electric & hybrid
vehicle technology international

JANUARY 2017

We investigate EV range claims and discover how the all-new WLTP standard will shake up development of battery vehicles forever

TOP CAT

The launch of the I-Pace SUV is not just big news for Jaguar, it's a massive momentum shift for the EV movement

ON A MISSION

It's not easy chasing down Tesla, but that's what Michael Steiner, Porsche's R&D guru, is aiming for as launch of the Mission E nears

RACE READY

As JLR and Audi join Formula E, will the electric racing series become the number one motorsport competition?

The Heartbeat of Powertrains, Big and Small.

Life has never been tougher for the internal combustion engine. Higher temperatures, increased cylinder pressures and tighter tolerances drive the need for improved efficiency.

When you are facing challenges like these, you need an expert partner. A company that understands engines like no other. Whether it is power-cylinder, sealing, bearing or systems protection components, Federal-Mogul Powertrain has a highly engineered solution for the most demanding application. To keep the heart of the powertrain beating strongly.

For more information on how our technologies meet the requirements of your engines, deliver improved fuel economy, reduce emissions and enhance durability, visit www.federalmogul.com.

FEDERAL-MOGUL POWERTRAIN

The Preferred Powertrain Solutions Provider

www.federalmogul.com

In this issue...

JANUARY 2017

HybridPACK™ DSC

Half-bridge module with Double-Sided Cooling for superior thermal performance and higher power densities

Building on our long-standing experience in IGBT power modules and trench-field-stop IGBTs, we have developed a new half-bridge module to increase inverter power density even further – the HybridPACK™ DSC. With its extremely compact design in a dual in-line package, our FF400R07A01E3_S6 device delivers superior thermal performance thanks to Double-Sided Cooling (DSC). This makes it ideal for today's hybrid and electric vehicle designs.

Highlights include low stray inductance, integrated current and temperature sensing and higher blocking voltage. Integrated isolation means these new modules can be directly attached to a cooler without external isolation. Discover a new dimension in inverter power density, system efficiency and monitoring capabilities today!

www.infineon.com/hybridpack

FEATURES

CONTENTS

PRODUCTS & SERVICES

EDITOR'S NOTE

One thing that particularly stood out as I was doing the final read-through of this issue of *Electric & Hybrid Vehicle Technology International* was the number of instances where people talk with real optimism about how the electrified vehicle 'movement' continues to gather serious momentum. It struck something of a chord with me – when I joined this publishing company, nearly three years ago, I was the deputy editor on this very magazine and, I must confess, my exposure to electric and hybrid vehicles comprised little more than a few taxi rides in a Toyota Prius and some rather immature racing about in an electric golf cart.

But in just a few short years, I've had the privilege of interviewing some of the brightest minds the automotive industry has to offer, and experiencing some frankly remarkable step changes in technology. The first hybrid vehicles I drove when I joined back in 2014 were the Volkswagen Golf GTE and the Mitsubishi Outlander PHEV – both very different cars, but both left a lasting impression on me. The Golf GTE showed me just how smoothly an IC engine and electric drive could function in concert, and gave me a real sense of how nascent technology could have a subtle, yet very important effect on motoring. And gliding around in full EV mode in a car the size of the Outlander was an experience I'll never quite forget – although I've driven cars since then that have 'wowed' me to a greater degree in terms of performance (the BMW i8 will always have a special place in my heart) and practicality (I can think of numerous hybrid sedans that I could very feasibly live with, while a recent spell with the latest i3 left me staggeringly impressed), Mitsubishi's SUV left an indelible mark on my memory.

A year or so ago, I took a break from *E&H Vehicle* to cut my editor's teeth on a number of other titles, but before I stepped away from the magazine (although, I must confess, I often loitered near the automotive team's desks to eavesdrop on what they were working on), one of the last features I put together was a retrospective piece to mark the magazine's 20th anniversary. As I trawled through back issues, it was fascinating to revisit the industry milestones that have been passed; the remarkable progress that has been achieved in a relatively short period – setbacks and all – really hit home.

That said, however, there remain challenges that face the electric and hybrid market. One of the reasons that I haven't yet opted to swap my IC-engined car for one of those aforementioned hybrids is the practicality of charging. Installing a charge point at home, for me at least, remains impractical. The infrastructure to support electrification has some way to go, I fear, before consumers are ready to commit to EVs and HEVs on a larger scale. And, like many others, I can attest to just how stressful range anxiety can be when one is caught between charging points.

Boasts about EV range are fairly common, which is why this issue's cover story explores the differences between what some OEMs claim, and what drivers experience on the road. The investigation, which begins on page 40, is a fascinating exploration of what the marketing materials say versus what drivers experience first-hand on a cold morning drive to work, and how a new testing standard could go some way toward painting a more accurate picture of exactly where the technology stands right now.

Before writing this note, I looked back over previous issues for inspiration. In one particular intro – written by our now editor-in-chief, Dean Slavnich – it was noted that some of the major OEMs were beginning to dip their toes into the EV waters with genuine purpose. You only have to look at some of the vehicles we've covered in this issue (the Jaguar I-Pace is just one that springs to mind, turn to page 6 for more), and some of the technologies teetering on the brink of widespread uptake (our battery special on page 102) to see, once again, that progress, when it happens, can be spectacular. My last act as deputy editor in 2015 was to pick out just a handful of the industry landmarks from the last couple of decades. Charting the next set of milestones promises to be just as much fun. Enjoy the issue.

Matt Ross

The word wizards
Editor-in-chief: Dean Slavnich
Editor: Matt Ross
Production editor: Alex Bradley
Chief sub editor: Andrew Pickering
Deputy production editor: Nick Shepherd
Senior sub editor: Christine Velarde
Sub editors: Tara Craig, Alasdair Morton

Contributors
Josh Bentall, Lem Bingley, Philip Borge, Guy Cressingham, John Evans, Rachel Evans, Max Glaskin, Mark Hales, Graham Heeps, John Kendall, Robert Llewellyn, Mike Magda, Max Mueller, Bruce Newton, Marc Noordeloos, John O'Brien, Greg Offer, Chris Pickering, John Simister, Michael Taylor, John Thornton, Karl Vadaszffy, Richard N Williams

The ones who make it look nice
Art director: Craig Marshall
Art editor: Ben White
Design team: Andy Bass, Anna Davie, Louise Green, Andrew Locke, James Sutcliffe, Nicola Turner, Julie Welby

Production people
Head of production & logistics: Ian Donovan
Deputy production manager: Cassie Inns
Production team: Carole Doran, Bethany Gill, Frank Millard, George Spreckley
Circulation manager: Adam Frost

The ones in charge
CEO: Tony Robinson
Managing director: Graham Johnson
Editorial director: Anthony James

Commercial colleagues
Sales and marketing director: Simon Edmands
Sales manager: Jerry Dawson

How to contact us
Electric & Hybrid Vehicle Technology International
Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK
+44 1306 743744
electric@ukipme.com
www.ukipme.com/ev

Subscriptions
£70/US$108 for two issues

Published by
UKiP
UKIP Media & Events Ltd

ISSN 1467-5560 (print), ISSN 2397-6322 (online) *Electric & Hybrid Vehicle Technology International*. Printed by William Gibbons & Sons Ltd, Willenhall, West Midlands, UK.

Rightsizing the Electrification with 48V

"IDEAL" 48V POWERTRAIN INCLUDING OPTIMIZED BASE ENGINE AND ITS VEHICLE INTEGRATION

AVL supports the introduction of 48V electrical architectures in order to provide increased levels of power supply and energy recuperation at lower cost compared to full hybrid solutions. This opens new opportunities for efficiency improvement.

Benefit from AVL's overall system approach of a 48V powertrain integration, considering energy demand, cost, thermal management, aerodynamics and acoustics.

- Gain up to 20% CO_2 reduction from the 48V hybridization in WLTC cycle
- Potential for extended electric driving operations
- Tailored balance of electrical and mechanical functions to minimize overall system complexity and cost

AVL. Power to electrify
www.avl.com, info@avl.com

On the prow

The I-Pace has landed – a huge moment not just for **Jaguar**, but for the EV movement in general

WORDS: **MICHAEL TAYLOR**

Remember the time when Tesla had the big, luxury battery-electric car thing all to itself? Then Benz said it was coming, then Audi, BMW and Porsche all promised to join in, and Volkswagen dipped its oar in the water too.

And then remember when Jaguar had never built a production SUV?

Well, those days are long gone, with Jaguar confirming at the Los Angeles Auto Show in November 2016 that it will have its BEV I-Pace crossover SUV on sale to the public within two years.

And the British car maker is promising its first all-electric creation won't be its last, too, with the I-Pace being a strong pointer to the BEV futures of Land Rover and Range Rover.

Jaguar is promising the I-Pace will cover 500km (310 miles) of NEDC cycle running on a single charge of its 90kW/h lithium-ion battery pack, while belting noiselessly through to 100km/h in four seconds. Impressive stats.

The vehicle will use an electric motor on each axle to deliver its all-wheel drive, with the two combining to give the I-Pace 700Nm of torque – the same as the range-topping F-Type SVR – and around 400ps of power.

In-house expertise

The full five-seater crossover SUV sits on a custom-made BEV architecture that will spread through the JLR family, with Jaguar insisting it designed and engineered the batteries and the electric motors in-house, backing up its entry into this year's Formula E championship.

I-Pace will take two hours to charge on a 50kW fast-charging DC station, or 80% charging in 90 minutes.

"This is an uncompromised electric vehicle designed from a clean sheet of paper: we've developed a new architecture and selected only the best technology available," Jaguar Land Rover's technical development leader and former engineering director, Dr Wolfgang Ziebart, says of the BEV application.

"The I-Pace fully exploits the potential EVs can offer in space utilization, driving pleasure and performance."

The lithium-ion battery uses 36 pouch cells and Jaguar claims they deliver lower-than-usual internal resistance and excellent future development potential for energy density.

Jaguar has given the I-Pace a two-mode liquid cooling circuit, which relies solely on radiator cooling to take the cell heat from the cooling liquid in average ambient temperature settings. If the weather gets properly hot (though Jaguar doesn't specify exactly how hot that is), it uses a chilled circuit linked to the car's air-conditioning unit.

There's also a heat pump integrated into the car's climate-control system, designed to draw energy from outside air to heat the cabin rather than drawing current down from the battery.

The pack itself is located inside an aluminum housing that also forms an integral part of the I-Pace's chassis structure.

The e-motors are just 500mm long and run to 234mm of outer diameter. The synchronous, permanent-magnet motors don't follow tradition by mounting to a transmission in front of them, but use a concentric single-speed layout to help with packaging and ground clearance.

While the I-Pace is a two-pedal car, Jaguar insists the driver can ramp up the level of regenerative braking to effectively turn it into a one-pedal mover; with the car's maximum regeneration, the driver needs only to use a throttle lift-off instead of braking.

Although it insists it can stuff 500km worth of range into the I-Pace's battery, Jaguar also suggests that most people commute around 50km (31 miles) per day, meaning they'll only need to charge the I-Pace once a week.

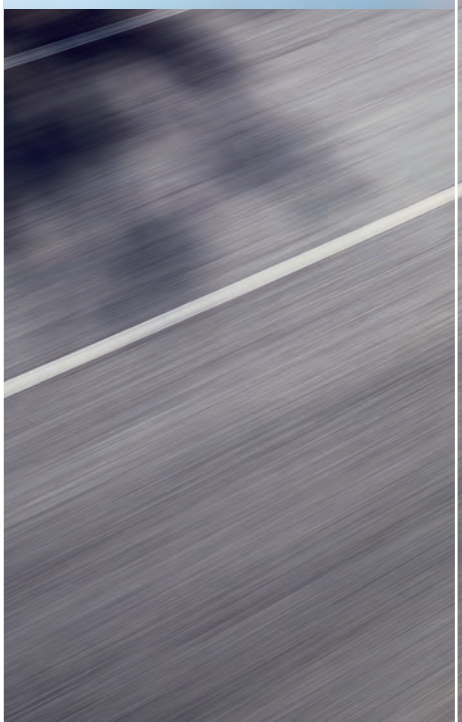
"Electric vehicles are inevitable – Jaguar will make them desirable. Zero emission cars are here to stay and the I-Pace Concept is at the cutting edge of the electric vehicle revolution," adds Ziebart

"As the charging infrastructure continues to develop globally – and with enough range to mean most people would only need to charge once a week – cars like the I-Pace will make drivers appreciate that an EV can be rewarding and practical enough to drive every day."

The second ever SUV from the pen of design director Ian Callum, Jaguar's I-Pace retains a conventionally large grille, even though it's not necessary for cooling, and has slashed its drag coefficient to just 0.29.

"This isn't just a concept. It is a preview of a five-seat production car that will be on the road in 2018," Callum states.

"This will be Jaguar's first-ever battery-electric vehicle and opens a new chapter in the history of our legendary brand."



Above and right: The I-Pace, despite being Jaguar's first all-electric vehicle, is said to have been developed to appeal to enthusiasts who love driving, and will deliver impressive performance from its permanent-magnet motor arrangement

TECH SPEC

Configuration	Permanent magnet electric motor – synchronous; single-speed epicyclic transmission; concentric with motor
Power	200ps
Torque	350Nm
Total system output	400ps/700Nm
Drivetrain	Motor and transmission integrated into front and rear axles; electric all-wheel drive
Battery configuration	90kWh Li-ion; liquid-cooled; pouch cells
Number of modules	36
Front suspension	Double wishbone
Rear suspension	Integral Link
Front tires	265/35/R23
Rear tires	265/35/R23
Steering	Rack-and-pinion; electromechanical
Length	4,680mm
Width	1,890mm
Height	1,560mm
Wheelbase	2,990mm
Drag coefficient	0.29
0-96km/h (60mph)	Around 4 seconds
Range (NEDC)	In excess of 500km (310 miles)
Range (EPA)	In excess of 355km (220 miles)

Above and left: The BEV rides on a long 2,990mm wheelbase, with a five-link rear design and the double-wishbone front-end design lifted from the F-Pace SUV


Zero emissions
are what drive us
BAE Systems' HybriDrive® power and propulsion system provides electric travel where and when you need it without range and charging limitations. It features stop/start technology for anti-idling and electric drive modes in emission and sound sensitive zones such as hospitals, outdoor shopping areas, or depots.
HybriDrive propulsion and power — the electric drive system.
www.hybridrive.com
HybriDrive® PROPULSION SYSTEMS
BAE SYSTEMS
INSPIRED WORK
CS-16-C46

Mass appeal

With its new architecture, powertrain and battery technology, could the fourth-gen **Smart** Ed finally break into the mainstream?

WORDS: **MICHAEL TAYLOR**

While product planning departments at the world's leading car makers scramble to find ways to extract battery-electric prices for small cars, Daimler is already there.

The product planners in Sindelfingen aren't exactly sitting on their hands, but two decades of losing money on the expensive Smart city car brand look like they might finally pay off.

Like the A- and B-classes, all Smarts were conceived with electric power in mind and the new one, which debuted at the Paris Motor Show in September 2016, will be the fourth generation of zero-emission Smart Fortwo runners.

But it goes further than that, with Smart now the only car brand in the world to offer electric versions of every model it makes, including what it (somewhat tenuously) claims is the only BEV convertible in the world.

Sharing an enormous amount of technology with Renault's Twingo hasn't hurt the electric Smart's development path, not least because it gave Daimler access to a five-door hatch.

At the core of the three-model range (Fortwo, Fortwo Cabrio and Forfour) is a separately excited three-phase synchronous motor that delivers 60kW of power and 160Nm of torque.

Smart is the only car maker to offer electrified versions of every model in its range

Motor and battery advancements

Like IC-engined Smarts, the motor in all three models sits over the de Dion rear axle. Unlike the IC Smarts, though, there is no dual-clutch transmission nestled alongside it. Instead, there is just a single gear and when in reverse, the Smart EDs run the electric motor backward.

This reversible single-speed drive system is claimed to be a bonus in heavy traffic and is built on the same Renault production line as the Twingo's setup, in Cléon, France.

The motor's rotor is magnetized whenever current flows, with the energy flow from the high-voltage, lithium-ion battery governed by (what used to be called) the ECU, which also controls the entire drive system.

All three versions share the same 17.6kWh battery pack sitting beneath the front seats (or, in the two-door versions, the only seats).

Built by Saxony's Deutsche Accumotive, Daimler's battery subsidiary, the pack uses 96 flat cells and its chemistry has been improved to the point that Daimler guarantees that the quoted capacity and power output rates will remain for eight years or 100,000km.

Deutsche Accumotive also made the battery pack for the third-generation BEV Smart Fortwo, although this one outstrips it by offering 160km (99 miles) of range on the NEDC cycle, limiting the top speed to 130km/h (80mph) to help the overall driving distance.

While the coming wave of premium EVs will use any number of custom-designed alloy cases for their battery packs, the Smarts sit theirs in a cage of high-strength steel tubes.

The new models will retain the standard clever features from existing Smarts, including a 6.95m kerb-to-kerb turning circle for the 2.69m Fortwo and Fortwo Cabrio.

The cars receive an upgraded onboard charger that halves the recharge time to two-and-a-half hours in the UK and US markets. There will also be a 22kW fast charger available from next year for Western Europe, enabling the cars to use three-phase power to cram an 80% charge into the battery in just 45 minutes.

Also keeping the BEV Smarts moving is an anticipatory radar-based energy recuperation system to minimize wasted braking energy by harvesting as much energy as possible.

Besides a softer throttle response and lower top speed, the Smart's more frugal Eco mode also gives up five rates of recuperation urgency, converting kinetic energy into electrical energy. Its radar monitors the surrounding traffic and lets the car coast if there's no traffic, then uses the electric motor as a generator to harvest energy depending on how quickly the car needs to wash off speed. The enthusiasm with which it harvests energy depends on the battery's temperature and state of charge.

It also saves energy by forcing the climate control to reach a preset temperature while the car is still attached to the charging station. This can be adjusted via a smartphone app, along with two preset departure times.

Smart has also countered concerns about pedestrian interaction with a quieter generation of urban transport by fitting the US cars with a weatherproof speaker in the grille. This speed-variable system mainly works below 30km/h and will be optional in Europe, where it will have a manual override switch.

A 60kW electric motor works at the rear of the Smart electric drive and transmits its power via a constant ratio to the wheels

How to shift the perception of hybrids

Hybrid and electric vehicles have always relied on a single speed electric drive. The problem is that they are then limited by either acceleration or ultimate top speed: above a certain speed a dog-clutch usually disconnects the electric power.

Light, compact and efficient, GKN's two-speed solution enables electric power delivery throughout the entire speed range. And, with smooth electromechanical actuation, the driver experiences the torque, not the shifts.

Introduced on the groundbreaking BMW i8, the flexibility of the eAxle means the system could improve the efficiency and performance of almost any vehicle. To find out more, visit: www.gkndriveline.com/i8

Automotive News PACE AWARD 2016 WINNER

ENGINEERING >THAT MOVES THE WORLD

Range finder

The latest revisions to the i3's battery pack see driving range extended by over 50% and charge times slashed thanks to advanced three-phase technology

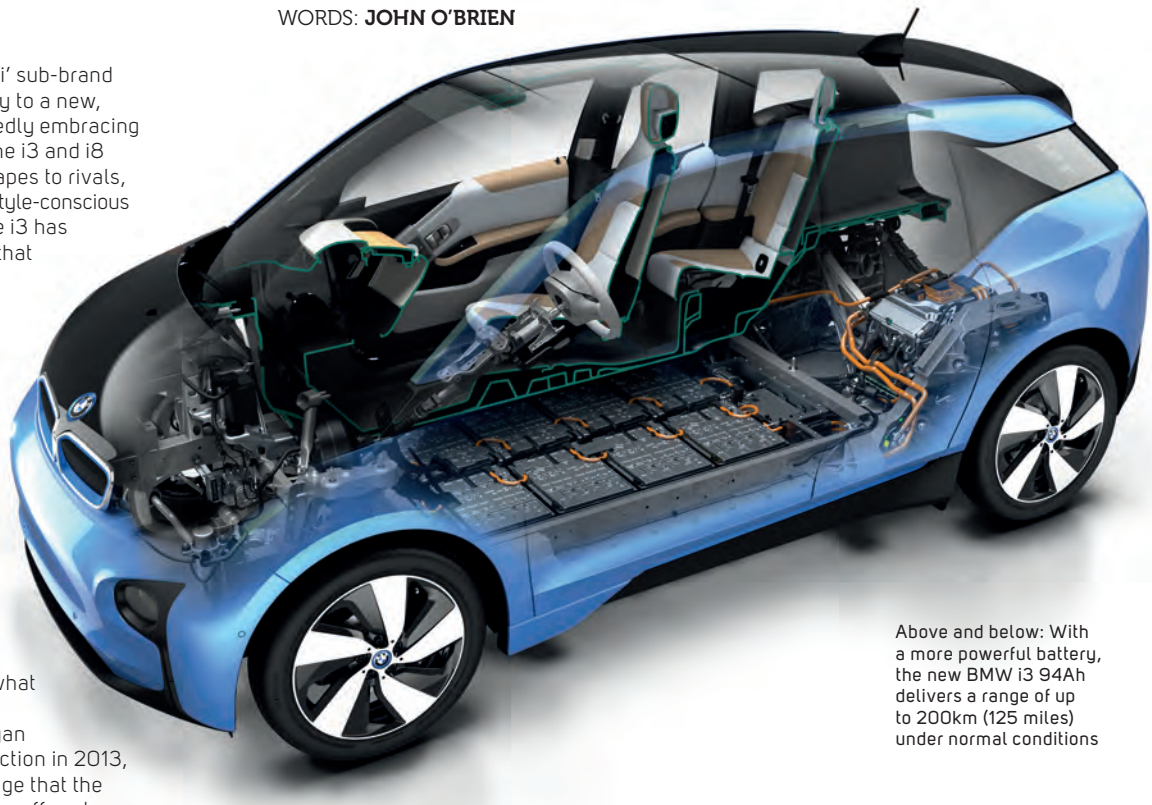
WORDS: **JOHN O'BRIEN**

It could be argued that BMW's 'i' sub-brand has helped introduce e-mobility to a new, wider demographic. Unashamedly embracing electrification as 'the future', the i3 and i8 models cut distinctly different shapes to rivals, appealing to technophiles and the style-conscious alike. For its 2017 model year, the i3 has undergone a number of changes that increase both battery power and range to yet again open up new consumer markets.

"The driving range the battery can generate remains one of the biggest hurdles with BEVs," explains Heinrich Schwackhöfer, product manager for the BMW i3. "On the one hand, we have learned that our customers typically drive 40-50km (25-31 miles) per day, which the 60Ah version comfortably covers. However, we want to grow the i3's appeal and there are a lot of customers who need more than what the 60Ah can offer."

Development of the new i3 began shortly after the original's introduction in 2013, and focused on improving the range that the eight-module lithium-ion cell setup offered without encroaching on existing architecture.

"What we have is an evolutionary development of the Li-ion cells, which has revised cell-internal packages with more electrolyte, and an adapted active material," explains Schwackhöfer. "As a result, we've increased the cell density of the pack, even though it is still in the same sized package. The density of the cells has improved by over 50%, which means the NEDC cycle operating range is up from 190km (118 miles) to more than 300km (186 miles), while real-world driving range is increased to around 200km (125 miles), maybe a little bit more. We're hoping that with this, range anxiety should become a thing of the past."



Above and below: With a more powerful battery, the new BMW i3 94Ah delivers a range of up to 200km (125 miles) under normal conditions

The underlying fear of range anxiety is something that BMW addressed at a consumer level. During development of the 94Ah, BMW turned to its existing 60Ah customer base, who provided feedback on areas of concern.

"The update was also to address the charging power," says Schwackhöfer. "Charging time is the same, despite the new capacity. We've done this by switching from AC 7kW to 11kW, and introducing three-phase charging. In doing so, we've kept charge time below three hours."

Charging forward

Changes in regulations across Europe also influenced BMW's decision to introduce the higher charging capacity: "There were regulations in a lot of countries that outlawed the use of the full 7kW charging capacity that we have now," explains Schwackhöfer. "In Germany, for example, where we have a three-phase grid, we couldn't use a high-power single-phase charge; we had to distribute it across all three phases. We lobbied for a change, and being able to go to 11kW from just 7kW will make a big change in charging times."

The introduction of the new i3, Schwackhöfer believes, is the start of a widely increased EV/BEV product range. In addition to the unveiling of the all-new EV offering, a range-extender option was introduced at the same time. The installation of a small 650cc two-cylinder gasoline engine on the rear axle delivers 38ps to power an onboard generator that ensures the battery never depletes below 6.5%.

"We still see potential to build on the capacity of the 94Ah battery, even when using the same type of cells," concludes Schwackhöfer. "It's not been decided on, but it's something that we're thinking of. I think that's the strength of this concept – we have a Li-ion battery pack of 96 cells that we can easily exchange with new technologies, so we can do updates quite easily with the same type of cells on the same architecture, meaning we stay competitive."


elaphe
Propulsion Technologies
elaphe propulsion technologies
M700 in-wheel motor
Peak torque 700 Nm
Efficiency >93%
Top speed 1500 rpm
Peak power 75 kW
Continuous power 50 kW
www.in-wheel.com
customer@elaphe-ev.com

ELECTRIC MOTOR PRODUCTION TESTING

TESTING THE FUTURE®

EPT-100

SEMI-AUTOMATIC ELECTRIC MOTOR PRODUCTION TESTER

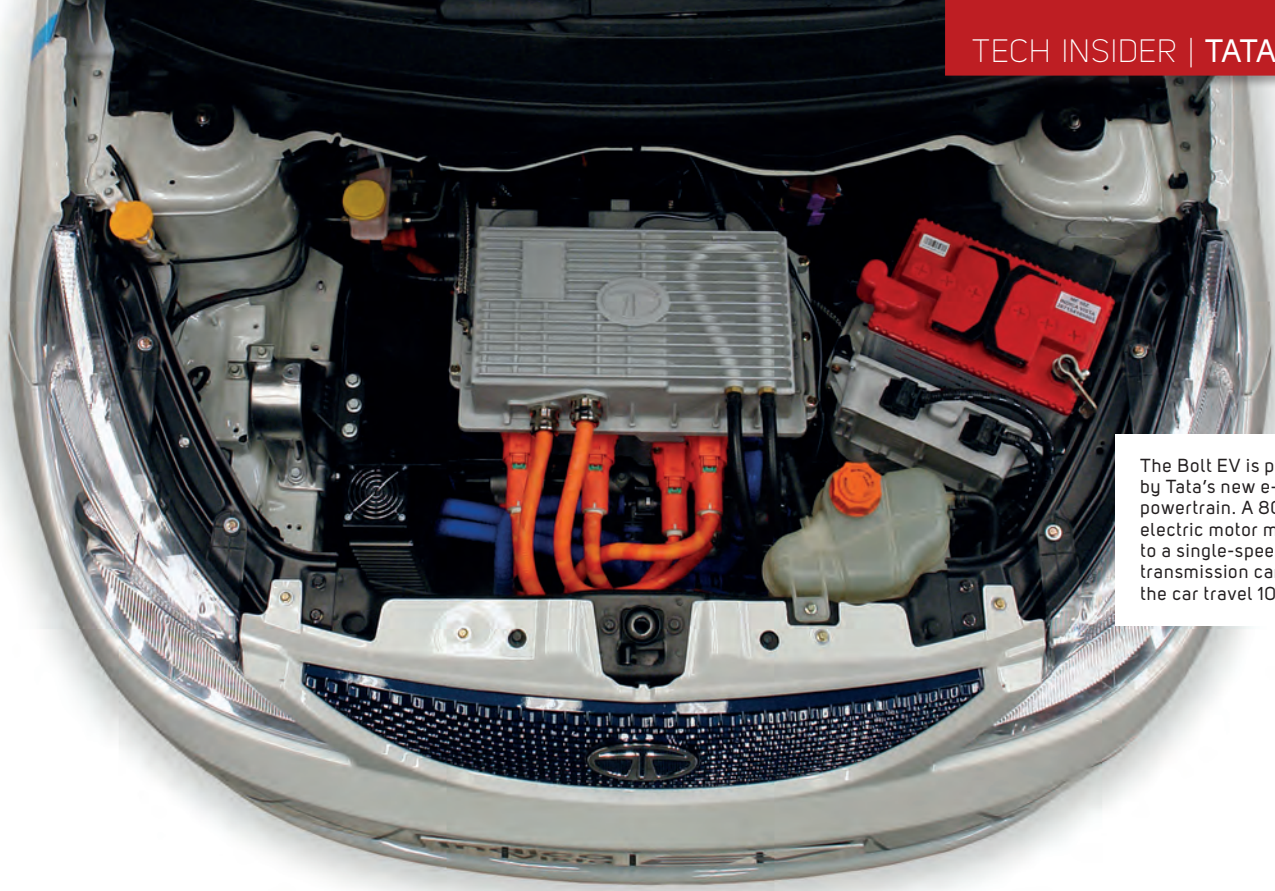
D&V Electronics builds electric motor testing equipment for performance evaluation, endurance testing and the EPT-100 for volume production testing. Accurate, fast, reliable and extremely durable, D&V's testing equipment is able to provide customers with the data to measure their product with confidence. The built-in function tests including BEMF, LOCKED ROTOR, COAST DOWN and FREE RUN provide easy operation of the machine.

To find out more about our end-to-end Electric Powertrain Test Systems visit www.dvelectronics.com or watch us on YouTube www.youtube.com/dvelectronics.

ARE YOU READY TO TEST THE FUTURE?

D&V ELECTRONICS LTD.
T: 905-264-7646 F: 905-264-0502
sales@dvelectronics.com www.dvelectronics.com

D&V ELECTRONICS LTD.



The Bolt EV is powered by Tata's new e-drive powertrain. A 80kW electric motor mated to a single-speed transmission can help the car travel 100km

Half price

Tata is aiming to create low-cost EVs for the masses and much of the R&D learning for that goal stems from the Bolt EV Concept Demonstrator

WORDS: **LEM BINGLEY**

Tata Motors European Technical Centre (TMETC), based in Coventry, UK, is currently developing a low-cost EV for India, its parent company's domestic market. Progress is at such an advanced stage that, in September 2016, the company demonstrated a prototype based on Tata's Bolt, an existing B-segment hatchback created under its Falcon program.

Tata's Bolt EV Concept Demonstrator (not to be confused with the Chevrolet Bolt) uses a GKN Evo liquid-cooled drive motor, developing 80kW and 240Nm. It drives the front axle through a fixed-ratio transmission. The battery has been developed in-house by TMETC using lithium-ion pouch cells from A123 Systems.

TMETC has created a modular design that's suited to a variety of configurations. Pouches are paired in cassettes, wired in parallel, and the cassettes are stacked into modules linked in series. With 24 modules of 10 cells, the battery runs at 396V and has a nominal capacity of 15.6kWh.

"The aim is to achieve a driving range of 120-140km," reveals David Hudson, group chief engineer at TMETC. "It's not intended to be an interstate vehicle. It's for congested cities and there are a few of those in India."

The Bolt's e-drive system is designed as a straight-up replacement for IC powertrains. The battery completely replaces the fuel tank and supplants the spare wheel. "It's fully under the floor, so there are no weird lumps and bumps," says Hudson. "All of the crash systems of the car are unaltered; the engine is also smaller, which is further good news for crash scenarios."

IC engine efficiency benefits

The battery is split into two parts, either side of the twist-beam rear axle. Chilled coolant is supplied via a dedicated system, although in production it would be integrated with the car's HVAC system.

At 1,265kg, the EV conversion fits within the weight range of existing Bolts, enabling brakes to carry over, although there is still work to do to integrate both regenerative and mechanical braking. Meanwhile, the suspension has been retuned to reflect the new weight distribution, but Hudson says the project "hasn't disrupted a car that we make in the tens of thousands".

The relatively modest battery helps to meet the project's goal of developing an EV that might be profitable in India. Trends in battery cell prices are also helping, as are changes in conventional engines. "Things such as electric water pumps have become commodity items," Hudson states. "We can go to Pierburg for an off-the-shelf item for US$50 and it's fully validated, compact and reliable. Five years ago they were all weird prototypes costing hundreds. The wider drive

for efficiency in IC engines is building a component library that helps us deliver."

Given the ready availability of parts, the OEM's job is seamless integration, Hudson argues. "We've put a lot of work into the driveability calibration and the energy management, which are all software functions," he notes, adding that this task will increasingly define brand values as EV makers converge on the same key suppliers. "How a car drives will come down to decisions in software tables," he states.

The approach to energy recuperation is already a key differentiator, from the fierce retardation of BMW's i3 to the default gliding mode of VW's e-Golf, supplemented by selectable levels of regeneration.

1

1. The Tata Bolt EV sprints from 0-100km/h within 10 seconds with a top speed of 135 km/h

2. The Low Cost Auxiliary Power Unit (LowCAP) project is looking into integrating Tata's two-cylinder engine with Ashwoods' motor generator and inverter technology, to develop a low cost auxiliary power unit for range extender EVs

"We don't intend to give people a choice, though there might be two power modes – an eco mode and a sport mode"

David Hudson, group chief engineer, Tata Motors European Technical Centre

"We don't intend to give people a choice, though there might be two power modes – an eco mode and a sport mode," Hudson says. "If you're going for sport mode you might want more engine braking." The prototype Bolt EV offers a lively sport mode through its rotary gear selector – a part borrowed from Tata-owned Jaguar Land Rover (JLR).

TMETC has also been working with JLR on the thorny issue of range prediction. "A storage battery is a very complicated thing, subject to a lot of variables," Hudson notes. "But the only thing the customer wants to see is how many miles they can go, so how do you tell people that? The answer the driver needs is what's most useful on the day; it may not always be the same. We've put a lot of work into this and have done a lot of collaboration with JLR, because the problem is the same for every EV manufacturer."

Range extender development

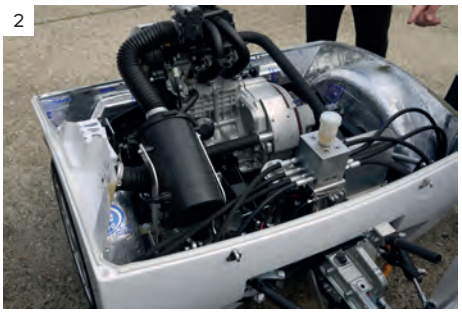
In September TMETC also demonstrated a potential application for LowCAP, an auxiliary power unit jointly developed over the past three years with Ashwoods Electric Motors and the UK's University of Bath.

The company is cooperating with French startup EP Tender, which aims to launch towable range extenders for short-range EVs like Renault's Zoe. The concept isn't new though – the best known precursor is the LongRanger trailer developed by AC Propulsion for Toyota's electric Rav4. EP Tender's business model is to hire out trailers to enable EV owners to tackle the occasional long journey.

The demonstrator trailer can generate up to 25kW and could provide up to 500km of range between fuel stops.

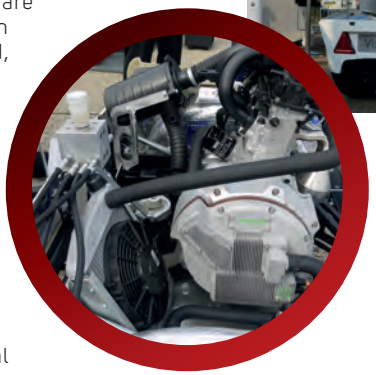
EP Tender will need to persuade EV makers to cooperate and provide a socket. Prototype units are connected via a junction box on the EV's DC feed, although software changes are not necessary. "The car just thinks it's doing really long regen," says Hudson. "There is also a CAN connection, so the trailer knows the host EV's state of charge."

LowCAP was initially developed as a potential internal range extender. It's based on the 624cc twin-cylinder engine from the Tata Nano, with an Ashwoods generator, controller and inverter.



2

3



3. The LowCAP system has been integrated into an EP Tender trailer, with a common coolant loop shared by the engine, generator and power electronics

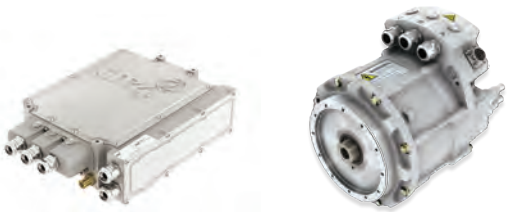
"We worked together on thermal and mechanical integration to allow a common coolant circuit," notes Hudson. "The engine is running a bit cooler than it might normally like, with the power electronics a bit warmer, but we have mapped all the efficiency losses and concluded that it's a very effective thing to do."

Coolant runs from the radiator to the power electronics, through the generator, up through the engine and back to the radiator. "It effectively runs an open thermostat, so you have as much temperature drop as possible," Hudson says. Output is from 10kW at 2,000rpm to 25kW at 4,000rpm, with claimed economy better than 270g/kWh.

4

4. Development of the Bolt EV prototype took place at the Tata Motors European Technical Centre (TMETC). In 2017, the Indian OEM's hybrid and EV capabilities will be further developed following completion of the National Automotive Innovation Centre. This new facility will bring together TMETC, Jaguar Land Rover and WMG

tm4 Electrodynamic Systems



Power & Versatility

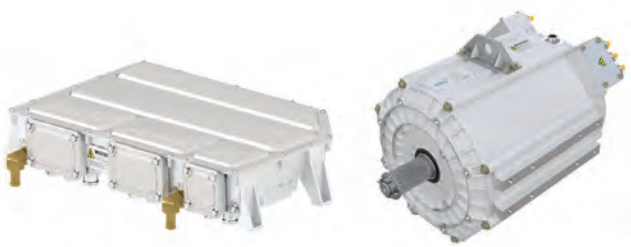
The TM4 MOTIVE™ systems use high RPM permanent magnet motors allowing for compact packaging and high power density.

Up to 110 kW / 255 Nm / 10,000 RPM

Reliability & Torque

The TM4 SUMO™ systems use high torque / direct drive motors for optimal powertrain efficiency.

Up to 300 kW / 3400 Nm



Headquarters
135, J-A Bombardier, #25
Boucherville, QC, J4B 8P1
Canada

+1-450-645-1444

tm4.com

China
No 3, Xiaopu South Street
Tongzhou District, Beijing
China

+86 (133) 7012 3615

bjpeps.com

MOTORS⚡GENERATORS⚡POWER ELECTRONICS⚡VEHICLE ELECTRONICS

Four

Japanese manufacturer **GLM** showcased its Tesla rival, the four-seater G4, at the Paris Motor Show

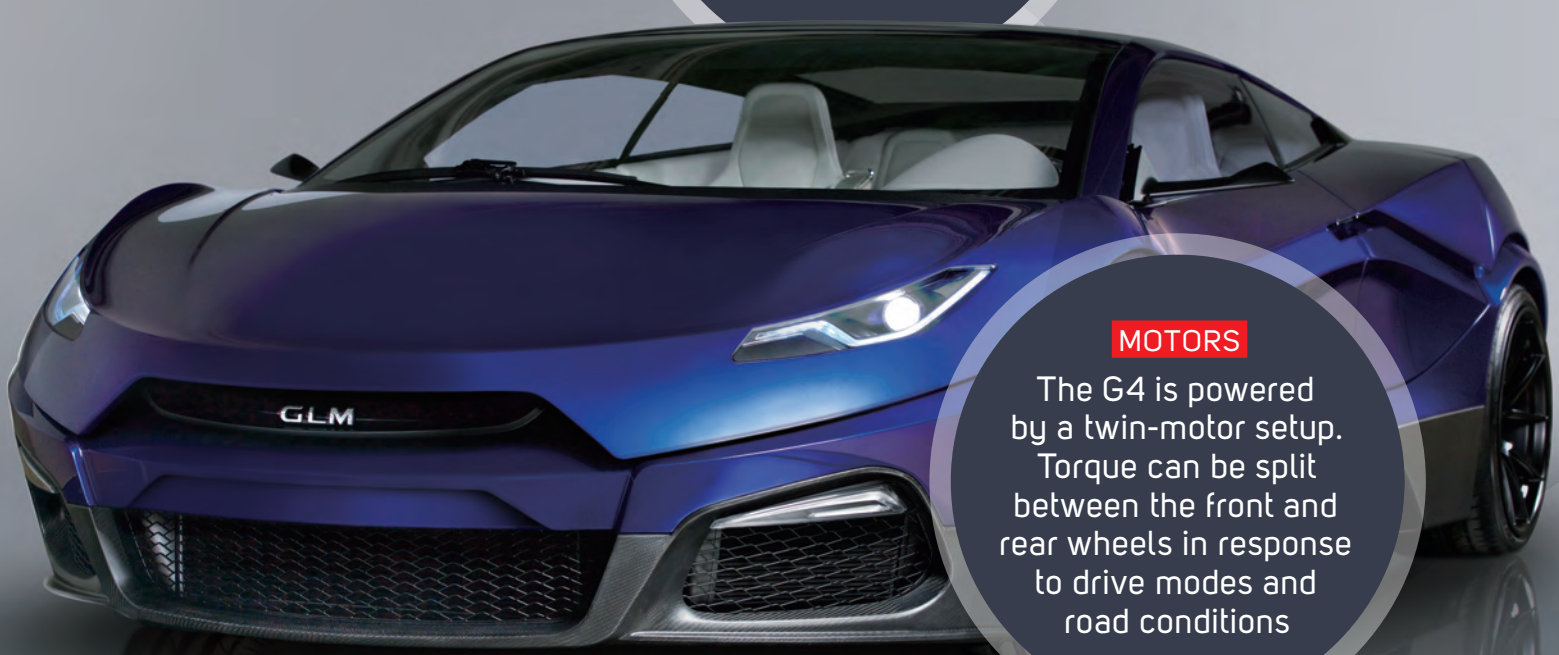
Unveiled at the 2016 Paris Motor Show, the new GLM G4 is, according to its developer, an electric supercar that combines the ruthless efficiency of its Japanese manufacturers with the promise of exhilarating performance not previously seen in an EV. A bold claim, indeed, and one that pits GLM directly against the likes of Tesla. There are certainly similarities between the two companies. Both entered the market with their own EV platform, paired with a third-party body – GLM's Tommykaira ZZ began production in 2013, and sparked understandable comparisons with the Tesla Roadster.

The luxury four-seater G4 is built on GLM's platform chassis – a modular system that can be configured for three different vehicle types: sports car, grand touring and small vehicle. The body design comes from GLM's partnership with Dutch design studio Savage Rivale, and was originally intended to sit atop a V8 supercar. In its new incarnation, the four gullwing doors open on a luxurious cabin, and the vehicle is powered by an all-electric powertrain.

At the time of writing, the G4 remains at the concept stage, and details on its powertrain are scarce. Here are some of the details that *E&H* has been able to glean.

BALANCE

The G4's batteries are divided between the front and rear of the vehicle to improve balance and stability



MOTORS

The G4 is powered by a twin-motor setup. Torque can be split between the front and rear wheels in response to drive modes and road conditions

star

POWER

The G4 produces 540ps, and maximum torque is 1,000Nm. The car sprints from 0-100km/h in 3.7 seconds. Top speed is 250km/h

TRANSMISSION

The G4 is fitted with a multistage transmission which, GLM claims, reduces current when cruising at "city-to-autobahn speeds"

RANGE

GLM reports a range of 400km (248 miles) on the (admittedly lenient) NEDC driving cycle

Forward motion

Toyota's innovative fuel cell concept, FCV Plus, is part vehicle, part powerplant, and is able to supply electricity to external sources

WORDS: **RACHEL EVANS**

At the 2016 Paris Motor Show, Toyota showed a European audience its vision for the company's hydrogen fuel cell technology – in the form of the FCV Plus. Having taken its fuel cell vehicle tech demonstrator from concept to reality with the launch of the production Mirai in 2015, the Japanese auto maker has ambitious plans for the FCV Plus – a next-gen city car that is designed to act as a power source itself.

FCV Plus and Mirai project manager, Takeo Moriai, says, "In the future we foresee a hydrogen society in which all houses and cities are able to supply hydrogen and can be powered by FCV Plus."

COMFORT ZONE

FCV Plus features a package specially designed to provide maximum interior space for passengers. The stack is mounted between the two front wheels and the hydrogen tank behind the rear seat. The miniaturized drive components, including the four in-house-developed independent in-wheel motors, are positioned at each wheel.

Having all functional parts and subsystems concentrated at the front and the rear of the vehicle also ensures an optimal weight balance and enables all-round visibility.

In addition to the vehicle's hydrogen tank, the car can generate electricity from hydrogen stored externally. It can therefore be used as a source of electric power for use both at home and further afield. When not being used as a means of transport, the FCV Plus could power other vehicles and local power grids via the built-in wireless battery charging panels on the rear wheels and under the front floor. This also means the vehicle can be used for purposes other than driving without depleting its own fuel tank.

The vehicle's fuel cell stack can also be removed and used as a separate electricity-generating device.

Perfect package

Toyota aims for the FCV Plus to achieve a driving range close to that of a current hybrid vehicle – 480-640km (300-400 miles).

