Remy, Delphi, Parker, UQM, Sevcon, Phoenix, VeeThree and Woodward. The wide supply base gives customers access to a properly sized propulsion system and the right supplier for the target volumes and vehicle size. The kits are expandable to incorporate a range of products, including electric motors, motor inverters, battery management systems, HVAC, CAN networking, low- and high-voltage electrical distribution, custom color displays and the controller hardware to integrate the solution.

New Eagle has assisted in the development of dozens of electric and hybrid vehicles of all types and sizes. These vehicles can be found all over the world, ranging from on- and off-highway prototypes to production vehicles. Two particular customers are Boulder Electric Vehicles and Zenith Motors. Both use a combination of New Eagle's supervisor software and EV system for delivery and passenger shuttles.



EV supervisor software on production hardware parts

The transitional nature of electric technology requires the control software and tools to be built on a flexible platform. New Eagle's supervisory software is based on validated software libraries and flexible tool chains. The software is built with a model-based design approach to enable quick additions of new features and customer-specific requirements. New Eagle also offers telematics solutions and builds software tools to assist in the development of complex systems.

Finally, New Eagle offers a complete electric or hybrid system and the company is uniquely poised to offer assistance to the next fleet or OEM conversion company. By leveraging the experience and existing design to manage this complex technology, there are new opportunities for customers to partner with New Eagle to bring their vehicles to market at a fraction of the cost.

New Eagle systems are found in a wide variety of vehicle applications

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ONLINE READER ENQUIRY NO. 535

E-mobility solutions

A new battery system based on lithium-iron-phosphate technology is being applied to an increasingly varied range of commercial EV applications, from trucks to trolley buses

Since its establishment in 1988 in the German town of Delbrueck, Paragon AG has steadily grown to become one of the best-known suppliers to the automotive industry. Listed on the stock exchange since 2000, Paragon uses innovative solutions that not only improve communication but also make the driving experience healthier, more comfortable and more efficient. Every employee at Paragon is passionate about automobiles. Every day they strive to be inventive, better and unique in all they do. Their dedication goes far beyond sensors and solutions for automotive interiors, however. Increasingly, Paragon has been embracing more sophisticated systems in segments such as electromobility, including high-power battery systems and body works kinematics.

Paragon's new F-Power battery system is based on modern high-performance lithium-iron-phosphate ($LiFePO_4$) cylindric cells (type 26650). The advantages of $LiFePO_4$ include no thermal runaway, very high cycle life, high efficiency (up to 95%), very low self-discharge (as low as 1%), and good energy density (by weight and by volume).

Thanks to an intelligent system set concept, Paragon is able to apply the best batteries to nearly any requirement of hybrid and pure electric vehicles, making the batteries quickly and cost efficiently.

Paragon's application engineers have created a sophisticated battery configuration tool. This tool is fed with all customer requirements and recommends the very best cell chemistry and electrical interconnection in order to meet the required capacity and voltage level, as well as the physical dimensions and optimum solution for heating and cooling.

Combined with Paragon's enhanced analysis software, it is possible to check all of the operating requirements against the suggested configurator concept. Naturally all standard driving cycles can be simulated (including NEDC, FTP75, Artemis URMXXX, US06, EUROPA ECE 15, JAPAN 10-mode, Artemis Urban, Hyzem Urban, USA NYCC, modem IM UrbanFreeFlow, modem IM UrbanSlow, PVU LightVan LUrban).

Modern trolley buses from central Europe to the USA now use Paragon's battery packs, located on top of the vehicle roof, to power their dual mode drivetrains

Paragon's F-Power battery system combines a stainless steel shell with a cutting edge BMS and climate control

The Paragon system set allows arbitrary parallel and/or serial battery configurations to achieve the right voltage level and capacity. The range covers capacities from 10kWh to 1,000kWh and voltages from 3V to 850V.

Combined with a robust, stainless steel containment; a self-controlled climate and heating installation; a state-of-the-art battery management system to fulfill functional safety requirements according to ISO 26262; and unique solutions for service and support, Paragon battery systems are ready for industry-leading applications.

All batteries are validated following extensive testing at established laboratories that use the latest equipment, according to common automotive specifications, such as inclusive shock and vibration, EMC and climatic tests. Today, various vehicles powered by Paragon batteries have proved their robustness in an array of climate zones from sub-zero Scandinavia to red-hot southern California.

Many applications have been in use in light commercial trucks, agricultural and ground handling vehicles for a number of years. In addition, Paragon battery packs now power modern trolley buses with dual mode drivetrains. In the near future, pure electric buses will also be powered by Paragon batteries. Production plants in central Europe and the USA ensure proximity to the customer.

The lithium-iron-phosphate cylindric cells used inside Paragon's F-Power battery system boast higher efficiency

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ONLINE READER ENQUIRY NO. 536

FPGA motor simulation

Field-programmable gate arrays are replacing commercial central processing units in order to successfully achieve high-fidelity simulation for testing control units for electric motor drives

As new generations of EVs and HEVs continue to roll off assembly lines, OEMs are looking to extract every bit of efficiency out of the electric motors in their vehicles, while ensuring safe and reliable performance. A critical part of achieving this objective is having an effective control unit for the motor drive. The control unit optimizes and maintains performance over a range of operating conditions and also compensates for nonlinear effects such as field saturation and high-order harmonics. Furthermore, the controller needs to operate safely in failure modes, for example when there is a fault in the power electronics that drive the motor.

For the mechanical systems in vehicles, such as IC engines and transmissions, controllers are tested and validated using hardware-in-the-loop (HIL) simulation. HIL simulation connects the controller used in the vehicle with a simulated engine or transmission. This process enables the controller to be tested safely, quickly and cost-effectively, as a controller failure will only result in failure of the simulated engine or transmission. However, if the controller were tested in a lab with an actual engine or transmission, the engine or transmission could be damaged, and replacement is both expensive and time-consuming.

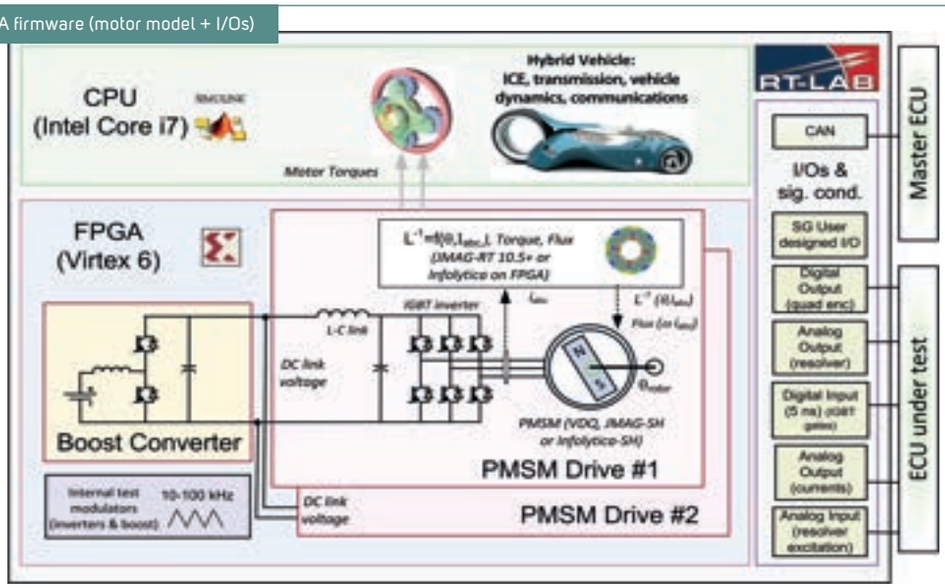
Mechanical systems typically have slower dynamics that can be simulated in real time using time steps of around 1ms. However, electric motor drives are typically driven by switching pulses that occur at 10s of kHz, and thus, real-time simulation of electric motor drives requires simulation time steps of the order of 1µs. Achieving these time steps is not possible on commercial CPUs, so high-fidelity simulation of electric motors has to be done on field-programmable gate arrays (FPGAs). FPGAs, however, are very difficult to program because one has to deal with low-level considerations such as fixed-point scaling and timing synchronization during execution.

The architecture of the FPGA-based simulation testing used by OPAL-RT

OPAL-RT has created a suite of tools to make FPGA-based simulation accessible to engineers developing controllers for electric drives. First, a set of real-time motor models, covering a wide range of motors used for automotive applications including PMSMs, SRMs and BLDC motors, has been pre-packaged to run on FPGAs. The users do not need to know how to program an FPGA for simulation; they merely need to parameterize the motor appropriately using an intuitive GUI. The simulated motor inputs and outputs are converted to signals that can then be connected to the controller to complete the test setup. Next, the FPGA motor-test package enables the user to create power electronics faults to validate failure-mode operation of the controller. Third, the motor simulation can be integrated with a full-vehicle simulation running on a CPU for integration with other controllers, such as an ABS controller, that may need to be tested. Finally, OPAL-RT provides a test automation package that allows the development of test scripts to run whole batches of test sequences, thus providing an efficient method of conducting exhaustive controller testing.

FPGA-based simulation testing is a powerful method that ensures the controllers for next-generation electric drives meet exacting performance requirements. OPAL-RT is making this technology accessible to every automotive engineer in the field.