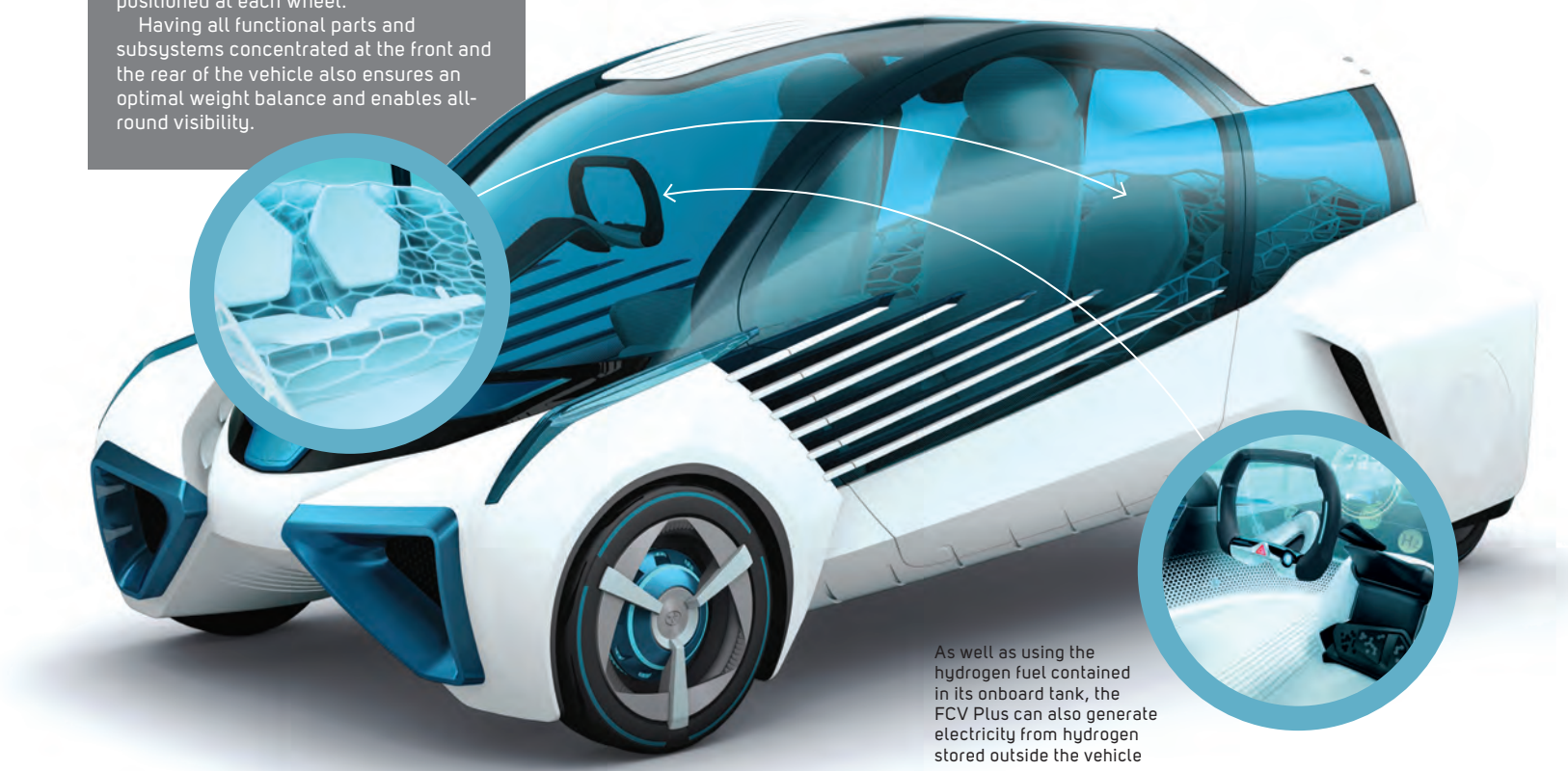
"The biggest difference between a pure electric vehicle and a fuel cell vehicle today is range," Moriai notes. "To fully maximize that for a fuel cell vehicle, there are two key elements. One is to create a lightweight package and the other is to optimize the power generation efficiency of the hydrogen stack."

At just 3,800mm long, 1,750mm wide and 1,540mm tall, the FCV Plus is extremely compact and features an aeropackage designed to enhance fuel efficiency. The interior trim and seats use the same advanced 3D processing and other techniques that give the car its light and highly rigid skeletal structure.

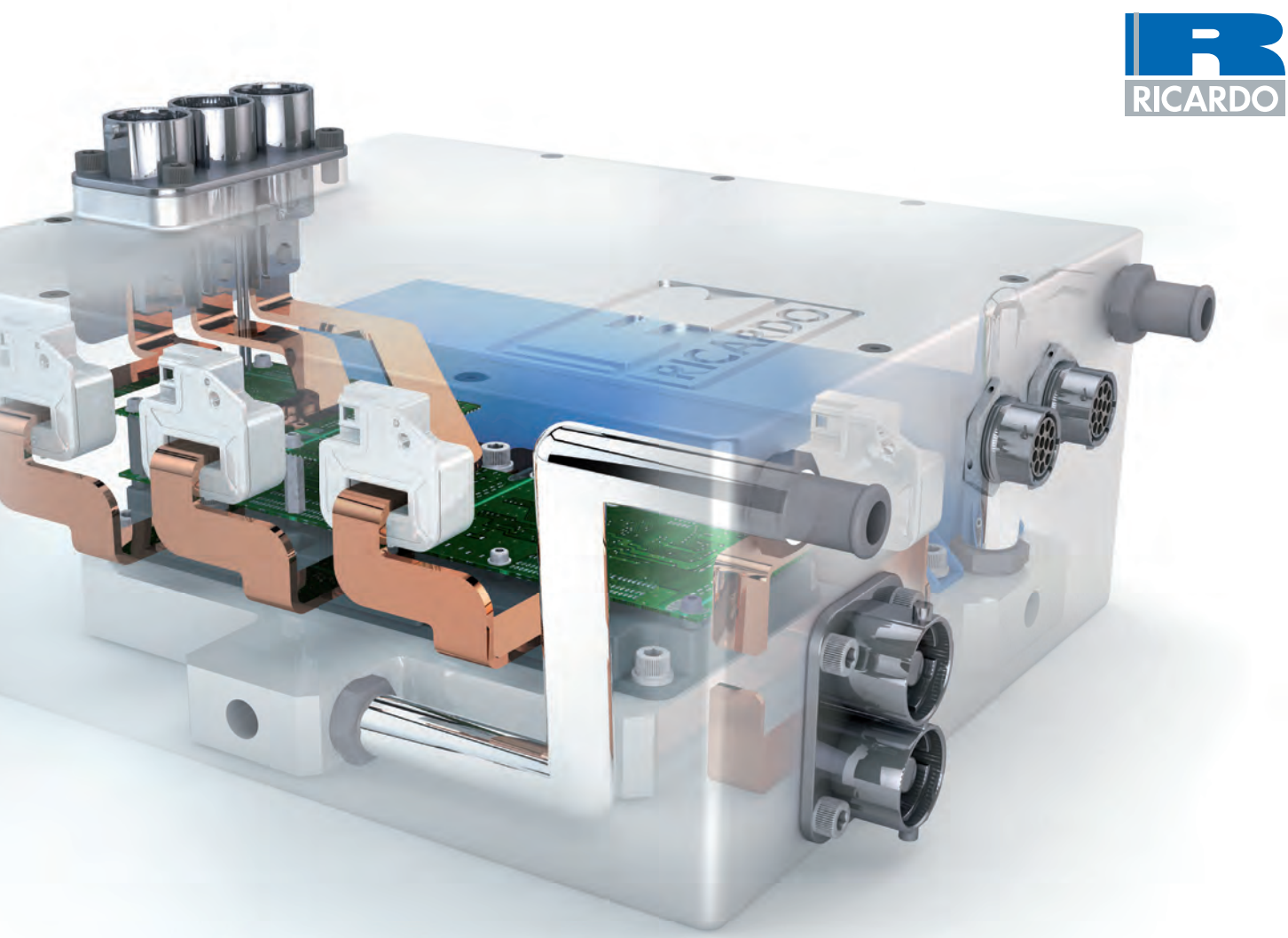
Meanwhile, Toyota aims to reduce the vehicle's weight from around 1,630kg to just 907kg . There are also plans to reduce the size of the current fuel cell stack by half and the number of onboard hydrogen tanks from two to one.

"We are confident that we will able to reduce the size of the stack with the development program we have in place," Moriai explains. "In order to have just one tank, mass reduction and optimization of the aerodynamics is key."

Although there are no immediate plans to develop the concept into a production model, Toyota envisages the introduction of elements from the FCV Plus into a market vehicle in the next 20 years.



As well as using the hydrogen fuel contained in its onboard tank, the FCV Plus can also generate electricity from hydrogen stored outside the vehicle



Highly efficient, cost-effective power electronics for electrified vehicles

Just as our clients aspire to manufacture the world's best hybrid and electric vehicles, Ricardo continues to evolve its expertise and skills in the design and production of traction inverters, on-board convertors and charging systems.

By applying parallel device gate drives and optimized switching patterns, Ricardo can deliver fully integrated, compact and robust designs for the automotive industry.

Our experience of using wide-band-gap devices, enabling high power density and high-efficiency power transfer, combined with a deep understanding of development and manufacturing costs with modern simulation processes, ensures we can support our clients in developing product from prototype through to mass production.

Find out how our experts can help you power the vehicles of the future.

Email: info@ricardo.com **Tel:** +44 (0)1223 223200

Diesel hope

Just when you thought diesel-hybrid tech was on the wane, Renault has teamed up with Continental to create an all-new 48V powertrain system that promises benchmark fuel consumption and emissions performance

WORDS: **RACHEL EVANS**

Continental has developed a compact hybrid drive that will be implemented in new diesel variants of both the Renault Scénic and Grand Scénic models – the first application of the Tier 1 supplier's 48V hybrid assist technology in production vehicles.

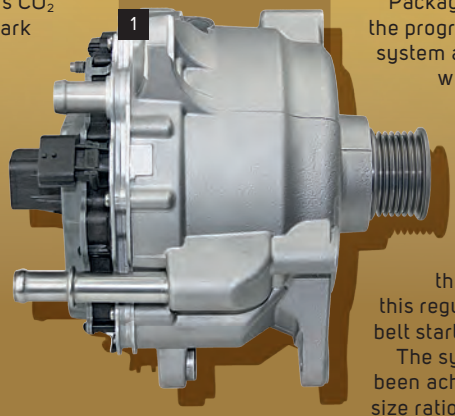
Conti engineers worked in close collaboration with Renault on the development of the hybrid drive, which is said to be cost efficient to produce, making it an attractive option for mid-sized cars.

Instead of the conventional starter generator, this highly efficient system uses a water-cooled electric motor with a continuous output of 6kW (10kW temporary), which drives the engine crankshaft via a belt.

With the new system, Renault hopes to achieve a combined fuel consumption level of 3.5l/100km (80.7mpg). Meanwhile, the partnership aims to reduce the Scénic's CO_2 emissions to 92g/km – a new benchmark in this vehicle class.

This impressive figure is made possible thanks to the electric motor operating as a generator to convert a large proportion of the braking energy into electricity. This electricity is temporarily stored in a small battery and can then be specifically used to relieve the IC engine.

The 48V technology also ensures that the diesel engine dramatically reduces NO_x and exhaust particulate output, especially during stop/start urban traffic driving.



1. The e-motor with integrated inverter is produced at the Continental plant in Nuremberg, Germany, which already specializes in highly complex electronic modules

Packaging issues

Development for the system took around three years and was predominantly carried out at two Continental locations: electronics work was conducted in Regensburg, Germany, while development of the motor was based in Berlin.

According to Dr Carsten Götte, who is responsible for 48V development in the hybrid and electric vehicle business unit within the powertrain division at Continental, the short timescale of the project placed huge demands on the team. "The timing was a particular challenge," he says.

"Further unforeseen challenges arose as a result of the tough timescale, however the very transparent and constructive working style between both companies was the key to solving issues quickly with positive results."

Packaging was a particular focus during the program, to ensure the compact size of the system and enabling it to be easily combined with pre-existing IC engines. As such, the hybrid drive occupies the same space as a conventional starter motor unit.

Götte notes, "Both project teams worked to optimize the mounting space and find the best solution. We exchanged packaging data at the start of the project and discussed this regularly. Mechanical integration of the belt starter generator [BSG] was a challenge."

The system's compact dimensions have been achieved thanks to the high power-to-size ratio of the electric motor, which does

MAXIMUM POTENTIAL

Continental's new hybrid drive is said to make more consistent use of the advantages of the diesel engine.

For example, the 48V system in the Diesel Eco Drive mode is also used to prevent the combustion engine from operating in unfavorable states. This is particularly the case during vehicle acceleration. Here, the torque request sent to the combustion engine can be reduced and the missing torque is instead provided by the electric motor.

"In this way, the diesel engine can be operated more consistently and under the most favorable conditions," explains Dr Oliver Maiwald, Continental's head of technology and innovations in the powertrain division. "With this option, developers can mitigate the build-up of nitrogen oxide and soot in certain load ranges."

Depending on the OEM's engine development objective and the exhaust aftertreatment technologies that are in place, such as SCR, there is greater freedom to optimize the efficiency of the engine and vehicle emissions in equal measure.

2. The new Scénic features Renault's Hybrid Assist electrification technology which is available with the model's core-range dCi 110 diesel unit and mated to a six-speed manual

2

not contain rare earth materials. Helping matters further is the use of water cooling of the stator and the high efficiency levels of the induction motor.

Space is further saved by having the inverter integrated into the housing lid of the electric motor package.

The team also developed an optimized operation strategy with engine systems, based on virtual simulation and physical analysis conducted using both Conti and Renault test vehicles featuring different types and sizes of IC engines. "Regular exchange of data and experiences from the tests throughout the project ensured matching of the BSG to the combustion engine," adds Götte.

Future forecasts

In addition to designing and developing the 48V hybrid drive system for the crankshaft of the diesel engine in Renault applications, Continental is also working on other areas of application. For example, the electric motor can also be placed between the IC engine and the transmission – thus enabling pure electric driving in inner city areas, or within zero emissions zones.

Götte further explains, "The current solution is a P0 configuration BSG, which means the crankshaft is connected via a belt to the BSG.

"In engineering collaboration with Schaeffler, we have developed a prototype module named P2-BSG with a 48V BSG and integrated belt drive, which is constructed for side-mounting between the IC engine and the transmission."

The new module is scheduled to be ready for volume production in 2020 for an as yet unnamed car manufacturer.

The German supplier, which most recently showed a second-gen Gasoline Technology Car tech demonstrator with 48V that promises about 25% better fuel economy, will also launch a new 48V hybrid drive system in 2017 and has projects ongoing with car makers in Europe, North America and Asia for development of the technology for diesel and gasoline applications. ■

Out of office

An extra-curricular project has resulted in a **Nissan** Leaf with twice the battery capacity of the production model

WORDS: **MATT ROSS**

A team of Nissan employees have given up their spare time to build a prototype Nissan Leaf with double the battery capacity of the production model. The project, which was undertaken by a group of technicians from the OEM's innovation team, has yielded a Leaf with a capacity of 48kWh, increasing the everyday driving range by 75% over the standard model. The prototype – which is code-named Cocoon, in reference to the 1985 sci-fi film – was built to compete in the Spanish ECOseries motorsport event.

"In 2011, we created the Nissan ECOTeam to race in the ECOseries championship," explains Dario Fernandez, senior engineer at the Nissan Technical Centre Europe – Spain. "It started with a few volunteer people preparing and racing a Nissan Juke diesel. Gradually we were adding vehicles to the team line-up, and we included the Nissan Leaf in the EV category. We were doing well, but we wanted to stand up-front. We believed that we had the best EV, but we knew that we didn't have the best range. So we came up with this idea of the double pack to increase the capacity."

The team dedicated to the 48kWh Leaf project consisted of around 12 volunteers, keen to work on the vehicle in their spare time. "When the idea was presented to the management at NTCE, we were ready for a reluctant position from them," says Fernandez. "But on the contrary, we got full support to go ahead with the idea. Nissan's brand promise is 'innovation that excites', and this project had all the innovation and excitement you can think of."

Time and space

Indeed, the bosses at NTCE were so enthused by the project that they gave the volunteers their own space in the workshop, and allowed them to utilize all the facilities and resources available to any other development.

The most complicated aspects of the project, Fernandez says, involved redefining the battery layout and the battery control unit. He adds, "We are very proud that this 48kWh Leaf is as safe as any other Leaf on the market. Not only that, but every single system works perfectly – there is no system fault if you check the vehicle with a diagnosis tool."

The Cocoon is based on the MY13 Nissan Leaf and retains the standard 80kW (254Nm) asynchronous electric motor. However, as Fernandez explains, "We have doubled the modules from 48 to 96, which means 384 cells. Total capacity grows to 48kWh with the nominal voltage unchanged at 360V. The weight increase is 147kg, but the overall energy-to-weight ratio goes from 16.86Wh/kg to 30.57Wh/kg." The range of the prototype is approximately 370km on a single charge.

Due to its status as a voluntary venture, the Cocoon is not directly tied into the OEM's wider development program but, Fernandez believes, the benefits will inevitably spill over into more official projects. "This is not part of the global EV strategy of Nissan. We wanted to innovate and to discover what could be done in terms of battery capacity and range. But obviously we learnt many things during the course of the project and this will be reflected in our day jobs."

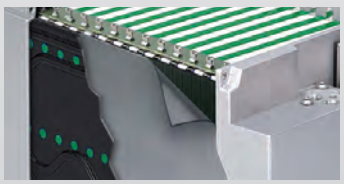
"While there are no plans to put this prototype into production, it serves as a useful exercise in thinking outside the box, something that our engineers and designers do on a daily basis," says Gareth Dunsmore, director of electric vehicles at Nissan Europe. "The Nissan Leaf 48kWh showcases the passion our employees have for their work."

The ECOseries project vehicle has double the battery capacity of the production Nissan Leaf

BERGQUIST

THERMAL SOLUTIONS FOR ENERGY STORAGE AND CONVERSION

Henkel's BERGQUIST brand of thermal products consists of many industry leading thermal materials used to dissipate heat and keep electronic components cool. Henkel brings high standards and focused leadership, supplying such well recognized names as GAP PAD™, Gap Filler, SIL-PAD™, BOND-PLY®, HI-FLOW® and TCLAD™ to the automotive and electronic industry.



ROBUST DIELECTRIC MATERIALS

Henkel's brand of BERQUIST thermal materials offer a wide variety of thermally conductive products to protect and cool components in power generation, conversion and storage applications.

SILICONE-SENSITIVE APPLICATIONS

The increased use of camera and sensor applications have created the need for products that possess low volatility silicones or are completely silicone-free.

LOW PRESSURE MOLDING MATERIALS

Henkel's broad portfolio of printed circuit board (PCB) protection materials safeguards electronic components from damaging environmental factors, such as extreme temperatures, fluids, corrosive elements, shock and vibration.

Henkel Excellence is our Passion

www.henkel-adhesives.com/thermal

ELECTRIC POWERTRAINS **ON TEST**

Our thoughts on cars we've tested recently, all of which feature some sort of advanced powertrain electrification

BMW 330e

The BMW 330e PHEV – the latest 3 Series variant – marks the most recent instance of the German car maker extending its i-derived eDrive technology across its model range. And it works. Combining high-quality dynamics and extremely low fuel consumption – 2.1 l/100km (112mpg) – the fusion of the e-powertrain (developed under the Efficient Dynamics banner) with a BMW turbo gasoline engine has resulted in a dynamically adept, locally emission-free and efficient plug-in hybrid mover.

With CO_2 emissions coming in at 49g/km, the plug-in drive system delivers familiar BMW dynamics by pairing a 65kW electric motor that develops peak torque of 250Nm with a four-cylinder engine that produces 184ps. With a total system output of 252ps and torque of 420Nm, this eco-friendly sedan accelerates from 0-100km/h in 6.1 seconds before powering on through to a top speed of 225km/h (140mph).

The electric motor and IC engine send their power to the car's rear wheels via a standard-fitted 8-speed Steptronic transmission. The arrangement of the e-motor in front of the transmission allows the gearbox ratios to be used in all-electric mode as well, meaning a torque converter can be omitted, which partially cancels out the extra weight of the additional drive unit.

A 5.7kWh lithium-ion battery pack located underneath the trunk enables an all-electric and locally emissions-free range of around 40km (24 miles), meaning the 330e should suit the needs of city dwellers and commuters.

BMW i3 94Ah

Tesla Model S aside, for us here at *E&H Vehicle*, the BMW i3 is probably the best example of the modern-day e-powertrain revolution, pipping the VW e-Golf and Golf GTE by the finest of margins. Having been a trailblazer when launched three years ago, the highly impressive e-drive unit range-extender engine package in the i3 has been significantly updated. All the revised tech details are revealed on page 14, but the main message here is the best has just got better, thanks largely to a new battery that boasts an improved range of 313km (195 miles) in everyday driving conditions.

Branded i3 94Ah, replacing the 60Ah model, the latest BMW i offering has a 33kWh capacity thanks to the higher storage density of lithium-ion cells. The pack consists of eight models, each with 12 individual cells, and has had its capacity increased without any structural hardware changes. In essence, the extra battery power has come about thanks to engineering upgrades to the cell internal packages having more electrolyte and adapting the active material. Battery enhancements aside, everything else on the i3 remains much the same, meaning this is a complete e-powertrain package that boasts all the usual brilliant BMW characteristics.

KIA OPTIMA PHEV

Perhaps the biggest surprise out of all our e-powertrain test cars of late has been the Optima plug-in hybrid. Why? Because at an affordable showroom sticker price, here's a stylish, efficient, tech-laden hybrid that works so well in the real world – and all this with the normal Kia traits of reliability and durability. The thing with the Optima is this: you have to go some to get the IC engine – a 156ps 2.0 DI four-cylinder – to spark into life; that's how good the e-drive system is. Heated seats and steering wheel on, air-con whirring, radio blasting, windows down, and going at speeds of up to 117km/h (73mph) – although Kia officially states 120km/h (75mph) – and all that's moving the Optima is one powerful 50kW electric motor that's powered by a 9.8kWh lithium-ion polymer battery. It's hard not to be impressed with the Optima PHEV in real-world wintry (at the time of testing) conditions.

There are, says Kia, up to 53km (33 miles) of all-electric driving to be had before the battery needs topping up or the IC unit kicks in, and this means emissions are officially rated at just 37g/km CO_2.

Fuel economy is 1.6 l/100km (176.6mpg). Total system power tots up to 205ps and 375Nm, but more impressive than that is how smooth the Optima PHEV is, gliding comfortably in congested city centers as well as on the open highway, and that's thanks in part to the e-motor replacing the torque converter as part of the package for the smooth-shifting 6-speed auto.

MERCEDES-BENZ C 350 PLUG-IN HYBRID

Daimler has extended its e-powertrain line-up with the highly acclaimed Mercedes-Benz C-Class getting a PHEV setup. Going directly up against the BMW 330e, the C-Class pairs a four-cylinder gasoline engine with a powerful electric motor that results in total system output of 282ps and 600Nm, far more than its BMW counterpart. Continuing the obvious comparisons, the M-B PHEV has a corresponding CO_2 figure of 48g/km (49g/km for the estate), and an efficiency rating of 1.7 l/100km (134.5mpg), again getting the better of the 330e. Where the C-Class isn't as good as the BMW is crucially in the electric operating mode: here you get 30.5km (19 miles) of BEV driving, somewhat less than the 40km (24 miles) offered by that other German PHEV. On the road, and in reality, the C 350 PHEV is a dream operator, fusing together the best of today's Mercedes-Benz technology and design with a state-of-the-art plug-in powertrain. We'd even go as far as to say this is the best hybrid offering yet from M-B/Daimler, and our pick of the highly impressive C-Class line-up.

PROFILE: LARS LAGSTRÖM

Job title: XC90 product development engineer
Company: Volvo

What career did you want when you were growing up, and what was your first job?
I've always been a car guy. My father breathed cars and had more than 60 in his lifetime, from big American muscle cars to small European ones – all brands, sizes and engines. So I have it in my DNA, and I always wanted to pursue a career in vehicle development, influencing product. I studied Mechanical Engineering at the University of Gothenburg. And I still love to get my hands dirty, playing with cars in my free time.

What was your career path to the position you currently hold?
I've been at Volvo for more than 35 years, across many different divisions. The last 11 years I've been in product development on large cars. So my last projects were S/V60 and XC60 facelifts and then I joined the XC90 program, developing an all-new SUV.

What are the best and worst elements of your job?
If I'm being honest, I hate the administration. In fact, I always say, "Can't we do it easier and quicker – why do we have to follow these procedures?" But actually those procedures are important and are in place to make the company better. The best aspects? Being able to influence development, that's amazing. So I was the person who stressed the need for front heated electric windows or gearshift paddles or full USB connectivity on the first-gen XC90.

What car do you currently drive?
I have a crazy taste in cars. For example, I own a Suzuki Cappuccino that I actually bought on eBay in the UK. I've done a lot of things to that car, like add an independent management system, bigger intercooler, new throttle system, and so much other stuff. I've not blown anything yet – I'm up to 90ps on that engine. I'll soon replace that engine with another chain-driven – not belt – engine with 110ps. Then, I have an American tuning kit that'll take the engine to 165ps. So soon my Suzuki Cappuccino will be a double espresso! My everyday car is a Volvo V40 Cross Country, D3 automatic. Once we've met all customer orders, maybe I'll get an XC90 T8.

> Combustion engines will still be around, probably in 1-liter, three-cylinder turbo form, but the turbo will be electric. Maybe electric motors will feature too

What would be your dream engine specification for today's eco-friendly world?
For a totally eco-conscious world, I'd opt for an electric fuel cell vehicle. I'd use a new electrical engine that I've been reading about lately that's 75% smaller than current engines with exactly the same output. These engineers have created a smaller engine because they've succeeded in controlling the heat, which allows for 75% shrinkage. So if I can have this 87ps small electrical engine, I'd put it in my Cappuccino – a perfect solution.

And if emissions weren't a factor?
For pure performance I'd go for another vehicle that I have in my garage – a Mercedes SL 55 AMG. So big displacement – 5.4 liters – with a Kompressor. I'd go for this engine type – supercharger boosting is so much fun.

In your opinion, what is the greatest engine that has ever been produced?
I'm impressed with the Nissan Le Mans engine with 400ps, 1.5 liters in size and three cylinders. Wow! That's a really high-tech piece of engineering. For automotive, I have a big heart for Mercedes performance engines. The 2.5 engine in the Mercedes 190 was stunning – real race performance on the road.

What do you think will be powering a typical family sedan in 2035?
In terms of power, you'll be looking at 150ps to 180ps. Car weight will go down, we'll be using different materials, but power will remain the same – we won't need much more. Combustion engines will still be around, probably in 1-liter, three-cylinder turbo form, but the turbo will be electric. Maybe electric motors will feature too.

Do legislators help or hinder your work?
We talk a lot with legislators, and in some areas, like safety, we actually do more than they ask – we push their boundaries. So when it comes to legislation, it's a balance.

Finally, which OEMs do you particularly respect in terms of engine development?
It has to be our three main competitors: BMW, Mercedes and Audi.

A star in the making

In a remarkably short period of time, Tesla went from a California startup to a major player in the EV game. *E&H Vehicle* takes a look back at the car that put the company on the map

WORDS: **MATT ROSS**

In 2007, the then CEO of Tesla Motors, Martin Eberhard, told *E&H Vehicle* why he thought early EVs had failed. "They weren't exciting. They were built to meet the zero-emissions mandate. From my perspective, there's a better place to enter the market."

That place, as it turned out, was the Tesla Roadster. The Palo Alto-based company might now be better known for the Model S, Model X, upcoming Model 3, Gigafactory, superchargers, home power products and even roof tiles – but it was the Roadster (code-named Dark Star during its development) that convinced car buyers that EVs didn't only have to be clunky metal boxes on wheels with laughable range. A 2004 meeting with Roger Becker, senior development engineer for the Lotus Elise, marked the beginning of a relationship between the two manufacturers that gave Tesla an engineering foundation to build on, access to a network of suppliers, and a production infrastructure. Lotus, under contract to Tesla, built the Roadster's chassis in the UK. Cars destined for North America were shipped to Menlo Park in California for installation of Tesla's proprietary powertrain, while those for customers in other countries remained in England for final assembly.

Tesla subsequently agreed a contract with Lotus for 2,500 gliders – but the Roadster is more than just a repurposed, electrified Elise. For starters, the parts overlap between the two cars is less than 7%. In fact, in Tesla's own words, "You could say the Tesla is similar to a Lotus Elise, except it has a totally different drivetrain, body panels, aluminum tub, rear sub-frame, brakes, ABS system, HVAC and rear suspension. The Tesla also neglects to carry over the gas tank, emissions equipment and exhaust. If you were to try to convert an Elise to a Tesla and started throwing away parts that aren't carried over, you would be left with a windshield, dashboard (complete with airbags!), front wishbones and a removable soft top."

The Roadster offered an EV solution that not only looked good, but was fun to drive. The three-phase, four-pole AC induction motor was rated at 185kW. A Sport model, introduced at the 2009 Detroit Auto Show, boasted a higher density motor with a hand-wound stator that upped the power to 215kW. It could do 0-97km/h in a swift 3.7 seconds. Reviews of the car were littered with superlatives and countless articles hailed the Tesla Roadster as a working example of the future for zero-emissions motoring.

Tesla head honcho Elon Musk took delivery of the first Roadster in 2008, the 1,000th was produced in 2010, and in 2011, a final run of 15 special editions was announced – five each for North America, Europe and Asia. The first-generation Roadster officially ceased production in 2012, though Tesla has supported the model with updates to its battery – from 53kWh to 80kWh. In 2015, however, Musk hinted at a second-generation Roadster, set to launch in 2019. Given Tesla's growth in the interim, it's a safe bet that the new Roadster will no longer involve a Lotus glider, and will instead be built on the company's third-generation platform, much like Model 3. In another very Tesla move, Musk also hinted that the new Roadster will offer 'Maximum Plaid' mode – continuing the company's fondness for performance modes that pay homage to Mel Brook's movie *Spaceballs* (following Ludicrous Mode in Model S).

Back in 2007, *E&H Vehicle* asked if the Tesla Roadster might be the ultimate EV. Perhaps by today's standards, the first-generation model has been eclipsed – but only by vehicles that have gone through the door that the original Roadster so spectacularly kicked open.

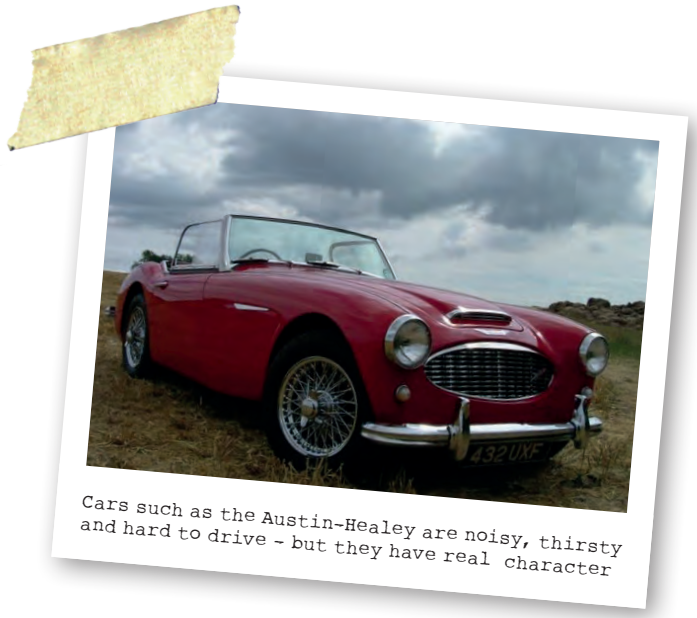
The original Tesla Roadster was the first highway legal serial production EV to use lithium-ion battery cells, and the first production EV to travel more than 320km per charge

STAY CHARGED

Professional sealed Battery Chargers and DC/DC Converters for harsh mobile environments, plugged in up to 660VAC, single and 3-phase mains grids, compliant with SAE J1772, EN61851, and more...
... to stay charged wherever you are.

EDN GROUP S.r.l.
Via dell'Artigianato 8, 20835 - MUGGIO' (MB) ITALY
Ph: +39 039 9402610, email: sales@edngroup.com

Llewellyn



Cars such as the Austin-Healey are noisy, thirsty and hard to drive – but they have real character

Last Saturday, a classic car rally noisily passed by my house. The air was blue with partially burned hydrocarbon fuels as 1960s Mini Coopers, Porsches, Ford Escorts, Austin-Healeys and Alfa Romeos thundered by.

It was glorious. The smell was fairly unpleasant, but it instantly took me back to my youth. It was reminiscent of a steam engine rally I attended as a child – brilliant old machines, lovingly cared for by their owners and steadily increasing in value.

As a fully committed electric car driver, the pleasure I got from seeing these old bangers rumble along the lane may seem contradictory. I would argue otherwise.

The occasional modern car that passed by was conspicuously dull. They all look the same – modern cars, regardless of their power unit, are all safer, quieter, more fuel efficient… and enormously boring.

That's what I think, at least. But I also believe it's a good thing.

The cars from the 1960s (and earlier) are lethal deathtraps. They have appalling brakes and rubbish road holding, they are chronic fuel guzzlers and noisy old stinkers. But they had character.

They are, like it or not, from a bygone age, and I admire the gentlemen of a certain age that keep them going.

> "Modern cars, regardless of their power unit, are all safer, quieter, more fuel efficient… and enormously boring"

As electric cars constantly increase in number, as their range and energy efficiency continue to improve, and as the public charging infrastructure grows exponentially, I truly believe these old clankers will grow in popularity and value.

If you own a mid-1960s Lotus Cortina, hang on to that baby – keep it trim, it's worth a bomb.

The internal combustion engine is, likewise, a relic of a bygone age. Sure, we are still producing a mountain of them every day but let's face it – the technology is dated, the modifications built into them are paltry, and the resulting energy waste from running them verges on the comically ridiculous.

They are the past, and the sooner that more people understand this the better. I accept that electric cars (and when I say that, I include hydrogen fuel cell cars – they're electric too, in case you were wondering) still occupy a tiny fraction of the market, but it is growing. Globally, sales are up, month by month. Plug-in hybrid sales are off the scale, which means more and more people are experiencing the benefits: the quiet operation, the greater economy and the reduced servicing costs.

Of course, arguments continue to rage about electric vehicles, and the materials and processes used in battery manufacture. But we now know that a battery has a very long life and a liter of hydrocarbons has a very short one. Sure, it greatly depends on where the electricity comes from, but increasingly (and especially at night, when most electric cars are charged), that electricity is cleaner.

We have to clean up our generating capacity, use smarter technology, and reduce the waste caused by transporting electricity over vast distances from centralized power plants to the consumer. All those things are going to happen anyway, and using electric cars is encouraging faster adoption of these emerging technologies.

There's plenty of research showing that people with electric cars want solar PV installed, and vice versa. Local generation and use of electricity is changing things pretty dramatically, and local storage capacities are increasing at speeds previously thought preposterous. Vehicle-to-grid systems are right around the corner, so next time a rally of gorgeous old classic bangers thunders past my home, I'll be running the house off the Tesla in the garage.

20, 21, 22 JUNE 2017 STUTTGART, GERMANY

PUT THE **DATES** IN YOUR DIARY **NOW!**

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

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

engineexpo2017

www.engine-expo.com

Greg Offer

Engineers at the start of their careers should carefully consider the trends affecting the balance between current and future technologies

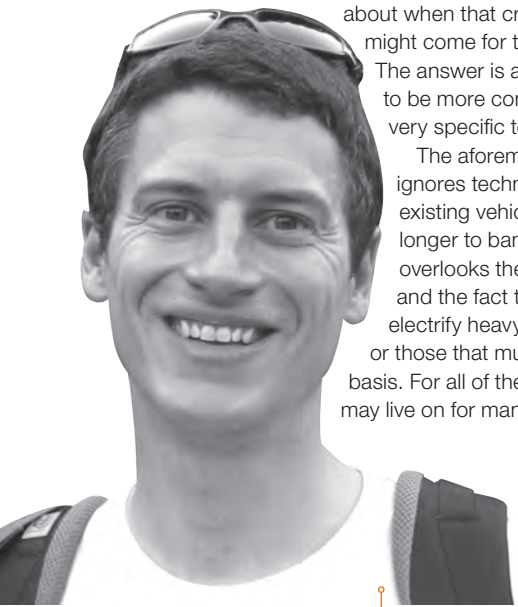
How long should we continue improving the internal combustion engine? The reason I ask this is not to cause controversy or annoy those who are passionate about the ICE, but to start a conversation. The trigger for my thoughts is the growing momentum in Germany to ban or limit sales of new combustion engine vehicles from 2030. Considering the time that it takes to bring new technology from the laboratory into the market, and based on the assumption that no investor wants a stranded asset, this is an important question.

Working backward from that goal of 2030, if the lifetime of a production run is, perhaps, 10 years, the time taken from when the product is designed to the first vehicle rolling off the assembly line is three years, and the time taken to incubate an idea in a company R&D division is another three years, then the last year that new technology from a research lab should have had a chance to make it into a production vehicle was 2014.

This timeline is obviously based on numerous assumptions, and I don't personally agree with such a simplistic analysis. However, I deliberately want to shock everyone, to get people thinking about when that critical moment might come for their company. The answer is always going to be more complicated and very specific to the market.

> "Working backward from 2030, the last year that any new technology should have had a chance to make it into a production vehicle was 2014"

The aforementioned timeline also completely ignores technologies that can be introduced into existing vehicles, and ignores markets that will take longer to ban combustion engine vehicles. It also overlooks the fragmented nature of the market, and the fact that it is going to be extremely hard to electrify heavy goods vehicles, industrial machines or those that must traverse long distances on a regular basis. For all of these vehicle types, combustion engines may live on for many more decades, if not longer.



However, at some point we are going to reach peak combustion engine production, and regardless of how soon you think that could be, it is going to have a dramatic impact on the large number of automotive engineers whose skills and knowledge may start to become redundant. It will also affect investment decisions, as the money likes to follow growth, not stagnation and decline. Those toward the end of their careers may not have to worry too much, but for young engineers who are just starting out, this is something to seriously consider. I would ask aspiring automotive engineers two simple questions: Do you want to become an expert in a technology that is to become less relevant and important, competing against experienced candidates in a shrinking jobs market, and face the prospect of having to retrain at some point? Or do you want to become an expert in a new technology that is growing in relevance and importance at an exponential rate, to be at the beginning of the curve with opportunities for rapid promotion as the sector grows, and to know that your skills and knowledge are likely to see you through until the end of your career? I asked myself these questions about 13 years ago at the start of my career, and it is no accident that my research group is focusing on the electrification of transport.

Dr Gregory Offer is a senior lecturer in mechanical engineering at Imperial College London. His research focuses on fuel cell, battery and supercapacitor technologies, mainly in transport

SEE the International Engine of the Year Awards presented *LIVE* on 21 June 2017!

20, 21, 22 JUNE 2017 STUTTGART, GERMANY

INTERNATIONAL engine of the year awards 2017

Presented by engine technology international *magazine*

Taking place on the second day of Engine Expo, the highly acclaimed International Engine of the Year Awards have become some of the most sought-after accolades in the industry, with the winners often using the logo as a centrepiece of their advertising campaigns. The ceremony attracts the most senior engine designers, executives and journalists from all over the world.

www.ukipme.com/engineoftheyear

engineexpo2017

www.engine-expo.com

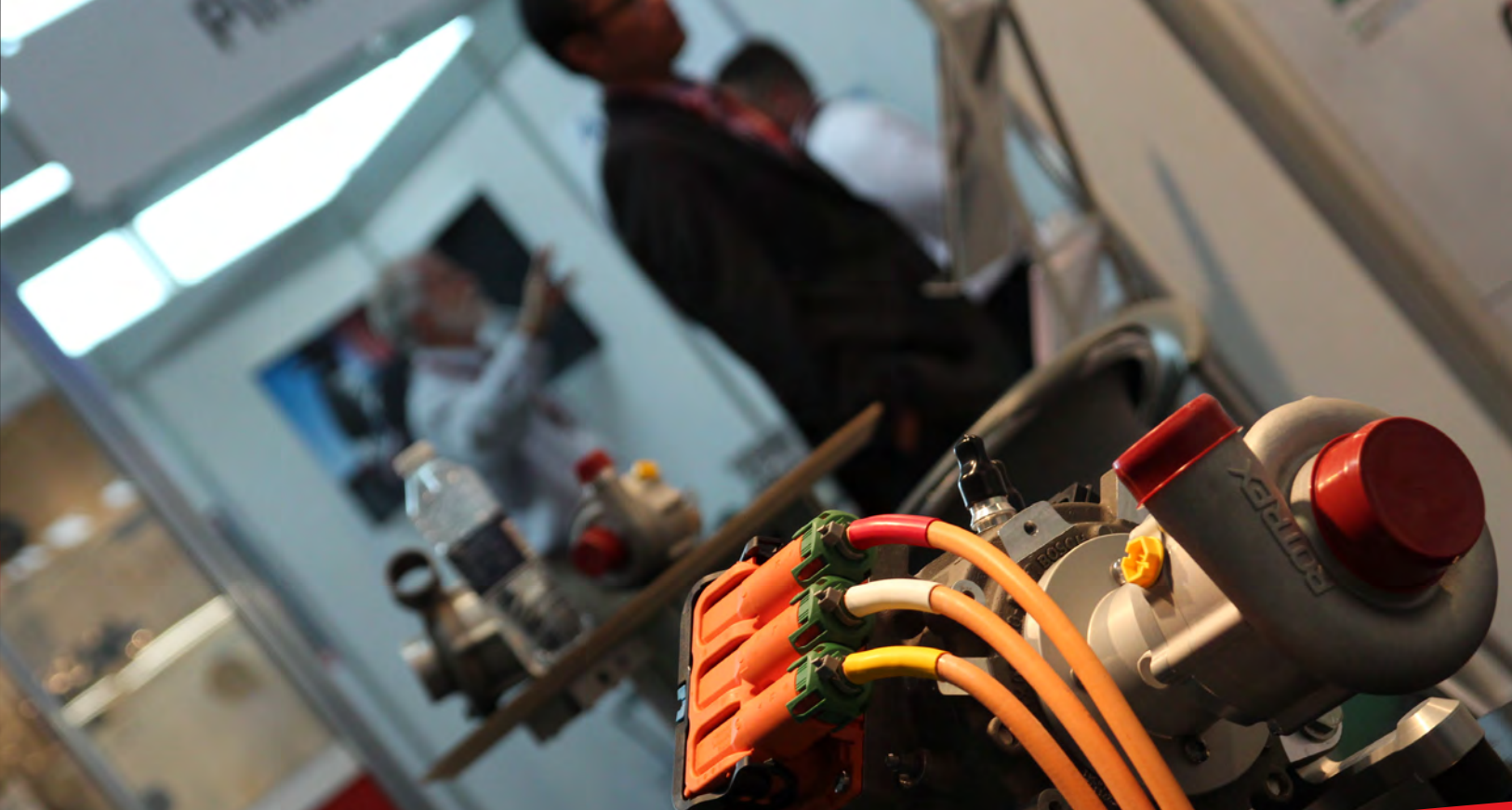
PUT THE **DATES** IN YOUR DIARY **NOW!**

20, 21, 22 JUNE 2017 STUTTGART, GERMANY

ON SHOW: ADVANCED INJECTION SYSTEMS, FORCED INDUCTION TECHNOLOGIES, HYBRID DEVELOPMENTS, COATINGS AND MUCH, MUCH MORE!

engineexpo 2017

THE DEDICATED TRADE FAIR FOR POWERTRAIN DESIGN, PRODUCTION, COMPONENTS AND TECHNOLOGY!



FREE TO ATTEND REGISTER ONLINE!

Taking place at the same time and in the hall next to **Automotive Testing Expo**

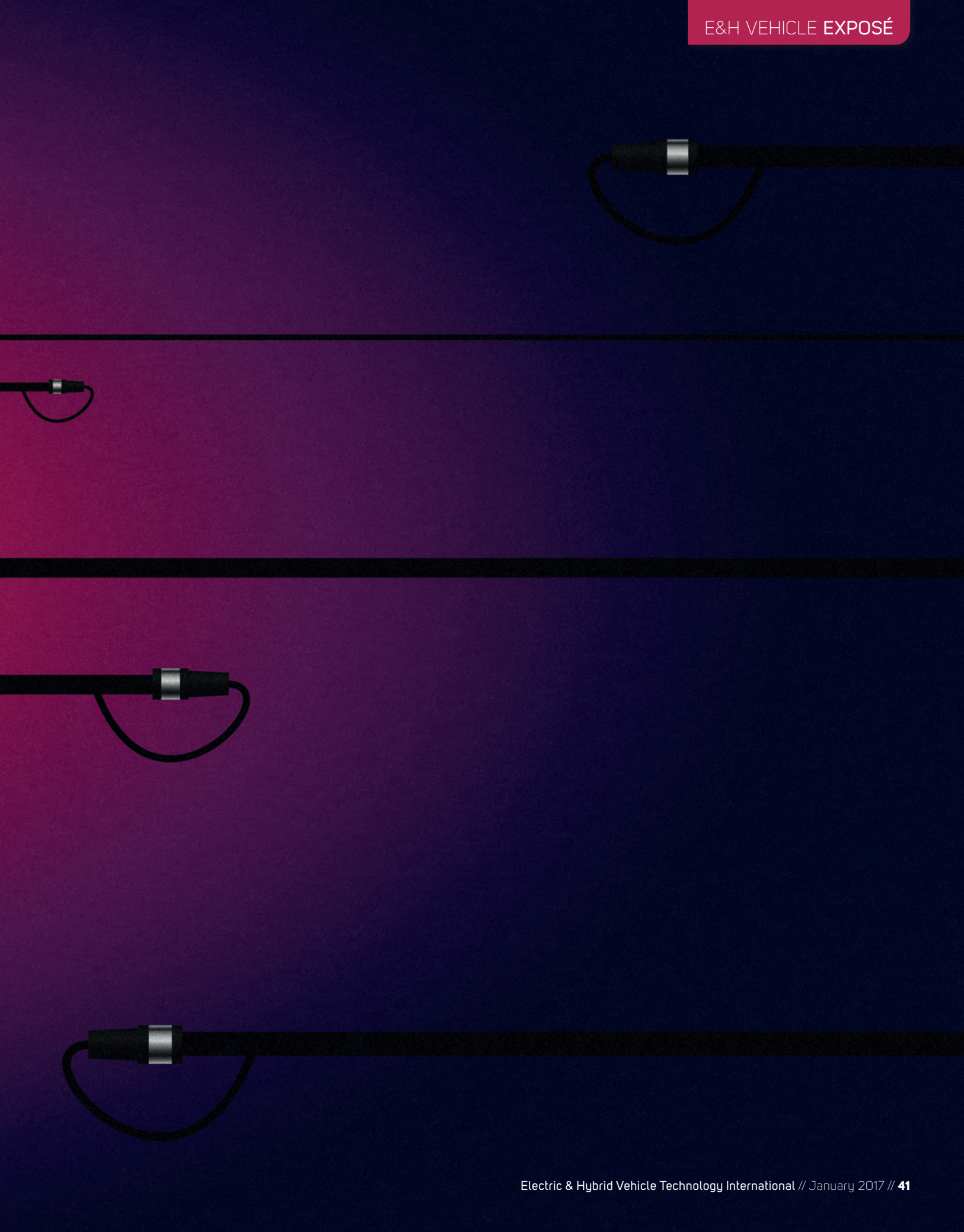
Featuring the **latest engine testing technologies** including emissions testing systems, power and efficiency validation, NVH testing, and electric and hybrid powertrain test and analysis tools

automotive testingexpo 2017 europe

www.engine-expo.com

E&H Vehicle investigates the huge gulf between official EV ranges and real-world figures, and looks at how the incoming WLTP standard could help paint a more accurate picture

WORDS: **LEM BINGLEY**



At the Paris Motor Show in September 2016, Renault-Nissan chairman and CEO Carlos Ghosn had barely sprung the surprise of a new 400km (248 miles) edition of the Renault Zoe before conceding that the improved electric car could not actually cover that distance. "It is 400km NEDC, which is the official standard. It's 300km (186 miles) in real life," Ghosn admitted.

NEDC – the New European Driving Cycle – is the test that all manufacturers must use to establish the official range of battery EVs sold in Europe. Exactly the same test is used to derive fuel economy and CO_2 figures for conventional IC engined cars – and there are steadily growing gaps between test results and typical owner experiences in the real world.

A hard-hitting study published in September 2015 by consultant Element Energy and the International Council on Clean Transportation (ICCT) found the gulf between NEDC figures and real-world CO_2 emissions for new cars increased from 10% to about 35% between 2002 and 2014. Ghosn's remarks, plus real-world data collected by the Spritmonitor website in Germany, suggest EVs suffer to much the same extent.

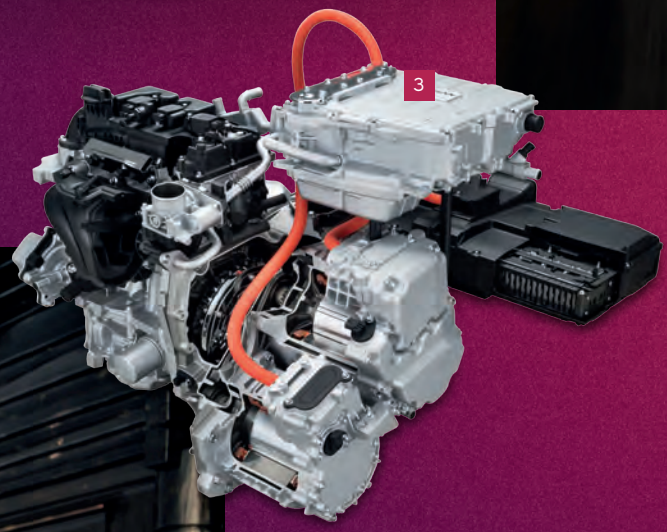
No matter which way one looks at it, it's hard to imagine another area of commerce in which official yardsticks could become so stretched. Imagine if filling stations could charge per liter for every 750ml, or if 4kg bags of potatoes came up a kilo short. But that is exactly what European electric vehicle buyers face at present.

Further confusion arises at the global scale. EV buyers in North America, for example, are offered completely different official range measurements, based on test procedures set by the US EPA.

1

1. Renault estimates that the revised Zoe, fitted with the new Z.E.40 battery, has a real-world range of between 299km (186 miles) in temperate conditions and 199km (124 miles) in more extreme cold conditions

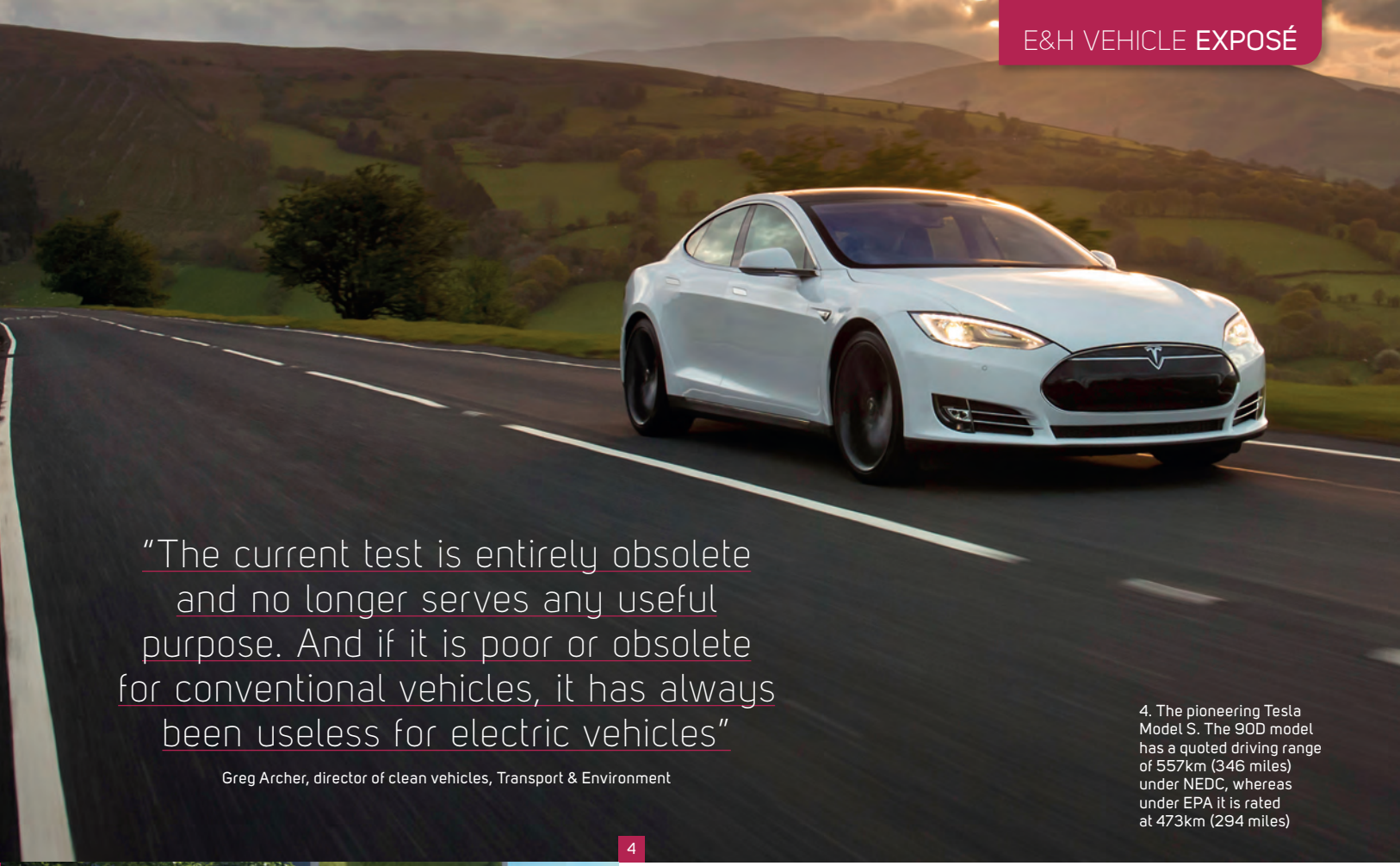
2



3

2. The Leaf 30kWh upgrade model delivers up to 249km (155 miles) of driving range on a single charge, claims Nissan

3. Nissan's e-Power innovation draws on the EV tech created for the Leaf. Unlike application in the all-electric Leaf, however, e-Power adds a small IC engine to charge the high-output battery when necessary, thereby eliminating the need for an external charger



"The current test is entirely obsolete and no longer serves any useful purpose. And if it is poor or obsolete for conventional vehicles, it has always been useless for electric vehicles"

Greg Archer, director of clean vehicles, Transport & Environment

4. The pioneering Tesla Model S. The 90D model has a quoted driving range of 557km (346 miles) under NEDC, whereas under EPA it is rated at 473km (294 miles)

4

5

5. The new e-Golf's average driving range has increased by around 50% to around 200km (124 miles), says VW. Driving range in the NEDC is up to 300km (186 miles)

The gap between NEDC and EPA figures can be large, but unpredictably so. For example, a customer considering a Tesla Model S 90D will see a quoted range of 557km (346 miles) under NEDC, whereas the same model is rated at 473km (294 miles) under EPA – a 15% reduction. And that drop provides no guide to the shortfall experienced by a 30kWh Nissan Leaf, which is rated at 249km (155 miles) under NEDC and 172km (107 miles) by EPA. That's a whopping 31% fall.

These gulfs arise because NEDC and EPA measure different things in different ways, and both are assessed under lab conditions. In turn, each is a world away from the comparative chaos of real roads, real drivers and real traffic.

WLTP takeover

The 'New' in NEDC is a misnomer. The test procedure dates back to the 1970s and hasn't been updated in almost 20 years. Greg Archer, director of clean vehicles at Brussels-based lobby group Transport & Environment, is scathing in his criticism. "The current test is entirely obsolete and no longer serves any useful purpose," he says. "And if it is poor or obsolete for conventional vehicles, it has always been useless for electric vehicles. It is a complete distortion of reality."

The NEDC's days are numbered, thankfully. It will be replaced next year in Europe by a new protocol, the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), which will employ a new test cycle, the WLTC.

WLTC is tougher than NEDC, but there will still be a gap between test CO_2 figures and real-world results of about 23%, likely to grow to 27% by 2030, the ICCT predicts. The move to WLTC is also expected to close some of the gap between Europe and North America, although the US system will still produce lower EV ranges more in line with the real world.

One major reason for this is that the US tests consider the impact of heating and air-conditioning, which can have a very distinct effect on an EV's range. "That will still be out of scope for WLTP," observes Phil Stones, chief engineer for powertrains at UK-based vehicle testing specialist Millbrook.

"There have been discussions for a number of years about creating a test called MAC – mobile air conditioning – however in Europe that hasn't been instigated," he says. "The federal test uses a five-cycle procedure and then takes a weighted average over all those cycles to get a declared figure. In Europe, we don't. So an EV doesn't have to do a test with air-con on."

There will also be a confusing period of transition in Europe between September 2017 and December 2019 when NEDC will be used for run-out vehicles while new models must quote stricter WLTP figures. A label to make sense of this overlap remains to be designed, just as many other aspects of WLTP are still being hammered out.

"A lot of it is still in draft at this time; still being agreed in Brussels," outlines Stones. "It's a very, very tight timeframe."

Creative freedom

While the nature of NEDC accounts for much of the gap between official and real-world results, manufacturers have deepened the problem through their creative interpretation of the rules and occasionally, as in the case of VW and the Dieselgate scandal, by outright cheating.

Before the NEDC lab tests can be conducted, the car first needs to be calibrated for road friction and aerodynamic drag. As a report published in March 2013 by Transport & Environment notes, "When the road load test procedures were drafted 30 years ago, no-one expected car makers to adjust the brakes, pump up the tires, and tape up all the cracks around the doors and windows to reduce the air and rolling resistance."

Similarly, during the actual NEDC testing phase, vehicle manufacturers can improve results through a variety of tweaks, such as pre-charging the battery to reduce the parasitic load of the alternator.

Millbrook's Stones says type approval inspectors generally do a good job checking that the rules are being obeyed, but that they can't stop things that aren't forbidden.

"There are tolerances on everything, but you don't have to go down the middle of those tolerances," he says. "If you were to go to the preferred end of those tolerances, then that's

WHAT THE INDUSTRY SAYS

GORDON MURRAY
CEO, GORDON MURRAY DESIGN

Range anxiety is one of the biggest issues, and I would back a complete overhaul of the way we measure energy consumption – whatever the powertrain. The difference with petrol and diesel cars with real-world consumption – and therefore emissions – and actual consumption, is about 26%, and that's because every manufacturer plays the game. For EVs and particularly hybrids, it's ridiculous how they are tested. Compared with the range you can actually achieve, it's a phenomenal difference – and that's because they are tested with no loads and in ideal conditions. I think it's about time the industry owned up and re-wrote all the tests because the public don't know these things are going on.

RALF HANNAPPEL
DIRECTOR FOR EUROPEAN ELECTRIFICATION, GM

We know that range anxiety is the biggest issue and we have anticipated that. This is a legislative thing because we have test cycles that we drive the cars on – about 500km (310 miles) in the NEDC and that will change when we go over to the WLTP, which is closer to reality. We have driven this car [the Ampera-e] on the new test cycle to give a preliminary range figure and we have estimated a range of more than 380km (236 miles), which is very realistic. If you look at the test cycles [NEDC], the car is driven on a certain speed range that the typical customer might not drive, so it's good for comparison, but for real life it's different. To make it more realistic, a more realistic test cycle is needed.

GERALD KILLMANN
HEAD OF POWERTRAIN, TOYOTA EUROPE

There are some circumstances that are valid for all auto makers, such as the reference of fuel consumption/energy consumption/range for any vehicle is done in a standardized cycle for fairness. This cycle differs from actual driving conditions. Depending on the actual driving style, you may get close to that range, or even better in some cases, or worse in others. One thing that is important to understand is that for any vehicle, energy consumption is being optimized constantly by all OEMs. There is a change coming to the test cycles from NEDC to WLTP, which will change the driving patterns, and I believe in the future that the difference in real-world driving and the cycle will be far less.

1. A lot of legislation still needs to be completed for electric vehicles, including standardized charging as well as the introduction of fairer test cycles that better represent real-world driving and ownership

legal. So, would I say that happens a lot? Yes. It's a competitive world."

It seems likely that EV makers will have used all the applicable tricks developed for IC-engined cars. "I don't have any direct evidence, but I see no reason why they wouldn't," confirms Archer. "Deploying various optimization strategies is what the manufacturers do. They used to deny it until the European Commission started to work out how to correlate between NEDC and WLTP, and suddenly they wanted to gain credit for all the flexibilities that are in the current test but aren't in the future one. All of a sudden, all the evidence came out."

More rigid rules provide another reason why EPA range figures tend to be lower. "There is less gaming done in the USA because the test procedures are more fully defined," explains Archer. "The other big difference is the system of approving vehicles.

GILLES LE BORGNE
EXECUTIVE VICE PRESIDENT, RESEARCH AND DEVELOPMENT, PSA

By the time of the next Paris Motor Show [2018] this issue won't be a problem. We're working with a new, third generation of lithium-ion batteries for our forthcoming BEVs – a combination of four B-segment and entry-level C-segment cars by 2021 – and they will be capable of doing 450km (280 miles). This new generation of lithium-ion is really outstanding in terms of performance. Today, everyone's BEV range readings are based on the current NEDC cycle, where you lose around one-third of the real range. But the forthcoming WLTP cycle is very close to real life. It's not exactly like real life, but it's much closer than NEDC, so the gap between real-world range and lab range will decrease.

MICHAEL WINKLER
HEAD OF POWERTRAIN, HYUNDAI-KIA

The key item is that with electric vehicles, you have to offer the customer a vehicle that fulfills their daily needs. The biggest need is to be able to get to work and back, and have enough range left in reserve. Even though we can achieve driving ranges in the region of 300km (186 miles), which is more than enough for the daily needs of a driver, the fear the customer has of range anxiety, we have to take seriously. The move toward WLTP should help with that.

JÜRGEN SCHENK
DIRECTOR OF E-DRIVE SYSTEM INTEGRATION, DAIMLER

No testing method – and that includes WLTP – will be able to provide a single realistic figure. This would mean that any driver, driving the same vehicle, anywhere in the world, in real life would always get the measured consumption, despite different climate zones, driving styles, loads and route profiles. To achieve a more reliable range indication – before and during the trip – the driver should enter the destination into the navigation system. This allows the car's software to adjust its battery range prediction according to the topography, factoring in climbs and opportunities for regen, as well as average speeds and traffic conditions along the chosen route.

In the USA, the initial approval is done by self-certification, but the US EPA then actually checks a sample of vehicles. And if they find disparities, they impose really punitive penalties." In 2014, Hyundai-Kia agreed to pay US$350m including a US$100m fine over inflated mileage claims, and other makers have faced similar costs. "Dieselgate was particularly egregious and that's why they've thrown the book at VW," adds Archer.

Similar processes to beef up type approval are being debated by the European Parliament.

"Our expectation is for a vote in January," continues Archer. "We could move toward a system whereby member states are doing the approvals but then there is checking by the European Commission or other third parties on how vehicles are actually performing on the road, and ensuring that they meet durability requirements, and so on. There are questions about how those tests should be done, but the current thinking is that we should move away from laboratory testing to on-road testing."

Emissions Analytics (EA) specializes in on-road testing and has conducted thousands of real-world tests to determine independent figures for fuel economy and emissions. It says it has created a test protocol that produces

1. Established in 2011, Emissions Analytics helps provide accurate fuel economy and driving range data for passenger cars. It has also grown to include the measurement of tailpipe emissions of CO, CO_2, NO and PM

> "In the USA, the initial approval is done by self-certification, but the US EPA then actually checks a sample of vehicles. And if they find disparities, they impose really punitive penalties"
>
> Greg Archer, director of clean vehicles, Transport & Environment

THE PROBLEM WITH PLUG-INS

Today's European range figures for EVs are assessed using the NEDC test cycle. "We drive the EV over repeated cycles on a dyno until the vehicle says 'stop please', or it can't maintain 50km/h (31mph)," explains Millbrook's Phil Stones.

"The test is done at 20°C, with no heating or air-con, and it's a very low-energy cycle. So it's kind of as good as you're going to get in terms of range."

While the figure that emerges may be unrealistic, it has the benefit of clarity. When it comes to plug-in hybrids, however, the situation becomes more murky. When a car can be driven on electricity alone, on fuel alone, or using an arbitrary mixture of the two, how do you arrive at a single figure for its performance?

Plug-ins are tested using repeated cycles to determine the electric-only range, followed by a fuel consumption test with the exhausted battery. The two sets of data are then merged using a weighting factor that reflects how often the typical owner is expected to drive on electricity. This calculation explains how a heavy seven-seat SUV like the Volvo XC90 Twin Engine can achieve an official CO_2 rating of 49g/km.

"The assumption is that the car drives on its battery 70% of the time," says Transport & Environment's Greg Archer. "But that certainly isn't what's being achieved at present. Plug-in hybrids in the Netherlands are being driven on battery about 35% of the time."

Archer adds that company car drivers who are allowed to claim fuel expenses, but not electricity costs, are in fact being incentivized not to plug in.

The situation has implications for policy in several areas, from CO_2 taxation to charging infrastructure. "As the range offered by battery EVs improves, they will have less need for recharging points," Archer observes. "But you will need those recharging points for plug-in hybrids, so that they can run on batteries more of the time. If you don't achieve that, then you're just carrying around a heavy battery in a not-very-efficient hybrid application."

1

2

repeatable results despite the variability of real roads. "The first stage is: keep as many things constant as you can," says EA founder and chief executive Nick Molden.

"We have drivers who are trained to drive the cars in the same way; we always set up the car in the same way, including the amount of weight in the vehicle. The second stage is that the test has to fall within some fairly tight parameters to be considered valid."

If traffic flow or temperature strays too far from the 'norm', the test has to be repeated. The next stage is statistical normalization in order to adjust for whatever deviations from the average were observed during the test.

The final leveller is time – an EA test runs for three and a half hours, whereas NEDC lasts just 20 minutes and WLTP takes 30 minutes.

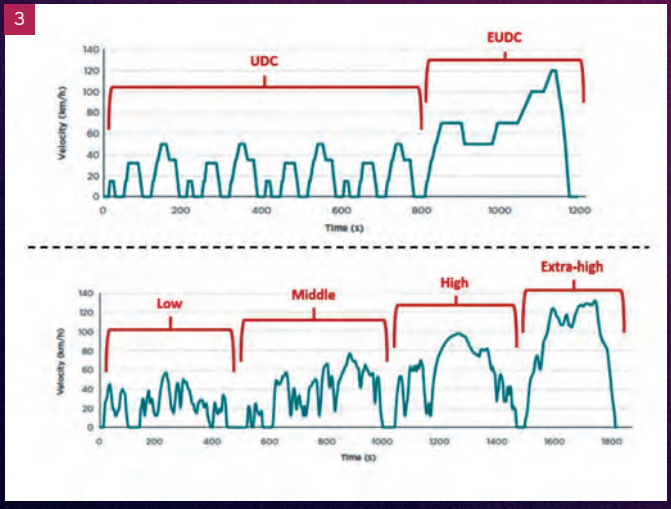
EA is still at the experimental stage when it comes to testing EV performance in the real world, but it has assessed several models including the Tesla Model S and Chevrolet Bolt. The company measures the net electrical charge used second-by-second over its usual test route, then converts the energy used to a mile-per-gallon-equivalent (MPGe) number, as well as miles per kilowatt-hour.

"If there's one reason to get out of the lab, it's that you need to take EVs up and down hills," adds Molden. "How much does it eat into the battery when you're going up a steep hill, and how much does it recapture going down the hill? Each technology is different. I think EVs will have even more exaggerated differences between laboratory and the real world because of factors like these."

Indeed, Molden argues that advances in mobile testing mean the role of lab testing ought to be questioned in general – and perhaps even assigned to the scrap heap. "There's a lot of habit and vested interest in maintaining a laboratory system," he notes. "It is very accurate, but if it's very accurately measuring the wrong thing, that's not actually helping anyone."

> "I think EVs will have even more exaggerated differences between laboratory and the real world"
>
> Nick Molden, founder and chief executive, Emissions Analytics

3



1 and 2. The Bolt EV, which is due to go into production by the end of 2016, will offer more than 320km (200 miles) of range on a full charge, claims Chevrolet and GM

3. A closer look at the NEDC and WLTC cycles

Electrical Architecture Expertise

Power Electronics & Battery Systems

Manufacturing Plants

Automotive Quality Standards

ACTIA ELECTRIC DRIVE SYSTEMS

30 years of Automotive industry experience

- An international group in 15 countries.
- The partner of passenger, commercial and industrial vehicle manufacturers.
- Intelligent solutions tailored to specific applications.
- High-end Automotive quality in all stages of development and manufacturing.
- Electronics manufacturing expertise in the group's medium and large production factories.

ACTIA®

www.actia.com

Running on PTY

As European countries push toward enforcing bans on IC vehicles, *E&H* speaks with leading legislative think-tanks to discuss the wider implications as well as what governments and OEMs need to do between now and then to ensure consumers remain mobile

WORDS: **JOHN O'BRIEN**

As knockout blows go, an outright ban on the sale of certain internal combustion engines is the kind of punishing body shot that could bring the heavyweight automotive industry to its knees. Possibly the biggest spark to ignite the debate on the future of IC engines comes from Northern Europe. In the early part of 2016, Norwegian business paper *Dagens Naeringsliv* ran a front-page news story reporting that the country's four leading political parties had agreed that, in order to improve the country's air quality, all IC-engined passenger cars would be banned from sale by 2025. Such a move would be a landmark precedent, but how likely are we to see such a ban ever implemented?

"If that's what they're going to do, which we're still not sure of at the moment, then it is a very bold move and a major change. In the UK the situation is different," explains Laurie Laybourn-Langton, research fellow at the Institute for Public Policy Research (IPPR). "The population is larger, and we've had specific policies put in place to push diesel. As with most things in Northern Europe, I'd say it is probably a bit easier for them to implement an outright ban than it would be in somewhere like the UK. But the concept of getting rid of the IC engine, and moving to a situation where we've got zero air pollution and zero emissions, is absolutely right. As technology advances we have less of an excuse to remain in the current situation."

"Although Norway and the Netherlands are both planning to ban IC engines from cities as early as 2025, the targets for that time frame aren't nearly as ambitious," adds Julia Hildermeier, clean vehicles and e-mobility officer at Belgium's Transport & Environment think-tank. "It's very important to help accelerate the eventual transition to e-mobility and to help improve air quality in European cities. The Dutch and Norwegian suggestions are not set in stone. They are suggestions put forward by national parliaments, but from a European perspective it is important that member states such as the Netherlands are

starting to take this shift seriously and are committed to help promote it."

Domino effect

For several years Norway has led the way in electric vehicle sales. In 2013 there were just 18,000 personal-use EVs registered in the country, but the introduction of legislation that allowed electric vehicles to use bus lanes saw total registrations soar to over 50,000 by 2015. Factor in value-added tax (VAT) and purchase-tax exemptions for EVs (which on average add 50% to the cost of an ICE vehicle), free charging, free parking, and road toll, tunnel-use charge and ferry charge exemptions, and buyers are left with a package that benefits not only the environment, but also their wallets.

"These incentives have been a substantial reason why Dutch and Norwegian consumers have purchased so many zero-emissions vehicles," explains Hildermeier. "If these countries could enforce a ban on IC engines as a precedent, it would provide investment security for all OEMs, the whole industry, and consumers as they would know that these vehicles would be available on the market within a couple of years. The EU needs to learn from Norway."

And it is, with an increasing number of European capitals and other cities introducing new regulations that limit IC engine use.

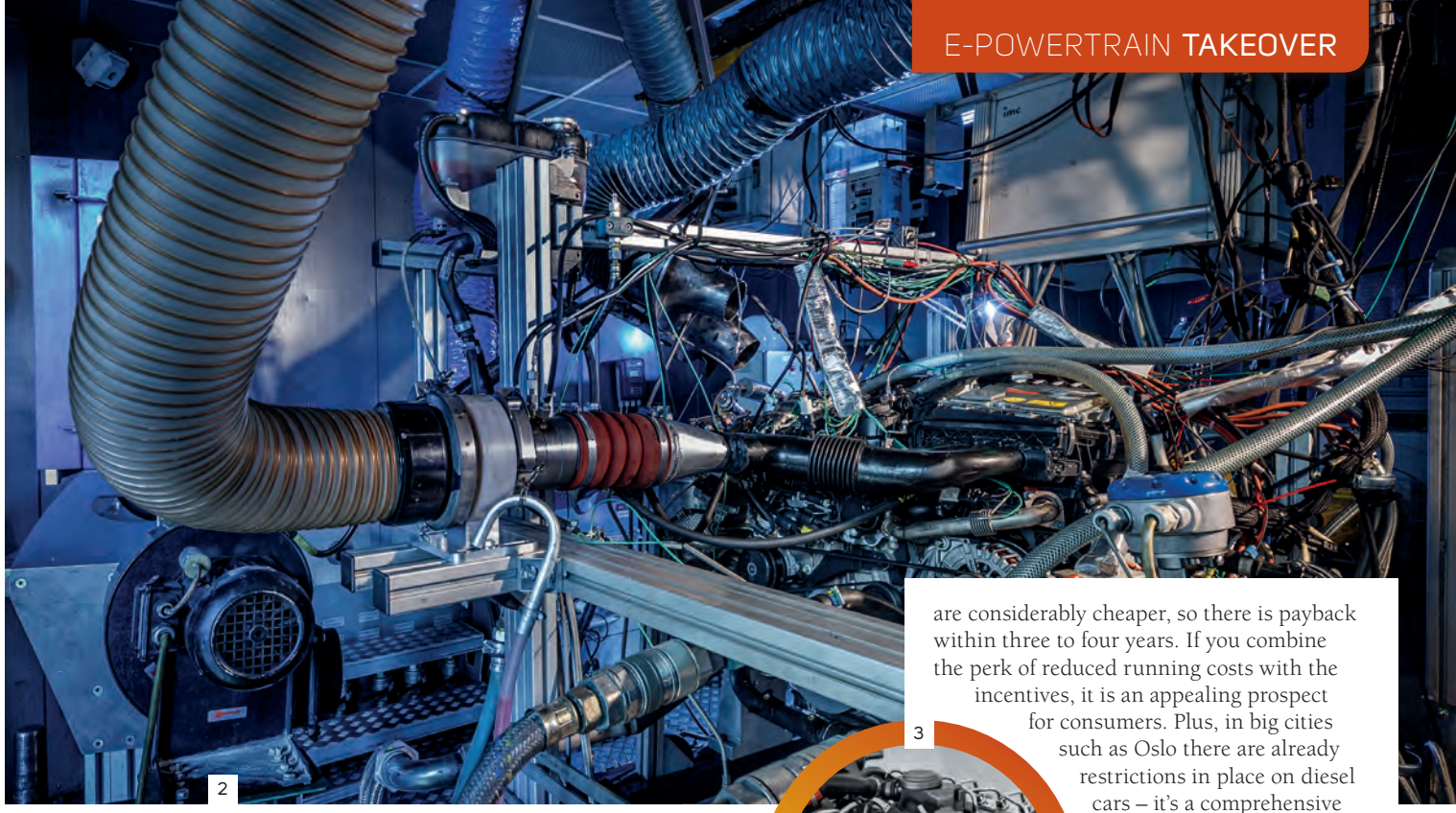
"We're currently looking at how to implement something in London," adds Laybourn-Langton. "At the moment we're talking about gradually phasing out diesel. In Paris, there are outright bans on vehicles with certain engines on certain days, but what we are proposing is a more sedate approach. An outright ban would have an enormous impact on a lot of people. In more rural areas, the idea of someone coming along and stopping you using your car has much more impact. The individual may agree that air pollution needs to be addressed, but that is countered by the impact it may have on their small business, commuting, etc. So one of the ideas put forward is to accrue revenue and have a slower phase-out period so that it's not as brutal. With a ban, it's final as it's either in place or it's not. With a graduated phase, you can adjust that accordingly."

Air pollution in London is currently a hot topic, high on Mayor Sadiq Khan's agenda. But the broader political climate in the UK, particularly in regard to the landmark decision to leave the EU, has the potential to dramatically alter the country's policies in unprecedented ways.

"As of a couple of years ago, it was largely specialist communities, scientists and those in the industry that were well aware of and making the loudest noises about air pollution," continues Laybourn-Langton. "We're pleased to have found that the issue has become more politically salient. But it's still an enormous problem and leaving the EU, in however many years' time, could end up being beneficial from a fiscal point of view for the UK, as it probably won't then be liable for fines for breaking these rules, which could run into millions and millions. This is a big moment. Politicians and rule makers need to

> "It is important that member states such as the Netherlands are starting to take this shift seriously and are committed to help promote it"
>
> Julia Hildermeier, clean vehicles and e-mobility officer, Transport & Environment

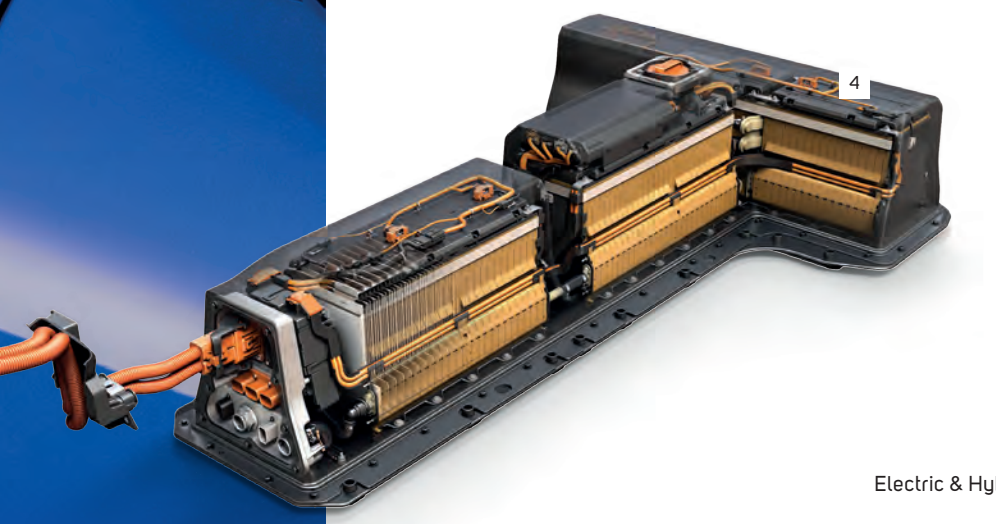
1. The all-new Chevrolet Volt is helping bring the benefits of electrification to the mass US market



clarify what is going to happen to a raft of environment legislation, particularly air pollution, because you could end up in the situation where we leave the EU, are no longer beholden to its laws, which could be repealed and changed so that there is barely any air pollution regulation in the UK."

The rules already in place across Europe, and those proposed by both Norway and the Netherlands, despite aiming to improve air quality, stand to have a major impact on consumers, with EVs currently costing considerably more than their IC equivalent, even with the aforementioned incentives.

"The legislation is mainly targeted toward manufacturers, as it is they who need to achieve homologation, but the benefits do extend to the consumer," counters Hildermeier. "While we know that EVs are more expensive than the IC equivalent, the running costs over the equivalent lifetime are considerably cheaper, so there is payback within three to four years. If you combine the perk of reduced running costs with the incentives, it is an appealing prospect for consumers. Plus, in big cities such as Oslo there are already restrictions in place on diesel cars – it's a comprehensive package that makes sense to consumers. That's what we would need in a much more developed fashion across Europe."



2. New test cycles and regulations are hoped to reduce the disparity in recorded emissions

3. Turbocharging has become a familiar tech among IC engines, in a bid to reduce emissions

4. Compact drivetrain of the 2017-spec Bolt

It started with Kyoto

As alluded to by Laybourn-Langton, the push toward diesel in particular across the EU can be traced back to the 2009 Kyoto agreement, in which governments championed the use of the fuel over gasoline to help reduce CO_2 emissions.

"When the UK government initially pushed diesel cars at the turn of the millennium, it knew there would be an increase in air pollution, but believed it would be vastly outweighed by the reduction in greenhouse gas emissions," he says. "Subsequently we've become better at being able to work out how bad diesel emissions are and just how bad the air pollution is as a result. That process hasn't been helped by the laboratory test used to work out these emissions turning out to be not very accurate. The New European Drive Cycle (NEDC) legislation in regard to real-world driving conditions is proof at a European level that we are trying to get a much better understanding of the real-world level of these emissions.

"Both diesel and CO_2 emissions impact the atmosphere and climate change, and the current focus toward the topic has been accelerated somewhat by the Dieselgate scandal," adds Hildermeier. "The first real push for OEMs to introduce electric vehicles was the CO_2 standards for passenger cars and vans in 2009, which run through to

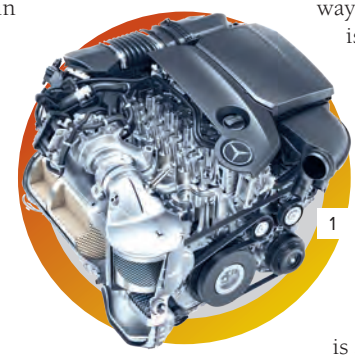
2021. The big discussion next year will be how the 2009 regulations are built upon. We definitely need much more stringent targets for passenger cars that they know in advance, so they can adjust their strategies accordingly and prepare. As part of these targets, we would like to see the sales quota for low-emissions vehicles in particular as it would help accelerate this market all over Europe because that law would apply to all of the member states."

Should a Europe-wide law come into force in the coming years, Hildermeier believes that it can be only beneficial to everyone: "If EU member countries were to enforce a precedent, it would provide investment security for OEMs, the whole industry and consumers as they will be in a position where they know that these vehicles will be available on the market within a couple of years.

"A movement like this really needs to happen across Europe, as we are speaking about a unified single market. At the moment, it's a little more diverse. Some European countries are quite advanced when introducing low-emission vehicles and banning older vehicles from cities, such as in Paris. The big problem with that, though, is it needs to be a Europe-wide approach, otherwise there simply isn't the market appeal for OEMs to produce these vehicles."

With this notion in mind, the European Commission made its first conscious effort to enforce a Union-wide strategy in 2016 to help improve air quality, issuing a strategy on decarbonizing the entire transport sector, with specific targets for incentivizing ultra-low- and zero-emissions vehicles.

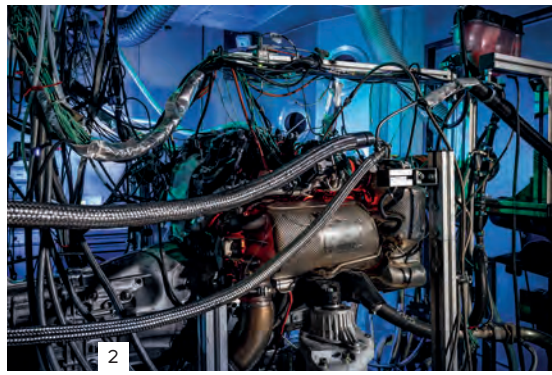
"That was very helpful, as it was the first time the Commission has specifically mentioned such a move," says Hildermeier. "We have been asking for the introduction of sales targets, similar to those California has in place for low-carbon and zero-emissions vehicles, into the forthcoming emissions regulations for cars. The way it would work in Europe is to build a flexible sales quota into the upcoming emissions standards."



As is often the case, the current political and social focus appears to be on rectifying today's issues through the regulation of existing technology – but Laybourn-Langton believes that there is a much bigger picture that can help accelerate the quest to improve air quality.

"While there is an environmental problem, a deeper, longer trend is that transport in itself is changing," he explains. "Because of advances in technology, we are looking at a situation where private ownership of vehicles

> "We've got a very clear indication of just how dangerous these pollutants are and we've also got OEMs exposed as cheats. So death. And cheating"
>
> Laurie Laybourn-Langton, research fellow, UK Institute for Public Policy Research



1. Technologies such as particulate filters and DEF have helped prolong the IC engine's existence

2. Lab-based test methods for IC engines have come under increased scrutiny in the wake of Dieselgate

3. Mercedes-Benz has strongly embraced EVs as the future of its range

"[The European and US OEMs] really need to step up their competitiveness"

Julia Hildermeier, clean vehicles and e-mobility officer, Transport & Environment

1

and the very way we interact with transport is going to change completely, particularly in regard to larger cities. The two transitions that are currently happening are moving toward an environmentally friendly fleet of vehicles, and then a more efficient and flexible use of those vehicles. We need to be intelligent enough to ensure that those happen at the same time, and as efficiently as possible."

Is it really end game?

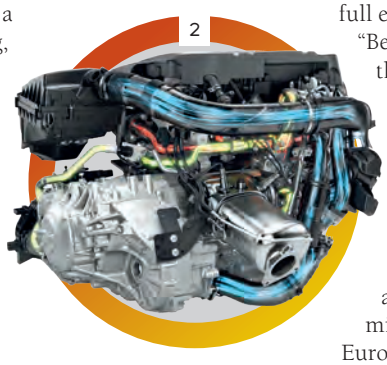
In early 2016, the *Financial Times* reported that sales of the Volkswagen Group's Audi division had slipped, with its long-held 69% market share dropping to 67% in the first four months of 2016, a downward trend mirrored across the entire diesel passenger car sector. The aforementioned Dieselgate scenario is considered a major contributing factor in this, with buyers seeking out gasoline and electrified alternatives, particularly as legislation changes to offer more appealing benefit-in-kind to fleet buyers. Air quality is once more a major political tool, high on the agenda for a number of politicians.

"With any physical change, there are a few things that can lead to it happening, and we have two of them right now," says Laybourn-Langton. "We've got a very clear indication, which is very easy to understand, of just how dangerous these pollutants are, and we've also got OEMs exposed as cheats. So death. And cheating. Those two are a pretty potent mix when it comes to making changes in society.

"The majority of the problem within London's congestion zone is caused by buses and taxis, not personal vehicles, largely because of the congestion zone charges," Laybourn-Langton continues. "There are a lot of people calling for the outright ban of diesel cars, but they need to remember that the contributors are many and varied. The policies need to be intelligent across all of them, as they all impact lots of different groups."

1. How we are likely to use future cars and personal transportation is perhaps the biggest question that remains unanswered by global policy makers

2. Despite continually advancing technologies in the IC engine, has its time finally been called?



2

A considered Europe-wide approach across a number of transportation methods may well be the solution, and some believe that the continent could set a global precedent. "The model can definitely be transferred to developing and motorizing nations. China is actually a very good example to see the push toward full electrification," Hildermeier concludes.

"Because of the air pollution problems that they do have, they have emerged as a front runner in e-mobility. Europe needs to learn from China, and not the other way around. The Chinese have chosen the right way, as they've built a national industry. They have electric car makers, suppliers, battery manufacturers; it's all in place and they apply the regulations. That's the sort of mix we need for Europe too, otherwise Europeans will end up buying Chinese EVs.

"The consumers may like that, but I'm not sure the policy makers will! The same can be said of European and US OEMs – they really need to step up their competitiveness."

3

3. Tesla has disrupted the automotive industry and forced established OEMs to up their EV game

Arbin

POWERING INNOVATION FOR OVER 25 YEARS

Engineered from a three year **ARPA-E** project, Meet Arbin's **Next Generation** Test Equipment!

True Bipolar Circuitry

24 bit resolution

2,000 pts./sec.

EIS Integration

The Highest Measurement Precision in the Market.

Arbin INSTRUMENTS

WWW.ARBIN.COM

+1 979 690 2751 | SALES@ARBIN.COM

ARBIN IS THE PROVIDER OF THOUSANDS OF ENERGY STORAGE SYSTEMS WORLDWIDE WITH IN OVER 50 COUNTRIES.

Hydrogen-powered vehicles may not be quite as niche as you may think. True Zero, in the USA, operates 14 hydrogen-refueling stations in California – soon growing to 19. While those numbers aren't particularly impressive, its first facility only opened in late 2015 and users have already accumulated more than 1,000,000 miles behind the wheel.

Toyota is one OEM that firmly believes in hydrogen fuel cell technology. It began playing around with the propulsion method in 1992. Fuel cell-equipped crossovers and buses followed, but the new Mirai sedan is the company's first purpose-built FCEV. Matt McClory, fuel cell vehicle group manager at the Toyota Technical Center, in California, is excited about the development of this forward-thinking hydrogen automobile.

"Our first demonstration of a fuel cell vehicle was in a parade in Osaka, Japan, in 1996," recalls McClory. "Our first lease began in 2002 and that continued all the way through the end of that body style (Highlander crossover) in 2008."

Watershed moment

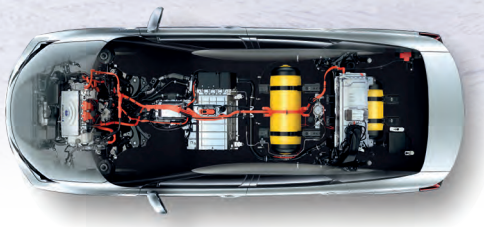
The Mirai promises to be the breakthrough application for fuel cell technology – and not just for **Toyota**, but the wider auto industry. As a result, the testing and development program was challenging and relentless

WORDS: **MARC NOORDELOOS**

"The key philosophy is minimizing the amount of high-pressure hydrogen on board and thus preventing a leak. We designed the system so the high-pressure hydrogen is only in the tanks"

Matt McClory, fuel cell vehicle group manager, Toyota Technical Center

1



The Toyota way

"Honestly, I don't think there's a difference," says McClory, when asked what's unique about developing a fuel cell vehicle. "We go through pretty much the exact same steps whether it's an advanced diesel engine or an advanced gasoline engine or a fuel cell."

That being said, there are some variances. "The development timeline is longer for more advanced technologies," admits McClory. "It's about three-to-five-years for developing a new vehicle or powertrain, but that depends on the technologies involved. The timeline is basically implementing the technology and testing. The configuration needs to be frozen years ahead."

With the Mirai, safety is one area where additional development came into play. "The key philosophy is minimizing the amount of high-pressure hydrogen on board and thus preventing a leak," explains McClory. "We designed the system so the high-pressure hydrogen is only in the tanks themselves. We don't have a bunch of lines carrying high-pressure hydrogen. We have about 5kg of hydrogen in the tanks and less than 1% of that is in the lines and the manifolds. The tank system, lines and fuel cell stack are all isolated and separated underneath the vehicle, so there's no way for leaking hydrogen to accumulate under the vehicle or make its way into the passenger cabin."

Keeping track of all the hydrogen is key. "We know where basically every molecule is going. We know what's being consumed in the fuel cell system and we know how much is in the tank. If there is a variance, we use that as a sensor to know that there is a problem or a leak and shut the system down. Also, there are valves inside the tanks that are normally closed, so if the power gets cut due to an accident or the system turning off, the valves close immediately."

Toyota also worked on the safety of the hydrogen tank itself. "We've designed the tank so that if there's a fire or a collision, there's an integrity of the system to be safe and maintained," notes McClory. "And that's achieved through regulated crash testing as well as other tests we do in-house. We have a lot of confidence that the hydrogen system is as safe as a conventional vehicle."

Development challenges

As we all know, hydrogen fuel cell vehicles emit water. But this seemingly harmless substance caused McClory some of his biggest development headaches. "If the water that gets produced inside the fuel cell freezes, it blocks the passages and you no longer have power. Additionally, freezing can damage the

1. Testing destinations for the Mirai FCEV included Yellowknife, in Canada's Northwest Territories, where winter temperatures can plummet as low as -30°C

2. The Mirai FCEV uses components developed by Toyota, including its own fuel cell stack, boost converter and high-pressure hydrogen tanks

2

1. Temperatures regularly soared to highs of around 46°C during hot weather testing in California's Death Valley

2. The Mirai fuel cell stack has a maximum power output of 114kW. The efficiency of its electricity generation has been improved by using 3D fine mesh flow channels to ensure uniform generation on the cell surfaces

fuel cell. Every OEM has its own process to deal with this," he says. "There's a technique you can do inside the fuel cell where water doesn't act like a normal liquid. There are techniques we utilize where the water won't freeze – it's more like a polymer. This keeps water from behaving like normal water."