FPGA firmware (motor model + I/Os)



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ONLINE READER ENQUIRY NO. 537

integral powertrain

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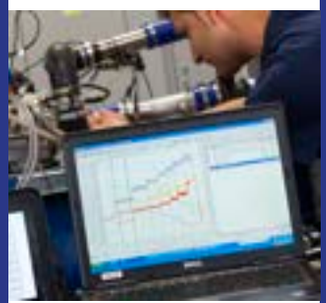
As a powertrain specialist, **Integral Powertrain** supports OEMs and Tier 1 suppliers in delivering competitive products to market. Our client list includes many prestigious companies in the UK, Europe, Asia and North America, operating in a wide range of sectors including passenger cars, on and off highway CVs and aerospace. Projects are undertaken at our Engineering Centre and at our advanced Emission and Climatic Test Centre (ECTC), both located in Milton Keynes.



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If you would like further information on our unique range of services and innovative technologies, please contact:

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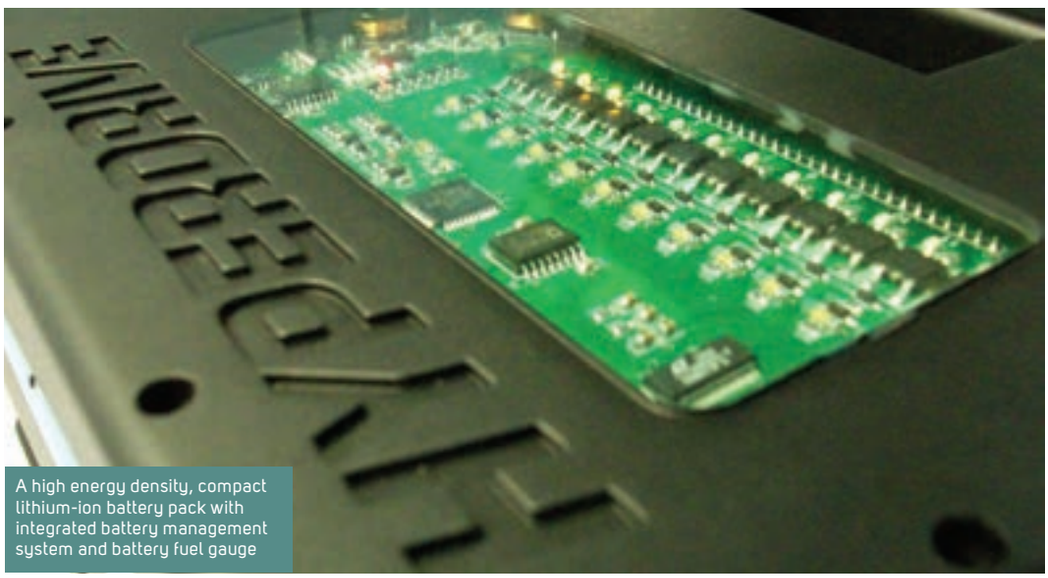
Range extending electronics

The compromise between battery size and vehicle range remains a challenge for all OEMs, but there is plenty of scope for innovative electronics to make a long-lasting impression

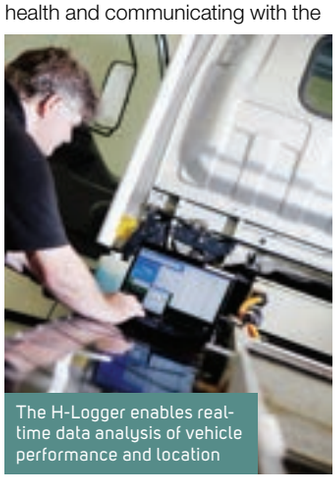
The range of pure electric vehicles is now up to around 115km (70 miles) but this driving distance can vary hugely depending on ambient temperature, driving style and use of ancillary systems. The recently launched Tesla model S is exceptional, with a marketed range of up to 425km (265 miles) from its large 85kWh battery pack.

Battery cell technology is improving all the time, and the commonly used lithium-ion chemistries cells now achieve up to 200Wh/kg. The automotive industry has a target to double this capability within five years, but even so, these batteries will still offer only around 1/30 of the energy density of petrol or diesel fuel. This issue will continue to restrict battery technology in automotive applications.

Hyperdrive Innovation manufactures battery packs, incorporating the company's in-house-developed sophisticated BMS, which automatically manages balancing between cells to optimize energy consumption and range. The BMS fits different cell chemistries and arrangements, controlling the charge and discharge of the individual cells, monitoring cell health and communicating with the other vehicle systems via the CAN. A separate fuel gauge product gives an immediate visual indication of the energy in each cell.



A high energy density, compact lithium-ion battery pack with integrated battery management system and battery fuel gauge



The H-Logger enables real-time data analysis of vehicle performance and location

Nevertheless, the challenges associated with incorporating heavier and more expensive batteries to provide more energy storage for electric vehicles and solve range anxiety will continue to hold back the industry.

Complementing the development of better batteries and BMS, range-extended electric technologies have a major role to play in increasing the uptake of low-carbon vehicles.

Not to be confused with parallel hybrids, range-extended electric vehicles are designed to be run from the battery, but have a petrol or diesel IC generator to recharge as required. Electrical drive backed up by conventional liquid fuel reduces the battery size and recharging times.

Hyperdrive Innovation has proved its range-extended electric systems with modified petrol and diesel IC engines, and these are now being deployed in new vehicles. The generator runs at its most efficient operating point and is turned off when not needed, for example while sitting in traffic or when the battery charge reaches its upper threshold.

In high-performance hybrid applications, such as racing cars, power density – high power and low weight – is the key requirement for maximum acceleration. Supercapacitor technologies can make a dramatic impact on performance when used to recover and reuse energy that would normally be wasted.

Hyperdrive's technology is attracting interest from outside the automotive sector, and can be adapted for industrial, marine and defense applications. Current projects include the development of new sensors in a drive-by-wire system on a combine harvester, and the design and build of complete hybrid powertrains for an unmanned marine vessel. The approach to developing an integrated electric drivetrain will usually necessitate new designs for electric circuits, firmware and battery packs.

The potential for better vehicle management to achieve efficiency gains shouldn't be underestimated, particularly for commercial fleet managers. Hyperdrive's H-Logger is a vehicle datalogger and telemetry system that enables any signal on the vehicle CAN to be recorded on board and sent via the mobile phone network to a secure server for storage. This has proved extremely effective in trials of new vehicles, where real-time data on vehicle location and fuel consumption can be accessed and monitored online at any time.

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PEV charging capabilities

Heavy-duty plug-in electric applications could benefit from a newly developed high-voltage three-phase onboard lithium-ion charger series that reduces costs and boosts performance

EDN Group, a full-service company established in 1993 that specializes in designing and manufacturing custom and standard power-converter solutions, recently announced the realization of a pure three-phase onboard charger series, from 11kW to 44kW, and up to 900V DC, to be mounted in heavy-duty plug-in electric vehicles (PEVs) such as trucks, buses and boats.

The novel converter architecture provides the best performance in terms of efficiency, power density, safety, durability and cost, raising customer expectations to a new level in the process, while also finally permitting onboard fast-charging in several different applications.

The new series meets all EU and US safety and electromagnetic compatibility (EMC) requirements, complying specifically with IEC 61851-1, SAE J1772, ISO 6469 and ECE R100. Two CAN interfaces will provide vehicle CAN and diagnostics, while SAE J1939 is also made available.

The company is also involved in the development of a bidirectional charger to enhance PEVs with vehicle-to-grid (V2G) services and exportable power (V2L, V2H) capabilities. The cost savings achieved by combining a versatile mobile system, grid power services and reverse flow capability, creates a new revenue stream for customers that reduces the time needed to offset a PEV's incremental cost compared with traditional mobile power generation systems. Features such as frequency regulation, volt/VAR optimization, spinning reserve, installation peak shaving, receptacles for tools and much more, can help the adoption of PEVs as a capital investment for a cleaner and quieter tomorrow. V2G chargers will be compliant with emerging standards. The product will be scalable with power ranges from 6.6kW to 22kW, single and three-phase line-voltages, and HVDC output up to 1,000V DC, providing compatibility with all US and EU electric passenger car and truck applications. The converter modules can be connected in parallel to efficiently increase offboard power capability.

EDN Group's high frequency battery chargers are used in industrial and commercial EVs

Efficient algorithms provide extremely fast charge times compared with non-controlled traditional battery chargers

A smart charging curve eliminates overcharging and prevents sulfate accumulation within the charger

EDN Group is a power converter expert in high-frequency battery chargers, DC/DC and power supplies. It offers a wide range of products from 3kW to 30kW, and up to 1,000V DC, for battery-powered vehicles. All converters are ready to be plugged in, from 120V AC to 480V AC, three-phase or single-phase mains lines, to permit useful recharging everywhere. This, combined with IEC61851 and SAE J1772 compliance, high protection (IP67, IP6K9K), high efficiency, water and air cooling, and safe and reliable operation in an outdoor environment, makes for a very usable charger module in every onboard PEV application.

The CAN V2.0B interface ensures excellent diagnostic, compatibility and parameter control for all battery management system technologies. EDN has extensive competence in designing power converters such as battery chargers, DC/DC and AC/DC converters suitable for PEV and PHEV applications. The company's know-how and core competence provides its customers with fast, cost-effective and customized solutions. There are numerous ways to make e-mobility sustainable, and EDN Group is absolutely committed to that vision.

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ONLINE READER ENQUIRY NO. 539

High efficiency 50kW drive system for e-mobility applications

Kolektor has unveiled its new high-efficiency 50kW drive system targeting e-mobility applications. The drive consists of a high-performance KM-400/50 motor-generator and a KMC-400/230 electronic controller, which is able to run in motor or generator modes. Units are available as a kit or as separate parts.

The KM-400/50 motor is based on robust radial flux brushless technology with continuous output power of 50kW at 7,000rpm, where it exhibits over 96% efficiency. Designed as a liquid cooled motor, it places special attention on the aggressive cooling of media such as salt water. When taking into consideration e-mobility applications, special attention is given to the construction of a vibration-tolerant solution. The unit is also equipped with integrated temperature and position sensors.

The KMC-400/230 electronic controller supports the electric requirements of the motor-generator. It can operate from 50V DC to 420V DC, while delivering a motor current of up to 250A per phase. The controller comes in an IP67-rated enclosure and provides a CAN J-1939 communication interface, over which the system can be fully parameterized.

Kolektor
W. www.kolektor.com

ONLINE READER ENQUIRY NO. 540

Integrated starter generator for hybrid electric propulsion systems

L-3 Magnet-Motor (L-3 MM) has been building innovative hybrid electric propulsion systems for over 30 years and today is recognized as one of the leading experts in its field.

In 2008, L-3 MM introduced its integrated starter generator (ISG) system in a first prototype application. The innovative system links electrical and mechanical driveline elements and, in conjunction with a high-power battery, constitutes an integral part in any vehicle requiring additional onboard and exportable power. Since then, the ISG system has been broadened and advanced to allow for a wider range of applications.

The ISG system is made up of a generator, a power electronics unit and different converters. The generator has an impressively slim design, which allows for easy integration between the diesel and the transmission, either as a new build or as retrofit. Other features include water-cooling, permanent magnet excitation and low-voltage engine start. Corresponding power electronic units are equally water-cooled and, together with the generators, create a continuous power rating of 60-70kW and peaks of over 100kW.

For all of its ISG applications, L-3 MM has created a family of DC/DC and DC/AC converters for use with an onboard and exportable power system. Bidirectional and galvanically insulated converters serve a range of different power levels up to 30kW.

Future versions will be offered with high-power batteries and will allow for hybridization due to advantages such as increased performance, improved driving dynamics, low noise levels and environmental considerations.

L-3 Magnet-Motor
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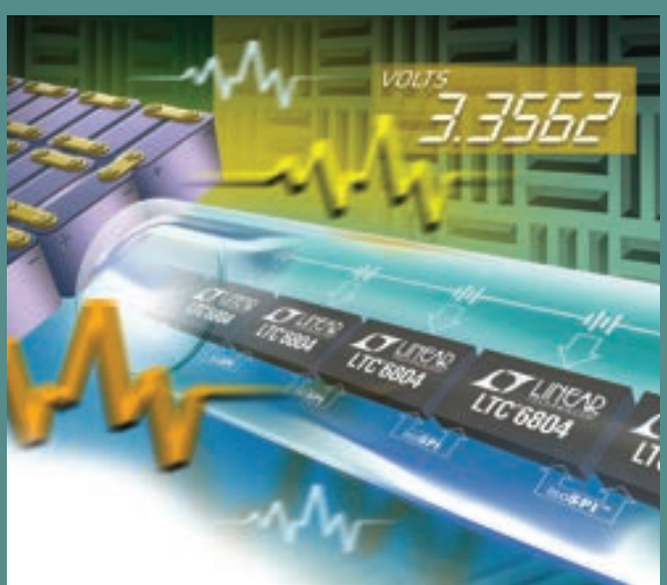
ONLINE READER ENQUIRY NO. 541

Guaranteed accuracy to within 0.04%



Linear Technology presents the new LTC6804 high-voltage battery monitor for hybrid electric and electric vehicles, and other high voltage, stacked-battery systems. An LTC6804 can measure up to 12 series connected battery cells at voltages up to 4.2V with 16-bit resolution and accuracy to within 0.04%.

This high precision is maintained over time, temperature and operating conditions by a sub-surface Zener voltage reference similar to references used in precision instrumentation. When stacked in series, the LTC6804 enables the measurement of every battery cell voltage in large high-voltage systems within 800µs. Six operating modes are available to optimize update rate, resolution and the low-pass response of the built-in third-order noise filter. In the fastest mode, all cells can be measured within 240µs.

Multiple LTC6804s can be interconnected over long distances and operated simultaneously using Linear Technology's proprietary two-wire isoSPI interface. Integrated into every LTC6804, the isoSPI interface provides high RF noise immunity up to 1Mbps and up to 100m of cable, using only a twisted pair.

The LTC6804 was designed to minimize power consumption, especially during long-term storage where battery drain is unacceptable. Samples, demonstration boards and the data sheet are now available.

Linear Technology
W. www.linear.com

ONLINE READER ENQUIRY NO. 542

High-performance lithium-ion battery systems

Fast sports cars and electric drives are no longer a contradiction. Akasol in Darmstadt has contributed to this development thanks to its highly efficient lithium-ion batteries. Besides several Artega SEs, the Lampo3 and the Roding Roadster, the specialist for high-performance battery systems has now been able to equip an eRUF Porsche with its AkaSystem 16M lithium-ion battery system, which consists of 16 modules. The liquid-cooled lithium-ion batteries possess a total capacity of around 38kWh and a nominal voltage of 710V at a discharging rate that exceeds 300kW. The AkaSystem implemented in the eRUF uses two troughs and weighs around 300kg.

The know-how that Akasol gains from developing batteries for sports cars is also applied to other areas. At the beginning of August, the Darmstadt-based company announced that it was to cooperate with Bombardier. The venture will see Akasol supplying the battery systems for the Primove rail and road vehicle project – systems that, thanks to wireless charging technology, are able to employ induction to automatically fast charge with a performance of up to 200kW. The first applications of this project are being used in electric buses in Brunswick, Germany and electric trams in the Chinese metropolis of Nanjing. Akasol will have supplied 5MWh to 10MWh of its lithium-ion battery systems to Bombardier by the end of 2014, a volume that will increase to a mid to high double MWh figure from 2015.

Akasol
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ONLINE READER ENQUIRY NO. 543

ASIL D platform control unit for the electric powertrain

Specially developed for monitoring and controlling electric powertrains, the latest platform control unit from TTTech Automotive, called the electric Powertrain Monitoring Unit (ePMU), enables flexible integration together with power inverters and DC/DC converters for different power ratings and also allows the integration of customer developed software functions for various safety levels (up to ASIL D).

The hardware and software of the ePMU were developed in compliance with the functional safety standard ISO 26262 ASIL D. The powerful controller kernel of the ePMU was specifically designed for safety-related automotive applications. The ePMU provides interfaces to various actuators and sensors, but at the same time it is the central system interface to the communication network of electric and hybrid vehicles. Embedded in the overall vehicle safety concept, the ePMU prevents the drivetrain from behaving uncontrollably in a variety of fault scenarios of the power inverter (such as unintended vehicle acceleration).

The core task of the ePMU is the accurate monitoring of the drive torque by means of constant comparison of the requested torque (set by the driver) with the actual torque at the drive wheels. A particular challenge is the safe detection of the rotation direction in the speed range close to vehicle standstill (0-2km/h).

Furthermore, the ePMU makes it possible to use OEM-, Tier 1- and Tier 2-specific software applications and basic software components that conform to the AUTOSAR standard or use existing (legacy) software.

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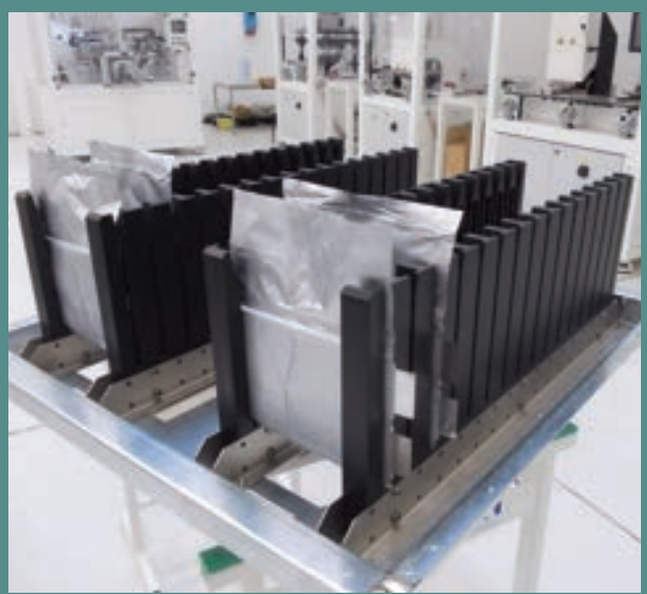
ONLINE READER ENQUIRY NO. 544

Testing innovation for advanced chemistries



Few companies have found themselves facing a once-in-a-generation opportunity to reshape not just an industry but a technology – and embraced it with such foresight as Bitrode.

Among the first in testing to recognize the potential in advancing hybrid and electric vehicle technology, Bitrode launched development and production of its first high-power, high-speed HEV equipment and test systems for cell, module and pack level testing well before auto makers stepped up investment in HV, EV and HEV technologies early in the last decade. Bitrode test equipment, known as the FTV Line, performs advanced applications that require fast switching speeds, extensive data collection, and a CAN interface for cell, module and pack level testing to assure that these advanced batteries can pass rigorous standard tests. The unit's regenerative capabilities can also return power back to the power grid, thus virtually eliminating heat dissipation, and recycling electricity.