Keeping costs down on Mirai was another key focus. First, the sedan shares Toyota's global MC Platform. "The big success with the Mirai FCEV isn't the technology per se but the cost reduction," adds McClory. "The high-voltage battery, inverter and traction motor were taken from the Camry Hybrid and Lexus RX Hybrid. We then developed a new converter to boost the voltage out of the fuel cell to match those components. This boost also allowed us to cut the size of the fuel cell, reducing costs further. So, even though we're adding another component [the converter], the overall net effect was a cost reduction due to sharing components."

The use of nickle-metal hydride (NiMH) batteries saved further costs. "Lithium-ion is typically suited when you want more energy density, not power density," notes McClory. "You can make lithium-ion perform for both energy and power, but we had a NiMH setup and know the pedigree and the costs. We're not looking for energy density; we're looking for the same type of energy size we'd have with a Prius-sized hybrid vehicle as far as power. The battery pack provides that extra boost in addition to the fuel cell for making the system more efficient."

Been around the world

The majority of development of Mirai took place in the USA and Japan: "Vehicle design was at Higashi-Fuji, our research and test facility, and Toyota City, where our design development group is located," says McClory.

"The cold test facility is in Shibetsu [northern Japan]. In the USA, we test on local roads in Los Angeles and go to Death Valley for hot weather testing. We use Fairbanks [Alaska] and Canada for cold weather testing, and we go to Colorado for high-altitude testing.

"So, the rough version of the vehicle is tested within the facilities in Japan. Then once it gets to a level where it's reasonable to drive on public roads, we [the US team] get the car and the majority of testing is done in North America. The testing we do is a more extreme version of what's done in Japan."

Various testing software packages were especially important for Mirai. "MATLAB, Simulink and Simscape allowed us to process data that we collected from the vehicle during testing, which in turn allowed us to make models of the system and make adjustments to those models. Simulink is our control space modeling system that allows us to calibrate or perform calibrations, whether it's on a bench or in a vehicle on the road.

"Testing the Mirai prototype before it became the production vehicle here on US roads involved controls evaluation updates – coming up with new control logs. From a testing standpoint, MATLAB has been a key tool for modeling the system, manipulating data arrays, reviewing data and making plot macros, as well as our controls development."

It's clear Toyota is committed to the future of hydrogen FCEVs and to bringing the price down even further. "Mirai is already a 95% cost reduction on our previous FCEV, but the key thing to remember is mass production does not necessarily bring the costs down by a significant amount. The first level of cost reduction comes in the actual design of the technology and in the manufacturing costs."

As Mirai spreads into further markets and the hydrogen infrastructure grows, it will be exciting to see where the future lies for the FCEVs as a truly viable alternative to both IC vehicles and PHEVs.

> "From a testing standpoint, MATLAB has been a key tool for modeling the system, manipulating data arrays, reviewing data and making plot macros, as well as our controls development"
>
> Matt McClory, fuel cell vehicle group manager, Toyota Technical Center

MACCOR

Battery & Cell Test Equipment Worldwide

The Right Choice!

For All of Your Energy Storage Testing Needs

From Materials to Grid Storage and Anything in Between

sales@maccor.com +1 918 446 1874

WWW.MACCOR.COM

We've sold more test channels than all other competitors combined!

Mission critical

Porsche is burying itself in Mission E development. But what's next after the Tesla Model S chaser has been launched? R&D boss Michael Steiner reveals all

WORDS: **MICHAEL TAYLOR**

There are logical product-planning rollouts that Porsche should be doing right about now. For starters, a modern 928 S should be fast and cost-effective to do, with a short-wheelbase, two-door version of the Panamera. Then there's a hybrid or plug-in hybrid version of the 911, which also seems like a no-brainer. And then there's the Pandora's box of throwback driving features demanded by everyone who fell in love with the 911 R (which was, by the way, everybody who ever drove it).

But Porsche isn't doing any of that – at least, not publicly. And that's because the OEM is burying itself in the Mission E battery-electric car that it says will set new industry standards in every imaginable criterion of very fast four-door BEVs.

After that vehicle finally goes on sale in 2020, Porsche, that great Swabian bastion of incremental, evolutionary, long-term planning, doesn't know what else it will do with all its freshly acquired BEV capability.

"For sure, there would be a market for a Panamera Coupe," Porsche's R&D boss Michael Steiner admits.

"This business is largely about the proportions of the look and the Panamera platform has the genes where you could do an attractive coupe. But really, we need one moment where there is a huge change in the business for electrically driven cars.

"So, with a given investment in R&D, we have to decide the next step. From this point of view, a coupe would be in competition with other segments we could attract or move into. We have it on the radar but there are other attractive alternatives in electrification and hybridization."


Porsche Team
Porsche
fiawec.com
MORI
RSCHE
TORSPORT
Mob

1

But just which alternatives are attractive for Porsche? It seems that the venerable 911 – a car whose sales have crashed in the once-stalwart USA since it switched to an all-turbo engine line-up – won't play a leading role in the new technical direction. Perhaps a 911 hybrid?

"It's possible, yes," Steiner admits. "It's possible to have 918-derived technology in a 911 but we have to decide the next step that is really needed. This solution can be done with today's technology in a 911 and we would be able to act within a reasonable timeframe, but if you look at the alternatives, what would be more important to us? It looks like the market potential of a new vehicle with completely electric power is more than another derivative of the 911. Also, a 911 hybrid would be in competition for resources within our development center in Weissach."

And therein lies the problem. For all the legendary engineering capabilities of the Weissach, Germany, think-tank, there are still only so many engineers and they can still only tackle so many problems.

More likely than a hybridized 911 is a model or two that will help amortize the enormous development costs of the Mission E and deliver economies of scale in production.

"We are at the end of the virtual development process, so Series development has started on the Mission E," says Steiner. "We will start testing parts in cars now and at some time in the future we will start building real cars.

"The modular battery architecture and chassis architecture gives us the potential to do more on this platform," he continues. "A lot of what we are doing now is conceptual work and we do a lot to be prepared for the future. If the battery-electric business will be faster growing – and we think the whole business will change pretty fast at some point – then [the Mission E] should not be the only battery-driven car for us."

"It looks like the market potential of a new vehicle with completely electric power is more than another derivative of the 911"

One mission

The Mission E was officially launched at the 2015 Frankfurt Motor Show to a stunned audience, with Porsche claiming it would deliver a full family of electric cars based on the sleek four-door coupe.

And it was also claimed to be fast, obviously, with 500km (310 miles) of battery range and the ability to punch to 100km/h (62mph) in "less than 3.5 seconds" and from zero to 200km/h (124mph) in just 12 seconds.

When asked about Tesla's Ludicrous Mode in the Model S outsprinting the Mission E's claimed time, Porsche's then-R&D boss Wolfgang Hatz confirmed that he meant "less than 3.5 seconds" – though he didn't say exactly how much less. Besides, he explained back in those heady pre-Dieselgate days, the Mission E would do it repeatedly without any overheating battery worries and would be run through the full Porsche validation process with no shortcuts or favors granted for its new battery-electric powertrain development.

1. Mission E is Porsche's Tesla chaser. Due at the end of the decade, the stunning four-door BEV boasts a 0-100km/h time of under 3.5 seconds and a range of more than 500km

2. Mission E's total system power is 440kW, and the production version could have even more on tap

3. As a consequence of the Mission E being given the green light for production, more than 1,000 new jobs are being created in Stuttgart-Zuffenhausen and Porsche is investing over US$742m in its main development center there

4. Inside the Mission E concept. Expect a similar high-tech interior for the production vehicle

5. Much of the Mission E's technology is derived from the gasoline-electric hybrid system in Porsche's Le Mans-winning 919 racer

Porsche claims the Mission E needs just 15 minutes for an 80% refill of its lithium-ion pack, adding about 400km (248 miles) to the driving range after a coffee break thanks to an 800V supercharging system developed by Hitachi.

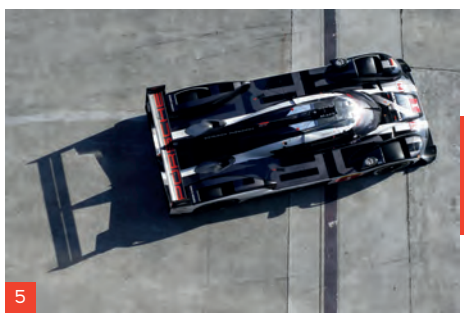
The Mission E's technology is derived from the gasoline-electric hybrid system in Porsche's Le Mans-winning 919. It will be driven by two permanently excited synchronous electric motors and already has a sub-eight-minute time on the Nürburgring Nordschleife, thanks in part to the two e-motors also harvesting braking energy.

It uses all-wheel steering, torque vectoring and an on-demand all-wheel drive system. Its lithium-ion pack sits between the axles and under the passenger compartment floor of the purpose-designed MEB architecture (which will be shared with Audi, Bentley and Volkswagen), while the body is a combination of carbon fiber, steel and aluminum.

But surely the vehicle can't come to series production still looking like the jaw-dropping concept seen in motor show trim?

"The Mission E is as close as possible to what we saw in Frankfurt," Steiner counters, and it's unlikely to stop there.

"After the Mission E, we are thinking about the second or third step," he adds. "There is no reason why this has to be just one body style. If you look back, whenever we introduced a new segment it was always with one body style. But it depends on how the success of [the Mission E] goes if we would add more body styles."



Just which body style that might be is anybody's guess, even anybody at Porsche, though an SUV has been flagged as a certainty at some point, with even Tesla acknowledging it's the large body style of choice in the US.

"With some modifications, Mission E could be made into an SUV," Steiner confirms. "The technology is available, so it's not complicated. That could be a step. On the other hand, within the VW Group we have the potential to use the components and the platforms for another vehicle and another brand."

There's a reason Porsche isn't committing to its second BEV body style, and it's not the one you might think. The company is as interested

in gathering intelligence with the Mission E and its in-service life as it is in bursting open a new segment.

"We should have as much knowledge as possible [regarding] the acceptance of the technology and some feedback from the customers [about] their experience before we do the next car," Steiner insists. "There are also good reasons [in thinking] that the costs to us should be a little bit easier and development should be faster to do additional derivatives of BEVs."

That, he thinks, will be the key difference between the well-trodden route of IC vehicle development and BEV model lines, but he's still not completely sure. Steiner insists that ICE cars have lower per-unit costs but higher development costs, while BEVs will have higher component costs (on current material pricing) and lower development costs.

> "We will spread the (plug-in) technology to more drivetrains. We will do one more hybrid version of the Panamera"

1

2

1. Revealed at the LA Auto Show in December 2016, the Panamera 4 E-Hybrid Executive boasts combined fuel consumption of 2.5 l/100km (112.9mpg) and CO_2 of just 56g/km

2. The current Panamera 4 E-Hybrid model has a combined electricity consumption of 15.9kWh/100km

"With IC cars, the main issue is not the next car or derivative but the costs to stay legal in all emissions regulations," he explains.

"We have to develop for emissions and CO_2 [regulations] for internal combustion and have to upgrade the whole engine within every vehicle to the next emissions level when it comes into force. This takes some effort. That should be better and more cost-effective with BEVs."

Yet the Mission E's arrival doesn't foretell the abandonment of plug-in hybrids for Porsche. Quite the opposite, with Steiner insisting the next generations of its PHEVs will be even faster, with even more range.

"We will spread the (plug-in) technology to more drivetrains. We will do one more hybrid version of the Panamera and that will be more in the direction of a high-performance variant. It will be better performing than the existing one, with much more performance, agility and range. So, like we did in the past, we first think and then we act."

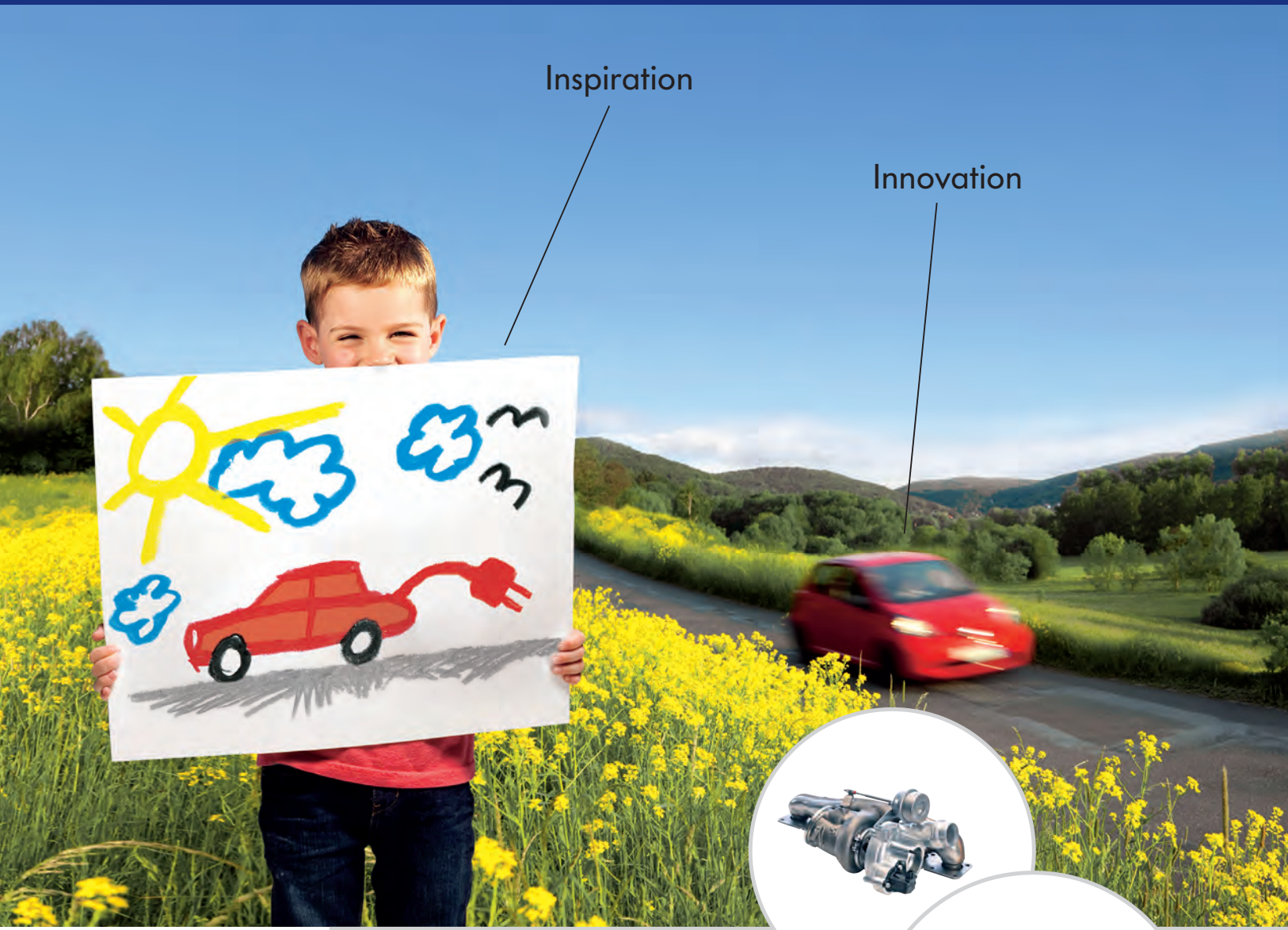
In the past 12 months, Porsche's vaunted engineering division took a major hit by being dragged into the Volkswagen Group's Dieselgate affair via Audi's 3.0 V6 TDi, but Steiner insists that wouldn't happen today.

"It was the last thing we did like that [taking the engine straight from Audi and bolting it in place]. We took it as the piece was the same across the Group. Today we could question it [that decision]. Back then [the V6] was more or less plug-and-play. It was in the platform we used and it was already developed. Why wouldn't we?"

For all that, Porsche isn't giving up on diesel, even as it forges ahead with electrified powertrains, though Steiner admits there are tough times ahead for compression technology, both in public perception and in meeting regs.

"It depends on how we measure it, but the NEDC gives the plug-in some benefits over diesel. There is a trend that gives an advantage to PHEVs. So we have to invest more and more technology in the emissions side [for diesel] to be in line with the regulations, and there will be additional disadvantages for diesel as time goes on. They will start to disappear from small cars but not for the larger premium cars."

Innovative electrification. We know how.



Hybrid and electric powertrains use less fuel and emit lower emissions. But drivers want more mileage and better performance. BorgWarner knows how to improve efficiency, reduce weight and boost performance for the fun-to-drive experience drivers crave. As a leading automotive supplier of powertrain solutions, we support your engine and drivetrain designers to meet specific challenges and optimize systems. For powertrain innovations that deliver results, partner with BorgWarner.

BorgWarner

feel good about driving

borgwarner.com

Power ranger

The charismatic man behind Formula E's unprecedented commercial success outlines his vision for the all-electric formula

WORDS: **LEM BINGLEY**

GOODBYE WEC, HELLO FORMULA E

Audi has terminated its FIA World Endurance Championship (WEC) commitment with immediate effect at the end of the 2016 season as part of a 'realigning of its motorsport strategy'. Instead the German car maker is now taking up a factory-backed commitment in Formula E.

Speaking to 300 employees of the motorsport department, Rupert Stadler, chairman of the board of management at Audi, explained the 'strategic decision' in the context of the current burdens on the brand, pointing out that it was important for the company to focus on the things that would help keep it competitive in the years ahead.

"We're going to contest the race for the future on electric power," said Stadler. "As our production cars are becoming increasingly electric, our motorsport cars, as Audi's technological spearheads, have to be even more so."

In its press statement, Audi explained that the 'FIA Formula E' championship has been identified by the brand as 'the racing series with the greatest potential for the future'. This news follows the announcement that Audi has intensified the existing partnership with Team ABT Schaeffler Audi Sport in the current 2016/2017 season. On the road toward a full factory commitment, the manufacturer is now actively joining the technical development.

No final decision has yet been made concerning a future involvement in the FIA World Rallycross Championship (World RX). In the current 2016 season, DTM factory driver Mattias Ekström in his Audi S1 EKS RX quattro clinched the World Championship title early, competing against numerous factory teams. Up to now, Audi's involvement has been limited to supporting the private EKS team. The brand is currently evaluating a possible extension of the commitment, the exciting topic of electrification being on the agenda in rallycross racing as well.

The departure from the WEC marks the end of a successful era for Audi. For 18 years the brand was active in Le Mans prototype racing. During this period, it scored 13 victories in the Le Mans 24 Hours.

"After 18 years in prototype racing that were exceptionally successful for Audi, it's obviously extremely hard to leave," says Dr Wolfgang Ullrich, the head of Audi Motorsport. "Audi Sport Team Joest shaped the WEC during this period like no other team. I would like to express my thanks to our squad, to Reinhold Joest and his team, to the drivers, partners and sponsors for this extremely successful cooperation. It's been a great time!"

Few people could have predicted Formula E's rapid rise in popularity. Surprisingly, that includes the man who has been the driving force behind the championship, Formula E chief executive Alejandro Agag, who says the series has leapt ahead of even his most optimistic early projections.

"I was looking at all the PowerPoint presentations we made when we were looking for investors for the project four years ago," Agag explains. "We said by Season 5 we expected to have three manufacturers on board. And here we are in Season 3 and we have six really big ones."

Those six include current competitors Renault, DS and Jaguar, more prominent backing from Audi and BMW for their respective partner teams this season, plus Mercedes pledging to take up its option to race in 2018's Season 5.

Agag admits that this enviable roster is not entirely due to Formula E's planning and execution, but rather part of a shift in priorities among manufacturers. Almost every car maker is bringing electric propulsion to the fore, hoping it might soon provide a competitive edge. And where better to hone a competitive edge than in competition?

Indeed halfway through our interview, Agag checks his beeping phone: "I just got a message from Nelson Piquet, saying Red Bull Global Rallycross will add an electric series from 2018," he says. "It's all going in the right direction. We were the first ones, but the more electric motorsport the better. There's the Electric GT series that is being started, now rallycross, and that's all positive news for electric motorsport and the planet."

Right from those early pitches, Agag has been keen to stress the connection between what races on a Sunday and what sells on a Monday. "A championship like Formula E can affect the barriers faced by electric cars, like technology and perception," he notes. "We have a 25-year license with the FIA, during which period we think we will have caused the introduction of 66 million additional electric cars. But of course we are still at the beginning of those 25 years."

One of the other reasons that makers find the series attractive is its relatively modest cost. While current Formula 1 budgets are measured in the hundreds of millions per season, Agag says today's Formula E teams will have spent about €25m each to date. And that is now the cost of taking up the vacant number 12 garage, on offer from Season 5. "We've set that price not as a random figure but because that is the amount invested so far across two seasons by the current teams," he asserts. "It makes sense that whoever comes later has to make a similarly sized investment."

Agag says the full tally of teams will be kept at 10 until 2018, when Mercedes will join as number 11. "We have an absolute maximum of 12," he adds firmly.

The arrival of big brands with deep pockets is bound to change the sport, despite the presence of rules designed to curb cost escalation – such as strict limits on track testing time and on the number of personnel allowed trackside. It's notable that the first two team titles were won by Renault e.dams, one of the better funded entries, which also happens to have the factory facilities of a Formula 1 team behind it.

"Obviously they are going to have an impact, but I think it's going to be a positive one," Agag says of the incoming multinationals. "And as you know we have this important rule where every manufacturer needs to share its technology and its powertrain with two other teams," he notes, referring to an obligation on teams to sell key items at a fixed maximum price. "So I think the impact is going to be positive in terms of technology development, and let's say moderate in terms of the competition because other teams can get access to the technology."

Audi's switch

Audi recently announced that it would withdraw from the World Endurance Championship (WEC) to fuel its new focus on Formula E (see *Goodbye WEC, Hello Formula E*, opposite), but Agag is not concerned that this shift might trigger a backlash among motor racing fans.

"This kind of movement among manufacturers has been happening all the time in the history of racing," he notes.

"I think the impact is going to be positive in terms of technology development, and let's say moderate in terms of the competition"

OEM MASS APPEAL

Jaguar is the latest global OEM to join the ranks of Formula E. Developed in partnership with Panasonic, the I-TYPE 1 is serving as a rolling test bed for developing new advanced powertrain technologies.

At the start of the current season, Gerd Mäuser, the chairman of Panasonic Jaguar Racing, said, "Today marks a new chapter in the history of Jaguar Racing. As the first premium car manufacturer in Formula E, we are proud to be back in top-level motorsport. The future is changing and we're part of that change. Formula E is the perfect platform to inspire the next generation."

Nick Rogers, executive director for product engineering at Jaguar Land Rover, underlines the important role Formula E will play in developing next-generation electric vehicle technology and the importance of electric vehicles in JLR's future product portfolio.

Rogers added, "The championship will enable us to engineer and test our advanced technologies under extreme performance conditions. We will apply this vital knowledge as part of our real-world development. At Jaguar Land Rover we employ 9,000 engineers and the team will draw on these engineers to extract data and push the boundaries of electric technology in a race environment."

Prior to the start of Formula E's season three, the team successfully completed 21 test days, including the last Formula E public test, which took place at Donington Park Circuit in the UK.

James Barclay, director of the Panasonic Jaguar Racing team, said at the time, "Today is a proud moment for myself and the entire Panasonic Jaguar Racing team at our official launch. Everyone has worked very hard over the last nine months to prepare for our debut in the Championship. I am delighted to welcome Adam, Mitch and Ho-Pin, Panasonic, Lear and all of our new fans into the Jaguar family.

"We want to be successful on and off the track. We know that the challenge will be strong – our competitors have a two-year head start. We will be keeping our expectations in check in our first season. Ultimately we're here to win but we're here to innovate too. I would like to thank Jean Todt and his team at the FIA and Alejandro Agag and his team at Formula E for their vision in building this innovative series and for their help and support over the last 12 months."

"It's no drama, just changes. I'm sure other manufacturers will go to WEC, maybe some will leave Formula E, and life goes on. For us, what is very important is the budget control, to keep the cost low for running a team. As long as that's the case there will be no problems and the health of the teams will be good."

That strategy is why today's Formula E teams all run with the same chassis, aero package, tires, front suspension and battery. They are free to design their own power electronics, software, electric motor, transmission and rear suspension.

The same arrangements extend until Season 5, when a new battery will dispense with the current need for drivers to swap cars halfway through each race. To achieve the required range, incoming battery supplier McLaren will need to design a 54kWh battery – almost twice the capacity of today's 28kWh battery built by Williams – within tight mass and volume limits. The maximum weight of cells stipulated in the contract is 250kg, just 50kg more than at present.

A new Spark-Dallara chassis will also be supplied for Seasons 5 and 6. What happens beyond that, from 2020, is still being ironed out. "It's FIA doing the plan," Agag cautions. "We of course give our opinion but I wouldn't be surprised if from Season 7 there would be freedom on the

"Perhaps a more pragmatic way to go would be to have three different batteries instead of 9 or 10, with a few teams using each battery"

battery. It would probably be the way to go, particularly as we see the level of manufacturers coming in. Perhaps a more pragmatic way to go would be to have three different batteries instead of 9 or 10, with a few teams using each battery." That would echo Formula 1 where there are fewer engine suppliers than teams.

Long-term visions

In the meantime Formula E is moving toward a more settled race calendar. "I think this Season 3 is a bit of a transition year, where we switch some of the races we did in Season 1 for races that are going to be much more permanent and where we want to end up, like Hong Kong, New York, Montreal, Paris," Agag says. He adds that a London ePrix, missing from Season 3, still sits firmly on his wish list and is likely to return in Season 4.

"We are interested in the Middle East, Australia, one more race in Asia, perhaps another in North America," he says. "If we achieve all that we will have a global calendar covering most of the world, and then we'll be happy."

Agag is clearly delighted that two rounds of Season 3 will be contested in New York, in July 2017. "It's the capital of the world. You have people from all over the world in New York, and we have drivers from all over the world, so I think that event is going to be simply huge," he enthuses, adding that the New York mayor's office has been extremely supportive. "We're going to be in Brooklyn, overlooking downtown Manhattan and the Statue of Liberty. We were really lucky to find that spot."

Aside from Mexico City's central circuit, Formula E is contested entirely on temporary tracks close to city centers, and that's a strategy that Agag doesn't foresee changing. "That's our DNA – the street circuit, the city circuit. Of course if the performance of the cars continues to improve we may have a problem with the homologation of the tracks, but I don't see that happening for the next 5 to 10 years." Even then, as Agag suggests, it is more likely that rules would be changed to cut speed rather than the championship shift to conventional circuits.

Returning to Season 3, Renault got off to a good start defending its championship. Unlike Formula 1, Formula E's racing hardware is fixed for the whole season, so the French team could well be on course to complete a hat-trick across the first three seasons of the championship.

Regardless of the big names coming into the sport, Agag waves away suggestions that Renault's dominance might be a problem. "There should be a reward for the people who make the best technology and I think for the moment Renault is that team," he states. "I'm not worried that they might win – as long as they're not winning too easily."

Silent partners

In prep for the third year of the all-electric racing series – and with the cars armed with more technology than before – Formula E engineers give *E&H Vehicle* a rare glimpse into the behind-the-scene rigors of pre-season testing and development

WORDS: **LEM BINGLEY**


RENA

When the latest Formula E championship began in October, it marked the culmination of three years of preparation. The electric racing series may have now reached its third season, but this year's opening race in Hong Kong was arguably the first opportunity for the teams to really hit their stride.

In Formula E's maiden season, which ran from September 2014 to June 2015, all teams used identical machinery. Then, in the second season, when the teams were allowed to create their own powertrains for the first time, they had a very tight timeline. "The decision to open powertrain competition was taken very late in 2014," recalls Vincent Gaillardot, project leader of Renault e.Dams. "We had six months to develop a full electrical powertrain. That was very, very challenging, so I think we all arrived at the Donington test in July 2015 with very little experience."

Despite the constraints, Renault went on to win the championship for a second time. Now Gaillardot is focused on competing for a third title with "a much more comfortable schedule". Comfort is relative, of course. There is still enormous pressure to get the cars right first time. Unlike Formula 1, Formula E rules out almost all mid-season development. While suspension is set up for each track, various other hardware is fixed for the whole season – the FIA will permit changes only to correct demonstrable reliability problems. Software, however, can be freely rewritten. "The control of your motor is the one area where you can play during the season," says Gaillardot.

Developed within

Formula E's constraints may curtail costs, but they also place a heavy burden on pre-season development and testing. This is tackled by Formula E constructors, which can be distinct from the racing teams, as Thomas Chevaucher, technical manager for DS Performance, explains: "All our development is done by DS Performance, which is part of the PSA Motorsport division. And then our partner, Virgin Racing, is in charge of the race cars."

> "All our development is done by DS Performance, which is part of the PSA Motorsport division. And then our partner, Virgin Racing, is in charge of the race cars"
>
> Thomas Chevaucher, technical manager, DS Performance

While a race team may have 15 people running four cars – two per driver – the factory side tends to be leaner. "We have five or six people involved in Formula E," says Chevaucher. "It's not small – just a bit smaller than a World Rally Championship (WRC) team. But we have the motorsport division behind us."

Arrangements at Renault are similar, Gaillardot says. Fewer than 10 people develop the Renault car, but they can call on the expertise of Renault's motorsport unit, which includes the Renault F1 team. However, not every constructor has the luxury of a large motorsport division behind it. "This is our first single-seater championship," says Vinit Patel, chief engineer at Mahindra Racing. "I don't doubt

Prior to the start of Season 3, all teams were entitled to an additional 15 days of private vehicle testing

BIG CAT

Formula E's third season marks Jaguar's return to professional racing after a 12-year absence, joining the competition with help from Williams Advanced Engineering (WAE).

Craig Wilson, race director for Panasonic Jaguar Racing and managing director of WAE, says the schedule was tight: "We only started in November last year and we had to homologate in March – that's an FIA requirement. So we had a very, very aggressive timeframe. That included the manufacture of off-tool parts for testing, and the FIA crash test. So the actual development time was probably only two months."

WAE worked on all parts of the car that can be modified. Its design uses a single motor and two-speed transmission – the same approach developed by champions Renault for Season 2. "In any form of product development, you look at what your competitors are doing and of course you benchmark," Wilson says. "So [Renault's setup] was something we were aware of but our decision was inevitably from our own simulations."

1. Mahindra Racing completed more than 4,100km of testing in its M3Electro race car during the run-up to Season 3 of the FIA Formula E Championship

2. Renault e.dams was the first Formula E team to test its Season 3 powertrain on track, completing a brace of three-day runs in April

3. Audi is planning to increase its involvement with the ABT Schaeffler Audi Sport Formula E team by incorporating the race series into a factory-backed motorsport program as of the 2017/2018 season

that the likes of Renault and DS have an edge, but it's my job and that of my colleagues at Mahindra to prove ourselves, and get the investment required to try to match or beat their facilities in the long run." Mahindra also aims to catch up through its partnership with Magneti Marelli, the Italian electronics firm with a long motorsport pedigree.

> "It's a great formula for engineers; like motor racing in the 1960s and 1970s, when solutions to problems in Formula 1 were very different"
>
> Vinit Patel, chief engineer, Mahindra Racing

Small team ethos

As Chevaucher points out, big teams aren't required in Formula E as the constructors don't build an entire car. Everyone still uses a standardized chassis, aerodynamic package, tire, front suspension and battery. The teams design and build their own motor, transmission and rear suspension. "The heavier the powertrain is, the easier it is to make it energy efficient, but if the car is too heavy you will lose performance," Chevaucher notes. "This is what makes all the difference between competitors."

Constructors are limited to 15 days of track development, between January 1 and July 31. The cars are then handed over to the racing teams for track testing ahead of the opening round. Constructors allot their 15 days as required. "You're free [to do what you like], although whether you test for one hour or nine hours, it counts as one day," says Gaillardot. Simulation or static tests – including an entire car on a dyno – aren't counted. As a result, this is where most development is carried out.

Work starts with establishing the design approach and component sizing. "You have to identify the most beneficial first-order parameters for your performance, by doing raw analysis and a lot of simulation," Gaillardot says. Development then moves into its physical phase: "We have the capability of component testing in isolation and also full-powertrain dyno capability, with dynamic behavior. We can do a replay of a lap or test an endurance-specific scenario." Some of this equipment is shared within Renault.

Like most motorsport teams, Renault is cagey about its precise test procedures and is unwilling to name which suppliers it works with. That being said, the battery is a known quantity. All teams use the same liquid-cooled, lithium-ion package designed and built by Williams Advanced Engineering. Little has changed since Season 1, with the energy storage system providing up to 28kWh per race. Peak output of 200kW is available during testing, qualifying and for fleeting periods of the race via Formula E's Fanboost facility. Normal race output is capped at 170kW, up from 150kW in Season 1.

The battery case is a structural chassis member, crash tested as part of the car. That's one reason why the drivers change cars rather than swap batteries halfway through each race. And with a capped battery, power at the wheel depends on powertrain efficiency. The short development window for Season 2 led to a wide variety of solutions. NextEV and DS Virgin Racing used twin motors with fixed output ratios. Torque vectoring is outlawed, so the twin design was chosen for packaging or efficiency reasons.

All the other teams used a single motor plus gearbox. Championship winner Renault used two gears; ABT Schaeffler Audi Sport used three; Dragon, Venturi, Trulli and Mahindra Racing chose four; while Aguri and Andretti stuck with Season 1's five-gear drivetrain.

Diversity has continued in Season 3. "There's still variation, with twin motors, single motors, more and fewer ratios," says Mahindra's Patel. "It's a great formula for engineers; like motor racing in the 1960s and 1970s, when solutions to problems in F1 were very different. Today, F1 quickly converges on a single solution."

More variety is likely to be injected during Season 5, which will see a new chassis and improved battery, ending the need for car swapping. Beyond that, perhaps from Season 7, constructors expect to build their own batteries – a challenge under investigation already. As Gaillardot says, "The fact that we're free to do any development at the factory, on any rig or calculation, gives us the flexibility to work ahead."

High Performance

Battery Management and Vehicle Control

Integrated control solutions for your EV/HEV powertrain

High performance electric and hybrid-electric vehicles require vehicle control strategies that are well-integrated with an onboard Battery Management System (BMS) to ensure long-term, reliable operation. A seamless integration between a primary Vehicle Control Unit (VCU) and BMS allows for maximum utilization of the battery in a variety of conditions, while respecting operating limits to protect cycle and calendar life.

Stafl Systems, LLC has developed a portfolio of BMS and VCU products that are designed to integrate seamlessly, allowing for rapid control software development for a number of vehicle applications. Our highly configurable products are used in a number of transportation projects, including high performance electric cars and electric aircraft.

Contact us today to see how we can help you.

www.staflsystems.com | Based in San Francisco, CA

STAFL SYSTEMS

Spread

Having started with a spec formula in the first season, Formula E teams have now embraced a diverse range of motor and gearbox combinations – and with Season 3 underway, they can openly discuss some engineering secrets about Season 2

WORDS: **CHRIS PICKERING**

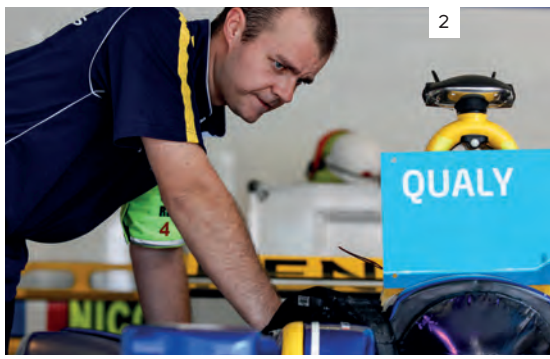

RENAULT
Julius Bär

1. As part of the Formula E roadmap to enable the teams to develop new technologies, Season 2 opened the regulations to allow them to design and build their own powertrains

2. Renault Sport's Formula E engineers opted for a clean sheet design, a single motor mated to a 2-speed gearbox

3. Renault's gear setup minimized inefficiencies from shifting up and down through the gears and maximized the power off the starting grid

1



2

3

The start of the 2015/2016 season marked a significant watershed for Formula E. A year earlier, the world's first all-electric race series had essentially kicked off as a single-make competition. All teams in the debut season were required to use the same hardware, with a McLaren motor based on that of the P1 supercar, a lithium-ion battery from Williams Advanced Engineering, and a 5-speed gearbox from Hewland.

For the second season, however, the teams were able to develop their own powertrains. And this stimulated a burst of creativity, with eight of the nine teams developing platforms. It resulted in a fascinating technical battle, with some teams running one motor while others used two; and gearbox options ranged from fixed-ratio to five speeds. So what were the choices facing the teams?

Despite this new-found freedom in the drivetrain, the trusted Williams Advanced Engineering battery remains mandatory. Its output is capped at 200kW for qualifying and 170kW for race sessions, with a maximum energy consumption of 28kWh (including regenerative braking). Drivers who exceed this limit are penalized, although there is a reserve capacity to get them back to the pits, taking the total allocation to 30kWh.

Occupying a volume of roughly 700 x 800 x 500mm and weighing 320kg, the battery pack is comprised of more than 150 pouch cells, with a bus voltage of 1,000V. It uses a sophisticated liquid cooling system and a hard outer shell to cope with FIA crash test requirements. Another unusual feature of the battery assembly is that it's a load-bearing part of the chassis, sandwiched between the carbon-fiber monocoque and rear suspension.

Although the battery was a spec unit for Season 2 – and indeed remains so for the foreseeable future – its specification had a very direct impact on the development of the new motor and gearbox subsystems.

"The fact that we were limited on power and energy out of the battery meant that we needed to work on efficiency as a priority," explains Vincent Gaillardot, Renault Sport's project leader for Formula E. "When we started looking at our powertrain choices, we analyzed all the possible combinations."

Develop powertrain, not chassis

Formula E rules state that the cars must use no more than two motors, driving the rear wheels only, via a fixed mechanical differential. This is to prevent the use of torque vectoring, Gaillardot says, pushing the teams to focus on development of the powertrain rather than the chassis.

The regulations state that the gearbox must have no more than six gears (with a reversing mode provided electrically by the motor) and the use of DCTs or F1-style seamless shift gearboxes is banned. Apart from that, basically every detail of the motor and gearbox was free to be developed.

However, this presented a dilemma. The teams could reduce the weight and parasitic losses of the gearbox by using fewer speeds, but this would require a comparatively large high-torque motor (or a pair of motors). In contrast, a smaller, lighter motor would still be capable of delivering the right peak power output, but only with a multispeed gearbox to provide the necessary spread of torque. This meant the motor and gearbox had to be considered as a combined unit, along with the shift systems and power electronics.

"It is really a question of the size of motor – or motors – you're going to run," comments Gaillardot. "You can optimize the motor or gearbox within a given weight, but you have to think about mass distribution and center of gravity."

Four on the floor

Most of the teams have now abandoned the original 5-speed configuration. DS Virgin Racing and NEXTEV TCR both opted for single-speed transmissions for the 2015/2016 season. They were also the only teams to adopt the twin-motor configuration, although the exact specifications haven't been released. The logical assumption is that these teams split the torque evenly between two identical motors, although it is possible that some sort of twin-stage system was employed.

A majority of the other teams have gone with modified versions of the old 5-speed Hewland gearbox. These use basically the same pattern with one or two of the ratios removed to save weight and inertia, resulting in a 3- or 4-speed design. Some teams have also swapped the paddleshift system's onboard compressor for a pre-pressurized air tank.

Renault, on the other hand, used a single motor developed in conjunction with an undisclosed supplier (rumored to be Zytek Automotive) and mated to a bespoke 2-speed gearbox from Sadev. This not only slashes the weight of the geartrain, but removes the compressed air system. Instead, in a rather ironic move, the Renault Z.E 15 became the first top-level single-seater in a decade to use a cable-operated manual transmission.

All is not quite as it appears, though. The first gear is usually only used for the standing start at the beginning of the race. After that, the 2-speed Renault is largely a single-speed device, Gaillardot admits: "Sometimes the drivers use first gear for low-speed hairpins, but most of the time they're in second."

He's coy on the motor specification, revealing only that it used a high-grade permanent magnet with the latest stack and wire technology: "We have a state-of-the-art motor and inverter package, but I wouldn't say there's anything unconventional about it. It's just the best of what is out there currently."

This combination put Renault in good stead in the 2015/2016 season. The Z.E 15 won on its first outing at Beijing and captured both the teams' and drivers' titles. But that's not to say the single-motor 2-speed approach emerged as the default choice. ABT Schaeffler Audi Sport was a relatively close second in the teams' championship with a 3-speed gearbox, while next in line was DS Virgin Racing with its single-speed setup.

"We probably had the best all-round package for that season, but it's certainly not the only way to do it," says Gaillardot. "A lot comes down to the hardware that's available to the teams. If you have a supplier that can give you a low-torque motor with a much higher efficiency than a high-torque motor, then a 4- or 5-speed gearbox is probably a good choice."

Renault developed a carbon-fiber gearbox casing to help the car meet the FIA's 888kg minimum weight requirement

SEMIKRON
innovation + service

Most Compact Motor Controller for Electrified Utility Vehicles

Up to 250kVA

For electric and hybrid drive trains

$V_{battery}$: 150V up to 800V

3-phase IGBT inverter

EMI compliant in accordance with 72/245/EWG

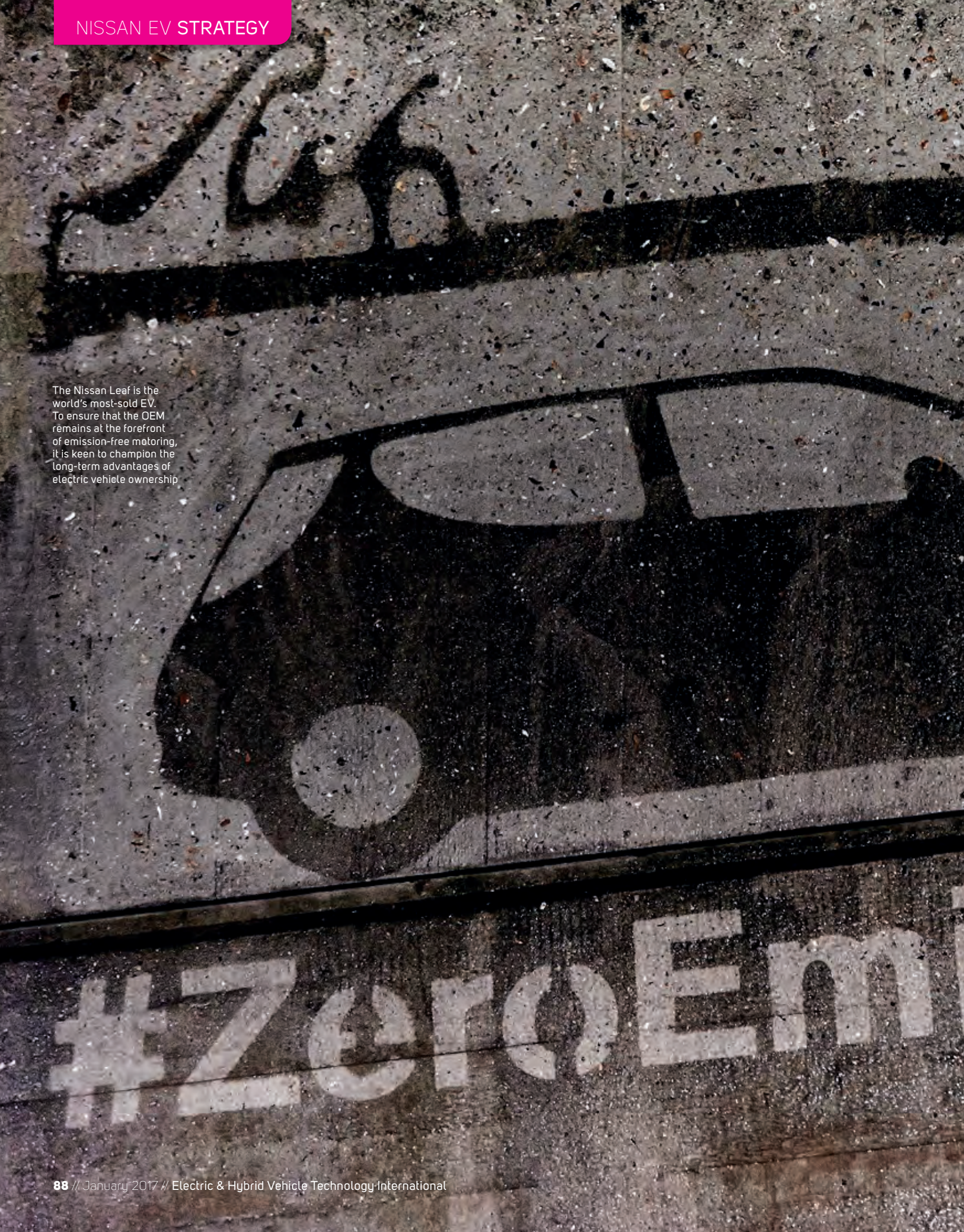
Sintered chips

Utility Vehicles

Urban Transport Equipment

www.semikron.com

shop.semikron.com



The Nissan Leaf is the world's most-sold EV. To ensure that the OEM remains at the forefront of emission-free motoring, it is keen to champion the long-term advantages of electric vehicle ownership

WORDS: **JOHN O'BRIEN**

Nissan is working to change preconceptions of electric vehicles, particularly among business users, with a fresh approach to marketing the benefits of EV ownership as new fleet-wide tax breaks kick-in

The Leaf has been an unparalleled success for Nissan, accruing over 260,000 sales since its launch in 2010 – and making it the most-sold EV in the world. Customers have racked up over 4.1 billion real-world kilometers (2.6 billion miles) of testing, helping to solidify Nissan's position as a major force in the EV market. The way in which the company has approached the marketing and sales of its models is helping further this position – with Nissan extolling the virtues of EVs beyond the short-term gains of reduced ownership costs. For the Japanese OEM, the future vision extends into how the car integrates with its owner's pattern of use, and how it benefits the environments it interacts with.