Since the release of Bitrode's first machine in 2003, the company has been an industry leader in complete turnkey solutions for HEV/EV cell, module, and pack testing, providing such clients as General Motors, Magna, Enersys and CATL with the means to advance their batteries' performance and accurately predict working life. Bitrode not only provides customized software engineering and tools, battery simulation, and other proprietary solutions for the most sophisticated of battery engineers, it is also among the very few companies with the capacity to provide complete turnkey solutions to manufacturing projects.

Bitrode continues to be a leading company in the testing sector in the support of advanced battery chemistries, not only within the EV movement, but also in the utility industry, which is now exploring new ways to manage and use traditional and new clean energy sources.

Bitrode
W. www.bitrode.com

ONLINE READER ENQUIRY NO. 546

PowerPac traction inverter

Arens' PowerPac traction inverters provide vehicle OEMs with compact, high-power reliability for truck, bus, agricultural and construction equipment applications. Arens' next-generation traction inverters are the result of nearly 13 years of production experience in the most demanding applications. With over 500 million vehicle miles, Arens' traction inverters are able to provide customers with reliable operation for years to come.

Arens' PowerPac inverters feature one of the industry's highest power density, automotive grade components, industry-leading power-cycle life, cast enclosures sealed to IP67/6K 9K, intelligent thermal protection and one of the smallest footprints available.

The standard PowerPac traction inverter is rated for 360V DC input with peak power of 60kVA, however, many variations are available. Arens can provide a custom variation for any specific vehicle and system requirement. Whether the customer requires a traction inverter, export power or power distribution, Arens is the source for medium- and heavy-duty hybrid vehicle solutions.

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ONLINE READER ENQUIRY NO. 545

Lightweight materials for future powertrain design

Axon Automotive has moved into a new and exciting phase of its development. It has been party to a vertical integration with FAR-UK, a revolutionary composites components design and manufacturing company. As a result of this move Axon Automotive can now look forward to improved end-to-end capability, access to further process development, and a wider commercial base with an enlarged network of contacts.

Axon Automotive is currently involved in developing a new automotive frame for an OEM. This is the result of many years of development and demonstrates that OEMs are looking very seriously at all the ways in which they can make their vehicles as light as possible. Watch out for more news of Axon's frame technology in the next issue of *Electric & Hybrid Vehicle Technology International*. The company believes that carbon fiber and other lightweight materials will become the future of all mainstream vehicles in the coming months.

It is as a result of this requirement that FAR-UK has been successful. OEMs and first tier suppliers are increasingly looking to find ways in which they can reduce vehicle weight and emissions as cost-effectively as possible. FAR-UK has innovative processes in composite design and manufacturing, while Axon Automotive has experienced carbon fiber experts who understand the market and have access to the latest technology.

FAR-UK's experience is built on many years of process and product development in the automotive industry. The team believes that its knowledge of materials development, lean thinking and continuous improvement will drive the performance of its customers' products and processes.

Axon Automotive
W. www.axonautomotive.com

ONLINE READER ENQUIRY NO. 547

Designing energy-efficient motors

Energy-efficient electric motors are essential in the design of next-generation hybrid and electric vehicles. For more than 30 years, Cedrat has developed simulation tools and specific expertise in the field of rotating machine modeling.

In 2D and 3D, the company's Flux software has become a reference and enables users to reproduce virtually the operation of motors, considering movement and electric circuit connections. The tool provides a deep insight into the physics and enables calculation of key characteristics such as losses or machine efficiency.

In order to search the design space in an efficient way, optimization techniques can be coupled to Flux. This can be used, for example, to find the best configurations that minimize the energy consumption of the machine during standard driving cycles.

As noise is a very important criterion for car users, the vibrations of the motor should be looked at very closely. As such, Flux proposes well-suited tools and couplings with vibro-acoustic simulation software. Once again, optimization can be used with noise reduction as a target.

Flux can be connected to control simulation or to system simulation tools, which results in a broader view of the global system performance. This is an essential element, since it is at system level that efficiency has a real meaning. The design of position and speed sensors, of electric valves actuators, evaluation of EMC issues and energy management are also typical topics covered by Cedrat's solutions in order to help car manufacturers and OEMs build more energy-efficient cars.

Cedrat
W. www.cedrat.com

ONLINE READER ENQUIRY NO. 548

High-efficiency electric powertrain solutions

Bonfiglioli Mobile Solutions has developed a range of products for several application areas within HEVs and EVs.

The Italian transmissions manufacturer, with 3,300 employees and numerous offices around the world, supplies the electric car market with low noise drives with a maximum torque output ranging from 1,000Nm to 3,000Nm, integrated with electric motors with power from 5kW to 45kW, driven by inverters. These solutions are supplied to customers who are proving silent, energy-efficient operation and extended autonomy from the battery in their vehicles, thanks to optimized gears and lightweight construction in cast aluminum.

Bonfiglioli is also leveraging its 50 years of experience to support the trend of electrification in its traditional areas of heavy-duty applications, where OEMs are looking for solutions that can increase efficiency, productivity and reduce the total cost of ownership for the end user. Bonfiglioli has proved to be a leading partner for machine manufacturers when it comes to powertrain electrification and when the hydraulic motors conventionally installed in the machines must be replaced by electric motors.

Noticeable results achieved by the company include being appointed the supplier of planetary driving axles by one of the world's leading manufacturers for electric counterbalanced forklifts, and winning innovation prizes at a leading trade fair for designing planetary electric wheel drives with very compact 44kW rated electric motors, used to move a 19-ton agricultural machine.

Bonfiglioli Mobile Solutions
W. www.bonfiglioli.com

ONLINE READER ENQUIRY NO. 549

Lightweight electronic all-wheel drive system

Global automotive supplier BorgWarner acquired the Traction Systems division of the Haldex Group in 2011, combining the all-wheel drive expertise of both companies to produce exciting innovations for the future. Recently, BorgWarner invited engineers to Arjeplog to test its electronic all-wheel drive (eAWD) system.

To serve the growing market for hybrid and electric cars, BorgWarner designed a lightweight, all-wheel drive system that offers the same traction and stability as a conventional mechanical four-wheel drive. Hybridization and the powertrain are combined into one compact, robust package consisting of two electric motors as a rear axle module. In addition, the system has a built-in torque vectoring function to selectively distribute driving torque to the wheels, which receive the precise amount of power needed for smooth vehicle yaw rotation for optimum handling and stability. The first electric engine provides propulsion torque to the rear wheels via a planetary gear arrangement. A much smaller electric motor adjusts the differential torque left to right between the rear wheels on a balance shaft for torque vectoring.

The system delivers increased stability and vehicle dynamics independent of vehicle speed. The always-active eAWD system can reduce fuel consumption by up to 25% compared with a conventional mechanical all-wheel drive system.

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ONLINE READER ENQUIRY NO. 550

Giving electrification a boost

Imagine a vehicle buyer could choose the level of electrification they want in their new model from a menu of finely graded steps. If the technology for that existed, vehicle manufacturers could offer more electrification levels in existing models. Car buyers would benefit by balancing the fuel savings they want against the system cost. This idea was Continental's starting point for developing the 48V Eco Drive. It closes the gap between an affordable 12V stop/start system that marks the entry level of electrification, and a high-voltage hybrid drive system that normally adds some serious cost to the vehicle.

The 48V Eco Drive system saves more fuel than a micro hybrid with 12V stop/start, but avoids the cost drivers of high voltages. Instead, the modular system offers mild hybrid functions at low voltage. It consists of four main components: a 48V water-cooled starter-generator that replaces the generator; an air-cooled 48V lithium-ion battery from the SK Continental E-motion venture stores energy; a bidirectional DC/DC converter; and a sophisticated energy management that controls the energy flows.

In its Eco Drive demonstrator car, the supplier measured fuel savings as high as 17-22% in inner-city traffic, compared to a conventional IC drive. During the NEDC cycle, with its lower share of transient operation, a 13% benefit could be demonstrated. To make integration in existing models easier, the Eco Drive can either be belt-driven or fully integrated.

Continental Automotive
W. www.conti-online.com

ONLINE READER ENQUIRY NO. 551

Hydrogen fuel cell power for heavy-duty vehicles

Heavy-duty vehicles (HDVs) such as trucks and buses are responsible for about a quarter of CO_2 emissions from road transport in the EU and for some 6% of total EU emissions. Despite some improvements in fuel consumption efficiency in recent years, HDV emissions are still rising, mainly due to increasing road freight traffic.

Hydrogen fuel cell powered buses are clean all-electric vehicles with many environmental and operational benefits. With hydrogen fuel cell power, there are no particulate emissions such as harmful PM2.5 and no greenhouse gases are produced. Hydrogenics offers one of the most cost-competitive, market-ready fuel cell power systems for both medium- and heavy-duty commercial vehicles with proven and unsurpassed durability and simple integration.

Hydrogen fuel cells are a proven technology, with many years of development. It has been very successful in powering transit fleets around the world, with benefits including smooth acceleration, quiet operation, high efficiency, long range, long operating life, and short refueling times. Each year, more and more zero-emissions vehicles that use hydrogen fuel cells enter into service. For example, in the upcoming months, a new fuel cell articulated bus will be running on the streets of Helmond, near Eindhoven, Netherlands, and four heavy-duty class 8 fuel cell trucks will be built for the city of Los Angeles – all of them using Hydrogenics' proven technology.

What's more, hydrogen fuel can be produced from local renewable clean energy sources such as hydroelectric, solar and wind energy. With the supply of electrolyzer equipment to more than 45 hydrogen fueling stations worldwide, Hydrogenics is helping customers across the full spectrum to enable zero-emissions transportation.

Hydrogenics
W. www.hydrogenics.com

ONLINE READER ENQUIRY NO. 552

New high-speed battery simulation system

For testing of HEV or EV powertrain products with a battery simulation system, Heinzinger can provide a new high-speed interface. With this system, it is possible to directly log on to the inner digital loop of the Heinzinger test bench energy systems (ERS series) to realize high-speed simulation of batteries.

A full duplex serial interface with a 10MB data transfer rate allows the operator to change the setting values continuously within an access time of <50µs and to receive the actual current and voltage measurement values in the same timeframe.

With this high-speed access, it is possible to connect the ERS system to an external computer such as a DSP, on which a calculation of a complex battery model is running. Every time a new result of the battery voltage setting calculation is available, it can be transferred with less than 50µs cycle time to the ERS closed-loop control. Afterward, and with a fresh actual current measurement value, a new battery model calculation can be started.

A check sum calculation, with additional time-out control for the data stream in both receive and transmit directions, guarantees a safe and stable communication to an external automation system.

The ERS series is available off-the-shelf in classes of 600V or 1,000V and includes many of the features needed for battery testing or battery simulation applications, and DC inverter test stands.

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ONLINE READER ENQUIRY NO. 553

Charging 2.0

In the future, more than 90% of all charging procedures will be completed at home or at work. Therefore, the creation of a full coverage e-charging station network, such as that for gasoline, is no longer the key issue. Of greater importance is the intelligent control of electricity sourcing during battery recharging. Keba's KeContact enables extremely comprehensive and finely tuned control of the charging process – and thus efficient load management.

A variety of charging strategies can be established using KeContact that allow an EV to be charged in an hour or overnight. Should several EVs or an entire vehicle fleet be connected to the wallboxes, it is then possible to determine for each one how fast, at what time, and which vehicle should be charged, even in the case of vehicles that can only be charged on the basis of IEC 61851 Mode 3.

For cars that are charged according to ISO 15118, the control unit can provide an even more differentiated charging strategy through its linkage of the data of the vehicle, the owner or fleet management, and the data of the power supplier. This is aimed at securing the most efficient and inexpensive charging procedure.

To avoid overloads, which as a rule constitute the most expensive electricity, KeContact limits the charge performance or shifts the charging point to a lower-cost window. In coordination with the energy provider, the system automatically reduces performance peaks and smoothes electricity intake, which, above all, saves costs.

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ONLINE READER ENQUIRY NO. 554

Hybrid and plug-in battery system developments

Johnson Matthey Battery Systems, the new name for Axeon, supports electric and hybrid vehicle manufacturers with battery design, development and supply for a wide range of demanding applications. The company works extremely closely with its major OEM customers to design and manufacture custom batteries.

Its battery systems can be found in vehicles as diverse as hybrid buses and trucks, to performance hybrid super cars; and from pure electric vehicles, to plug-in hybrids and range-extended electric vehicles. It is focused on optimizing battery performance, cost, weight, reliability and life.

The company has produced one of the highest performance automotive battery systems in the world, which provides a hybrid super car with 135kW (180kW peak) of instant additional power at the press of a button, from a battery pack that weighs just 92kg, resulting in a peak power-to-weight ratio of 1.96kW/kg. And through the EU-funded SmartBatt program, the company has achieved breakthrough energy density for production car battery packs at a system level of 148Wh/kg.

Johnson Matthey Battery Systems' technical capabilities include electrochemistry expertise, with an active technology roadmap for battery materials, specifically in the area of electro-active energy-storage materials; and electronics expertise, offering a full range of battery management systems depending on the application. The company also possesses strong credentials in the areas of battery safety, power management, quality and manufacturing technology. Johnson Matthey Battery Systems serves a range of major automotive customers and its battery systems have been used in groundbreaking EVs by Jaguar Land Rover and Rolls-Royce.

Johnson Matthey Battery Systems
W. www.matthey.com
ONLINE READER ENQUIRY NO. 555

Laminated flexible bus bars

Flex-Cable has been a pioneer in laminated flexible bus bars since the early days of modern electric cars. Most people think of round wires when they think of electrical conductors; however, bus bars have always been used when space is at a premium. Forma-Flex high-voltage bus bars are constructed using high-conductivity copper that is covered with an insulating material. The ends are fused, creating a solid and highly conductive termination point that can be tailored to meet customers' requirements.

Capable of much tighter packaging than round conductors, bus bars maintain the same voltage and current ratings as round conductors. Packaging of the conductors inside of the battery packs is easier with flat bus bars since the flat construction facilitates flat turns, bends and holding methods that allow for much tighter battery pack covers.

Cooling of the bus bar conductors is facilitated by a much greater surface area for a given conductor size. For instance, two 34mm^2 (2 AWG) conductors have an outside surface area of 390mm^2 per centimeter of length for the round conductor, and the outside surface area for the rectangular conductor is 500mm^2.

The fused ends of the laminated bus bar can be punched, sheared and formed to fit many different termination methods, which facilitates applying these to different module and pack configurations. Patented cell-to-cell connection bars, incorporating bending and flexing in all directions, lessen the stresses placed on the cell terminating hardware. These bars can be developed in a number of different configurations.

Each bus bar is made to order, from prototype quantities up to high volume production. Each completed unit is dimensionally checked and hi-pot tested before shipping. This one-piece construction eliminates the possibility of failure due to crimped connections, while making installation quick and easy.

Flex-Cable
W. www.flexcable.com
ONLINE READER ENQUIRY NO. 556

From the publisher of *Electric and Hybrid Marine Technology International*

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Lightweight material for EV battery components

The drive is on to make batteries lighter and stronger so that the cars they power are more energy efficient. A material that has emerged as a top candidate to achieve these objectives and support powertrain hybridization is Noryl resin, a modified polyphenylene ether (mPPE) material. This lightweight engineering thermoplastic resin helps to ensure long-term durability, save cost and improve power density – a key element to energy efficiency.

A number of vehicles on the road today use Noryl resin in battery components and the list is growing. They include Nissan's all-electric Leaf, which uses the resin for key components of its lithium-ion battery pack system to save up to 20% in weight for those parts; to benefit from the resin's long-term dimensional stability; and to achieve enhanced flame retardancy with a UL94 V-0 rating.

This application was a finalist in the Electrical Systems category of the Society of Plastics Engineers' (SPE's) Automotive Innovation Awards, the oldest and largest competition of its kind in the automotive and plastics industries. The Nissan Leaf joins the Volkswagen Touareg hybrid and the all-electric Ford Focus as vehicles with battery components featuring Noryl resin that have been recognized and honored as finalists in this distinguished competition.

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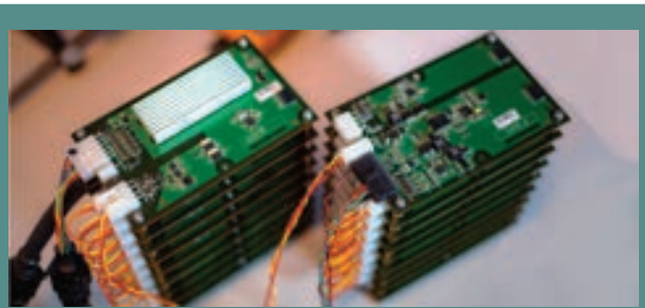
ONLINE READER ENQUIRY NO. 557



BMS advances for multi-applications

Lithium Balance has delivered battery management systems (BMS) for large-format lithium-ion batteries to industry for the past five years. The launch of version 6 of the company's successful s-BMS family provides customers with a short cut to a successful lithium-ion battery pack solution for almost any application on land, sea or air.

An accurate and high-performance BMS has been engineered onto an extremely EMC-resistant hardware platform (exceeding applicable environmental test standards by a factor of 7) that can handle packs up to 1,000V.

By making the CANbus platform configurable down to bit level, and providing a range of logical and arithmetical transformations on the data, the s-BMSv6 requires no tools beyond the PC software to perform a full CANbus integration with the application.

A high-effect balancing circuit means larger pack capacities can be effortlessly handled, while a choice of current sensors and a selection of installation accessories make light work of any integration.

For customers in a hurry, or for customers looking to save money on their battery implementation, the s-BMSv6 from Lithium Balance is a universal, safe and affordable choice.

Lithium Balance
W. www.lithiumbalance.com

ONLINE READER ENQUIRY NO. 558

Delivering a smarter route to EV infrastructure deployment

For companies serving the fast-developing EV infrastructure market, Delphi is ideally positioned to provide comprehensive support. Recognized as a global leader in the design and production of charging system solutions for low/zero-emissions vehicles, the company has created a portfolio of components that is fulfilling the needs of numerous OEMs around the world.

From the earliest stages of the EV/HEV development cycle, Delphi has worked in partnership with OEMs to pioneer the development of innovative products that meet the exacting demands of high-voltage automotive environments. Specifically for the EV infrastructure market, these include portable mode 2 electric vehicle supply equipment (EVSE), mode 3 charge coupler connector pigtails and jumpers, cable assemblies and inlets. All are fully compliant with relevant standards, GB/T 20234, IEC62196 Type II and SAE J1772, but at Delphi, such certifications only represent a starting point.

Leveraging extensive field experience, product specifications have been continually refined and enhanced to exceed these basic requirements and deliver outstanding reliability, durability and interoperability. Key features include different types of ergonomic handles, drain holes in order to prevent water accumulation, and multiple cable configurations from 16A single-phase to 32A three-phase.