"We have a strategy in place called intelligent mobility, which is based on three pillars," explains Gareth Dunsmore, Nissan Europe's electric vehicle director. "The first concerns intelligent drive and the introduction of autonomous aids, ensuring the level of safety is there, and progressing that. The second is intelligent power, and making sure we put in the right options to reduce the impact on the environment and head toward a zero-emissions society. The final pillar is integration. It's great seeing rivals finally waking up and realizing that they need to launch an EV by 2020, but it's about so much more beyond the vehicle."

1

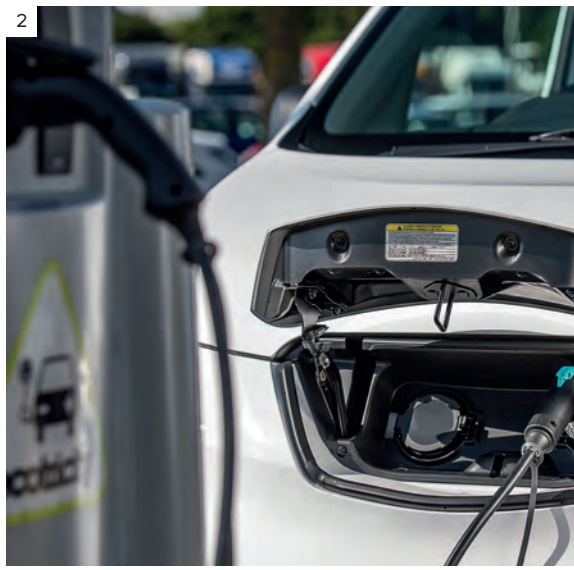
ON A PERSONAL LEVEL

In addition to Nissan targeting commercial users with its new strategies and financial incentives, it is also offering personal-use consumers the ability to take full advantage of cheaper electricity and energy. "Early in 2016 we launched X-Storage, which is a scheme that, for €4,000 [US$4,278], we will take a second-hand Leaf battery pack, refurbish it, repackage it up with our partners at Eaton Energy, and install it in a home," explains Dunsmore. "All the energy for the house then flows through that system. It allows users to take energy at night when it's cheap and use it when it's expensive during the day. It also makes energy sharable by allowing the house owner to take energy to sell to other consumers at a cheaper rate [than if they purchased from the supplier]. We're starting to get to the age where we have to think about being more than a car company, which is why it's incredibly exciting."

Electric heart

At the core of Nissan's strategy, according to Dunsmore, is the battery pack within the electric powertrain. The 30kWh unit found in the third-generation Leaf is developed and manufactured in-house. The latest generation battery from the Leaf is also installed in the e-NV200 van and is helping Nissan make inroads into the light commercial sector, an area Dunsmore believes is ideally suited for the adoption of e-power from environmental as well as financial perspectives.

"For businesses, fleets and offices that have a lot of staff that commute, if they want to reduce their carbon footprint there are huge benefits from a monetary point of view – and


2

1. As well as producing no tailpipe pollution – and thus having a hugely positive effect on NO_x levels – the e-NV200's e-motor produces no noise while its smooth, gearchange-free drivetrain means a more relaxed driving environment

2. The van's battery can be recharged in eight hours using a 16A domestic single-phase 3.3kW charger, or in four hours if the optional 6.6kW/ 32A charger is fitted

3. The e-NV200 has a practical 170km (106-mile) range and a 122km/h (76mph) maximum speed

INTELLIGENT EVOLUTIONS

The 'intelligent' part of Nissan's three-pillar strategy is based on catering for global requirements and customer needs. The company is positioning itself to cater for a global customer base by presenting several new powertrain and mobility solutions, each tailored to a specific region. "In the summer, we announced an e-bio fuel-cell project based on the NV200 van," explains Dunsmore. "It uses a base NV200, adds a small ethanol fuel tank and a solid-oxide fuel cell converter, and that gives over 600km (372-mile) range on 30 liters of water-ethanol mix. In Brazil, that's the perfect solution as you can buy that fuel over the counter – this isn't an infrastructure problem, it's a revolution problem. In terms of prototypes, we'll keep on working on that over there, but it's important for us to understand that customer demand and use is different the world over. So it's important to make sure that a solid, core base of models is in place."

the only thing they have to do is buy the type of vehicle they'd buy anyway to run their business," he explains. "If every vehicle in the UK were an electric vehicle, and all were plugged in at the same time, some might be concerned that the grid would be unable to cope with sudden demand. But we look at it as an untapped opportunity.

"We have a quick-charging solution for the Leaf and e-NV200 called Chademo, which allows the bidirectional flow of electricity to and from the car. That means you can take energy out of the car and put it back into the national grid on a minute-by-minute basis. We have one customer in Denmark with a fleet of 10 e-NV200s who is earning €50 (US$53.65) per week per van because he allows them to be plugged into the energy grid. So suddenly, it's an opportunity for society, and not a risk or problem."

3

POWER TO THE PEOPLE

As another part of its intelligent mobility electrification strategy, Nissan has also introduced its new drive system – e-Power – to its customers. It draws on the EV technology created for the Leaf. Unlike application in the all-electric vehicle, however, e-Power adds a small IC engine to charge the high-output battery when necessary, eliminating the need for an external charger.

The Nissan e-Power system features a full electric motor drive, meaning the wheels are completely driven by the e-motor. The power from a high-output battery is delivered to the e-Power's powertrain, which is comprised of a gasoline engine, power generator, inverter and a motor. In conventional hybrid systems, a low-output electric motor is mated to a gasoline engine to drive the wheels when the battery is low (or when traveling at high speeds). However, with the e-Power system, the gasoline engine is not connected to the wheels; it simply charges the battery.

Nissan claims that this system structure generally requires a bigger motor and battery because the motor is the only direct source to drive the wheels, making it rare in small car applications until now.

Benefits of the e-Power system include the instant delivery of large reserves of torque and quiet system operation. Nissan also states that, because the system relies on the engine much less frequently, its fuel efficiency is comparable to that of leading conventional hybrids, 'especially during around-the-town commutes'.

1

2

Currently Nissan is the only brand that offers the ability to feed energy back into a country's national grid, and Dunsmore believes that this symbolizes the manufacturer's intelligent mobility strategy best of all.

"It is all about thinking beyond the car and understanding that we have to produce a more sustainable mobile society, not just sustainable vehicles," he explains. "In fact, the cradle-to-grave gives a clearer image of what a 'green' car is. Without looking at that, you focus on a small part of the vehicle's carbon footprint and miss the wider picture."

Cash back

The Danish example that Dunsmore cites also exemplifies why he believes that the light commercial world has the biggest potential, perhaps, when it comes to making the en masse step change to electrification that is still needed by society.

"There are so many benefits to mass EV use. The first is that you could get to a point in some countries, where conditions are right, where you could drive for free. But that's a future vision, that's not where we are today," he explains.

"It is all about thinking beyond the car and understanding that we have to produce a more sustainable mobile society, not just sustainable vehicles"

3

1. The latest Nissan Leaf has a 240km (155-mile) driving range on a single charge, representing a 25% increase in range on the previous-generation Leaf

2. Nissan was the first to introduce a 30kWh battery into the sector

3. Developed under its Intelligent Mobility strategy, Nissan's e-POWER drive system draws on the EV technology created for the Leaf, albeit with a small IC engine to charge the battery, thus eliminating the need for an external charger

4. Nissan's IDS Concept represents its vision of future autonomous driving and zero-emissions EVs

"So, €50 per week is not quite enough yet to offset the full cost of the car. But for a business, that's incredibly important. Not only does using an EV reduce the running costs of the vehicle (as there are fewer mechanical parts and less maintenance), but it allows them to make use of their vehicles – even when they're not being used. In Denmark that was through normal, daily use. The fleet vehicles aren't specifically being used as storage devices, they're being used daily as utility vehicles. It's just that when they're plugged in, that's the value they're getting out of them. That's the really cool thing for me."

To support this point, Dunsmore highlights that one of the biggest things Nissan is doing with its electric range is workplace promotions to engage with potential users first hand. "We're going into businesses, explaining the product to them properly, and allowing staff to take test drives and experience it first hand," he explains.

"We also say to the company, 'If you do purchase, we'll support you in putting in charging at the office, and move toward this holistic solution.' With the people that move toward it, we've failed them if they come back and complain about the range of the cars. But in doing it this way, there are more people satisfied with the Leaf than with any other car in our range, including the Qashqai, which is saying something."

While e-NV200 is making sizeable inroads with SMEs, taxi firms and other inner-city businesses, Dunsmore believes that Nissan and other OEMs are only just beginning to scratch the surface of what is possible, and what should be done to achieve a zero-emissions society.

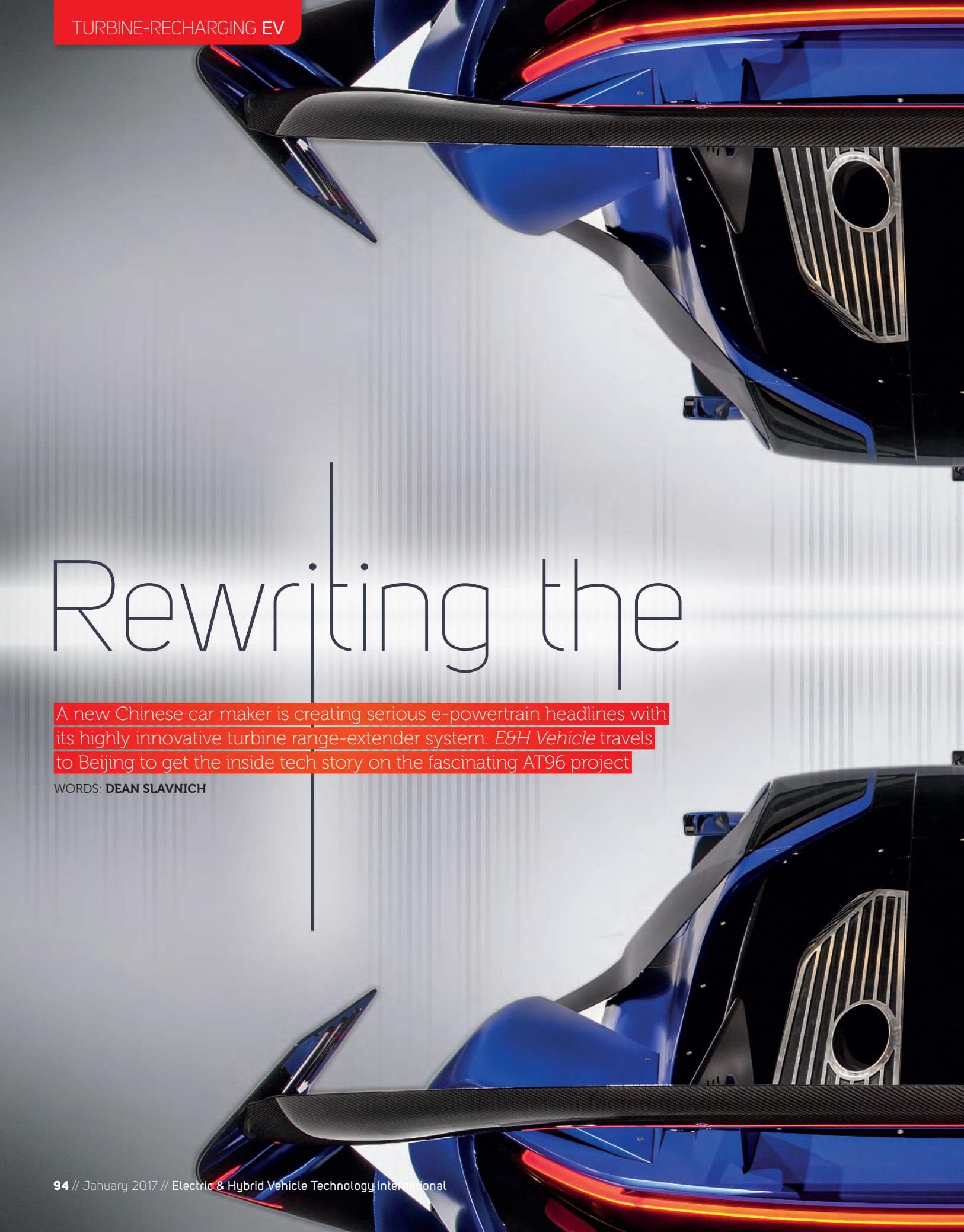
"I think the future opportunity that excites me most at the moment is last-mile delivery,"

4

he says. "There is absolutely no reason why the vast majority of municipality town deliveries shouldn't be done by an electric van. There is a project in Rome where people deliver goods in a zero-emissions zone using two van-shared vehicles. It shows that there's a huge potential to do something different, as it's not about sales volumes – it's about changing society a little bit."

Dunsmore's proposal for a slight change to society involves removing light commercial vehicles from the roads during peak commuter hours and shifting them to the middle of the night. Such a move is facilitated by the silent nature of EV powertrains, and yields multiple benefits for cities and towns.

"All the vans that are delivering at 8am or 9am could do it during the night as it's quieter on the roads. They're silent so there's no noise pollution and its zero emissions, so it's cheaper," explains Dunsmore. "Suddenly the car flow improves around the town, regardless of whether masses move to electrification or not. There's less pollution and less time wasted sitting in traffic. There's a really interesting benefit to moving toward electric CVs that represents a huge opportunity for all."



Rewriting the

A new Chinese car maker is creating serious e-powertrain headlines with its highly innovative turbine range-extender system. *E&H Vehicle* travels to Beijing to get the inside tech story on the fascinating AT96 project

WORDS: **DEAN SLAVNICH**

rules

While the likes of Tesla take most of the global media attention when it comes to furthering the electric powertrain movement, it's actually in China where battery electric technology is progressing most quickly.

One company making serious headway is Techrules, which debuted its innovative Turbine-Recharging Electric Vehicle (TREV) technology last year. Developed by William Jin, the founder and CEO of Techrules, the pioneering range-extender powertrain system uses a microturbine to generate electricity that charges the battery pack. In turn, the battery provides power to the traction motors that drive the wheels of the vehicle. Jin's son – Techrules CTO Matthew Jin – says a newly developed battery management system enables superior charging operation, while the high efficiency of the range-extender unit results in fewer batteries, saving weight and space.

Techrules plans to begin series production of its TREV technology in a low-volume supercar of its own design within a couple of years. It plans to begin production of higher volume city cars a few years later

Air drawn into the microturbine is passed through a heat exchanger, where heat from the exhaust air is transferred to the cold intake air after it has been compressed. Ignition of the compressed and heated fuel-air mixture generates massive energy that is then channeled at very high speeds to turn the turbine vanes. As hot exhaust gas is expelled, it passes through the heat exchanger to ensure that the heat energy is recuperated and transferred to the cold intake air.

"As turbines have always been a very inefficient way to convert chemical energy into useful wheel-turning mechanical energy, only a few have tried to use a turbine in the powertrain system, and none have succeeded commercially," explains Matthew Jin.

"But, with EVs, an electric motor is used to drive the wheels, which effectively frees the IC engine to convert chemical energy into mechanical energy and finally into electric energy. This is a major breakthrough, making it possible to use the highly efficient turbine engine as a superb range-extender unit."

Jin argues that microturbines are far more efficient than piston engines in range-extender applications, mainly due to less energy being sacrificed in frictional losses, meaning more of the fuel's chemical energy is harnessed.

In the TREV configuration, the turbine and generator share the same shaft and rotate at over 96,000rpm, in turn producing 36kW. Of this specific output, 30kW powers the generator with 6kW directly powering auxiliary equipment such as the inverters.

The two Techrules concept cars use six electric traction motors in total, each weighing 13kg and each one of which is coupled to its own dedicated inverter. Each front wheel is driven by a single electric motor, while each rear wheel is driven by a pair of motors.

A development prototype of the AT96 was tested last year at Silverstone race circuit in the UK

The combined peak output of the motors is 768kW (1,044ps), with torque expected to exceed 8,600Nm. Such huge power outputs mean the concept cars could feasibly achieve a 0-100km/h sprint time of 2.5 seconds with a restricted top speed of 350km/h.

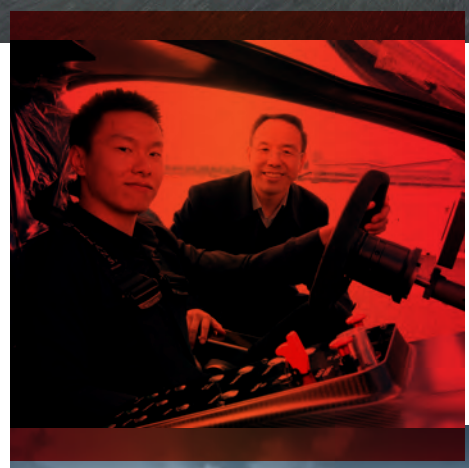
Fuel consumption is projected to be just 0.18 l/100km under plug-in operation. But, with a full charge provided entirely by the TREV tech, consumption is expected to be around 4.8 l/100km.

Cross-industry engineering

While Techrules' hybrid powertrain has been patented, it's not a totally new concept, at least not outside of the automotive industry. The idea of using a microturbine generator is common in the aviation world as well as in the large-scale power generation sector.

"This type of turbine technology was used as a static generator to supply electric power to a small village in China," explains Matthew Jin. "Because this type of turbine has a high shaft speed, and the battery system is very difficult and expensive to produce, only a few companies are going down this business line."

What helps Techrules' cause is that it is part of cross-industry engineering powerhouse TXR-S. This has allowed Techrules to look at other routes to mass production. As such, the EV and HEV sector was his 'light bulb' moment. "Using new technology, we've made the air bearing system more reliable and precise, with greater relaxed tolerances and easier to produce, which means a lower price."



Left: The TREV employs a smart battery management system that optimizes the efficiency of battery charging and power balancing between the battery cells

Below left: A turbine shaft powers a generator that produces electricity to charge the vehicle's battery cells

Below: Techrules employs air bearing tech – a high-pressure feed of compressed air – instead of a conventional oil lubricant film to separate the shaft from the bearing

Unlike many previously developed turbine powertrains, TREV's setup has no direct electrical feed from the generator to the e-motors, meaning the technology is a pure series hybrid range-extender design.

But how do the Jins get around the fact that cars spend most of their lives encountering bumpy, uneven roads, dynamically challenging corners and, in some places, harsh potholes as well? "Our technology is a hybrid bearing system – it's magnetic and air bearing technology together," counters Jin. "So the magnetic bearing controls the bumping and cornering, while the air bearing loads the shaft. They take care of separate businesses while cooperating with each other."

The air bearing technology uses a novel high-pressure feed of compressed air instead of a conventional oil lubricant film to separate the shaft from the bearing, resulting in fewer frictional energy losses as it eliminates the parasitic losses of a mechanical bearing. But what is particularly noteworthy is that the air bearing is also supported by a magnetic field that allows for precise adjustment of the high-speed shaft. Both bearing solutions work together in order to maintain stability. As such the magnetic bearing allows for a far greater clearance between the shaft and its wall lining, which delivers advantages for the durability of the system.

And, as Jin alluded to earlier, this is an especially important consideration in automotive applications of turbine systems because – unlike in stable power generation conditions – the entire assembly must be capable of withstanding volatile operating conditions that result from, for example, vertical shocks from uneven road surfaces and lateral forces in cornering.

A new design of internal foil is used for the bearing liner that supports the air pressure and flow. The foil is made from a brand-new compound material, says Jin, which gives it superior durability. Just as important, this foil enables the mass production of the bearing liner at the required production tolerances, at a high-volume scale at low cost.

Meanwhile, the engine itself has been developed in-house: "The Chinese aerospace industry has its own suppliers," outlines Jin. "But not for us. When this technology goes into production for automotive, we will be responsible for production."

Battery boast

While most of Techrules' innovation lies in the turbine technology and air bearing arrangement, there are also key standout engineering features for the battery system. For example, a new smart-charge balancing strategy works to harness the excess voltage in cells that charge more quickly, in the process sharing their charge with slower-charging neighboring cells to achieve an optimal balance.

The TREV technology makes use of readily available cylindrical 18650 lithium manganese oxide cells. As a result, Techrules estimates a 90% charge can be completed in just 15 minutes.

Based on initial testing, a production Techrules supercar will be able to travel around 150km on battery power alone. Combined maximum range – based on battery configuration in the concept supercars – is projected at more than 2,000km from 80 liters of aviation kerosene.

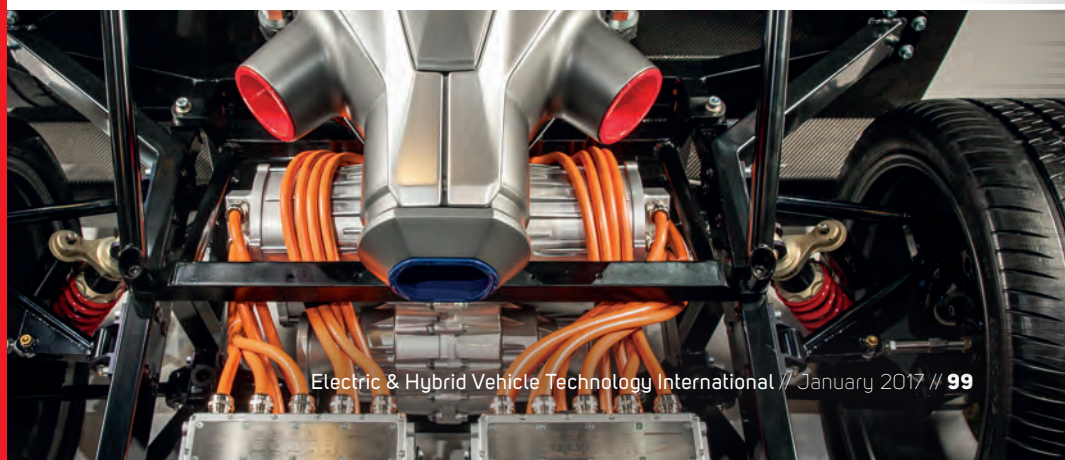
Matthew Jin says so far the testing phase has been extensive – having to prove this technology's durability is key, he adds: "We have worked with the aerospace industry in China – we provide the technology and they manufacture the piece. The prototypes are working perfectly because air bearing tech on that scale is not difficult to perfect. The

FAMILY TIES

Described as an R&D organization by founder William Jin, Techrules is essentially owned by TXR-S, a parent company that provides funding and support. The latter is a huge industrial player in China, spanning the biogas, aerospace, high-tech materials and auto industries.

And it's the group's cross-industry expertise that's proving to be vital to Techrules, as Jin Senior explains: "Our business works together with top players in China's aerospace industry to test and develop aviation power systems. At the same time, we've been working with specialist vehicle companies to further the development of the EV. That's why we combine these two expertise groups and technologies together [for Techrules]."

Recently, the Beijing-headquartered startup has begun the process of identifying potential locations for its European production base. It already works with engineering partners in Italy and the UK.



The AT96 concept produces peak power of 768kW. Initial projections indicate 0-100km/h acceleration in 2.5 seconds, a top speed of 350km/h and a range of more than 2,000km. Under plug-in operation, it achieves fuel consumption of 0.18 l/100 km (1,569mpg)

difficult aspect is the ability to produce as many as 100,000 air bearing pieces and all of them to work perfectly."

The entire package is sealed, barring the intake and exhaust, but this doesn't create problems later down the line when it comes to maintenance and servicing. "It's barely an issue – and this is really an amazing point: when the car completes its life, the engine wouldn't have needed a service.

"For example, if the engine runs for, say, 4,000 hours, you'd need to clean the air filter; however, on a 4,000-hour cycle with this engine, the vehicle would have covered perhaps 150,000km. This means that this type of turbine engine could actually be recycled because the life of the turbine is so long. Our technology will actually outlast the car – you can change the car but keep the engine!"

In the two two-seater all-wheel-drive supercar concepts showcased by Techrules at the Geneva Motor Show in 2016, the turbine generator is placed right behind the passenger cabin and in front of the rear wheels, making the vehicles 'mid-engined' EVs.

The first concept, the AT96 – AT stands for Aviation Turbine – sees the turbine configured to run on liquid fuel such as aviation kerosene. Meanwhile, the GT96 – Gas Turbine – has been designed to run on gaseous fuel, such as biogas and natural gas and is seen as being more of a super/hypercar application. Both concepts weigh around 1,300kg, although the production target is to get below 1,000kg dry weight.

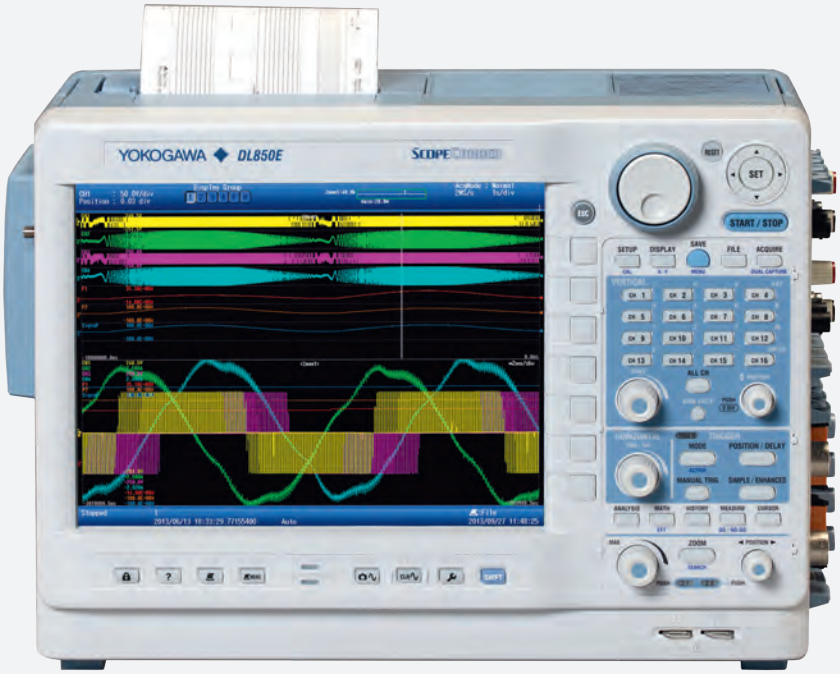
Techrules has some big ambitions for the technology. Amazingly – but at the same time somewhat typical of China's huge tech R&D acceleration – Jin is aiming to launch the technology in an EV application by 2018. "Our plan is to have a production, road-going supercar in two years. After that, a further three or four years later, we'll then launch a passenger car. We've planned for the turbine to be in mass production within one to two years, but designing a real production car takes a lot longer."

In terms of supercar numbers, Matthew Jin admits that it'll be small to start with: "We're looking at 100 or 200," he says.

Such a short development timeframe means that Techrules has a chassis supplier, which means it's not having to develop its own full architecture. "We can't reveal names, but it's the top supplier," hints Matthew Jin.

The story is even bolder for the passenger car. Having gained core architecture and chassis experience from the supercar project, "We will perhaps develop the architecture by ourselves for the passenger application – a four-to-five-year timeframe is a long time in the automotive industry," concludes Matthew Jin.

The total weight of the TREV system – including microturbine, inverters, fuel pumps, air pumps, and generator, but not batteries and motors – is approximately 100kg



Oscilloscope + precise data acquisition

Meet the **ScopeCorder**, a flexible all-in-one solution designed to solve electromechanical measurement challenges in fields like automotive, lighting & power electronics.

- Capture and analyse both transient events and trends up to 200 days
- Combine measurement of electrical signals, sensors and serial buses (CAN / LIN / SENT)
- Acquire data from up to 128 channels with isolation up to 1 kV
- Trigger in real-time on power measurement calculations

Read the 10 reasons to choose a ScopeCorder as your next measurement instrument
www.tmi.yokogawa.com/10reasons

Hot properti

ies

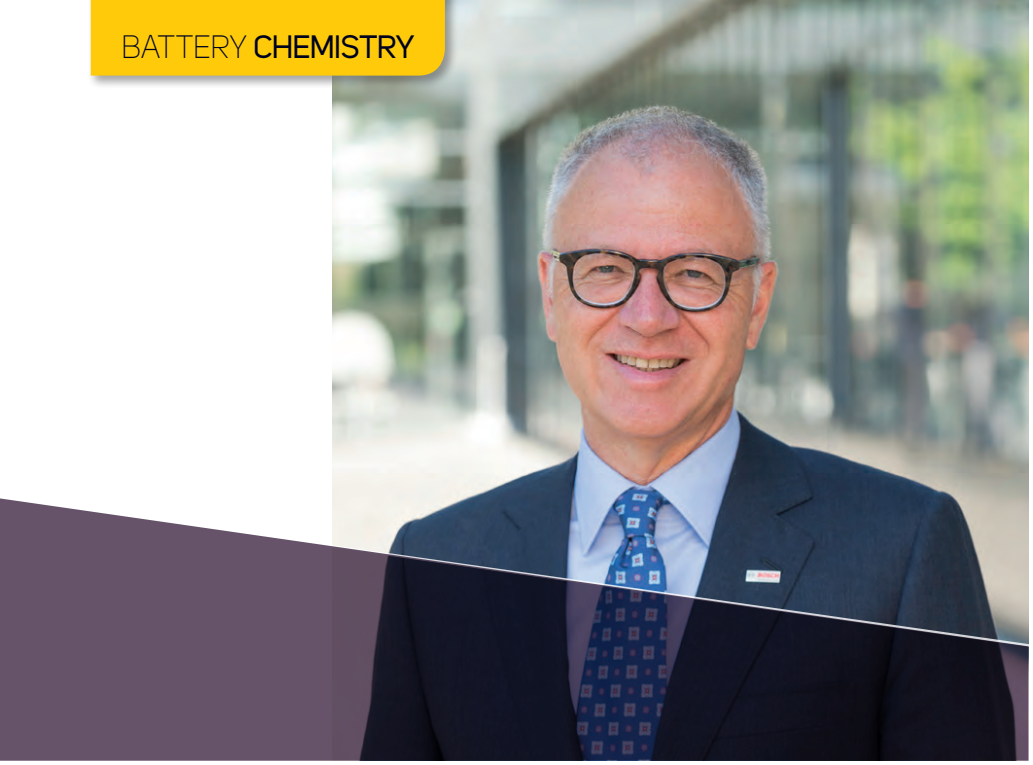
From solid-state and air-based cells to lithium-sulfur, could a new generation of battery chemistry help realize the sustainable transportation dream and finally put to bed long-held consumer worries about EV technology?

WORDS: **CHRIS PICKERING**

Over the past decade, demand for EVs has soared. Cars such as the BMW i3 and Tesla Model S have brought EV technology to the brink of the mainstream. But most would argue it's not quite there yet – range anxiety and the high purchase cost of EVs are still putting off consumers.

The cost of lithium-ion cells has fallen faster than predicted and it could be as little as US$100/kWh by the end of this decade (equating to US$150-200/kWh for complete batteries). But will that be enough to ensure the technology's dominance?

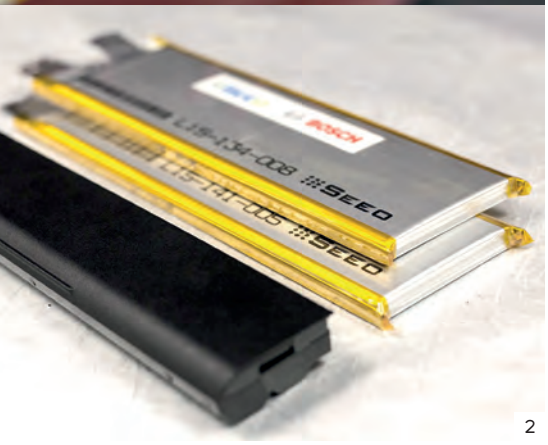
"I think that we're starting to approach the practical limits of performance for today's conventional lithium-ion cells," says George Crabtree, senior scientist at Argonne National Laboratory and director of the Joint Center for Energy Research. "They might get 50% better, but we're not going to see a step change in performance. In 5-10 years' time, I think we'll reach the limits of cost too. If we want to get to the next level, we may need a new generation of chemistry."



"Using lithium-ion technology, we believe we can achieve twice the energy density and half the cost of present-day batteries by 2020"

Stefan Seiberth, electromobility executive, Bosch

1



2

Perhaps the two most likely candidates are solid-state cells and lithium-sulfur cells. The argument posed for replacing a conventional gel electrolyte with a solid-state alternative partly comes down to safety. At 140-150°C conventional lithium-ion batteries can go into thermal runaway, with the cathode reacting with the liquid electrolyte. Once it starts, the reaction is very hard to stop.

By their very nature, solid-state electrolytes are less volatile and easier to manage. There's also the potential for higher energy densities and lower costs, but the problem is that charge tends to move quite slowly in these materials, limiting power density.

"If you knew how to develop a solid-state electrolyte for a lithium-ion battery you'd do it," explains Crabtree. "Right now, the general consensus is that it's too expensive and doesn't perform well enough for an EV battery, but lots of people are working on that and I'm hopeful we may see something before too long."

He expresses the same cautious optimism when it comes to lithium-sulfur. Here, one of the main issues is that the sulfur-based cathode becomes coated with an insulating passivation layer: "You have to have a nano structuring and do various other things to ensure that the sulfur has a chance to react, so it's by no means easy. In theory, though, you can get higher energy density and you can get the cost down because sulfur is almost free. So there's a chance the two things you really care about on an EV could be addressed. It could make a huge difference."

Further down the line, lithium-air has been heralded as the holy grail of EV batteries. In theory, it offers a specific energy of close to 12kWh/kg – similar to that of gasoline. In practice, the real figure is likely much lower, but still potentially as much as 10 times that of current lithium-ion cells.

Practical challenges abound, however. For a start, the reaction requires virtually pure oxygen, stripped of carbon dioxide, nitrogen and atmospheric moisture. That means adding a system to purify the air or carrying tanks of oxygen – either of which incurs extra weight and cost. There are also electrochemical challenges, such as limiting discharge products like lithium peroxide, which can block the porous cathode.

Multiple approaches

It's not just changing consumer habits that's driving interest in EVs and hybrids, though. As Stefan Seiberth, electromobility executive at Bosch, explains, "In Europe, manufacturers will have to achieve a fleet average of 95g/km of CO_2 by 2021 and most of them won't be able to do that without electrification.

"We expect to see a mass market for electric vehicles from around 2020. By 2025 we think approximately 15% of all cars worldwide will be electrified in some way and by then we expect them to account for one-third of all new passenger cars sold in Europe."

The German company takes this emerging market so seriously that it plans to make a decision next year on whether or not to begin cell production in-house. Already it has a joint venture with Mitsubishi and GS Yuasa working on advanced lithium-ion batteries. Though

1. Following its acquisition of Seeo in 2015, Bosch believes solid-state cells could be a breakthrough technology for lithium-ion batteries in EVs, potentially doubling pack energy density by 2020

2. Bosch says its solid-state batteries require no cooling system and won't be prone to thermal runaway the way conventional lithium-ion batteries are. They are also reported to be much lighter and cost less to manufacture

3

3. REAP Systems supplied the BMS to South Korean battery cell manufacturer Kokam for a hybrid bus project for the Korean Rail Research Institute. The bus has a 50kWh battery system with 620V (12 modules with 14 80Ah cells per module)

4. In 2003, Dr Dennis Doerffel, founder and CTO of REAP Systems, developed a concept HEV that used lithium-ion batteries as a supplementary power source to IC engines

perhaps even more intriguingly, Bosch has also recently acquired US start-up company Seeo, which specializes in developing new solid-state EV technology.

"Using lithium-ion technology, we believe we can achieve twice the energy density and half the cost of present-day batteries by 2020. We see a further market for 48V micro-hybrid systems too, where cost is going to be a major factor. For the foreseeable future, these will be based on lithium-ion technology."

In contrast, solid-state batteries, he says, will have "a clear focus on pure EVs" where larger capacities are required and discharge tends to be more sustained. Seiberth doesn't give any figures, but hints that the energy density and cost incentives will be greater than those of next-generation lithium-ion. Bosch's solid-state batteries will be "market-ready in four-to-five years" Seiberth estimates, and much of the remaining work is focused on fine-tuning the familiar NCM (nickel, cobalt, manganese) cathode chemistry.

CHIP CHAT

Battery management systems (BMS) have evolved rapidly in recent years. Although the functionality remains much the same, they have become smarter, lighter and more integrated.

"When we produced our first BMS in 2003 the individual chips had to communicate via CANbus," recalls Dr Dennis Doerffel, founder and CTO of REAP Systems. "That's quite an expensive way of doing things, because you need a CAN transceiver, isolation and a DC-DC converter in every module. The latest chips can do this all on one device, talking to each other directly rather than over a CANbus.

"Chip manufacturers are trying to make them faster and more accurate, but – with the exception of some hybrid applications – I don't think that's necessary. It's mostly about cost reduction and I think that will come as more manufacturers enter the market."

Typically, each individual chip can handle voltage and temperature measurements for 12 or 16 cells. REAP uses a second chip as a backup for each to check that the signals are all in range. There's also a large number of wires and sensors for the complete BMS, plus PCBs and power supplies, so it's a substantial portion of the overall powertrain.

Lower cell voltages for some more exotic chemistries may require the use of additional cells, and hence more BMS inputs in the future. But on the upside, improved thermal stability and higher operating temperatures could simplify the job of battery management.

"Generally, it is much easier to warm a battery up than it is to cool it down, so in my opinion 'warm' cells would be a good solution," says Doerffel.

Photo: Nitoo Kohan Photography

4

1

LIVE FOREVER

Researchers at the University of California, Irvine (UCI) have stumbled across a new technology that could result in virtually limitless battery life. The team, led by Mya Le Thai and Reginald Penner, set out to investigate the degradation and failure of gold nano wires used for energy storage. They built a test rig with two cathodes, designed to cycle each other to destruction. The only problem was that the nano wires refused to fail. After 200,000 cycles they were still going strong.

"It was pure luck," admits Penner. "We were doing our normal electrochemical characterization and cycle stability testing when it suddenly became clear that they just weren't going to die. Needless to say, Mya and I were both pleasantly surprised by the results!"

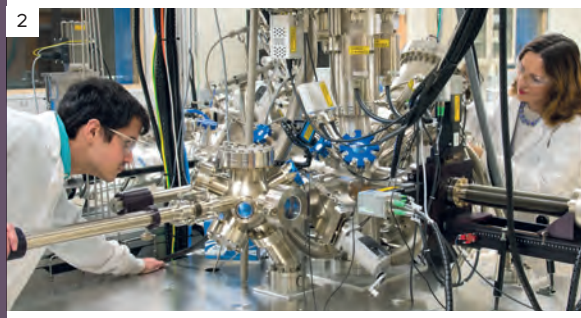
The UCI rig is a long way from being a functioning battery at present and it's not even clear what caused this extraordinary behavior. But it still raises the tantalizing prospect of cells that could last – more or less – forever.

"I think that we're starting to approach the practical limits of performance for today's conventional lithium-ion cells"

George Crabtree, senior scientist, Argonne National Laboratory and director, Joint Center for Energy Research

Photos: Argonne National Laboratory

2



1. Postdoctoral appointee Zhenxing Feng examines battery materials in a double-sided glovebox at the Joint Center for Energy Research in the USA

2. Scientists collaborating on pioneering next-generation battery research in the Electrochemical Discovery Laboratory.

"You can end up with a battery suitable for very high levels of discharge – the sort of thing you need for a short hybrid boost – or one that delivers a constant flow of energy for a more prolonged period, as you would need for an EV cruising along the motorway," he notes.

Bosch appears to have made considerable inroads with the power density of solid-state cells, but there is still work to be done. "One of our development goals is to have batteries that can be charged to 80% in 15 minutes," says Seiberth. "It comes back to the chemistry – a composition that allows you to charge the battery very rapidly doesn't necessarily provide the energy density that you want – so we need to work on that before we reach these targets. But we are confident."

Battery life of more than 1,000 cycles has already been seen in testing and Seiberth says the target is a battery that provides a range of 300km and retains 80% of its initial capacity after 12 years or 300,000km.

Immense potential

Lithium-sulfur is another strong contender, with a high specific energy and inherent safety benefits over lithium-ion. And it could be here sooner than expected. Having worked on the technology since 2005, UK company Oxis Energy has developed lithium-sulfur pouch cells, which it says could power mainstream EVs in as little as five years' time.

"The theoretical energy density of lithium-sulfur is around 2.7kWh/kg – five times that of lithium-ion," says Dr Mark Crittenden, head of battery development and integration at Oxis. "We've achieved 325Wh/kg and hope to have a 400Wh/kg battery operating by 2017, with 500Wh/kg a reality by 2019. One rule of thumb is that the practical limit is usually around one-third of the theoretical limit. If you look at lithium-ion, it's actually done a bit better than that and I think that lithium-sulfur could do better still. We are looking many years ahead here, but I think 1kWh/kg will eventually be possible."

Historically one of the main obstacles to lithium-sulfur technology has been cycle life, but Crittenden says around 1,500 cycles is now possible. Also, he claims that the electrolyte chemistry developed by Oxis completely

1. Oxis Energy believes that the future of EV battery technology lies in lithium-sulfur chemistry, which it claims has a theoretical specific energy nearly five times higher than that of lithium-ion

2. Over the next few years, scientists at Oxis Energy aim to further tweak the latest battery chemistries, as well as roll out automated manufacturing

"We've already achieved 325Wh/kg and hope to have a 400Wh/kg battery operating by 2017, with 500Wh/kg a reality by 2019"

Dr Mark Crittenden, head of battery development and integration, Oxis Energy

avoids the swelling issues that are sometimes seen with other designs. The active ingredient in the cathode is sulfur, but it is mixed with carbon in order to improve conductivity, while an undisclosed polymer is also used to bind everything together.

Much of the company's present work focuses on reducing other ingredients and maximizing the quantity of active sulfur, says Crittenden: "We're at higher than 70% sulfur, of which more than 70% is actively involved in the chemistry. The target now is to reduce wastage and to improve efficiency. One way to do that is by increasing the capacity of the cells. Four years ago the cells we produced were 1.7Ah and a lot of the material was used inefficiently. You've got a very small cell that still has two full-size tabs on it, for example. We can now build 40Ah cells with the same number of tabs, meaning that the percentage of non-reacting mass is now much smaller."

Further tweaks to the chemistry are planned over the next few years, as is the roll-out of a new automated manufacturing process. There's also work to be done on integrating the cells into a larger battery pack.

Conventional battery management systems (BMS) should still be able to work with lithium-sulfur, but there will be a couple of factors to bear in mind when it comes to battery management, as Crittenden points out: "The voltage is lower – lithium-ion cells generally fall between 3-4V, whereas our cells are typically around 2.1V, so the BMS needs to be able to understand that. Secondly, the state of charge is harder to predict – with lithium-ion you can just measure the voltage and reference that to a look-up table to see how much energy is left in that cell; for lithium-sulfur it's a little more complicated, but we have algorithms in place in order to measure the state of charge."

Crittenden believes that lithium-sulfur will one day dominate lithium-ion – perhaps as soon as within a decade. "Lithium-ion went from zero to a US$80bn-a-year sector in approximately 30 years," he says. "And we can see a similar trajectory for lithium-sulfur – our target is to have approximately 10% of the lithium-ion market by 2020. The potential is absolutely immense."

Striving to maintain what we all hold dear

The Highlands of Scotland is a perfect place for doing big things with batteries;

- Scale up of new cell technologies
- Sub-contract cell manufacture
- EV, PHEV and renewable energy storage

There's no doubt that Scotland has great scenery and there's no questioning its commitment to renewable energy. 57% of its electricity came from renewables in 2015. With an abundance of waves, fast flowing tides, plenty of wind and even a little sun AGM Batteries in the Highlands is part of a fast growing local supply chain developing and manufacturing the technologies that'll be key to all of our renewable powered futures.

AGM Batteries Limited has proven flexibility to deal with a full range of chemistries and are;

- **Developing new cell technologies for EV's, PHEV's, renewable energy storage & the oil industry.**
- **Scaling up new cell technologies through to volume manufacture.**
- **Providing a contract manufacturing service to electrochemistry developers**
- **Licensing cutting edge technologies.**

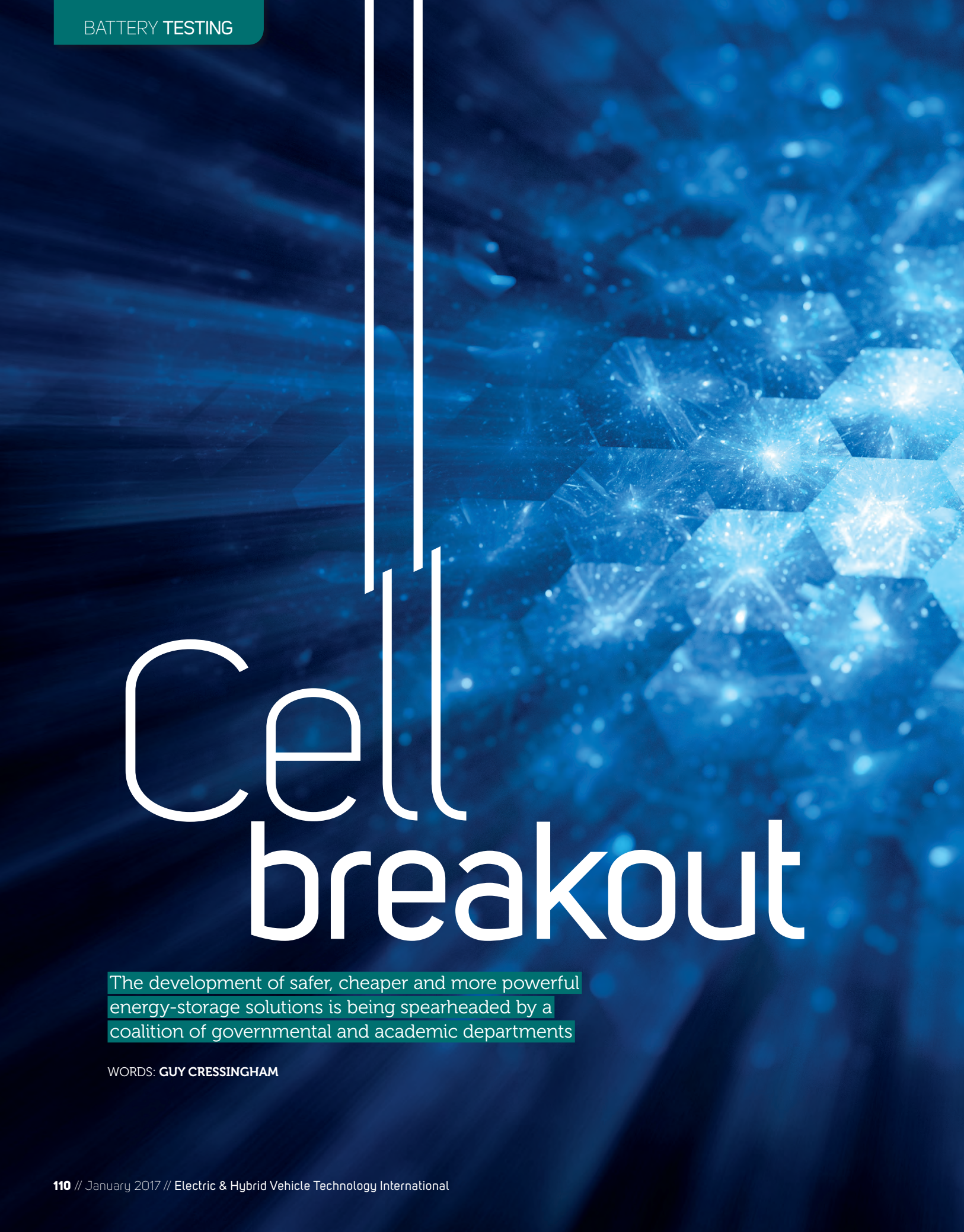
Collaboration is at the heart of our operation and we're proud of the progress we're making working closely with our existing partners in the business of developing materials, cells, BMS, packs and power conversion systems.

WHAT CAN WE DO FOR YOU?

enquiries@agmbatteries.co.uk
www.agmbatteries.com

AGM Batteries Ltd.

Photo; AGM photographer. www.angusmackay.co.uk



Cell breakout

The development of safer, cheaper and more powerful energy-storage solutions is being spearheaded by a coalition of governmental and academic departments

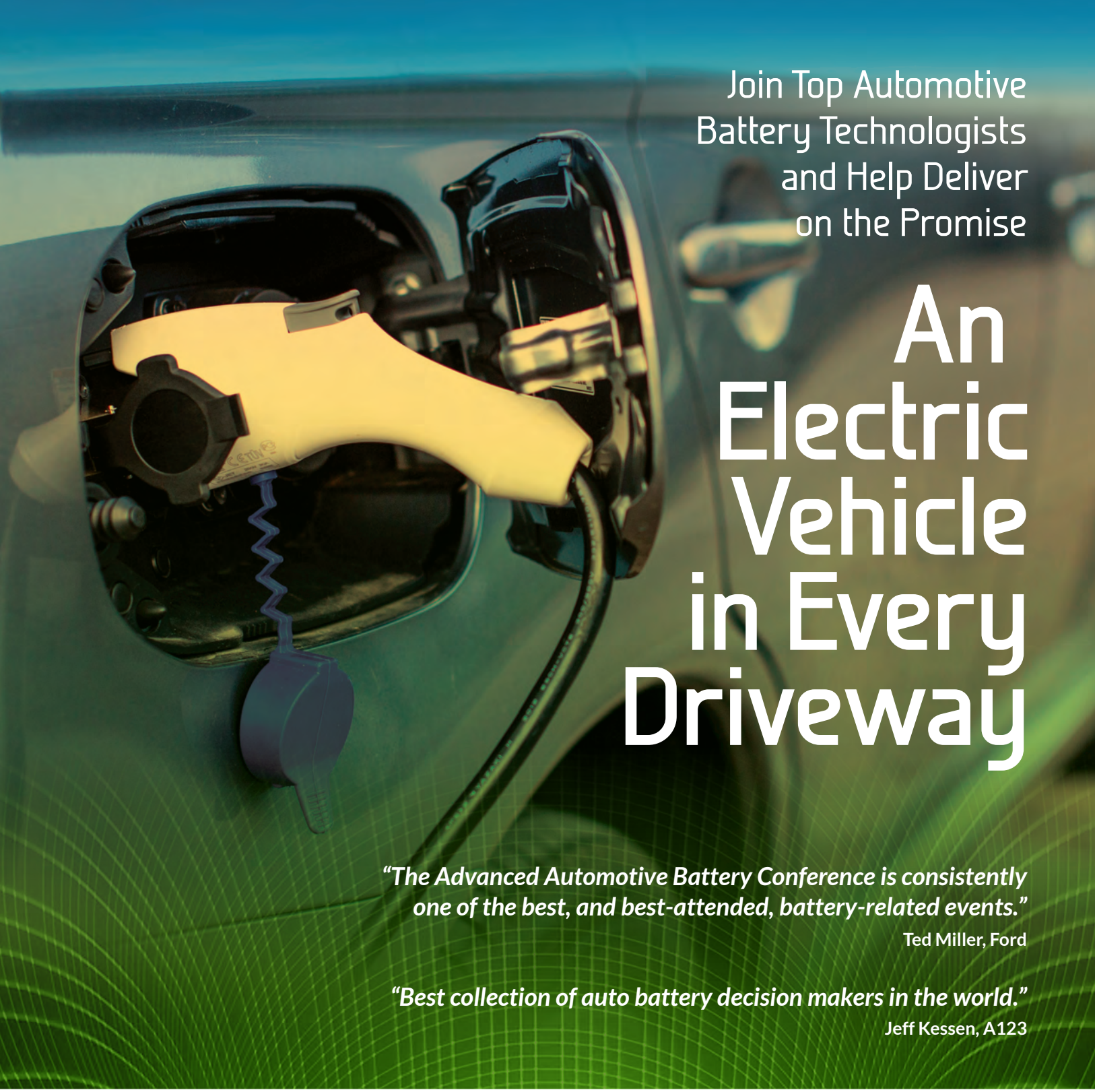
WORDS: **GUY CRESSINGHAM**

Although testing of an electric or hybrid vehicle is not substantially different from that of any other automotive product, the energy-storage component of the vehicle powertrain requires dedicated assessments at various stages. Cells and chemistry are tested, as are the complete battery and pack, for energy density, consistency, stability and safety. Testing is regulated by a variety of standards and is undertaken in the laboratory and real-world environment settings.

The US Vehicle Technologies Office (VTO), part of the US Department of Energy (DOE), oversees extensive testing of batteries for EVs. The VTO's major goals include achieving a reduction in the cost, volume and weight of batteries together with an improvement in performance and durability – intrinsic to the overall strategy of increasing the commercial viability of BEVs and HEVs.

PHEVs are predicted by the VTO to play a key role in the USA's transportation future. As such, the VTO's battery development, system analysis and testing activity includes performing repeatable test procedures that enable researchers to consistently evaluate batteries on key characteristics such as cycle life and abuse tolerance. Benchmark testing for batteries sets a base level against which companies can reliably compare improvements on a consistent basis.

"Batteries play a vital role in achieving petroleum and greenhouse gas savings," states DOE representative David Howell. "Batteries are the only fuel storage on board BEVs and store a large amount of energy in PHEVs. Therefore, more focus has been placed on battery testing, especially as vehicles age. The Advanced Vehicle Testing Activity [AVTA] at the Idaho National Laboratory [INL] benchmarks both battery aging and



Join Top Automotive Battery Technologists and Help Deliver on the Promise

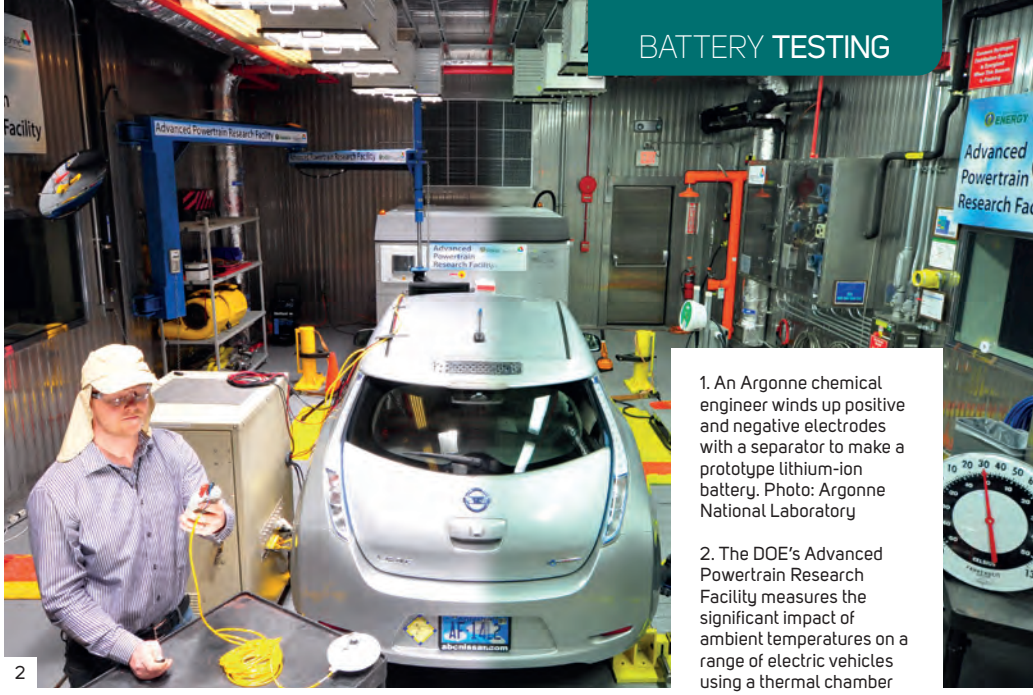
An Electric Vehicle in Every Driveway

"The Advanced Automotive Battery Conference is consistently one of the best, and best-attended, battery-related events."
Ted Miller, Ford

"Best collection of auto battery decision makers in the world."
Jeff Kessen, A123

aabc europe
advanced automotive battery conference
30 January - 2 February 2017 • Mainz, Germany
AdvancedAutoBat.com/Europe

aabc
advanced automotive battery conference
June 19 - 22, 2017 • San Francisco, California
AdvancedAutoBat.com/US



1. An Argonne chemical engineer winds up positive and negative electrodes with a separator to make a prototype lithium-ion battery. Photo: Argonne National Laboratory

2. The DOE's Advanced Powertrain Research Facility measures the significant impact of ambient temperatures on a range of electric vehicles using a thermal chamber

associated decreases in capacity. The data is then used in many applications, such as determining the overall lifetime vehicle costs and modeling inputs."

As part of its R&D contracts to improve battery performance, the VTO produces cells that are delivered to the DOE to be tested under protocols that are developed with OEM partners. These cells are compared with other R&D programs and benchmark results from commercially available batteries, with the test results used to help direct future R&D requirements and funding.

"The AVTA has accumulated upward of 250 million miles of EV test data," says Howell. "In addition to technical evaluations of performance and efficiency, the collected data helps determine how people operate vehicles and where they prefer to recharge."

The AVTA uses US Advanced Battery Consortium test procedures to conduct battery testing at different predetermined mileage intervals during fleet testing of an EV. Howell says that as battery and charging technologies change, the AVTA re-evaluates its testing procedures and, where warranted, modifies them with industry partners: "New procedures ensure that proper and valid data is collected for new technologies."

The power of five

In 2012 the Joint Center for Energy Storage Research (JCESR) was founded as a result of a US$120m DOE grant to establish a new batteries and energy-storage hub over a period of five years. The JCESR combines the R&D capabilities of five DOE national laboratories, five universities and four private organizations to radically improve battery performance for use in EVs and the electricity grid. The goal, often referred to as the 5-5-5, is to develop a battery that is five times more powerful and five times cheaper than current offerings within five years.

> "Most of our work is done at the materials design level, not the pack development level. We take the same approach in understanding chemistries and technologies when we test research cells"
>
> Dr Brian Ingram, materials scientist, Argonne National Laboratory

Dr Brian Ingram, materials scientist at Argonne National Laboratory, one of the five DOE labs involved in the research, explains its testing of EV batteries, which are being assessed for energy density and commercial potential: "We test cells from small research level up to pre-commercial prototypes of approximately 1Wh in size.

"Most of our work is done at the materials design level, not the pack development level. We take the same approach in understanding chemistries and technologies when we test research cells. Techno-economic modeling plays a critical role in understanding how our results extrapolate to pack-level cost and over performance."

The JCESR uses techno-economic models to design virtual batteries for all three energy storage concepts. This comprises multivalent intercalation, which involves the replacement of singly charged ions in a lithium-ion battery with new double- or triple-charged ions; chemical transformation, which involves the replacement of intercalation of the working ion at the anode and cathode with higher-energy chemical bonds; and the replacement of solid electrodes with energy-dense liquids.

Ingram says the JCESR is very interested in new technologies, and an entire section is dedicated to non-aqueous flow batteries: "Due to the specific nature of a flow battery versus a more conventional electrochemical cell, a new testing procedure and cell had to be developed."

Volker Blandow, global head of e-mobility at test, certification, inspection and training provider TÜV SÜD, says the organization tests every type of lithium-ion battery at the cell, module and pack level. For full battery packs, its maximum performance level is now 800kW of battery power for charging and discharging. ***[Continued on page 116]***

FROM THE PUBLISHER OF ELECTRIC & HYBRID VEHICLE TECHNOLOGY INTERNATIONAL MAGAZINE

the FUTURE of TRANSPORTATION World Conference

The Future of Transportation World Conference will be a multiple-session forum bringing transportation experts together to discuss the future of transportation at the macro, societal and technological levels

5-6 JULY 2017

COLOGNE, GERMANY

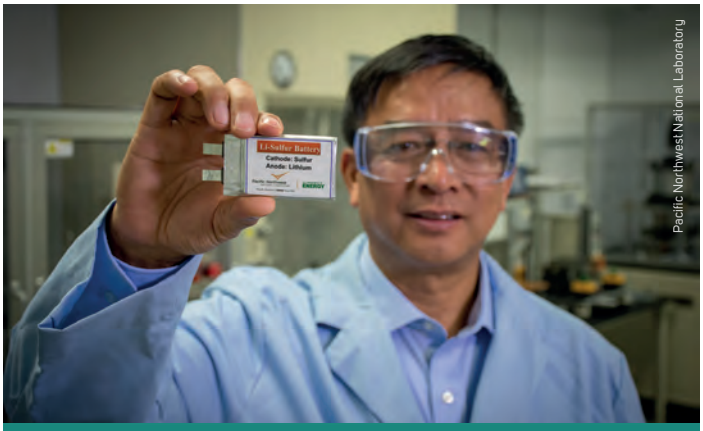
2030 AND BEYOND...

Sessions will include

Getting Transport Off the Ground: how PATS (personal airborne transportation systems) will shake up personal transport before 2030; **Autonomous Vehicles**: mobility for ageing populations and safer surface transportation – issues and processes for successful mass implementation; **The Future of Rail**: is there a role for this form of transport? Rail and mass-transit operators will present their visions of the future. Plus break-out sessions on Highways of the Future, Funding and the Challenge for Vehicle Manufacturers

VISIT THE WEBSITE FOR **MORE DETAILS** AND **TO REGISTER**

WWW.**THEFUTUREOFTRANSPORT**.COM



Pacific Northwest National Laboratory

TRIPLE FIVE

Electric vehicles with smaller, lighter and less expensive batteries could be on the horizon if a new US research effort achieves its goal of improving on the batteries that power today's EVs.

Led by Pacific Northwest National Laboratory (PNNL), in Richland, Washington, the Battery500 consortium will receive up to US$10m a year over five years from the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy. The multidisciplinary consortium includes leaders from DOE national laboratories, universities and industry, working together to make smaller, lighter and less expensive batteries that can be adopted by manufacturers.

"Our goal is to extract every available drop of energy from battery materials while also producing a high-performance battery that is reliable, safe and less expensive," says consortium director and PNNL materials scientist Jun Liu. "Through our multi-institutional partnership, which includes some of the world's most innovative energy-storage leaders, the Battery500 consortium will examine the best options in order to create the most powerful next-generation lithium batteries for use in electric cars."

Beyond PNNL, the consortium also includes Brookhaven National Laboratory; Idaho National Laboratory; SLAC National Accelerator Laboratory; Binghamton University (State University of New York); Stanford University; University of California, San Diego; University of Texas at Austin; University of Washington; and IBM, as an advisory board member to the group.

Battery500's goal is to develop lithium-metal batteries that have almost triple the specific energy found in the batteries that power today's EVs. The consortium aims to build a battery pack with a specific energy of 500Wh/kg, up from the 170-200Wh/kg in today's typical EV battery technology.

The team hopes to reach these goals by focusing on lithium-metal designs, which use lithium instead of graphite for the battery's negative electrode. Lithium will be paired with two different materials for the battery's positive electrode. While studying these materials, the Battery500 consortium will prevent unwanted side reactions in the whole battery that weaken performance.

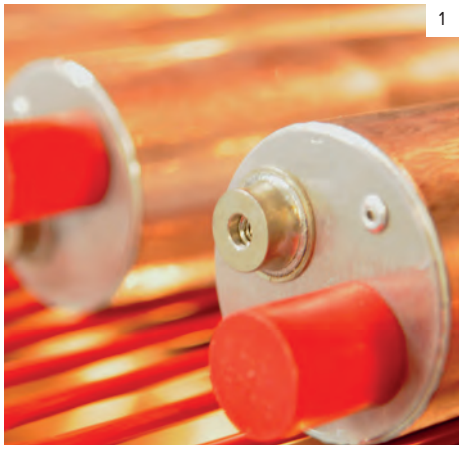
The team will set aside 20% of its overall budget for seedling projects, or work based on proposals from throughout the battery research community. Though the immediate goal is to make effective, affordable batteries for EVs, Liu expects the consortium's work to also advance stationary grid energy storage applications.

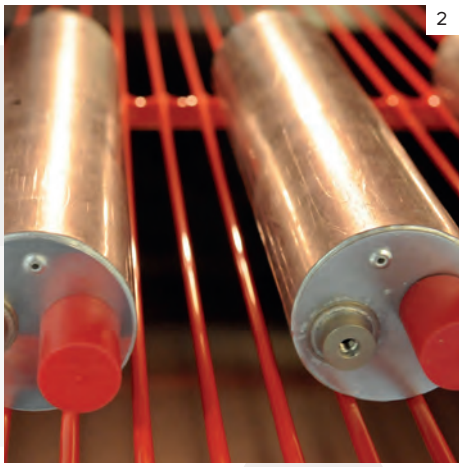
Battery500 is also expected to take advantage of DOE facilities, including the fabrication equipment at PNNL's Advanced Battery Facility and materials characterization instruments at EMSL, the Environmental Molecular Sciences Laboratory, a DOE Office of Science User Facility on PNNL's campus.

TÜV SÜD's abuse test bunkers are specially equipped to conduct a range of tests, including nail penetration, thermal stability and cycling without active cooling

"We contribute heavily to the R&D process, as clients can do strange and nasty tests with us, such as injection of electrolytes or cooling liquids into a battery"

Volker Blandow, global head of e-mobility, TÜV SÜD





1. Battery cells are prepped for testing at Argonne's electrochemical analysis and diagnostics laboratory

2. With custom-built equipment, simulations are performed to provide information on battery characteristics such as life cycle and calendar life

3. Cell-testing equipment used by the JCESR. This is where all the materials that have been designed and made into battery electrodes are put through specific cycling tests to see the performance of electrode assemblies under certain protocols

4. A Lawrence Berkeley National Laboratory scientist holds a coin cell sized battery that is used to evaluate high energy density electrode formulations at the lab's environmental energy technology division's battery testing facility. Photos: Argonne National Laboratory

SUPER STORAGE

Researchers at Swinburne University in Melbourne, Australia, have invented a new energy-storage technology that could soon replace the batteries used in BEVs and HEVs.

The new super battery, which is actually a supercapacitor, is reported to be able to store as much energy per kilogram as a lithium-ion battery, be charged in minutes or even seconds, and uses carbon instead of more expensive lithium. It can also be charged and discharged millions of times.

Previously, a major problem with supercapacitors has been their low energy density levels. However, this problem has seemingly been overcome by using sheets of a form of carbon known as graphene, which has a very large surface area available to store energy.

Large-scale production of the graphene that would be needed to produce these supercapacitors was once unachievable, but using a 3D printer, scientists say they are able to produce graphene at low cost.

According to Blandow, there are three key battery test areas: performance and lifecycle; environmental; and safety (abuse) testing. "All safety tests can lead to explosion, venting or fire, so they need to be performed in an appropriate environment to guarantee safety and environmental protection."

"In some tests we force fire and explosion to see the worst-case scenarios when all safety measures fail. Here we contribute heavily to the R&D process, as clients can do strange and nasty tests with us, such as injection of electrolytes or cooling liquids into a battery."

A wider part of abuse testing is the UN ECE R100 type approval testing, in which the battery must perform in difficult tests, including crash, crush, fuel fire, vibration, mechanical shock, thermal shock, overcharge and short circuit. All these tests are usually destructive, and are a mixture of mechanical impacts and electrical safety validation. If a battery passes this test regime it gets a type approval and may be used in an EV.

"The trend to higher-power, super-fast charging will, generally-speaking, lead to more sophisticated batteries," predicts Blandow. "But it can also result in higher risks in failure situations, so we will need even smarter management systems and smarter battery testing procedures."

Risk management

Addressing critical failure situations, such as thermal runaway, may also be achieved by exploring alternative chemistries and technologies. In terms of overall system safety, lithium-sulfur is considered to be one of the most promising chemistries for batteries in EVs and HEVs due to its ultra-high-energy density levels.

At more than five times the capacity of standard commercial lithium-ion batteries, this high lithium-sulfur density makes it possible for BEVs to travel longer distances on a single charge.

According to reports, Professor Andy Xueliang Sun and his University of Western Ontario research team, in collaboration with Dr Yongfeng Hu and Dr Qunfeng Xiao from the Canadian Light Source (CLS), Canada's national synchrotron light source facility, located in Saskatoon, Saskatchewan, have developed safe and durable high-temperature lithium-sulfur batteries by using a new coating technique called molecular layer deposition (MLD). The breakthrough is essentially an ultra-thin-film technique with applications in energy-storage systems, providing precise and flexible control over film thickness and chemical composition of the target material at the molecular scale.

According to their research, the MLD alucone-coated carbon-sulfur electrodes demonstrated very stable and improved performance at temperatures as high as 55°C, which, the teams says, will greatly prolong battery life for high-temperature lithium-sulfur batteries in EVs.

Test Equipment for cells, modules and packs

Highest accuracy

Fastest Rise Time

Climate Chamber Control

BMS Communication

Auxiliary IO’s

www.peccorp.com | +32 16 39 83 39 | Peter.Ulrix@peccorp.com

Leuven (BE) | Berlin (DE) | Boca Raton (USA) | Shanghai (PRC) | Tokyo (JP) | Seoul (KR) | Budapest (HU)

Synced up

The connected vehicle has now become a reality thanks to the e-powertrain movement

WORDS: **RICHARD N WILLIAMS**

In the early part of 2016, Nissan suspended the functions of its NissanConnect EV app to enable engineers to work on a fix for a technical flaw – a weakness that could have allowed hackers to run down the battery of a car and even see data about journeys that the vehicle had recently made.

The NissanConnect EV app is one of a number that are available for electric vehicles, but how important are they for the EV market, and more importantly, given Nissan's trouble, is being able to control aspects of your vehicle on your smartphone a good idea?

"For the EV market, I think that the app is a necessary requirement," says Henry Bzeih, head of infotainment in the USA for Kia. The OEM's app, My Uvo, is available for the Soul EV.

"The difficulty with EVs is that range is a real anxiety source. The app provides you with the ability to find out what's going on with the car battery at any time, and the ability to control it and work with the car. You can also locate charge points, so that you can plan journeys. There is no direct communication with the phone and the car itself. Both connect to the internet, [over] a secure, non-public connection, so it doesn't matter where you are, you can still connect with your car."

The Kia engineer says the big asset for EV owners is that the tech allows drivers to know their range and how much charge they need to ensure that they can complete their journey, something that can help alleviate the anxiety of EV ownership.

"Apps for EVs are expected, and I'd say a must-have. Not just to alleviate range anxiety, but EV drivers tend to be tech savvy and the app brings car and customer together," he adds.

Jeff Haase, product manager at OnStar RemoteLink, GM's app subsidiary, agrees: "It's something GM is investing heavily in. It's a very effective communication tool for drivers. You know in the palm of your hand how far that vehicle will take you, so it helps put the customer at ease.

"They can plan routes, find charge points, and reroute journeys to help customers better plan a trip. This is extremely important for customers, and even when range improves for EVs, there will still be a desire for this sort of information."

Safe and secure

Despite Nissan's problems, OEMs don't believe these apps offer any inherent security or safety risk for EV owners.

"Apps for EVs are expected, and I'd say a must-have. Not just to alleviate range anxiety, but [to bring] car and customer together"

Henry Bzeih, head of infotainment, Kia USA

"It is security by design. Everything along the way has security in mind, and we feel we have done everything possible to minimize risk," counters Bzeih.

"The more interfaces we have, the more important security becomes," adds Alf Pollex, head of infotainment and connected car at Volkswagen (VW), who says almost every car in the modern VW range is now offered with its Car-Net app, including the e-up EV.

"In general, it's extremely hard to realize a 100% secure system anywhere, but as a manufacturer, it is our goal to set the wall for intruders as high as possible," he admits.

GM's Haase is on the same page: "We do everything with safety first and foremost. There are capabilities we've discussed that might be nice for our customers, however because of safety we've decided not to do it at this time."

He says one suggestion for the app was to have the ability to close windows and sunroofs remotely – useful if there's a sudden downpour.

"We thought about it, but what would happen if there was a child or pet inside the car unbeknown to the driver? If a child was poking their head out of the sunroof it could be very dangerous, so we didn't pursue the idea."

Third-party development

OEMs aren't the only ones developing apps for electric vehicles. All sorts of third-party apps are available and one of the most popular in the USA is ChargePoint.

"We're the world's largest and most open electric vehicle charging app on the market," claims Simon Lonsdale, the vice president of business development at ChargePoint.

1. With GM's RemoteLink app, Chevy Volt owners can check the battery charge, electric range, electric miles and eMPG

2. Volkswagen's Car-Net e-remote includes a battery management function, designed to give the driver control over the charging process of their VW EV, including the ability to set the power input supply as required

1

"We try to be as fast as companies in the field of consumer electronics but, on the other hand, they generally do not have to fulfill automobile quality standards"

Alf Pollex, head of infotainment and connected car, Volkswagen

2

He says the app doesn't just offer the locations of all the nearest charge points, it also provides users with how much battery life they have left, reminders to set charging, a wait feature for when electricity prices are cheapest, and even how much charge is needed to complete a specific journey.

However, the app has no access to the car's hardware or propriety software. "We know how many miles you've done and what car it is," adds Lonsdale. "At the moment, we work on averages, but if we had interaction with the car we would be more accurate, but it is up to the OEMs to open it up to developers.

"We would love to dip into the car. I think there's a lot of innovation to be had, but the car makers are naturally cautious," he says.

Kia's Bzeih sheds a car maker's perspective on this: "We did start down this road, to other apps to operate with the car. But in many ways Apple CarPlay and Android Auto have done away with this."

Apple CarPlay and Android Auto are smartphone casting technologies, enabling vehicles to display the smartphone interface on its touchscreen and drivers to access the apps

THE 10 BEST EV APPS AROUND

1. **PLUGSHARE** (iOS, Android)
Allows users to find and review more than 39,000 charging stations in North America and 86,000 globally, as well as connect with other EV owners

2. **CHARGEPOINT** (iOS, Android)
More than 33,000 charging stations on its network and 250,000 users, ChargePoint also has numerous other features, including range calculation

3. **GREENCHARGE** (iOS only)
GreenCharge provides charging information and lets environmentally conscious HEV and EV drivers work out the financial and environmental impact of their trips

4. **WAZE** (iOS, Android)
Crowdsourced navigation app that uses Google Maps to provide accurate directions, the best routes and traffic data

5. **WITNESS DRIVING** (iOS, Android)
Turns your phone into a dashboard cam, allowing you to record your journey as well as time, speed, acceleration and location

6. **CHARGE YOUR CAR APP** (iOS, Android)
Similar to ChargePoint but specifically for UK EV drivers, it has a large network of pay-as-you-go recharging stations

7. **CHARGEMAP** (iOS only)
A community-driven map of charging points for electric vehicles that enables users to add and edit details of the points

8. **LEAFSPY** (iOS, Android)
An app that uses Bluetooth to connect to an OBDII scanner so that you can read the Nissan Leaf's CANbus information on your phone

9. **WHITE CAR** (TBA)
Planned for release soon, White Car is a UK app that will enable people to hire a Tesla EV and collect it from a White Car hub

10. **PLUGSURFING** (iOS, Android)
Perhaps the most extensive charging point location app in Europe, PlugSurfing also lets you find and pay for charging at all major European networks

1

"We would love to dip into the car. I think there is a lot of innovation to be had, but the car makers are naturally cautious"

Simon Lonsdale, vice president of business development , ChargePoint

in the car. However, it's not a technology available in all EVs.

"While we're not compatible with Apple CarPlay and Android Auto, they are very important technologies that we are keeping abreast of," admits Haase.

Another problem that EV manufacturers have is keeping these technologies relevant, especially as cars take years to develop.

"Yes, the pace is challenging," admits VW's Pollex. "We try to be as fast as companies in the field of consumer electronics but, on the other hand, they generally do not have to fulfill automobile quality standards such as rigorous robustness tests. This takes a little more time. But we're getting faster."

Bzeih adds, "We're seeing all sorts of technology arrive now – auto-park and autonomous systems, even self-driving cars. Apps provide a connection between car and driver, so ultimately we may see all sorts of technologies accessible by the phone."

Pollex agrees: "Finding charging stations or remote heating is just the beginning. The point is, the big three future technologies for the automobile industry fit perfectly together: autonomous driving, connectivity and electromobility. Separately they are very important, but combined, they are a real game changer."

2

1. In February 2016 Nissan disabled its NissanConnect EV smartphone app after reports that the HVAC systems of Leaf EVs could be hacked. The problem was fixed and the app is once again available to use

2. ChargePoint's mobile app enables EV owners to find available charging stations, activate their charging session, check their charging status and view their charging history

HUBER+SUHNER
Excellence in Connectivity Solutions

High Power Charging.

HUBER+SUHNER cooled cable and connector puts super-fast charging within reach. This development allows to multiply the power-throughput of a charging cable and keep charging times below 20 minutes (80% State of Charge) even with big battery packs of new electric vehicles and trucks. The cooled cable is available with Combined Charging System (CCS) type-1 and type-2 connectors.

› hubersuhner.com/cooled-cable

eCarTec
AWARD
WINNER

HUBER+SUHNER, Inc. 8530 Steele Creek Place Drive, Suite H, Charlotte NC 28273/USA
HUBER+SUHNER AG 8330 Pfäffikon/Switzerland, hubersuhner.com

Let's get physical

Development programs for electric and hybrid vehicles are costly things, so here is a top-tip guide to saving on budget, time and engineering complexity

WORDS: **JOHN EVANS**

Strength in numbers

Pooling resources is a sure-fire way to cut development time and boost innovation. For example, a consortium led by Controlled Power Technologies, a developer of vehicle driveline electrification based on switched-reluctance machines, and including Ricardo, Tata Motors European Technical Centre and Provector, an expert in battery management systems, is to apply its low-voltage electric motor technology to the rear driveline of a B-segment city car. The consortium claims it will help to accelerate the introduction of advanced 48V mild hybrid functionality to mainstream vehicles. The so-called FEVER project will run for two years and aims to culminate in the development of two 48V electrified rear-axle demonstration vehicles.

PARTNER WITH ACADEMIA

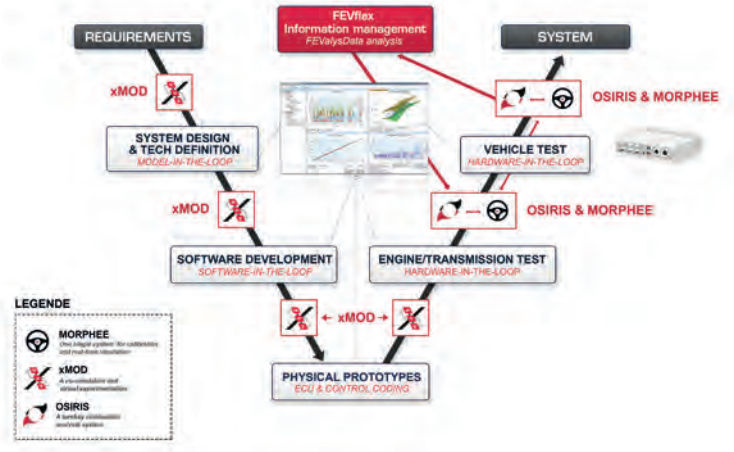
Richard Fox, business engagement partner at the College of Engineering & Physical Sciences, University of Birmingham, says academia has much to offer development engineers in the EV sector. For example, the university has just taken delivery of a Hyundai ix35 hydrogen fuel cell vehicle to support the work of its Centre for Fuel Cell and Hydrogen Research. The center focuses on R&D, applications and demonstrations of hydrogen and fuel cell systems, and has numerous patents in fuel cell tech. Work there also focuses on the implementation of a hydrogen and fuel cell supply chain, working with around 60 SMEs to develop components and subsystems.

REDUCE TEST ENGINEER SUPERVISION

Cell 28 is Intertek UK's newest test facility. It is specified for high-voltage/high-power EV traction motor development testing. The large test cell contains a custom-designed, high-speed electric motor dynamometer rig, plus associated motor and inverter cooling, as well as datalogging systems. The dyno rig can test motors up to 18,000rpm maximum speed, and up to 300kW maximum power. It can also measure maximum performance of a machine, as well as run fully automated drive cycles to measure energy consumption and temperatures over the cycle. According to David Meek, chief engineer at Intertek, once the test motor and instrumentation are set up, the rig can run tests with minimal supervision, thus saving considerable engineer time.

Cut standard development process time by half

Together, xMOD, an advanced simulation integration platform, and MORPHEE, unique automation, calibration and real-time simulation software, hugely slash development process time, says Stéphane Pelletier, project manager at D2T. Using model-based design, xMOD structures and organizes the development process, accelerates simulation up to 100-fold, and enables engineers to go from the development phase to real testing using the same model. MORPHEE, on the other hand, centralizes all measurements from the ECU and vehicle sensors, and has a direct interface with xMOD. By using plant models, xMOD can validate a hybrid architecture and enable engineers to pre-calibrate the EMS strategy off-line. It is then possible to simulate the hybrid part of a vehicle (in xMOD) linked to a real engine (in MORPHEE).



Avoid expensive component relocation

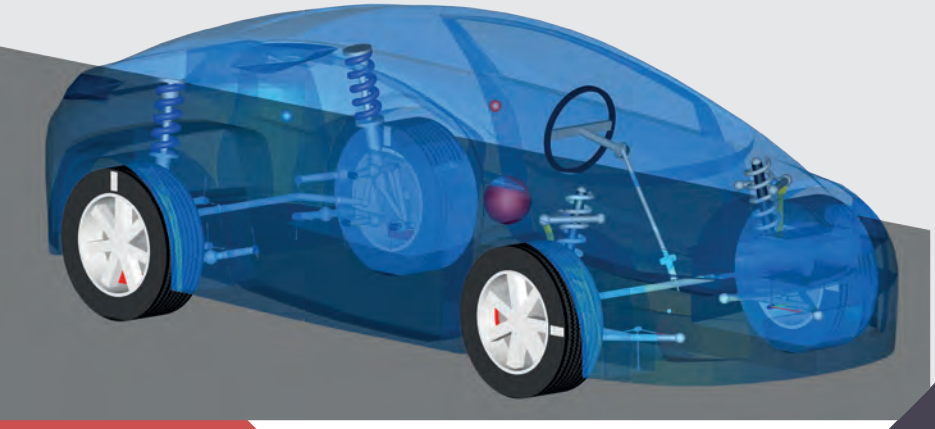
A founder member of the Research Council for Automobile Repairs (RCAR), and member of Euro NCAP, Thatcham Research can help EV development engineers in the areas of component positioning and safety, says Andrew Miller, CTO of the organization. Locating components to comply with stricter safety standards, and designing them with vehicle insurance and repair costs in mind are areas that the company can advise on. For example, locating an expensive component such as a condenser in the front bumper area exposes it to the risk of accident damage, and a consequent increase in the vehicle's insurance rating. Battery safety is of particular concern to Euro NCAP's test engineers, and here, Thatcham can also offer its expertise and guidance.

GOVERNMENT AFFAIR

Governments have a role to play in assisting domestic EV development by providing funding support and facilitating partnerships. For example, over the course of the current financial year, Innovate UK, a government development agency in the UK, will invest £561m (US$682.5m) helping businesses to innovate. A key activity will be to support early-stage manufacturing and materials concepts. It's currently helping fund the model-based real-time systems engineering (MORSE) project, led by Ford and supported by AVL Powertrain UK and Claytex, which aims to validate the responses of simulated control systems testing and verification. Ford hopes to save three months from its development and validation processes as a result of this R&D project.

Time saver

Dymola is a multi-domain, physical modeling and simulation tool used to simulate the complete EV system, says Mike Dempsey, managing director of Claytex. It can be coupled to rFpro to provide a complete virtual test environment and enables engineers to test all the vehicle systems before prototypes are available in a realistic virtual environment. An example of its usefulness is in the development of advanced driver assistance systems (ADAS), which require all the vehicle control systems to be tightly integrated. The development and validation of ADAS can be done in the virtual environment using Dymola and rFpro. Dymola provides the complete vehicle system model and rFpro the virtual environment, simulating the vehicle sensors as well as the driver.

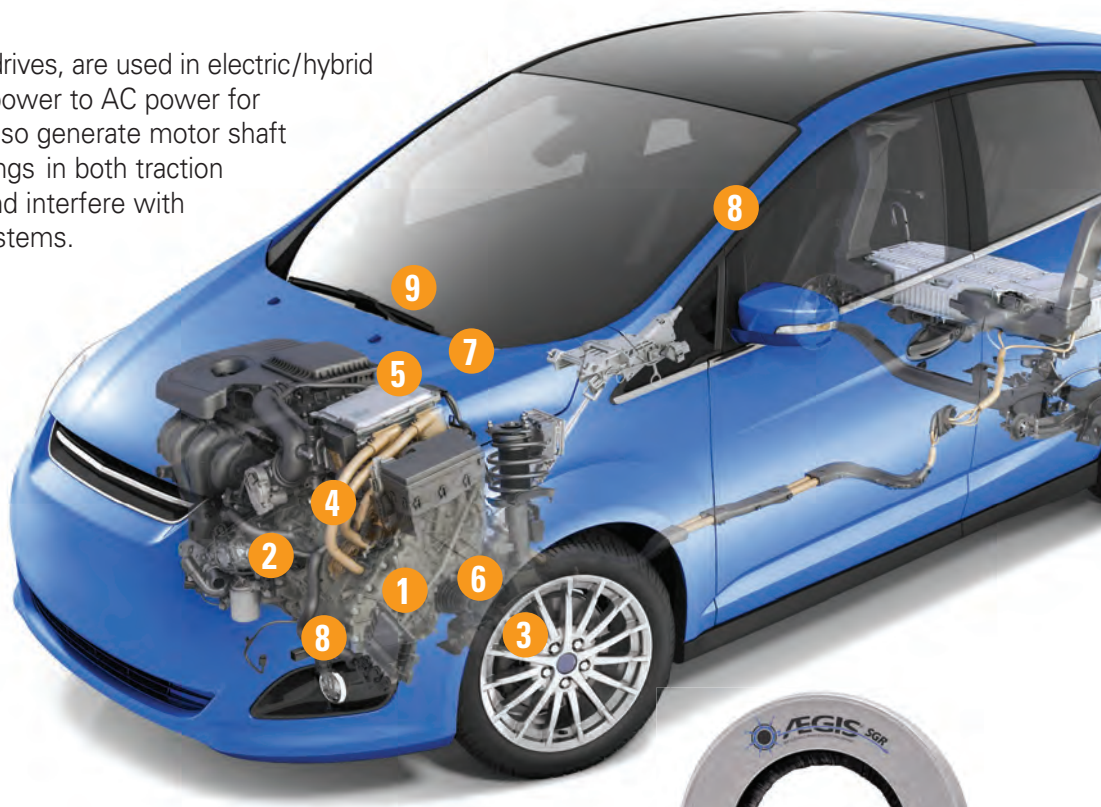


Making the right noise

The CAE Auditioner is a special functionality within B&K's NVH simulation software that converts CAE data into models to be run in the simulator software, explains David Bogema, simulator engineer at the company. It enables engineers to create a model of the NVH of a future EV using a mixture of real-life test data and purely CAE simulation data. The process works like this: a manufacturer of an IC engine vehicle may need to make a hybrid version. As a result, engineers and non-experts alike can drive NVH simulator models of competitor hybrids, listen to and feel the NVH of the vehicle (as opposed to just looking at numbers), evaluate this experience and vote on a target sound. Any modifications to the modeled sound are translated for the CAE design team to achieve, and they can then evaluate, or audition, each new component design iteration. This early approval of NVH targets from management means EV engineers can be confident their designs are on-track and problem-free.

Protect Electric Vehicles from Bearing Damage and EMI/RFI

Inverters, or variable frequency drives, are used in electric/hybrid vehicles to convert DC battery power to AC power for traction motors. But, inverters also generate motor shaft voltages that can damage bearings in both traction motors and coupled systems and interfere with electronic or communication systems.



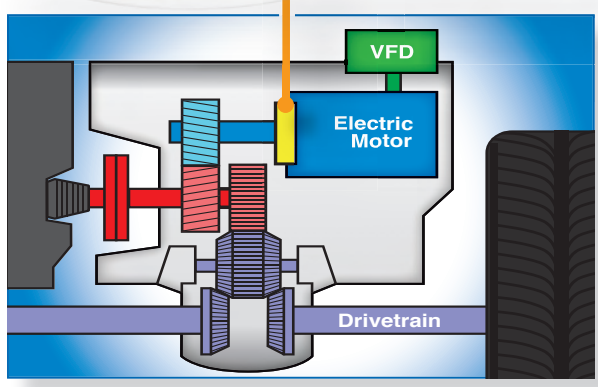
Bearing Damage:

1) ***Traction motors***
2) ***Transmission bearings/gears***
3) ***Wheel bearings***
4) ***Gasoline engine bearings***

EMI/RFI:

5) ***Onboard computer controls***
6) ***Wireless vehicle sensors***
7) ***AM/FM radio***
8) ***Bluetooth® communications***
9) ***Personal electronic devices***

AEGIS®
BEARING PROTECTION RINGS



AEGIS® Rings channel harmful inverter-induced voltages away from bearings safely to ground:

- Mitigating damaging shaft voltages
- Protecting motor bearings and other drive system components
- Reducing/eliminating EMI/RFI

Download "Protecting Electric Vehicles from Bearing Damage and EMI/RFI" white paper at: www.est-aegis.com/evpaper.

1-866-738-1857 | sales@est-aegis.com

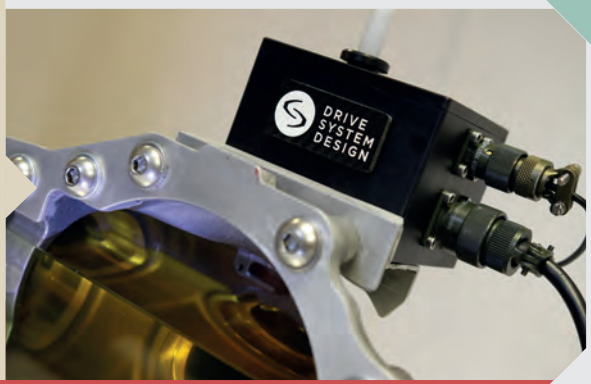
Electro Static Technology™
An ITW Company

CONTROL MEANS POWER

Delphi's work in integration and tech optimization has been applied to the development of 48V systems control, resulting in a powerful control system. However, it is vital that the software and control architecture are structured to help engineers achieve the best calibration, quickly. In a hybrid application, Delphi's ECU, which provides greater resolution and fast system response, enables engineers to effectively increase the proportion of regenerative braking without compromising refinement. Meanwhile, its modular structure can increase the speed of development and validation. Testing demonstrates that when applied to Delphi's new 48V mild hybrid system, engineers can quickly develop a calibration that captures 85% of the braking energy available on the WLTP cycle, while achieving a premium driving experience.

Set me free

Drive System Design (DSD), developer of the MSYS EV transmission, has launched an automated mobile oil expulsion detection system that claims to reduce development time and cost. Called VENTS, the system monitors oil expulsion through the breather system of a driveline unit during testing. Traditionally, this would require continuous engineer observation over a period of up to eight weeks. However, VENTS cuts this timeframe to three weeks and requires little involvement from engineers, so freeing them for other development tasks. "Nobody wants their engineers just observing a test, even if it is necessary," says Rob Oliver, chief engineer at DSD.