"The next few years will see an explosion in demand for new EV charging stations," says Dirk Sänger, director global sales, commercial vehicles and transportation. "For companies looking to take advantage, Delphi offers all the commercial benefits of a global footprint, combined with a range of components that reflect in-depth understanding of the automotive sector."

Delphi
W. delphi.com

ONLINE READER ENQUIRY NO. 559

EV drivetrain optimization

As one of the UK's leading suppliers of electric drivetrains for commercial vehicles, Magtec is no stranger to the level of engineering that can be required to put an EV into revenue-generating service, with maximum performance, reliability, and a realistic ROI.

After more than 20 years of designing, manufacturing, supplying and installing both EV, and HEV drive systems for buses and commercial vehicles, including driver interfaces and whole-vehicle commissioning, Magtec is perfectly placed to act as a one-stop shop for vehicle OEMs and converters.

Magtec drive systems offer high efficiency and high performance, in a range of power ratings that are designed to be straightforward to integrate mechanically and electrically – while offering all of the benefits of the latest permanent-magnet technology in a cost-effective package.

So it was no surprise that when, during the summer of 2013, a major UK bus manufacturer required a better EV drivetrain for its existing, proven electric bus, it came to Magtec. Within two months, the first Magtec traction motor and controller had been installed and commissioned, packaging neatly into the envelope that the previous drivetrain occupied – allowing the vehicle to be type-approved and put into service with minimal fuss. In line with the predicted improvement in efficiency, the customer was able to reduce the installed capacity of its lithium-ion battery pack, further reducing costs and weight.

Following this success, Magtec has become the OEM's preferred drivetrain supplier, with scheduled weekly line-side deliveries enabling electric buses to be assembled alongside standard diesel vehicles.

Magtec
W. www.magtec.co.uk

ONLINE READER ENQUIRY NO. 560

Electric in-wheel motors primed for road-going EVs

Protean Electric's in-wheel motors deliver torque where it's needed, right at the wheel. The company creates new design freedom without the need for drive shafts or transmissions. So the creation of an all-new architecture or integration of hybrid, EV or plug-in-hybrid powertrains into an existing architecture just got a lot easier.

It is one thing to design show vehicles with in-wheel motors, but something else entirely to engineer them for the requirements of the global automotive market. Protean Electric is engineering in-wheel motors for OEM and Tier 1 commercial use, and they are now ready for a mainstream automotive development path.

How does the company address issues of unsprung mass, brakes, safety, durability, and shock and vibration, just to name a few? Protean Electric has a unique approach to designing out the old problems that have challenged in-wheel motors for more than 100 years.

The company's patented design integrates the power electronics, controls and friction brake into a single package that occupies the space behind an 18in conventional road wheel.

It has amazing power and efficiency, and two motors are sufficient for most light-duty cars, trucks, vans or crossovers. Protean Drive can also retrofit onto existing platforms, whether they start out as a front-wheel drive, rear-wheel drive, or an all-wheel drive application.

Think of it this way: what could a customer do with reduced fuel consumption and 100ps more in each wheel, all packaged in the space free behind the wheel? It's time to take a closer look.

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ONLINE READER ENQUIRY NO. 561

Battery management in vehicle electrification

The GRX-5000 EV Battery Module Diagnostic Station is a platform that was first created for Nissan's Leaf program. It can perform both battery module balancing and diagnostics, allowing OEMs to implement a more cost-effective battery pack service strategy.

An alternative strategy, supported by the GRX-5000, is to design and build the battery pack with removable modules in order for service to be performed below the pack level. Here, a pack with a problem could be removed from the vehicle and disassembled to the required module level. To confirm that the vehicle pack will function correctly with the replacement module, the GRX-5000 performs a balancing function to make sure it matches the correct state of charge/state of health for the given pack.

The GRX-5100 Hybrid Battery Pack Diagnostic Station has been specifically designed to perform a full pack service, including balancing, full discharge and diagnostics, or as a jump-start unit for either NiMH or lithium-based hybrid vehicles. It can perform a full pack discharge, so that damaged packs can be discharged to a safe level prior to vehicle storage, and can perform safety checks, diagnostics and discharge, whether a pack is in or out of the vehicle.

The HYB-1000 is a diagnostic tool for hybrid battery packs that enables driving tests to be performed while connected to the vehicle's onboard diagnostics system.

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ONLINE READER ENQUIRY NO. 562

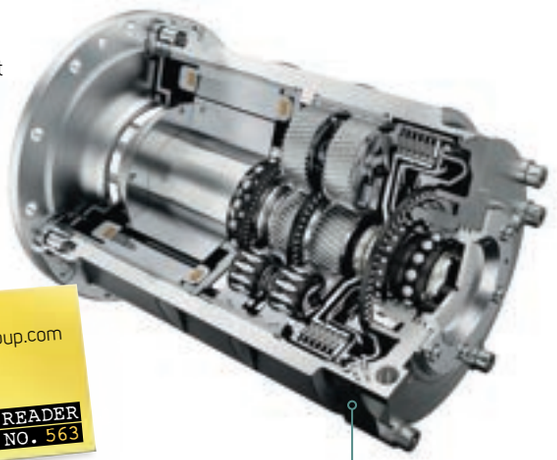
On the path to efficient mobility

The increasing electrification of the drivetrain will continue to make an important contribution to the energy efficiency of automobiles with IC engines.

Schaeffler – a renowned supplier to the automotive industry with headquarters in Herzogenaurach, Germany – offers a wide range of innovations in this field. This encompasses various solutions for comfortable high-performance engine start-stop functions, hybrid clutches, hybrid modules, and drive solutions for hybrid vehicles.

Many of Schaeffler's ideas for hybrid vehicles with a high-performance low-voltage power system are bundled together in Schaeffler's 48V system. The central element is a 48V drive module. "Using a 48V solution makes it possible to achieve outputs of up to 12kW," summarizes Professor Peter Gutzmer, CTO at Schaeffler. "This entry-level hybridization thus already offers the essential advantages of a hybrid vehicle and, at the same time, is an economically attractive, low-cost option that allows CO_2 emissions to be reduced by up to 15%."

Automobile manufacturers who decide to install a second low-voltage onboard electric system (48V in addition to the standard 12V system) can also integrate other suitable high-performance innovations into the vehicle. These include high-performance, rapid-reaction actuators that enable roll stiffness and ground clearance to be regulated, which has a positive effect on the vehicle's aerodynamics and therefore fuel consumption.



Schaeffler
W. www.schaeffler-group.com
ONLINE READER ENQUIRY NO. 563

Battery compartment foam sealants

High-performance foams with great compression set and low stress relaxation are used in a multitude of applications in the batteries of today and the new designs of the future.

Designers are constantly looking to optimize designs with high–performance materials that demonstrate proven durability for lasting performance to enhance battery life. As production speeds increase along with the demand for reliable environmental seals that provide excellent ingress protection even after opening and closing, design is becoming increasingly important. To further this challenge, designers must find materials that also meet stringent fire, smoke and toxicity ratings.

But foam materials prove useful inside the battery compartment as well. To ensure optimal performance, battery packs and cells must be protected from vibration and shock transferred from the road or the body of the vehicle. Additionally, using foams to absorb the expansion and retraction of pouch cells can help to extend battery life while providing more freedom in pack design.

Rogers Corporation's Poron urethane and Bisco silicone foams are industry-leading specialty materials that help increase the durability and reliability of hybrid and electric vehicles while allowing designers to design with confidence. In fact, Poron urethane and Bisco silicone materials are constantly being tested and developed to meet the evolving needs of this growing market.

Rogers Corporation
W. www.rogerscorp.com
ONLINE READER ENQUIRY NO. 564

Energy-efficient propulsion systems

UQM PowerPhase systems are intelligently designed for maximum performance and versatility. Providing up to 95% energy conversion efficiency, these production-ready propulsion systems consist of two primary frame sizes: up to 135kW for passenger vehicles and small trucks/vans and up to 250kW for larger trucks and buses.

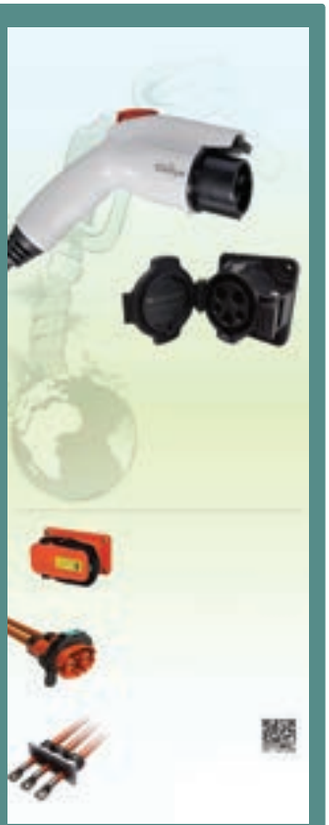
Each PowerPhase system consists of a high-performance, liquid-cooled permanent-magnet motor and a high-power, liquid-cooled inverter with a full-featured digital signal processor.

The innovative PowerPhase brushless permanent-magnet motor has been specifically developed to deliver high levels of torque efficiently at various rotational speeds, transitioning from high torque to a relatively constant power curve as the rotational speed increases. The motor can be operated in forward or reverse direction of rotation, and either in motor or generator mode, with the ability to dynamically change from one mode of operation to another in millisecond response time.