PASSING THE TEST

With more than 2,000 engineers, subsidiaries in 24 countries, and one of Europe's most comprehensive independent proving grounds, Applus IDIADA, headquartered in Spain, is able to provide design, engineering, testing and homologation services to all corners of the automotive sector, says Laia Sala, product manager. The company has many years' experience with electric and hybrid vehicles, as well as with the development process from vehicle benchmark and validation projects, up to production-ready development projects. It has a specialist team for EV charging and a charging infrastructure interoperability testlab supporting EV manufacturers. In addition, it develops its own test equipment.

TEMPERATURE CHECK

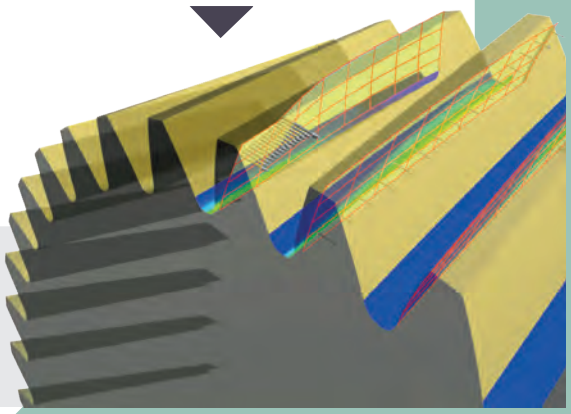
Obtaining high-quality test data of EV battery temperature distribution under all operating conditions is essential, says Luna engineer Geoff McCarty. As a result, the company has developed an advanced strain and temperature measurement system that uses unaltered fiber-optic cable as a distributed sensor. When illuminated with laser light and installed in a battery, a single fiber forms a sensor that replicates a virtually continuous line of discrete temperature sensors. The same technology can be used to measure the temperature of a vehicle's inverter, as well as strain within structural components. Luna's distributed fiber-optic sensing system enables engineers to get the answers they need to some of EV's most challenging development questions, faster.

Chemistry lesson

Dr David Ainsworth, CTO of Oxis Energy, says the company is working with development engineers across all sectors, including EV, to help tailor the supplier's innovative battery technology to specific applications. Li-S offers several key benefits including higher storage per unit weight and lower materials costs over competing chemistries. The company takes its core technology and works with its customers' development engineers to design, test and validate batteries. Every EV customer's requirements (size, weight, capacity) are different and Oxis Energy is rapidly acquiring broad experience in this critical sector, adds Ainsworth. Ongoing work includes the Innovate UK-funded Revolutionary Electric Vehicle Battery (REVB) project, as well as work with OEMs including VW and Daimler.

Design right, first time

MASTA 7.0, the latest version of the complete transmission system analysis tool, allows EV design and development engineers to model a full transmission from start to finish, within the same software package. According to Gareth Cooper, senior transmission engineer at SMT, this benefits the engineer by saving time that would normally be required to perform analysis of different types of components, and the full system, in separate packages. A typical application is the design of an EV transmission for minimum noise. A design engineer can use MASTA to design gear geometry for low noise, while an NVH engineer can use the same model to assess the system's natural frequencies and excitation by the gears. MASTA saves time and ensures a design is correct, first time.



READY-MADE DEVELOPMENT PLATFORM

A fast market penetration for EVs demands not only that the cars are efficient, but also that they are at least as reliable, good to drive and attractive as vehicles with conventional IC powertrains, says Dr Peter Prenninger, corporate research coordination engineer at AVL. OEMs must develop the next generation of EVs to precisely meet these customer expectations, he adds. AVL has therefore extended its Integrated and Open Development Platform to suit all types of HEV and EV applications. This development platform offers a seamless tool chain from full, virtual analysis based on pure simulation via mixed virtual-real development tools (X-in-the-loop) to EV test environments for testing under real driving conditions, including future Vehicle-to-X connectivity functions.

KEEP THE SAME WORKSPACE ENVIRONMENT, FROM DESIGN TO PHYSICAL TESTING

Hybrid powertrains are complex systems, mixing various technologies.
They require a unique collaborative workspace environment. Combine the co-simulation and integration platform xMOD and the Automation and on-line calibration System MORPHEE to boost your development process.

FEV

Buck fast

After two years of frustration, the Venturi-sponsored, Ohio State University-built VBB-3 set a new electric vehicle land speed record at Bonneville

WORDS: **GRAHAM HEEPS**

The world's fastest EV is now the Venturi Buckeye Bullet 3 (VBB-3). Roger Schroer, a performance driving instructor from the Transportation Research Center in Ohio, piloted the EV streamliner to a two-way average world record (pending FIA certification) of 341.4mph (549.4km/h) on September 19, 2016.

The Buckeye Bullet crew, based at Ohio State University's Center for Automotive Research, is no stranger to breaking records. The student team's previous vehicle, VBB-2.5 (a BEV version of the fuel cell powered VBB-2), set the previous mark of 307.6mph (495km/h) in 2010. VBB-3 was unveiled in 2014 with the goal of taking the record above 400mph (644km/h), but since then, unfavorable conditions on the salt flats of Bonneville, Utah, had prevented a record attempt.

Venturi 2016 Shivraj Gohil/Spacesuit Media

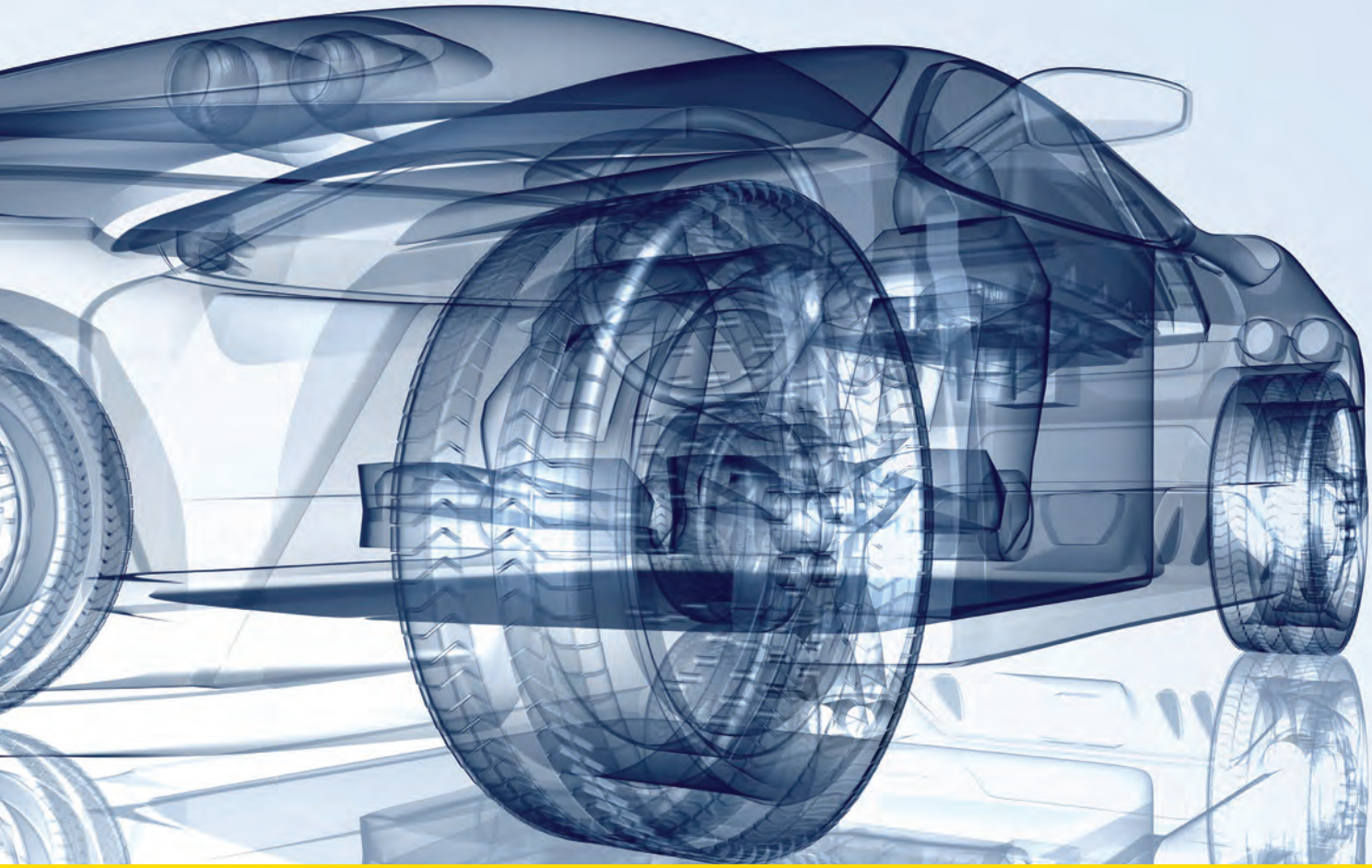
evs30

The 30th International Electric Vehicle Symposium & Exhibition

October 9–11, 2017

Messe Stuttgart, Germany

www.evs30.org



Industrialization and market – the sustainable path to electromobility

Hosted by

AVERE The European Association for Electromobility

mea

In Collaboration with

EDTA Electric Drive Transportation Association

EVAA

Organized by

Messe Stuttgart

PETER SAUBER AGENTUR Messen und Kongresse GmbH

e-mobil BW State Agency for Electric Mobility and Fuel Cell Technology Baden-Wuerttemberg GmbH

bsm Bundesverband Solare Mobilität

Stuttgart Region Economic Development Corporation

bw-i Baden-Württemberg International

Roger Schroer, a performance driving instructor from Ohio's Transportation Research Center piloted the VBB-3 prototype race car when it established a new electric world land speed record

Back at the workshop in Columbus, the team used the intervening time to make several modifications to the 4WD VBB-3. Key to improving acceleration within the 11-mile (17.7-km) course was being able to shift using the Hewland-made 2-speed gearbox. In 2015, runs were made either in first gear, compromising top-end speed, or second, which limited low-end acceleration.

Automating and synchronizing the shift and re-engagement of VBB-3's two drivelines – one driving the front axle, one the rear – proved to be quite challenging, as any errors or inconsistency threatened to disturb the stability of the vehicle during its 270mph (435km/h) shift. "Even in the days leading up to our departure, we still weren't confident in the shift," says student team leader Michael Johanni, who joined the Buckeye Bullet team eight years ago when still at high school. "We could actuate it, but we were having a hard time verifying the engagement of second gear and the re-engagement of the clutch. There was a lot of electrical noise on the signals from our data acquisition system and we were having difficulty filtering it out."

Bonneville testing

Following two full days of testing the shift at Bonneville, the team built up confidence in its function. They gradually fed more power into the drivetrain, initially using only one of the two front-axle electric motors, then one at the rear, both at the front, and so on, until all four motors were engaged during gearshift.

"Once we were able to get the full vehicle shifting, we were able to trim down the shift time a little more, and add more power," he says. "There's still more tuning we can do back at the shop over the coming months to get Roger back on the power earlier."

VBB-3's basic setup of two custom-built, synchronous permanent-magnet Venturi electric motors per axle, coupled to a common shaft, was unchanged from previous years, however upgrades were implemented for serviceability and cooling. The motors are liquid cooled by automatic transmission fluid (ATF); this year, for the first time, an additional chilling system was plugged in during the turnaround pitstop between passes through the measured mile, to reduce motor temperatures. That system consists of a copper coil that cycles the ATF through a chilled ice bath during the 45-minute pitstop. "Until this year we hadn't been able to push the motors hard enough for it to become an issue," says Johanni. The aluminum front cooling tank was also redesigned after vibrations from the bumpy salt surface caused it to split in 2015.

Major upgrades were made to the motor controllers and inverters for 2016, enabling VBB-3 to get power from the batteries to the

VBB-3 is the third land speed car to come from Ohio State University's Center for Automotive Research in Columbus. The car took the student team 18 months to build

Venturi 2016 Shivraj Gohil/Spacesuit Media

1. Two custom-built, synchronous permanent-magnet Venturi electric motors provide a total of 3,040ps to the front and rear axle and a Hewland-made two-speed gearbox

2. A carbon-fiber body wraps around VBB-3's 3,495kg steel structure, which also includes eight large blades of lithium-ion batteries weighing 1,589kg

"Once we were able to get the full vehicle shifting, we were able to trim down the shift time a little more, and add more power"

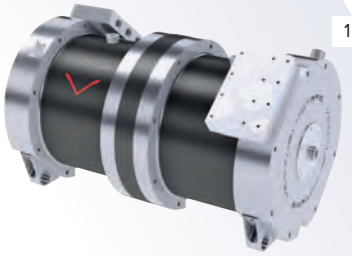
Michael Johanni, student team leader, Buckeye Bullet team

Venturi 2016 Shivraj Gohil/Spacesuit Media

wheels more efficiently than before. Previous issues with the inverters overheating led to a switch in supplier, with the team opting for Rinehart Motion Systems and its PM250 inverters. "We've been incredibly impressed with their device," says Johanni. He adds that despite the absence of active chilling – the team simply packs the tanks with ice and glycol before each run – very little heat was generated by the inverters. "The rise in temperature was roughly one-third of the value permitted before the device begins to degrade or shut off. They gave us a significant mass reduction, too." A new water pump, to account for the higher pressure drop in the revised cooling system for the inverters, completed the package.

The battery pack, made up of 2,000 A123 cells arranged into modules of 25 and then into eight large blades (four each at front and rear), was largely unchanged. Johanni and the team switched from cylindrical to pouch cells when it designed VBB-3, but their chemistry is said to be similar to those in the VBB-2.5 design. Johanni notes that A123 made the bus bars that connect the individual cells together within the modules twice as thick as they would normally be, so that the team could draw more current through the pack without it overheating.

Simulations have indicated that VBB-3 could run a 16- to 18-mile (26-29km) course on the available battery power. For now, this overcapacity for the shorter Bonneville course has two important consequences. One is that no active cooling of the pack is required; the second is that the recharging time between record runs, using a 200kW custom DC fast charger powered by a diesel genset, is cut to around 20 minutes.

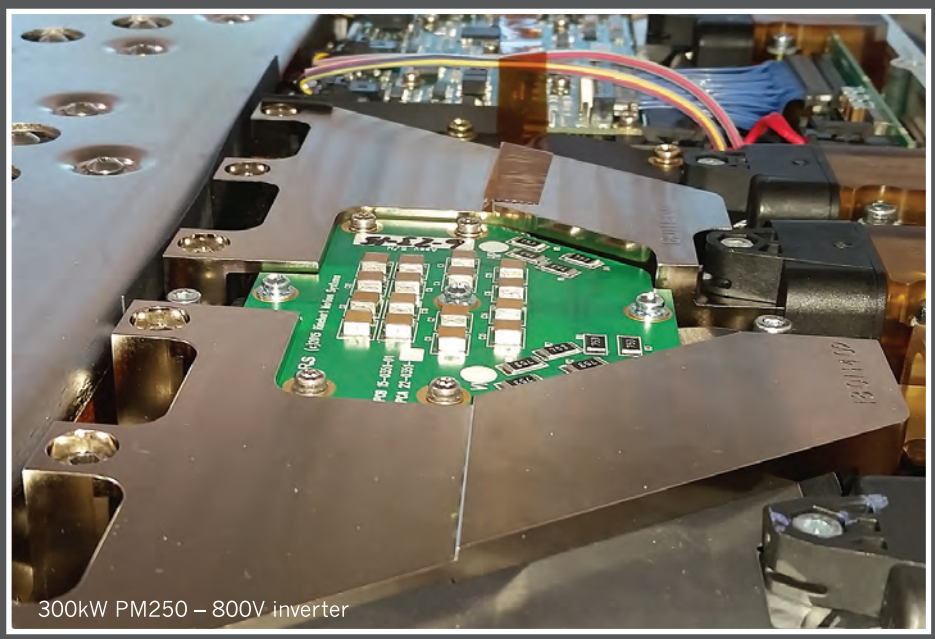


1

2

A longer course will likely be required if the team is to fulfill its ambition of breaking 400mph (644km/h). The Speed Week held on Lake Gairdner in South Australia is one option, but shipping the team there would present logistical challenges and incur expenditure well above the substantial cost of running VBB-3 at Bonneville.

A new, lower-ratio gearset is also being considered as a means of accelerating VBB-3 more quickly while sacrificing top-speed potential. The current second gear is good for 452mph (727km/h) at a tire diameter of 25in. That represents a growth at speed from the nominal 24.5in tire size and the team expects them to be closer to the 26-27in diameter range by the time VBB-3 is beyond 400mph (644km/h), which would give a theoretical top speed as high as 488mph (785km/h).


300kW PM250 – 800V inverter


PM100, PM150, PM250 100kW – 300kWpk
Lightweight High Power Density Inverters

Motivating the **HIGHEST PERFORMANCE** ROAD CARS in the World

Let us help you bring to life whatever you can imagine

- Standard or fully bespoke
- 50kW – 500kW and beyond
- Low volume or high volume
- Built in the US or China

And some of the most FUEL-EFFICIENT heavy duty trucks in the world...

PROPELLING INNOVATION in ELECTRIC PROPULSION

www.rinehartmotion.com

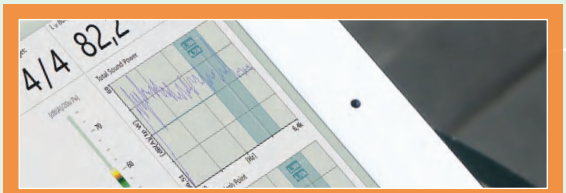
RMS™

Rinehart Motion Systems LLC
7929 SW Burns Way, Suite F,
Wilsonville, OR 97070 USA

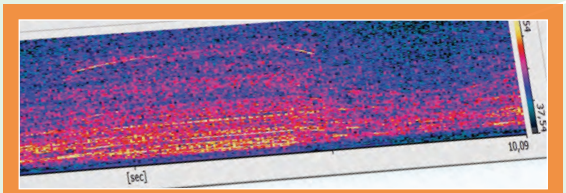
NEW PULSE REFLEX™ **ACOUSTIC CAMERA**

SEEING
IS BELIEVING

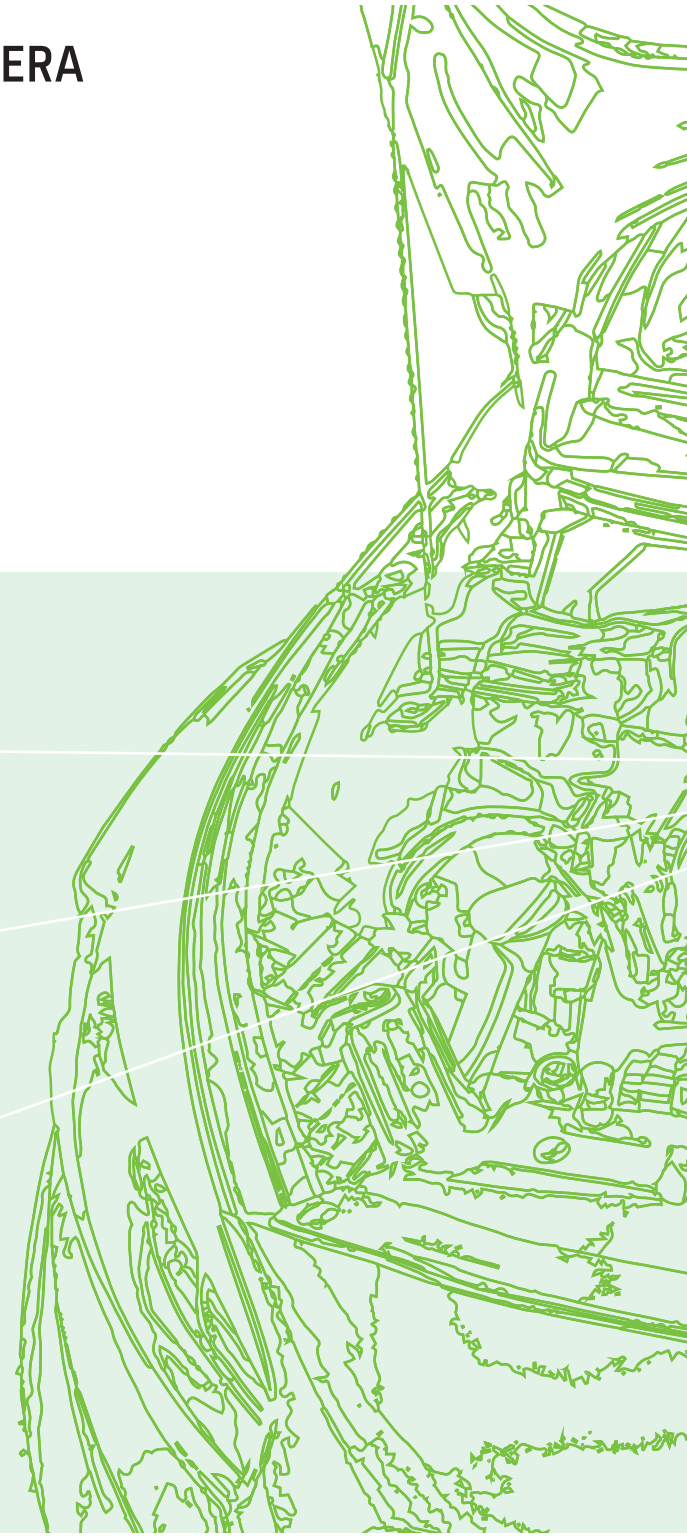
Take a snapshot or shoot a video for instant sharing



Noise spectra with clear indication of overall sound power values



Spectrogram for clear visualization of structure in the noise



You might not believe how fast the latest addition to the PULSE Reflex™ family is to set up. The acoustic camera, offering all the well-known reliability and quality of Brüel & Kjær, is an easy-to-use, portable system for visualizing sound and detecting buzz, squeak and rattle in vehicles – and it takes less than four minutes to be up and running.

The compact size makes the camera highly suitable for confined spaces, allowing you to clearly view sound sources in vehicles. You can take both stationary and non-stationary measurements and troubleshoot problem areas, instantly sharing snapshots and analyzing recordings.

www.bksv.com/acousticcamera

Brüel & Kjær

BEYOND MEASURE

BN 1848 – 11

As the drive to improve the environmental friendliness, safety and comfort of new vehicles continues, test and measurement instruments are playing an increasingly fundamental role

Made to measure

WORDS: **KARL VADASZFFY**

With experience in developing measurement systems that dates back over a century, Japanese company Yokogawa is focusing its automotive arm on the measurement challenges associated with energy conservation, efficiency and sustainability – in the belief that, sometime between 2030 and 2050, the use of pure internal combustion engines will dwindle or disappear, and electric and hybrid vehicles will take over.

Of the company's vast portfolio of products that help users to save and accurately measure energy, 2-, 4-, and 8-channel oscilloscopes play a central role in capturing, analyzing and troubleshooting data in both electrical and real-world physical signals. In recent months, new bus support has been added to Yokogawa's oscilloscopes, most recently to facilitate PSI5 – a product mainly used in airbag testing.

Adaptable technology

The company also offers the ScopeCorder product family – high-performance and flexible multi-channel test instruments that combine the benefits of a mixed-signal oscilloscope and a traditional data acquisition recorder. These offer more memory than an oscilloscope, the ability to have isolated inputs, and 16-bit high resolution. "They can be adapted according to the application and they can be changed, which means if users have a system that is complex, with a large variation of input types, the unit can accept these directly," says Clive Davis, Yokogawa's European product manager. "In an automotive and transportation environment, where there are lots of physical and electrical inputs, there are buses in the vehicle. One of the challenges is to diagnose the interaction between the physical sensors, the ECUs, and anything else that is going on in the vehicle, so for those sorts of application we also offer serial bus monitoring such as CAN, LIN, and SENT, and then users can categorize the whole system irrespective of what the actual inputs are that are coming in."

A ScopeCorder can be used to decode CAN, LIN-Bus, or SENT signals and display information on physical data, such as engine temperature and vehicle speed, as analog waveforms. This can then be compared with data coming from real sensors.

While external packages can be supported, much analysis can be completed within the product itself, as well as outputting data in real time, so "if a user has data-sensitive applications, we can maintain redundancy on that data by simultaneously capturing both internally and externally", adds Davis. With up to 2GB of acquisition memory in the instrument, the data can be searched and viewed with ease.

Yokogawa's ScopeCorder DL850E and ScopeCorder DL850EV are aimed at whole-system diagnostics and characterization, as Davis explains: "We have to continuously develop new features, new plug-in modules that enable the platform to address emerging application areas or satisfy our users who are currently utilizing the product but need to use it for different applications."

Practising precision

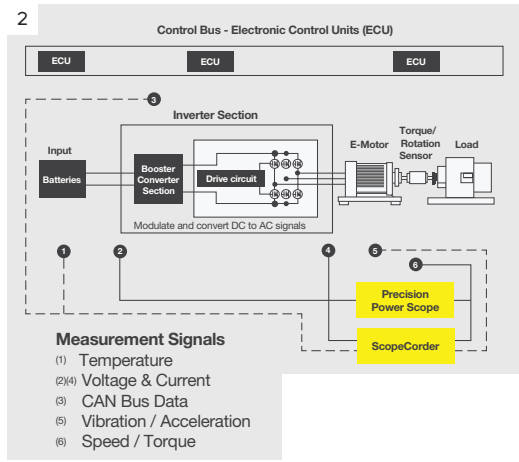
Yokogawa is also a market leader in precision power measurement. In the past few months, the successor to the company's WT1800 series has been introduced. "The WT1800E is our precision workhorse instrument," says Davis, "in that we have added new features including a more flexible data update interval setting with an automatic mode, for fluctuating input signal frequencies such as during motor startups. We have also reduced the influence of power factor on accuracy, increased the ability to handle large crest factors of up to 280 with specified accuracy, improved basic specified accuracy to 0.05% of reading and 0.05% of range, and enabled new interfacing to be performed." The instrument is available with up to six input channels at 2MS/s.

"What we find with our instrumentation," Davis continues, "is there's high usage in test benches. We see more and more automation of the testing process, so in those sorts of environments we install many power meters and data acquisition tools. We support a wide range of interfacing and language requirements, and offer native support for external analysis tools such as MATLAB, and we are now introducing Modbus/TCP and Ethercat support on our products as well."

One of the most important requirements for Yokogawa's customers, Davis states, is validation. This is in part due to their need to satisfy the requirements of the EU's climate and energy framework, and other regions' alternatives. "To fulfill this, you have to be able to measure very accurate energy usage and energy saving," he explains, "so we regard the ability to make the most accurate measurements in this area, for all products, to be of vital importance."

> "We have to continuously develop new features, new plug-in modules that enable the platform to address emerging application areas"
>
> Clive Davis, European product manager, Yokogawa

2



1: Test and measurement instruments are increasingly important to EV development

2: Test setup for powertrain drive system with a number of additional parameters and measurement points

3: Yokogawa's mixed-signal oscilloscopes now support PSI5

3

Measuring up

To this end, Yokogawa has developed its own ISO 17025-accredited laboratory at its European HQ in Amersfoort, Netherlands, where engineers can calibrate power up to 100kHz. "This is important because as we are looking at different ways to transmit energy – in the automotive industry, for example, as part of which there is discussion about potentially large uses of wireless charging – accurate measurements at higher frequencies are required," Davis explains. "So with our range of products that are able to cover this, and also offer the highest accuracy and validated measurements for this, it is an area where we will continue to invest in R&D. We can calibrate at 100kHz today, but as industry requirements change, and as the frequency requirements and transmission frequencies of power applications change, the level we can calibrate will, by necessity, have to increase."

When asked about the industry's current trends and how they might influence other future developments, Davis sees interest in increasing the level of power for electric vehicles. As this grows, he explains, energy demands will increase, as will the need to conserve energy. "Therefore, a product that is able to follow that energy and power usage, regardless of the frequency the device is using, will be important."

Rapid change

The performance and capabilities of power control systems designed for electric and hybrid vehicles are rapidly developing. Now is the time for the industry to turn the alternative into the trend

WORDS: **KARL VADASZFFY**

Specializing in battery management systems and vehicle control units for EVs and HEVs, Stafl Systems has plenty to celebrate. The American company provided the powertrain control system – through its BMS1000 series and VCU1200 – for Genovation Cars' GXE, a converted C6 Corvette. The vehicle set the world record for the fastest street-legal electric car, reaching 330.9km/h (205.6mph) in July 2016 at Florida's Kennedy Space Center. This broke the previous world record of 300.6km/h (186.8mph), also set by the Genovation GXE.

Released in 2016, Stafl Systems' BMS1000 series is easier to deploy and is more accurate than many alternatives. "A number of battery management systems have relatively complex calibration and configuration procedures, and typically only generate reasonably accurate SOC and SOH estimates," says Erik Stafl, the company's president. "Our system includes a dedicated calibration service, where a customer, typically a battery pack manufacturer, sends us cells for characterization and we put those through a procedure in our fully automated, San Francisco-based, battery test laboratory. There, we test cells against our proprietary sequence, which includes a range of charge/discharge rates and temperatures, so we don't have to rely on limited or overly optimistic manufacturer data." Indeed, this application of independently generated data enables the BMS to offer SOC calculations that are accurate to within 1%.

Accuracy is key

The BMS1000 series is currently used in a dozen vehicle programs, offering sub-millivolt cell voltage resolution thanks to a Linear Technology chipset. It can provide typical accuracy error of less than 1.5 millivolts and performs passive cell balancing via switchable 22Ω resistors. In addition, thermal safeties are built in to protect it from overheating.

"Accuracy is becoming more important, and in five years' time it'll be the absolute requirement," says Stafl. "At the moment, you can still find up to ±10% error on SOC algorithms in certain applications, but the tolerance for this won't last much longer.

"In addition, customers want a greater understanding in terms of how much energy remains in a battery pack as it ages," Stafl continues. "A higher level of accuracy of SOH – a measure of the degradation of a battery over time in terms of capacity loss – will continue to be a greater necessity."

problem with many industry VCUs is that they were initially designed for combustion vehicles. Our units are designed specifically for hybrid and electric drives, with completely agnostic inputs and outputs, which means they can be used to drive any number of relays or indicators, and can sense analog and digital signals from virtually any system."

The VCU1200 is a 60-pin unit and has two CAN ports, and is suitable as the main system controller on the vehicle. The smaller VCU1220 is a 48-pin unit, and also has two CAN ports, plus an RS485 port for communication with legacy devices. Its smaller size and different set of input-outputs make it appropriate for smaller spaces or as a body control unit. "They are designed to be fully flexible, and can communicate with a number of external systems," says Stafl.

Furthermore, looking to the future, Stafl cites the value of ease of initial deployment – and then the ability to scale at a reasonable cost for production while using the same system – as vital. "The primary challenge to having accurate SOC and SOH calculations is the amount of raw cell data that's required," he explains. "That's why our automatic cell testing service enables us to quickly and efficiently work with a higher level of data and fidelity than any other means."

Customizable control

Stafl Systems also provides vehicle control units, which are general-purpose, embedded controllers. Programmable by the customer, they manage a vehicle's entire operations and are highly configurable to suit a variety of requirements, including those of cars and motorcycles. Featuring a robust software library and flexible input-output circuitry, they're rugged, protected by IP67 waterproof enclosures, and designed to work with a vehicle's powertrain and other subsystems to regulate electrical functions.

"Often, for an EV or HEV, the challenge is system integration," Stafl continues. "The main

Speed of deployment

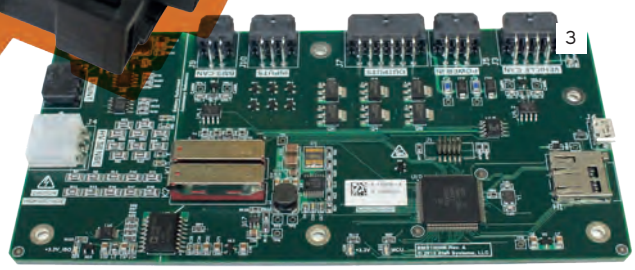
Today, one of the primary means of programming ECUs is through MATLAB Simulink, with vendor-specific code blocks, but this development environment can be extremely cumbersome and can impede rapid development across multiple team members. As an alternative, in September 2016 Stafl Systems launched Control Studio, a fully integrated C++ development environment that enables users to write custom code and rapidly deploy it to their VCU, assisted by proven tools for software engineering.

> "At the moment, you can still find up to ±10% error on SOC algorithms in certain applications, but the tolerance for this won't last very much longer"
>
> Erik Stafl, president, Stafl Systems

"The concept is the customer can have full control of their program and logic, and our engineering staff can assist as necessary," explains Stafl. "Control Studio has an efficient installation process and contains a number of well-documented example projects that make it possible to start programming within minutes." Indeed, in just 15 minutes users can install, build a first application based on a template, and load it onto a target controller, making it an ideal option for development programs working to tight timelines.

Stafl Systems' BMS, VCU, and Control Studio can be used separately, but Stafl argues that their greatest benefit comes when the systems are utilized together – which is precisely what Genovation Cars did in its recent world-record success. "Using everything together enabled us, with Genovation, to save a lot of time developing that particular application, and the success we experienced speaks for itself."

Control Studio will continue to develop, with an expanding set of features and code libraries. Stafl is keen to point out that the company will continue to add more features over the long term, including capability in terms of advanced program analysis, sophisticated debugging, and high-value, model-based design components.



1. The record-breaking GXE is the world's fastest street-legal electric car

2. The VCU1200 can be used as the main system controller on a vehicle

3. The BMS1000 series is easy to deploy – it is in use in a dozen programs

ELECTRIC VEHICLE AND HYBRID PRODUCTS AVAILABLE FROM DALROAD

Dalroad invest in a wide range of TE Connectivity (TE) electric vehicle solutions. TE is a global technology leader at the forefront of driving a greener, safer and connected future.

TE connectivity

AUTHORIZED DISTRIBUTOR

DELIVERING AUTOMOTIVE SOLUTIONS

High and medium power AMP+ connectors and automotive relays available to order today!

Dalroad

Dalroad Norslo Ltd, Enterprise Way, Luton, Bedfordshire, LU3 4BU
Tel: 01582 505252 | Fax: 01582 560060
Website: www.dalroad.com | Email: sales@dalroad.com

Charged atmosphere

Europe's premier showcase for electric and hybrid vehicle technology and innovation

Electric & Hybrid Vehicle Technology Expo Europe, April 4-6, 2017, Sindelfingen, Germany

In the first week of April everyone will want to be in Sindelfingen, Stuttgart – birthplace of the automobile – to be part of the most important European gathering on the electric and hybrid vehicle scene. A compelling and stimulating three days await.

Highly successful in the USA in recent years, Electric & Hybrid Vehicle Technology Expo now launches in Europe. Sindelfingen, Stuttgart, will host key decision makers from leading automotive OEMs, Tier 1s and the entire manufacturing supply chain. There will be more than 200 exhibitors, and more than 3,000 visitors are expected. Electric & Hybrid Vehicle Technology Expo Europe will be co-located with The Battery Show Europe – complementary shows that dovetail perfectly.

"Almost every major automotive OEM in Europe is developing some kind of hybrid and electric powertrain technology," says event director Steve Bryan. "Electric power is being used to help increase performance as well as to reduce our dependence on fossil fuels and make savings at the fuel pump. Our new European event is well positioned and perfectly timed to provide a vibrant forum and demonstrate all of the latest technologies under one roof."

The Stuttgart region of Germany is responsible for the manufacture of more than one million passenger vehicles annually, and has a strong commercial vehicle sector. Porsche, Audi and Bosch all have a major presence and Daimler/Mercedes-Benz has its largest production facility and technical center in Sindelfingen itself. The European Union is the world's largest investor in automotive R&D, spending around double the amount committed in Japan and three times that in the USA.

"In order to make mobility cleaner, smarter and safer in the future, the automobile industry will continue to play its role as a driving force for innovation in Europe," states Erik Jonnaert, secretary general of the ACEA (European Automobile Manufacturers' Association). "To that end, the automotive sector invests more than US$48.8bn in innovation each year."

All aspects of EV/HEV technologies will be on show, including those related to powertrains, batteries and energy storage, thermal management, electronics, safety and testing. Already, majors such as Daimler/Mercedes-Benz, Siemens, East Penn, FIAMM, TE Connectivity, Mahle, Huber+Suhner, Kolektor and Continental have all signed up to exhibit. In order to create further value for the Sindelfingen experience, a twin-track conference featuring more than 80 leading business and technical expert speakers will complement the supply chain exhibition.

Over the following pages we take a look at a few of the innovative technologies on display at Electric & Hybrid Vehicle Technology Expo Europe 2017.

ARADEX

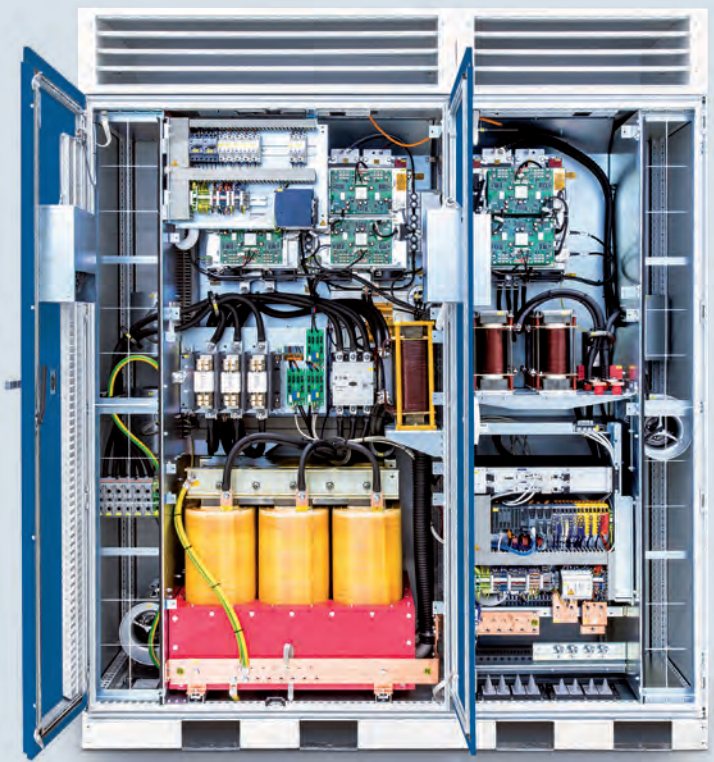
Visitors on the look out for peak performance for drive concepts will certainly be interested in Aradex's new, enlarged product portfolio for the electrification of commercial vehicles, including: Vectopower VP600 bidirectional DC/DC converters from 60kW to 200kW rated power and 800V DC voltage for safe connection of your batteries, and minimization of ripple voltage to ensure ideal battery safety. Also on display will be Vectomotor VM600m asynchronous electric motors optimized for traction drives for direct drive without additional gear reductions (power up to 320kW available). The motors are available with a continuous shaft for easy system integration.

Aradex will exhibit on Stand 415 **www.aradex.de**

PRODUCTS AND SERVICES ON DISPLAY INCLUDE:

• Cabling and connectors • Component manufacturing • Engineering consultancy • Magnetics • Automation equipment • Motors • Prototyping • Simulation and software • Testing • Thermal management • Power electronics • Transmissions • Battery/cell manufacturing • Battery management systems

200+ EXHIBITORS



AVL Deutschland

Accurate characterization is bound to be a key element at the expo and AVL will show its E-Storage BTE, a combined system that can be used as a battery tester and battery emulator (simulator) to validate and test batteries, as well as e-motors and inverters, in an early development phase. The system offers a combination of outstanding dynamic performance with the highest measurement and control accuracy. It not only reduces battery testing time by up to 20%, but also enables the faster characterization of reliable and durable e-drive components. Due to its high level of dynamic performance, enhanced accuracy, broad voltage range and low residual ripple, the AVL E-Storage BTE is the professional solution to emulate a real-world battery and follow a predefined load profile to expose the device under test to real-world operating conditions. Moreover, the system is not only fully compatible with AVL's engine and vehicle test systems but can also be operated as a standalone application. The integrated battery testing automation software AVL Lynx 2 makes the AVL E-Storage BTE compliant with the requirements of the very latest test run standards.

AVL Deutschland will exhibit on Stand 122 **www.avl.com**

electric & hybrid vehicle technology expo europe 2017

April 4 - 6, 2017 Sindelfingen, Stuttgart, Germany

Meet worldwide leading vehicle technology companies

including:

Amphenol

TRANSFLUID industrial transmissions

ZEUS KEEP TECHNOLOGY FLOWING

HUBER+SUHNER Excellence in Connectivity Solutions

LORD AskUsHow™

TE connectivity

SIEMENS

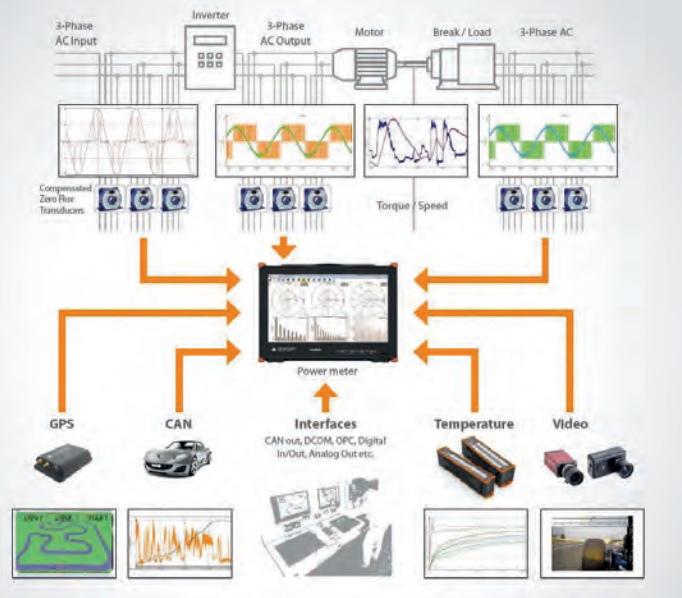
BizLink

CONTACT US TODAY

SECURE ONE OF THE LAST REMAINING BOOTHS

www.evtechexpo.eu

info@evtechexpo.eu



Dewesoft

Dewesoft will present its brand-new R8D power analyzer. This instrument delivers power analysis never before experienced. The R8D enables completely synchronous data acquisition from up to 64 measurement channels (whether voltage, current or any other signal). It's also possible to measure parameters such as temperature, video, GPS, CAN data, etc. On the software side, this instrument combines a power analyzer, scope, FFT analyzer, combustion analyzer, data logger, transient recorder, power-quality analyzer and a lot more. This flexible and high-accuracy hardware, combined with the powerful software, allows for comprehensive, unprecedented analysis in electric and hybrid vehicle applications.

Dewesoft will exhibit on Stand 519 **www.dewesoft.com**

EAST PENN MANUFACTURING

East Penn will show visitors how it is breaking the heat wave for batteries in commercial truck and other heavy-duty applications. It has developed an exclusive Fahrenheit Group 31 AGM design, featuring breakthrough thermal shielding technology that extends battery life under today's increasing battery-box temperatures. It also has a reinforced cycle service AGM design to better withstand the grueling demands of extra electrical loads in high heat environments. It cycles 50% longer than standard AGM in extreme heat tests, uses a heat-reduction catalyst that protects against thermal runaway, and is shielded by a thermal-resistant case that optimizes high-heat AGM performance. East Penn is a leading manufacturer of high-quality lead-acid batteries and accessories for the automotive, commercial, marine, motive power, UPS and telecommunication markets.

East Penn Manufacturing will exhibit on Stand 219
www.eastpennmanufacturing.com

LORD

With embedded sensing technology comprising part of the Lord exhibit, it will feature the 3DM-GX5-45 GNSS/INS inertial sensor, which provides highly precise and accurate measurement of position, velocity, attitude, atmospheric pressure, acceleration and angular rate. It features extremely stable and low-noise gyros, a new accelerometer with noise densities as low as 25µg/√Hz, a multi-constellation GNSS receiver, and M7 and M4 dual Cortex processors running a brand new auto-adaptive extended Kalman filter. This innovative filter has been proved to provide outstanding attitude accuracy, with almost negligible roll error during turns and other sudden course shifts. The GX5's footprint is approximately 44 x 36 x 11mm and it weighs less than 20g.

"Our GX5 inertial sensor also offers very simple integration for the customer," says Fritz Martin, Lord's sensing manager of inertial engineering. "Because it shares the same miniature footprint and API as our previous inertial lines, our users can quickly and easily drop the GX5 into their existing application."