The UQM PowerPhase microprocessor-based digital power electronic controller includes high-power operation, four-quadrant control, reduced switching losses, adaptive switch timing control and controller area network (CAN) capability. The control software features a patented method of control referred to as phase timing advancement, which enables UQM PowerPhase motors to deliver both high-output torque at low operating speeds and high power at increased operating speeds. UQM's software algorithms alter the switching strategy as a function of DC voltage, operating speed, output power and temperature to optimize system performance under dynamically changing conditions.

UQM Technologies
W. www.uqm.com
ONLINE READER ENQUIRY NO. 565

Charging connectors



Suzhou Chilye Green Technology is a leading expert in EV and HEV high-voltage connection and distribution systems. The company provides standardized and customized connectivity products for EV and PHEV applications. Suzhou Chilye's premium products include SAE J1772 standard Level 1/Level 2 and DC Combo; IEC 62196 standard AC Type1/ Type2 and DC Combo; and GB/T 20234 standard AC and DC charging couples.

Suzhou Chilye's high-voltage product range for EV and HEV applications includes high-voltage distribution units, high-voltage connectors, manual service disconnectors, electric motor connectors and battery connection bus bars.

Suzhou Chilye Green Technology
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ONLINE READER ENQUIRY NO. 566

BVN four-terminal precision measuring resistor

Isabellenhütte Heusler has added the new BVN four-terminal resistor to its measuring resistor range. It is exceptional due to its small size of between 3.3mm and 4mm, plus its extremely low temperature coefficient of less than 50ppm/K.

The BVN combines small mechanical dimensions with high measuring accuracy and low temperature dependence. The BVN can handle continuous loads of up to 100A with a resistance value of 0.5mΩ. Overall, it has excellent stability over long periods and is suitable for a broad temperature range between -55°C and 170°C as well as for soldering temperatures of up to 350°C.

The BVN can also be mounted on a variety of circuit boards and substrates. It can be mounted on the traditional FR4 material used in most standard applications and on DCB ceramics for high-current applications. The components are suited to use on ceramic substrates thanks to their excellent thermal-cycling resistance and the minimal footprint in high-current applications (control electronics, power steering).

The BVN four-terminal measuring resistor is suitable for numerous automobile and industrial applications, including frequency converters in drive technology and power modules in inverters, as measuring resistors in power hybrids, and for high-current applications in vehicle technology.

Isabellenhütte Heusler
W. www.isabellenhuette.de
ONLINE READER ENQUIRY NO. 567

Electrolyte optimization for lithium-ion batteries

Wildcat Discovery Technologies (WDT) accelerates battery improvements by using unique high throughput tools to investigate hundreds of new materials in the time it takes standard laboratories to look at a handful. Although WDT initially focused mainly on cathode projects, it turns out another area of the battery is in even greater demand for WDT's approach: electrolytes.

New electrolytes are critical to the development of improved lithium-ion batteries, as they impact cycle life, cost, low- and high-temperature performance, and safety. New electrolyte formulation opportunities are nearly limitless due to the large number of components, combinations and electrochemical test variables. For example, a five-component formulation with solvents, salts, additives, ratios and concentrations yields thousands of potential solutions. It could take years to explore these myriad possibilities via conventional research methods. At WDT, an electrolyte optimization effort can be completed in weeks.

Electrolyte development at WDT is performed in full cells and incorporates the use of fixed cathode and anode films from customers. WDT then evaluates hundreds or even thousands of new electrolyte formulations in independent cells built with those same customer electrodes. Any DC electrochemical measurement is possible, including tests at low and high temperatures. WDT can also include real-time gas evolution measurements – a capability that is proving popular on projects targeting next-generation materials such as high voltage cathodes or silicon-containing anodes.

Wildcat Discovery Technologies
W. www.wildcatdiscovery.com
ONLINE READER ENQUIRY NO. 568

Power conversion and transformation for commercial vehicles

As the transit industry desires more sustainable hybrid, electric and fuel cell vehicles, electrification has become the trend. However, simply replacing a mechanical accessory system with an electric one doesn't guarantee success. These systems must also exercise a level of intelligence to take advantage of energy efficiencies.

Working with OEMs and transit authorities, Vanner has made intelligent electrification an integral part of product development. Vanner's Hybrid Beltless Alternator (HBA) is a high-voltage DC/DC converter that powers accessory loads traditionally supported by an alternator in addition to powering the latest electric cooling fans popular with transit authorities. A single HBA makes 300A at idle available for accessory load power and up to 600A at idle in a dual HBA configuration.

Transit agencies using this technology have reported little to no maintenance with the HBA, resulting in improved vehicle up-time and reduced maintenance costs. Some agencies report 10-15% fuel economy gains beyond hybrid savings. The combined fuel and maintenance savings deliver full cost return within a few years. All-electric vehicle DC/DC conversion is available in an Electric Beltless Alternator (EBA) configuration.

Distributing hybrid high-voltage output to accessories is accomplished via the use of a High Voltage Distribution Module (HVDM). It acts as an intelligent electrical grid by using a microprocessor to control timing and monitoring system functionality via the CAN J1939 link, then safely coordinating with other bus accessory components such as an electric air-conditioner.

Vanner
W. www.vanner.com
ONLINE READER ENQUIRY NO. 569

European Lead Battery Conference

Lead-acid batteries have been used in automobiles for over 100 years for the classic roles of starting, lighting and ignition (SLI). The technology is often regarded as mature, with little prospect of major improvement or capability of breaking into new applications.

However, in recent years intensive research and development activity has taken place under the auspices of the Advanced Lead Acid Battery Consortium, with the result that batteries with vastly improved properties and performance have become widely available, providing automotive makers with the capability to achieve great improvements in fuel economy and CO_2 emissions at minimal extra cost.

For example, stop/start technology using advanced lead-acid batteries has emerged as standard on most vehicles. Mild hybrids based on lead-acid batteries are also entirely feasible – demonstration vehicles with lead batteries have already achieved over 160,000km under road conditions. Using advanced lead-carbon batteries, a super hybrid demonstrator achieved 25% CO_2 savings via engine downsizing and electric boosting – all at an add-on cost of less than US$1,500. Since many OEMs are now looking at 48V architecture for the vehicles of the future, a 48V lead-carbon variant of the super hybrid has been developed.

These developments and many others will be presented at the 14th European Lead Battery Conference (14ELBC) in Edinburgh, Scotland, on September 9-12, 2014. 14ELBC will provide an opportunity for the automotive industry to learn exactly why lead batteries should remain their batteries of choice.

International Lead Association
W. www.ila-lead.org
ONLINE READER ENQUIRY NO. 570

Advanced EV and HEV subsystem designs

In their drive to advance technology, a growing number of electric and hybrid vehicle designers are discovering how a simple spring can be used to make and maintain critical mechanical and electrical connections.

The Bal Seal Canted Coil Spring, offered by Bal Seal Engineering, presents the dual benefit of latching, locking or holding system components together, as well as efficiently managing high-current flow in tight spaces with minimal heat rise. The spring's independent coils provide multipoint contact, ensuring consistent transmission of electricity to and from the lithium-ion battery array and other vehicle systems. The spring also conducts power to the motor during low-speed operation and ensures reliable recharging through regenerative braking. Depending on its placement, the spring can also shield connectors and couplings from the harmful effects of electromagnetic interference.

In external charging, the Bal Seal Canted Coil Spring conducts electricity from a wall or base unit to the battery array. The spring automatically compensates for misalignment and surface irregularities that may otherwise compromise charging efficiency. It can also be employed to provide positive latching feedback that indicates proper charger connection.

With over 50 years of application experience and certification to ISO/TS 16949, Bal Seal Engineering specializes in helping OEMs develop performance breakthroughs.

Bal Seal Engineering
W. www.balseal.com
ONLINE READER ENQUIRY NO. 571

Pioneering show is hailed as a global success

EVS27 is a recognized leading event for the global electric transportation industry and this year's symposium was held at the Fira de Barcelona's Gran Via venue on November 17-20.

The event successfully brought together academic, government and industry leaders from around the world to explore technical challenges focusing on sustainable transportation. The symposium also featured an exhibition area dedicated to the latest innovations in electric, hybrid, plug-in hybrid and fuel cell transport and recharging infrastructure. Barcelona won a highly competitive bid to host this event over other European cities in an international tender.

This edition of EVS set new records across the board, including a record high number of scientific articles being proposed for the call for papers, with 541 in total, 14% more than the former record. In addition, the World Electric Vehicle Association (WEVA) used the event to honor the world's three most sustainable cities during the event, through the E-Visionaries Awards. These awards recognize the effort made by the regions that are considered pioneers in the development of initiatives that promote the electric vehicle as a sustainable transport alternative.

Created in 1964, EVS27 is organized jointly by the WEVA, the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles, the Spanish Association for the promotion of Electric and Hybrid Vehicles and Fira de Barcelona. The previous event was held in Los Angeles in 2012 and the next will be in Asia.

EVS27
W. www.evs27.org

ONLINE READER ENQUIRY NO. 572

Hybrid-electric systems and wireless machine communications

John Deere Electronic Solutions (JDES), previously known as Phoenix International, is a key partner with Odyne Systems. Delivering hybrid-electric systems and wireless machine communications, Odyne uses the JDES PD300 Power Inverter to drive electric motors with the engine off, safeguarding quiet neighborhoods from the noise pollution of heavy machinery.

Odyne also uses the JDES Mobile Telematics Gateway (MTG) in its advanced telematics data-acquisition system. This system enables state-of-the-art monitoring for fleet manager operational support by providing an array of data and offsite operational-detail changes. Diagnostic data enables problem reporting and resolution, drive performance data assists product engineers, and fleet managers are provided feedback that drives productivity improvements. Once the data is assessed, configuration changes can be sent from the manager's workstation to the MTG onboard device for instant upgrades.

Odyne's innovations are just one example of how OEMs can employ the high-quality, highly durable components developed by JDES in their own applications. And OEM customers can count on JDES support with the documentation and tools needed to adapt John Deere components as the OEM sees fit.

John Deere Electronic Solutions
W. www.deere.com

ONLINE READER ENQUIRY NO. 573

Power electronics modules for commercial vehicles

Lenze Schmidhauser, a leading manufacturer of drive solutions for mobile deployments, presented solutions for commercial vehicles and mobile machines at this year's e-CarTec fair in Munich. The main focus was on the mobile modular product system. This system comprises double inverters, DC/DC converters, and various combined modules – all designed specifically for use in commercial vehicles. The DCU devices are certified according to ECE R10 and marked with the E1 label.

These products make it quick and easy for manufacturers to create a custom-made solution for the drive control of auxiliary equipment and the power supply of the onboard electrical system – all from one catalog. Users can then cover a large spectrum of applications both economically and efficiently with just one product range.

The modular product system currently comprises multiple intelligent double inverters (DCU), two DC/DC converters (PSU), and various combination modules. The double inverters are each equipped with two motor or generator outputs in the 7.5kW to 60kW power range. The inverters can be used to control synchronous and asynchronous motors (three-phase – with or without resolver). They are therefore suitable for controlling (in V/f or vector operating mode) both auxiliary equipment and smaller traction drives.

Lenze Schmidhauser
W. www.lenze-schmidhauser.ch

ONLINE READER ENQUIRY NO. 574

ADVERTISERS INDEX

LAST WORD

The next 10 years could see some very interesting developments in the area of alternative powertrain technologies. This includes compressed air engines, as demonstrated in the Honda Air concept at the LA Auto Show in 2010

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

Although I am an electrochemist and spend most of my time working on batteries, supercapacitors and fuel cells, occasionally I raise my head and look at the alternatives for reducing emissions. The array, I must say, is impressive, and although I believe that the electrification of the powertrain is both inevitable and necessary, I am not blind to the fact that other technologies are competing and will find niches and even mainstream applications.

Flywheels, such as those developed by Flybrid and Williams Hybrid Power, originally created for Formula 1 KERS, are already finding their way into mainstream applications, such as hybrid buses and other heavy-duty vehicles. These are the natural competitors for supercapacitors and high power-density cells, with the technology able to provide a real kick of power very quickly and reliably with good all-round trip efficiency. The problem is that flywheels can't store the energy for very long, with high self-discharge rates.

Compressed air engines seem to be another idea that has come around again – a notion first realized by the Liquid Air Company in London in 1903. Honda explored this powertrain area more recently, showcasing its Air concept a few years ago. However, probably a more practical solution is the use of liquefied air, which is being pioneered by the Dearman Engine Company and promises zero emissions, similar (or better) range compared with battery electric vehicles, similar cost to an IC engine, and fast refueling with a liquid fuel. If this is demonstrable in practice, this technology could take the industry by storm and compete with both battery electric and fuel-cell vehicles head-to-head. However, supporters of this technology, like Dearman, need to take note and be quick. History teaches us that a technology that gets to market first can be very hard to dislodge – even by something superior.

> "History teaches us that a technology that gets to market first can be very hard to dislodge – even by something superior"

One of the craziest notions, however, is actually electrochemical based, and involves the recent excitement over metal-air batteries, kicked off by Tesla filing a number of patents earlier this year. This seems to have generated a lot of discussion among Tesla observers, and others are understandably jumping on the bandwagon. However, the practical problems around implementing a refueling network for metal-air batteries are not trivial, and the potential round trip efficiency is even more than problematic. There is also the point that if, for example, coal-fired electricity were used to recycle spent aluminum, this technology would actually end up being one of the worst emitting forms of transport ever invented. The performance and reliability of metal-air cells is also an issue, meaning that they are still a long way from being commercially viable. Therefore, until practical solutions to these issues are found, this technology is far more likely to find a niche in military applications where the unique selling points will outweigh the costs.

With so much innovation ongoing, the next decade or so promises much powertrain fun to be had.

Technical excellence in electrical drive systems

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hofer powertrain is a very strong and compact, full service engineering company for the automotive industry. The technical core skills of the hofer group are mechanical, electric and hydraulic components, modules and systems combined with a high level of expertise in software, testing, industrialisation and series production for complete drivetrains.
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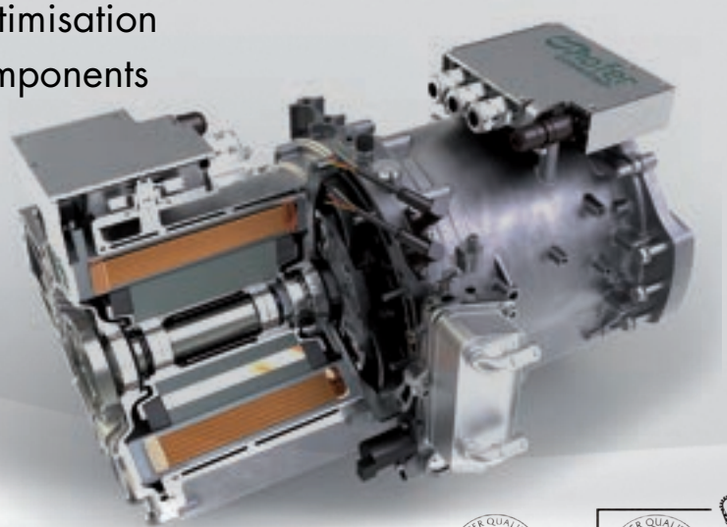

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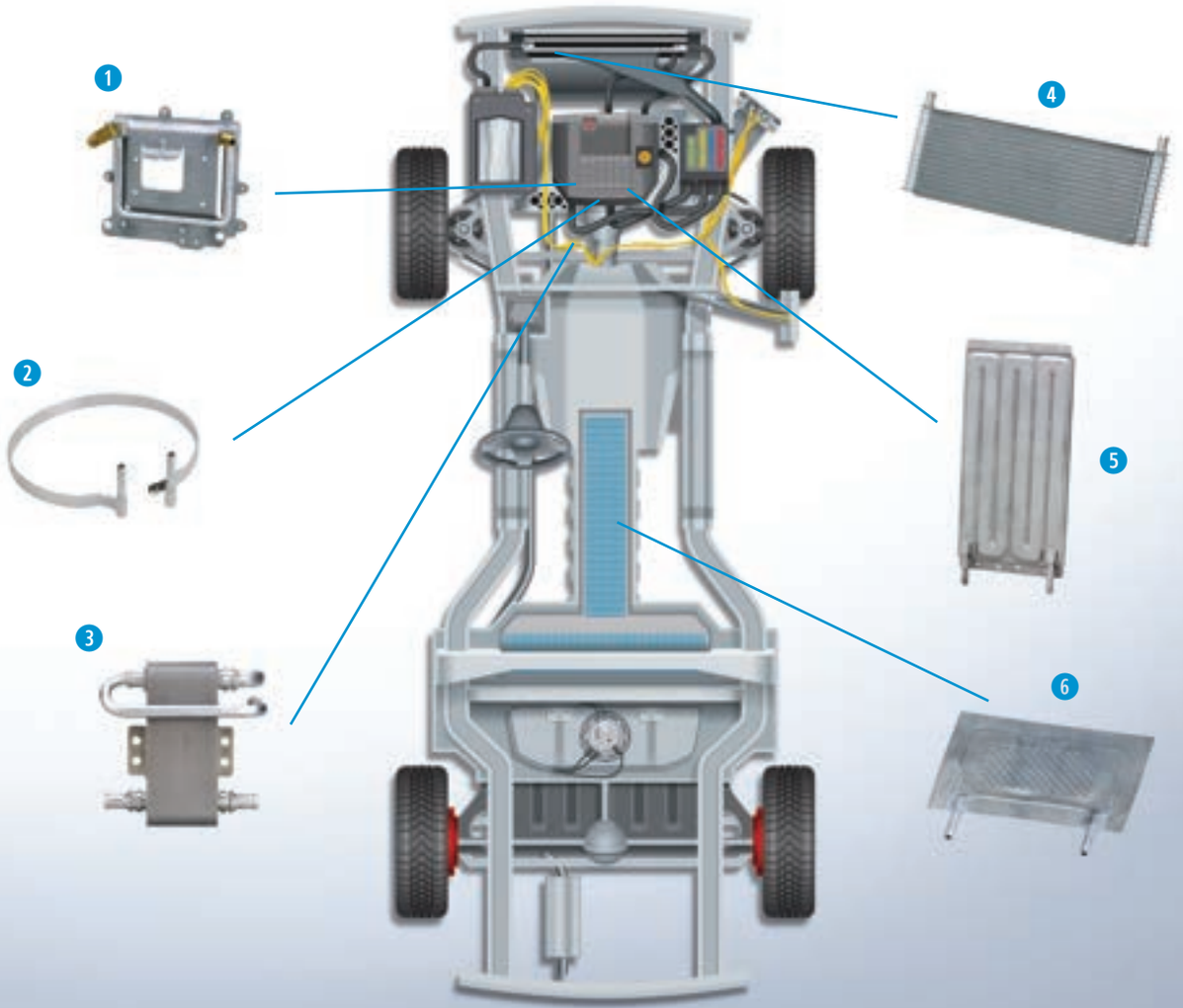

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