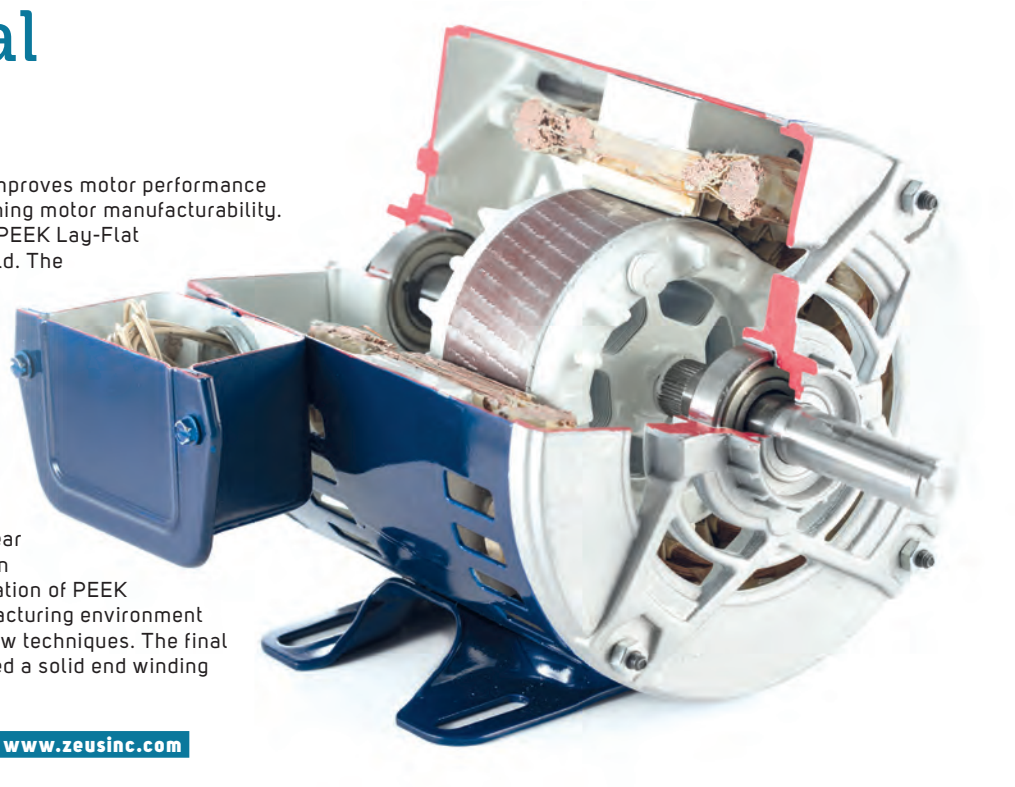
Lord will exhibit on Stand 524
www.lord.com

3,000+ VISITORS

CONFIRMED EXHIBITORS INCLUDE:

Voltabox • Rampf • Siemens • East Penn • FIAMM • Paraclete • TE Connectivity • Mahle • Huber+Suhner • Kolektor • Daimler/Mercedes-Benz • Continental

Zeus Industrial Products



Zeus Industrial Products will demonstrate how it improves motor performance with its own manufactured products while maintaining motor manufacturability. A recent case study examined the effects of using PEEK Lay-Flat tubing insulation and magnet wire in a motor rebuild. The study focused on manufacturability aspects of PEEK products compared with the OEM standard magnet wire and Nomex, Nomex laminate and Dacron-Mylar-Dacron insulation materials, which were initially installed in the motor. PEEK magnet wire and PEEK Lay-Flat insulating material displayed slightly increased stiffness and rigidity compared with the OEM products. PEEK magnet wire provided greater resistance to coil motion in start-up, surge and similar scenarios. PEEK Lay-Flat material exhibited greater resistance to tear than the OEM slot liner and retained its shape when installed, including cuff formation. The implementation of PEEK magnet wire and Lay-Flat products into the manufacturing environment requires no new tooling and minimal training on new techniques. The final motor displayed excellent appearance and exhibited a solid end winding and superior final electrical performance.

Zeus Industrial Products will exhibit on Stand 501 **www.zeusinc.com**

ELECTRIC & HYBRID VEHICLE TECHNOLOGY CONFERENCE

The dual-track conference offers delegates a unique opportunity to hear OEM and Tier 1 perspectives on state-of-the-art new technologies during the expert-led sessions, and view and experience them on the show floor. Co-located with The Battery Show Conference, the agenda will offer insights into important issues such as:

- The impact of electrification on future vehicle design
- Trends in urban electrification, personal mobility, autonomy and connectivity
- Specific market drivers and cost considerations behind the technology choices and roadmaps that the industry is adopting
- Mild hybrid and light electrification strategies and technologies for passenger vehicles
- Evolution of 48V architectures – system design specifications and strategies
- Determining the optimum 48V energy storage system
- Understanding the evolution of power electronics in plug-in hybrids
- Electrification and hybridization strategies and technologies for commercial, off-road and material-handling vehicles
- Electrification and hybridization strategies and technologies for buses and trucks
- XEV battery design and engineering challenges, trends and opportunities
- Defining future lithium-ion stop/start battery systems
- Designing and delivering high-voltage battery architectures
- Testing, modeling and simulation methods for structurally integrated EV batteries

The conference offers over 80 business and technical expert speakers from across the automotive OEM community and its supply chain, including: Franz Nietfeld, program chief – high-voltage systems, Mercedes-Benz; Mike Richardson, chief technical specialist, hybrids and electrification, Jaguar Land Rover; Christian Rosenkranz, VP advanced products and materials, Johnson Controls; and Heiner Hans Heimes, head of production engineering of E-mobility components, RWTH Aachen University.

For more information on the conference and booking a pass, visit **www.evtechexpo.eu**

electric & hybrid vehicle technology expo | north america 2017

September 12-14, 2017 Novi, Michigan, USA

Meet worldwide leading vehicle technology companies

including:

DANA · John Deere · GKN · Motor Design Limited · EastPenn · LORD Ask Us How™ · Applied Energy Solutions · BorgWarner

CONTACT US TODAY

SECURE ONE OF THE LAST PRIME LOCATIONS

www.evtechexpo.com

info@evtechexpo.com

Autonomous Vehicle TEST & DEVELOPMENT Symposium 2017

JUNE 20, 21, 22, 2017 STUTTGART, GERMANY

The world's **ONLY** conference dedicated to the **testing** and **development procedures** for autonomous vehicles and advanced driver assistance systems

The **Autonomous Vehicle Test & Development Symposium 2017** will bring together the world's leading engineers in the field of autonomous vehicle research, testing, validation and development. The conference will be held in Stuttgart alongside Automotive Testing Expo 2017, the world's largest exhibition dedicated to new vehicle development and testing, and in conjunction with *Traffic Technology International* magazine, the world's leading magazine for advanced highway and traffic management technologies.

Hosted at:

Autonomous Vehicle TECHNOLOGY WORLD EXPO 2017 | automotive testing expo 2017 europe

Over 50 of the world's **leading experts** in driverless vehicle testing will be presenting papers!

Book your delegate pass now!

***3-DAY PASS €1,950 • 2-DAY PASS €1,725**

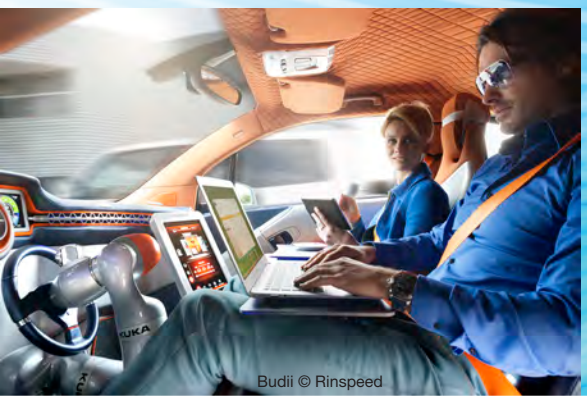
www.autonomousvehiclesymposium.com

*Prices correct at time of going to press

Brought to you by the publisher of:

traffic TECHNOLOGY INTERNATIONAL | automotive testing technology international | electric & hybrid vehicle technology international

Over 300 delegates attended the event in 2016!



Topics under discussion:

- Public road testing
- Virtual testing
- Simulation
- Traffic scenario testing
- Embedded software testing
- Safety and crash testing
- Fail-safe testing
- Cyberthreat testing
- Validation and verification
- Autonomy software
- VeHIL
- V2V and V2X testing
- Robotics
- Testing legislation
- Safety standards and legislation
- Case studies
- Possibilities
- Best practices
- Reliability testing of software and hardware systems

For more information about the Autonomous Vehicle Test & Development Symposium 2017,
please contact Andrew Boakes: andrew.boakes@ukipme.com
Tel: +44 1306 743744 | www.autonomousvehiclesymposium.com

Reliable chargers

These energy-dense battery chargers can connect to all power grids worldwide and are able to withstand the harshest of conditions, installed in confined spaces

The year 2025 is set to be the next important milestone in worldwide attempts to reduce air pollution caused by high-emission vehicles. Therefore, hybrid and electric vehicles are gaining in popularity. Demand for low- and zero-emission buses, trucks and delivery vans is also increasing in cities. In addition, for economic, safety and environmental reasons, other sectors such as underground and mining, marine, and off-road vehicles are looking toward battery-powered vehicles. These applications call for extremely high levels of quality, durability and environmental sustainability, due to potentially high costs incurred as a result of out-of-service periods.

EDN Group's product scope focuses on prime onboard chargers and converters for use in high-end commercial and industrial vehicle applications. With 23 years of power converter expertise and experience in military, electro-medical and automotive applications, EDN is continuously improving charging performance. The company designs and manufactures converters that provide high levels of performance, even in very harsh environments. EDN's systems comply with the most stringent demands for safety, sealing, temperature range, electromagnetic immunity, electromagnetic emission and charging performance. They are capable of withstanding harsh environments under mechanical stress and vibration, corrosive conditions, and situations where there are contaminants present.

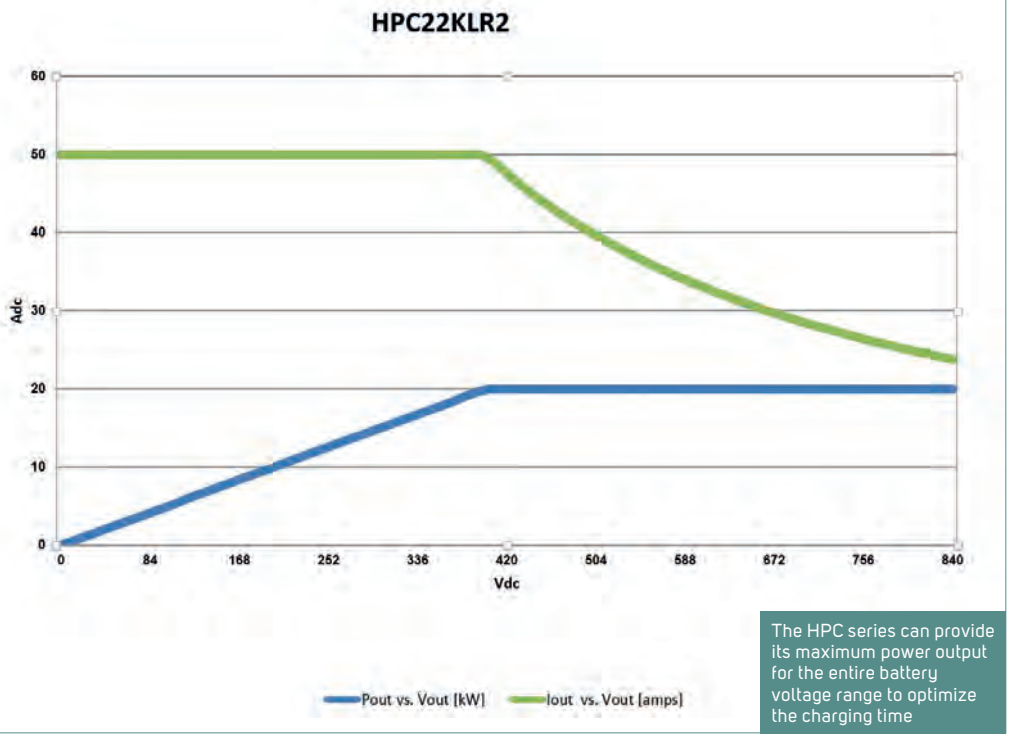
The supply of converters begins with a robust design and continues through to the manufacturing of the system. EDN Group's experts have a talent for innovation and take a customer-focused design approach, providing the highest levels of quality in functionality to ensure safe, long-lasting and efficient products, which exceed current customer expectations. Marco Cereda, CEO at EDN, is thrilled by the company's achievements and excited for the future of electrified vehicles. "In its years of experience, EDN has recruited a large number of system and power electronics engineers and its present team has extensive automotive and power electronics experience. EDN has also recently upgraded its quality system to the new ISO 9001:2015 improving risk management throughout its business. EDN's products provide very good value for customers, made with best practices, extensive environmental tests, and incorporating knowledge of lessons learned.

"EDN Group knows how to improve efficiency, reduce volume and weight, and boost power converter performance for continued improvements in sustainable logistics and mobility industries," explains Cereda.

EDN has developed a new series of 22kW onboard chargers, the HPC22KL, for use in heavy-duty applications. This series, which is the result of two years of research and development, adopts a new conversion technology that improves

EDN's HPC22KLR2 is a liquid-cooled, 22kW onboard charger. The product series was developed for heavy-duty applications

EDN Group has also developed the CMP505 series, which includes the CMP505-02 – a 600V AC, 20kW onboard charger



The HPC series can provide its maximum power output for the entire battery voltage range to optimize the charging time

power density and specific power and is cost-effective for volume production. With its extremely compact design, which halves the current benchmark dimensions, HPC22KL can be installed in any tight space of a vehicle.

Battery voltage can vary between 140V DC and 1,000V DC, and the series can be easily paralleled to support a nominal onboard power up to 220kW. HPC22KL can also provide its maximum power output for the entire battery voltage range to optimize the charging time – constant power curve (CPC). The AC grid connection is a pure three-phase (three wires + PE) no-neutral input and is suitable for nominal plug-in to 400V AC/50Hz (Europe) and 480V AC/60Hz (North America) mains grids and is fully compliant with SAE J1772 and EN61851, so it can be easily connected to the EVSE around the globe. The SAE J1939 standard CAN interface provides control, monitoring and diagnostics.

The HPC22KL during HALT testing

HPC22KL uses a built-in light aluminum liquid cold-plate, providing a very efficient thermal system to remove heat with very low pressure-drop. The entire charger has IP67 and IP6K9K protection rating, and galvanic isolation ensures definitive safety separation between the vehicle (IT) and the grid (TN). HPC22KL has been designed for a minimum service lifetime of 15 years, providing full power charging for 50,000 hours at nominal cooling conditions. HPC22KL has been through an extensive validation process based on SAE J1455 that covers the following areas: thermal cycle and shock testing; HALT testing; shock and vibration; dust and sand and water intrusion testing; chemical resistance and salt spray testing; electromagnetic immunity and emission testing; safety testing; and parametric and functional testing.

HPC22KL is CE marked and E(e) mark (ECE R100 and R10) is pending. HPC22KL, single or paralleled, covers a wide range of commercial and industrial plug-in hybrid electric vehicles (PHEVs) or pure electric vehicles. It is suitable for use with small to large buses, trucks and vans, underground vehicles, boats and more. Documentation will be available for customer review in Q1 2017, with products available for delivery in Q2.

The company has also launched its CMP505 series, a CSA- and UL-listed 20kW onboard charger, specifically designed for mining and underground applications, where it can be plugged into 480V AC and 600V AC three-phase AC mains grid. It is fully compliant with SAE J1772 and EN61851. Battery-pack voltage can vary between 266V DC and 800V DC and the series can be easily paralleled to provide a nominal onboard power up to 200kW. The CMP505 can provide its maximum power output with a CPC to optimize charging time. A proprietary CAN interface protocol provides control, monitoring and diagnostics to the system and matches several BMSs on the market. CMP505 series uses an aluminum liquid cold-plate, providing a very efficient thermal system to remove heat with very low pressure-drop. The entire charger has IP67 and IP6K9K protection rating and a galvanic isolation, a definitive safety separation between the vehicle (IT) and the grid (TN). CMP505 series is ready to order.

FREE READER INQUIRY SERVICE
To learn more about EDN Group, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 501

In-wheel motor design

Extensive development and testing of multiple designs played an important role in advancing mass-produced, in-wheel propulsion for the next generation of EVs

Figure 1: Extremely compact high-torque in-wheel motors from Elaphe, offering a peak power of 75kW and continuous power of 50kW with liquid-cooling, are ideal for the next generation of lightweight and efficient electric vehicle powertrain designs

The automotive industry is on the brink of change – electric vehicles are well on their way to becoming mainstream and promise to go some way toward making up for humanity's environmental transgressions. In the meantime, behind the scenes, the battle of e-technologies is unfolding. One of the contenders, and still an underdog in the view of the heavyweight automotive players, is the vehicle designers' favorite, the in-wheel motor – arguably the simplest and the most refined concept of all.

Elaphe Propulsion Technologies emerged from radical innovations in motor electromagnetic topology put on paper back in the late 1980s – thousands of scribbled pages, full of equations and drawings, noted down by hand.

Standing on the shoulders of the underlying physics principles, and applying the electromagnetic topology innovations – making use of methods such as multibody dynamics (MBD), finite element analysis (FEA) and computational fluid dynamics (CFD) – enabled Elaphe to become one of the leaders in high-performance, lightweight in-wheel motors. Faster development cycles and unique optimization software, predictive capability of CAE tools, modern prototyping, and advanced testing methods are enabling effective development and verification, including on-vehicle testing.

Many new developments in disruptive technologies, such as in-wheel motors, come out of necessity. These developments stem from the desire of innovators to radically challenge established technologies, in search of ways to change the industry and optimize its inefficiencies. It is amazing what proper EM design can do, when the equations of electromagnetism are rethought and some electric motor myths of the past decades are forgotten. A compact, light and powerful EM design really opens up development options.

In recent decades, several motor layouts (there were more than 15 different variants detailed in the original Elaphe drawings) were designed and prototyped to test for performance under real-world road conditions. These motors were extensively tested in electric vehicles, where theoretical innovations passed the real-world practical tests with flying colors.

Later, the most optimized Elaphe designs evolved through multiple generations and were also cycled through many more on-vehicle tests, from different passenger cars to high-performance SUVs, ATVs and public transportation vehicles. The

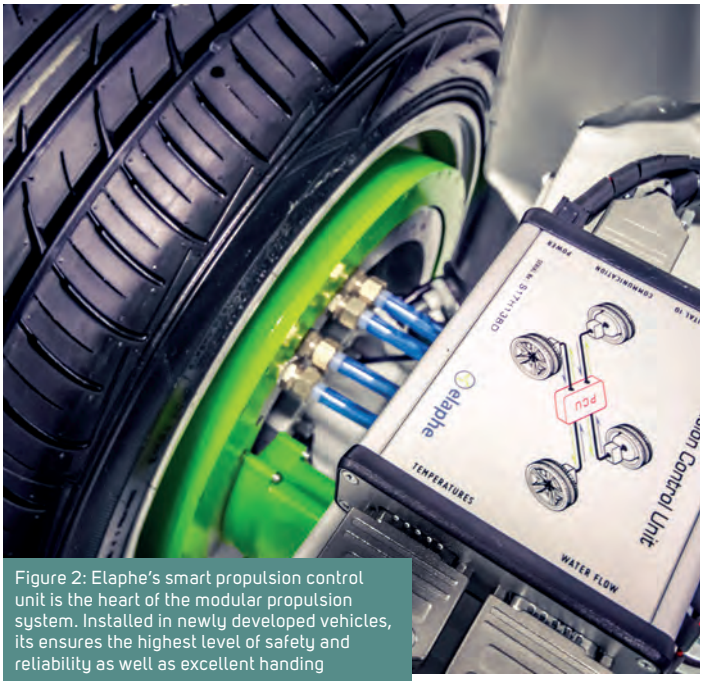


Figure 2: Elaphe's smart propulsion control unit is the heart of the modular propulsion system. Installed in newly developed vehicles, its ensures the highest level of safety and reliability as well as excellent handing

Figure 3: The Elaphe M700 in-wheel electric motor for passenger cars. This motor is the result of a development process that encompassed more than ten in-wheel motor designs with different layouts – including inner and outer rotor, liquid- and air-cooled, with integrated or onboard inverter and with voltages from 36V to more than 400V

experience gained from every test vehicle was leveraged for the next, and the knowledge embedded into Elaphe DNA.

Nowadays, utilizing that unique knowledge and innovation enables Elaphe motors to use less material more efficiently to produce unrivaled specific torques, enable extreme compactness, and reduce material cost. For example, take the Elaphe M700 in-wheel motor (Figure 4). It achieves its full torque of over 700Nm, while at the same time leaving space for integration of standard mechanical brakes.

Elaphe is also pioneering the manufacturing technologies of high-performance in-wheel motors, thus creating opportunities for vehicle designers and manufacturers along the way. The focus in the development and testing of in-wheel powertrains on cars and larger vehicles, and securing a robust supply chain, is enabling mass production and availability of Elaphe in-wheel motors for highly efficient electric vehicle propulsion systems.

To optimize the performance of test vehicles and employ advanced safety strategies, Elaphe motors had to be integrated with a smart control unit. With existing solutions nowhere to be found, the Elaphe team developed the propulsion control unit themselves (Figure 2), implementing advanced control software and optimizing the system, making it robust and reliable.

The Elaphe M700-based in-wheel powertrain (using either two or four in-wheel drives) is an off-the-shelf solution designed to set vehicles free. Tested on more than a dozen vehicles using Elaphe proprietary control software, and developed according to the highest industry standards, the technology means that engineers no longer have to struggle with finding space and suppliers for gears, transmissions and hundreds of other components to create the great electric vehicles of the next generation. Available for a wide range of voltages, the complete Elaphe propulsion solution offers precisely what customers require (Figure 3): the propulsion control unit, in-wheel motors and inverters – together with all the other required components (such as brakes) – can be installed as a turnkey solution or can be further adjusted in order to suit any specific customer requirements.

Figure 4: The Elaphe M700-based in-wheel electric powertrain, demonstrating the simplicity of integration as a turnkey propulsion solution, including Elaphe M700 motors, inverters, a wireless infotainment system and the Elaphe PCU

Currently, the implementation of artificial intelligence and Internet of Things connectivity are the next challenges for Elaphe heading forward. While artificial intelligence in manufacturing enables bridging of the gap to scalable and efficient mass production, its application makes vehicles safer, smarter and much more fun to drive. So, whether customers are thinking about building more energy efficient, safe and spacious vehicles, without compromising when it comes to performance, or simply contemplating modular, smart and easy-to-integrate systems, they can take comfort in the knowledge that Elaphe's innovators think alike.

FREE READER INQUIRY SERVICE
To learn more about Elaphe Propulsion Technologies,visit:
www.ukipme.com/info/ev
INQUIRY NO. 502

Taiwan International Electric Vehicle Show

EVTAIWAN

In conjunction with

MOTORCYCLE TAIWAN

Concurrent Shows:

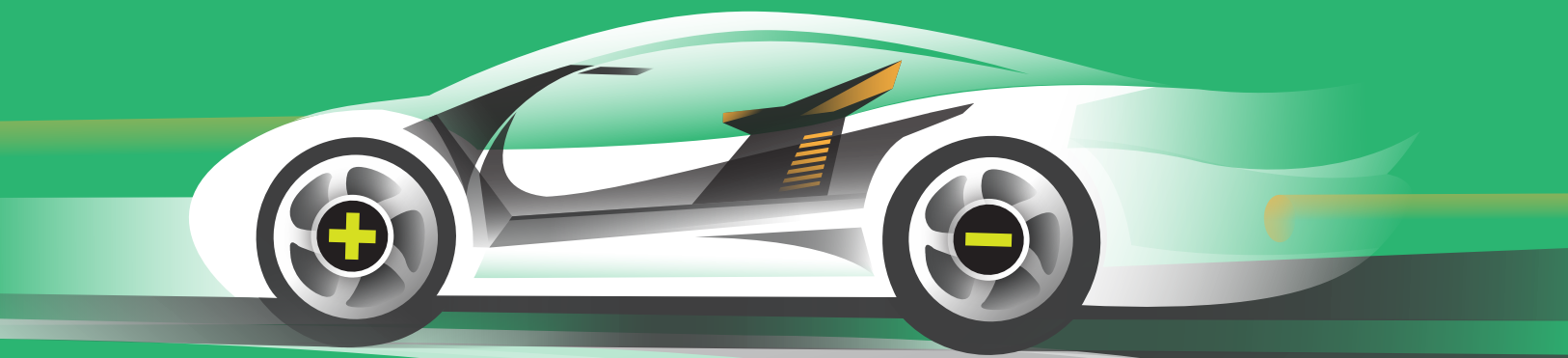
TAIPEI AMPA AutoTronics Taipei

Date: APR. 19-22, 2017

Venues: NANGANG Exhibition Hall & TWTC Exhibition Hall 1

APR. 20-23 2017

TWTC Exhibition Hall 1



Booths application OPEN!

Shifting into a new age of smart power!

www.EVTAIWAN.com.tw

Organized by

Bureau of Foreign Trade, Ministry of Economic Affairs (MOEA)

Implemented by

TAITRA TEEMA TTVMA

Get local assistance at the TAITRA branch nearest to you:

http://branch.taiwantrade.com.tw

AD by BOFT

Advanced battery research

A group of specialist companies has teamed up to prove that innovative battery technologies can seriously benefit performance and cost in smart powertrains

Electrification of the world's vehicle fleets is taking some time, but for the majority of us it is a question of when, rather than if. In global terms, companies in the automotive sector and many from parallel markets are working hard to make it happen. The UK has a solid track record of automotive innovation and the country has also been a major player in electrochemistry and battery technology.

The UK Automotive Battery Supply Chain (UK-ABSC) project has brought a group of companies together, each with aligned plans and intellectual property, and aims to convert world-class battery innovation into product. The project is supported by the UK's Advanced Propulsion Centre (APC), and will deliver highly innovative technology that has the potential to revolutionize lithium battery functionality, reliability and performance, and establish a robust UK supply chain for the complete manufacture of batteries – from 'powder to power'.

The UK-ABSC project started in July 2016 and is comprised of five partners: Cosworth, Dukosi, JMBS, WMG and the lead partner AGM Batteries, each of which brings key skills and knowledge.

AGM Batteries scales up new cell chemistries and designs for real-world manufacturing. Although the company is now independent, its history goes back to the invention of the original lithium-ion technology: AGM was originally a joint venture between AEA Technology (the original lithium-ion researchers), GS Japan and Mitsubishi Materials. The company has a good relationship with WMG, which provides valuable expertise in the early stages of electrochemistry and design for manufacture, speeding up realization of production standard cells. By incorporating 'on-cell' electronics, this project can provide a more integrated cell product, helping battery pack partners to bring new systems (tailored to automotive applications) to market more quickly.

The UK-ABSC project aims to convert innovation into real-world products and establish a robust UK supply chain

A large cathode and anode mixer at AGM's factory in Thurso, Scotland

Dukosi is developing a key aspect of the on-cell technology, which should bring considerable improvements to lithium batteries. Reduction of battery pack wiring will improve reliability, reduce weight and deliver accurate information to the BMS. There are tremendous advantages to making intelligent cells: the cell is recording state of health (SOH) data from the outset, before it is built into a pack and throughout its entire lifetime. This offers obvious advantages during application cycle life and provides crucial data to help justify second life, which is an important factor in many business cases. The partner companies have been working together to integrate the innovative electronics into the lithium pouch cell, and have held a series of innovation workshops that have yielded more ideas.

An electrode stacking machine, part of AGM's semi-automatic cell assembly line. The UK-ABSC project will see a fully automated assembly line installed in the Thurso factory

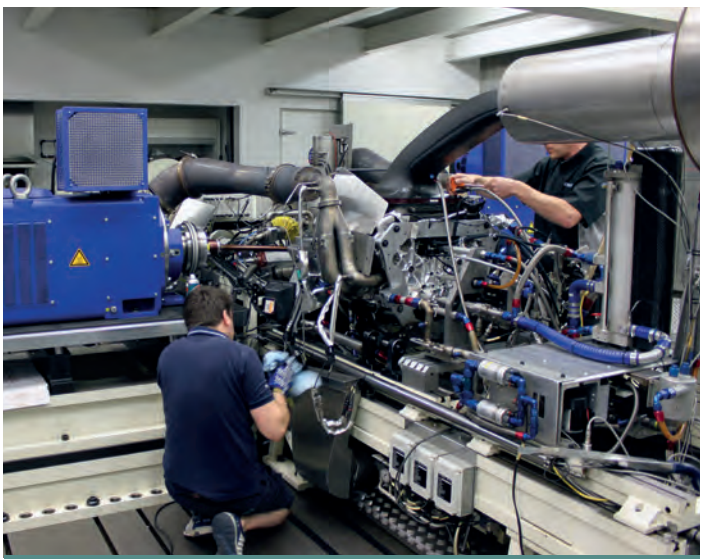
"We located the workshops in neutral locations, removing the usual daily distractions, helping us to focus on the complex challenges and allowing the ideas to flourish," explains AGM project manager Colin Arnold. "The results have been extremely encouraging, with several

innovation seeds planted. The first two workshops took place in the beautiful backdrop of the Highlands of Scotland, which can't fail to inspire and elicit creative thought."

The UK supply chain angle is creating substantial excitement too. LFP raw materials are supplied by Johnson Matthey's Battery Materials Division, and cells are designed and manufactured by AGM with assistance from the experts at WMG. The Dukosi electronics are integral to each cell. The cells are then assembled into a 48V pack and subsequent high-voltage hybrid pack by Johnson Matthey, with Cosworth proving the innovative pack on the company's advanced automotive testbed. The project's 'made in Britain' focus has already engaged other UK companies. "It's great being able to work together with partners in close proximity, but that's just the start," explains AGM's Arnold. "This is all about pulling new automotive battery technologies together with expert parties from each of the core powertrain areas. We are keen to engage globally with additional collaborators and potential users as early on as possible."

"We see the UK-ABSC project – with its focus on defining technology and supply chain infrastructure for the next generation of energy storage systems – as being exactly the right program to be involved with," adds Cosworth project manager Paul Freeland. "Cosworth is keen to share its experience on powertrain systems and installation requirements, and to offer its state-of-the art testing facilities to measure improvements in energy storage and transfer efficiencies.

"From Cosworth's perspective, the technologies developed in this project provide opportunities for significant improvements in aging characteristics and individual cell energy management. These lead to realizable benefits in reduced mass and overall energy density that can result in increased range, or higher power applications. Further on during the battery lifetime, the onboard record of the cell usage, efficiency and condition enable improved maintenance and the known provenance results in higher residual value. Further ahead, there is also potential to control hybrid chemistry cell arrangements more efficiently, thereby further optimizing the characteristics of the battery pack as a whole. In conclusion, the scope for making extremely significant impacts on the future of transportation is no less prevalent now than at the beginning of Cosworth's history. Even for an organization whose heritage is steeped in mechanical propulsion, the engineering challenges of the electric age are no less demanding and the satisfaction from developing elegant solutions no less rewarding."



Cosworth offered its experience of powertrain systems and installation requirements

Cosworth is one of the five partner companies involved in the UK-ABSC project, working with teams from Dukosi, JMBS, WMG, and lead partner AGM Batteries

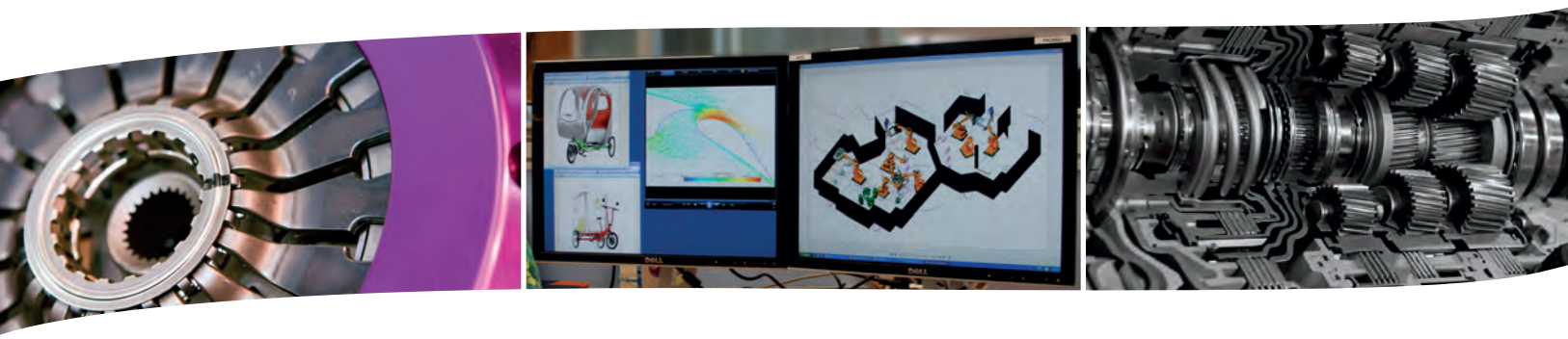
"Like the other partners, Dukosi's activity is steadily increasing," states Dukosi's commercial solutions director, George Paterson. "We've had several workshops with AGM to explore the integration of the device into the pouch cell, currently focused on the discrete version but mindful of the forthcoming ASIC solution.

"In parallel, Dukosi has been reviewing its technology with selected interested parties across the supply chain. The feedback has been very positive and highlighted benefits we'd not previously realized. This feedback has confirmed what we already knew: our technology is innovative and provides real benefits in cost reduction, improved performance and increased reliability to name a few. The benefits can be realized across the whole supply chain and will be exploited in the UK-ABSC project."

David Greenwood, professor of advanced propulsion systems at WMG, and the head of the APC Electrical Energy Storage Spoke, adds, "WMG has invested heavily in battery system research and development over the last decade, and was recognized as the APC UK spoke for electrical energy storage in 2015. We are pleased to support AGM, Dukosi, JMBS and Cosworth in taking this novel and promising technology toward production. The UK has a strong position in battery systems innovation, and we are delighted to be playing a formative role in its future."

"The UK has a strong reputation for automotive development and manufacturing and battery technology research," says Ian Whiting, business development director of AGM Batteries. "The project pulls much of this together, creating a team of aligned industry partners, each bringing a specialism to the table. It creates the basis of a complete UK supply chain for automotive batteries from 'powder to power'. We're also able to work with different cell chemistries, and have electric vehicle and renewable energy storage projects, so are keen to hear from companies operating in those spheres too."

Dynamik Technological Alliance is a multitechnological manufacturing basque group with a wide international presence suppling to the automotive industry high added value subassemblies



TOMORROW'S TECHNOLOGY TODAY

Dynamik Technical Center provides the group with the design, testing, validation and industrialisation of all the components to be manufactured and assembled in the group's facilities or in external ones. We supply high added value subassemblies to the automotive industry applying a holistic approach to reach the market in terms of time, quality and costs.

Examples of current project being undertaken by Dynamik are the 7 seater hybrid luxury SUV concept vehicle and the complete development of a full electric vehicle for the Mexican market.

Parque Empresarial de Boroa
Edificio AIC. Fase 2. Oficina 2.
48340 / Amorebieta-Etxano (Bizkaia) Spain
Tel: +34 946 734 751
group@dynamikalliance.com

dynamik
TECHNOLOGICAL ALLIANCE

www.dynamikalliance.com

Optimized engine concept

Evaluating the configuration of 48V powertrains – in terms of both the base engine and the electrification of auxiliary components – is key to reducing overall system energy demand

In order to meet fleet fuel consumption legislation of 95g/km of CO_2 in 2020, auto manufacturers will introduce various electrification measures, besides engine measures, to reduce the overall energy demand of vehicles. As seen in Figure 1, 48V architecture represents an attractive compromise between the standard 12V system and high-voltage hybrid systems.

The 48V system already offers attractive performance potential for moderate hybridization steps, while also opening up opportunities for the electrification of the IC engine and its auxiliaries, as well as other vehicle components with high power demand.

With increasing power levels for e-machines, it is important to assess the optimum configuration for a 48V system. Traditionally speaking, the 12V and 48V system has been situated in the FEAD, as it is a straightforward upgrade to an existing engine architecture with the lowest impact on vehicle package, cost, production and aftersales.

Current belt starter-generator systems already realize direct recuperation and torque boost functions. Additionally, they can support a highly effective electrical supercharging system, which is clearly superior to current multistage turbocharging concepts, particularly in transient response.

Electrified turbochargers with additional recuperation function are in early advanced development as a promising next step.

However, future applications with clean-sheet designs offer greater configuration flexibility in terms of the ideal position for the 48V electric motor. The combination of fuel reduction savings; the potential for temporary deactivation of the ICE and electric driving in coasting mode, city driving and at low speed for parking/pull away; as well as using the gear ratio of the transmission and eliminating the conventional alternator, indicates the flywheel side P2 configuration is ideal to reduce the base engine complexity. To avoid an increase of the powertrain length and enable use of a high-speed e-motor, the parallel P2 configuration is the solution for transverse powertrains.

Figure 1: 48V is an attractive compromise between 12V and high-voltage systems

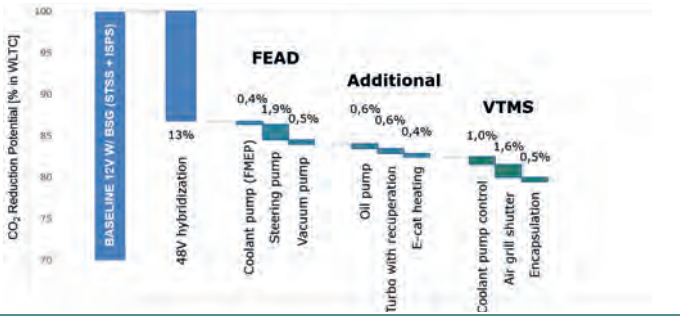


Figure 2: Electrification of auxiliaries can enable simplification for a beltless engine

In terms of the base engine, electrification of auxiliaries enables simplification for a beltless engine (Figure 3). Demand-controlled, electrical auxiliaries are already partially in volume production for cooling systems, vacuum systems and air-conditioning. Additional options – including the use of an electric oil pump and partial or full electrification of the valvetrain – have also been evaluated.

AVL has compared the options for the base engine, evaluating these in terms of function, added value and system cost, with the aim of minimizing overall system complexity through application-dependent balanced distribution of electrical and mechanical functions.

The extension of this approach involves the integration of the 'ideal' 48V powertrain, including the optimized engine. Additional opportunities (in terms of function and package) are created by increased flexibility in the position of auxiliaries as well as function integration. Optimized vehicle thermal management, including partial encapsulation and controlled cooling air shutters, enables further efficiency improvement.

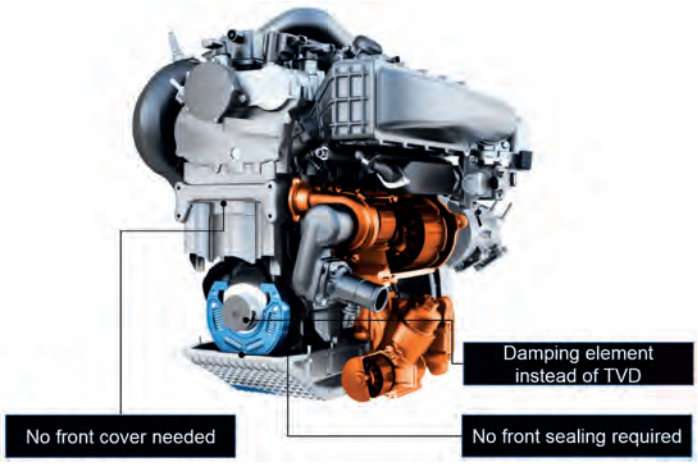


Figure 3: The AVL 48V concept demonstrated a considerable WLTC CO_2 reduction

In comparison with the baseline powertrain, simulation shows the AVL 48V concept has a considerable WLTC CO_2 reduction potential of up to 20.5% – a 13% CO_2 reduction for the 48V hybridization and a further 7.5% CO_2 reduction as a result of the additional measures (Figure 2).

An overall system approach to 48V powertrain integration is absolutely fundamental, considering energy demand, cost, thermal management, aerodynamics and acoustics, evaluated with the AVL Vehicle Attribute Engineering process to assess the balance between the technology options and vehicle attributes.

FREE READER INQUIRY SERVICE
To learn more about AVL, visit: www.ukipme.com/info/ev
INQUIRY NO. 504

SIEMENS

Ingenuity for life

Today's dreams need tomorrow's engineering.

Simcenter: Predictive engineering analytics for the new era of smart innovation.

Getting a dream rolling has never been more challenging. Products are smarter. Manufacturing processes are more complex. And design cycles are shorter than ever. Simcenter software can help. With its unique combination of multi-disciplinary simulation, advanced testing and data analytics, Simcenter gives you the power to explore alternatives faster, predict performance more accurately... and deliver innovation with greater confidence.

siemens.com/plm/simcenter

New frame-based modules

The extension of an existing frame-based product line offers high levels of performance in a smaller package, and with reduced production requirements

The worldwide hybrid and electric vehicle market is currently booming, leading to the most exciting growth seen in the automotive industry for decades. As a result, a wider spectrum of vehicles needs to be electrified, which requires scalable and cost-effective solutions.

Infineon continues to propose innovative new solutions on frame-based modules. HybridPack Drive is an extension of the company's well-known HybridPack family. With the introduction of PressFit and EDT2 technology, HybridPack Drive is 20% smaller than HybridPack 2, but offers equivalent performance. In addition, the new technology offers important improvements for easier utilization, reducing production effort.

HybridPack Drive has different types of mounting connectors, enabling customers to choose the solution that best fits their industrial process. Thus, HybridPack Drive is capable of having its power terminals welded into the system – saving assembly time when compared with screwing all nine tabs into place. Available are: short tab connectors without holes, thus enabling a fast welding process to connect cables; short tab connectors with holes to screw cables; long tabs with holes to screw cables and implement current sensors directly on the tab, such as LEM HAH3DR 800-S07.

HybridPack Drive also offers Infineon's PressFit technology on the signal pins, enabling PCB mounting in a few seconds. Plastic guides have also been implemented to achieve more accurate positioning of PCBs on top of the module. Both help customers to gain significant time during mounting.

HybridPack Drive is not intended to remain as a single device, but will be developed as a full platform. Products will be scalable for varying levels of performance and output power. Modules in the HybridPack Drive family will all have the same construction, reducing inverter design effort. Chipset, electrical behavior, driver board, DC-link capacitance, connectors and inverter housing will also remain the same. Performance will be scalable in terms of thermal resistance of the module thanks to the option of different baseplate interfaces.

Infineon is also beginning to offer pin-fin interface for HybridPack Drive. A flat-base product will follow to offer reduced performance and improved device cost. Finally, HybridPack Drive offers sufficient creepage and clearance distance to be ready for 850V DC link voltages and a 1,200V version is also currently in the concept phase.

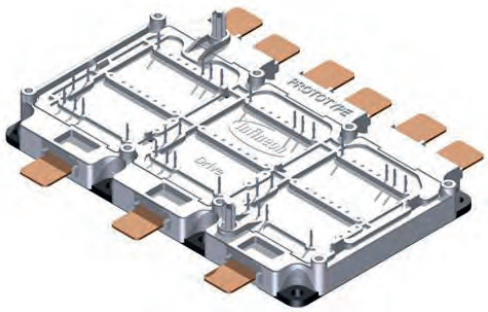
Two additional versions will be developed to complete the portfolio, with a new direct cooling interface (called ribbon bond) to offer an improved cost-performance ratio, and a high-end product to get closer to a 1,000A current capability.

HybridPack Drive uses the latest Infineon IGBT technology for the automotive sector – EDT2. This technology has been designed with the specific requirements of hybrid and EVs in mind, with a focus on increasing efficiency. Indeed, for a chip size of 300mm^2 (that is, with a nominal current of 650A), the conduction losses are reduced by 290W thanks to a reduction in collector-emitter saturated voltage of 450mV. EDT 2 IGBT technology even offers 220mV $V_{CE(SAT)}$ at a current of 800A compared with an IGBT3 chip 30% larger.

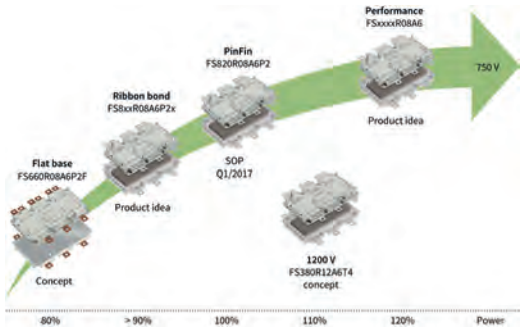
On top of the improvement in conduction losses, EDT2 has the best ratio of conduction to switching losses. Due to a 100V higher blocking voltage, fast switching can be realized in real-world application. EDT2 also enables operation at a junction temperature of 175°C. This reduction of conduction and switching losses comes with short-circuit robustness.

More specifically regarding switching losses, the technology combines ultra-low tail current and excellent light load switching losses. As a result, full performance can be obtained up to nominal current.

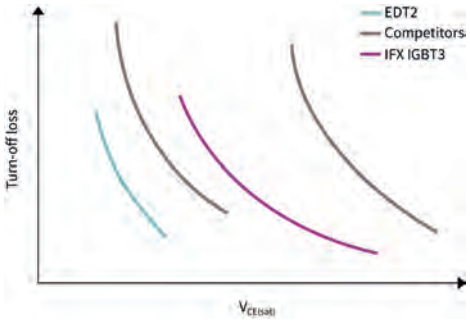
Measurements were performed at partial load on an evaluation kit, and 99% inverter efficiency has been observed under 400V, 40kW, 8kHz SVM, and 85°C conditions.



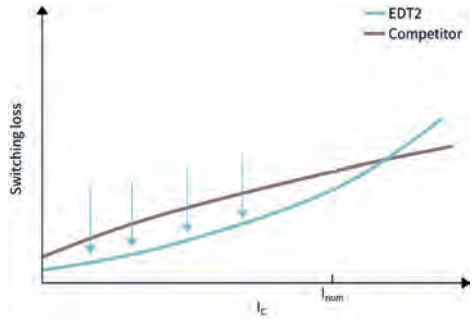
HybridPack Drive with short tab, without holes for fast welding



The scalable HybridPack Drive product family from Infineon



Infineon's IGBT EDT2's conduction and switching performance



Switching losses versus current, compared with competitors

FREE READER INQUIRY SERVICE
To learn more about Infineon, visit: www.ukipme.com/info/ev
INQUIRY NO. 505

ELECTRIC & HYBRID VEHICLE

Ultra Wide Constant

INNOVATION

HIGH

Future

Efficiency

NOW

SUSTAINABILITY

Power Range

E-MOTOR TECHNOLOGY

The beating heart of future cars

SRAM motor grants high efficiency and high peak power within the whole use range. Thanks to its huge field weakening, your vehicle will run on highways and climb steep slopes without gearbox. Contact us to learn more.

SRAM
TECHNOLOGY

www.sramtechnology.com

Cell balancing techniques

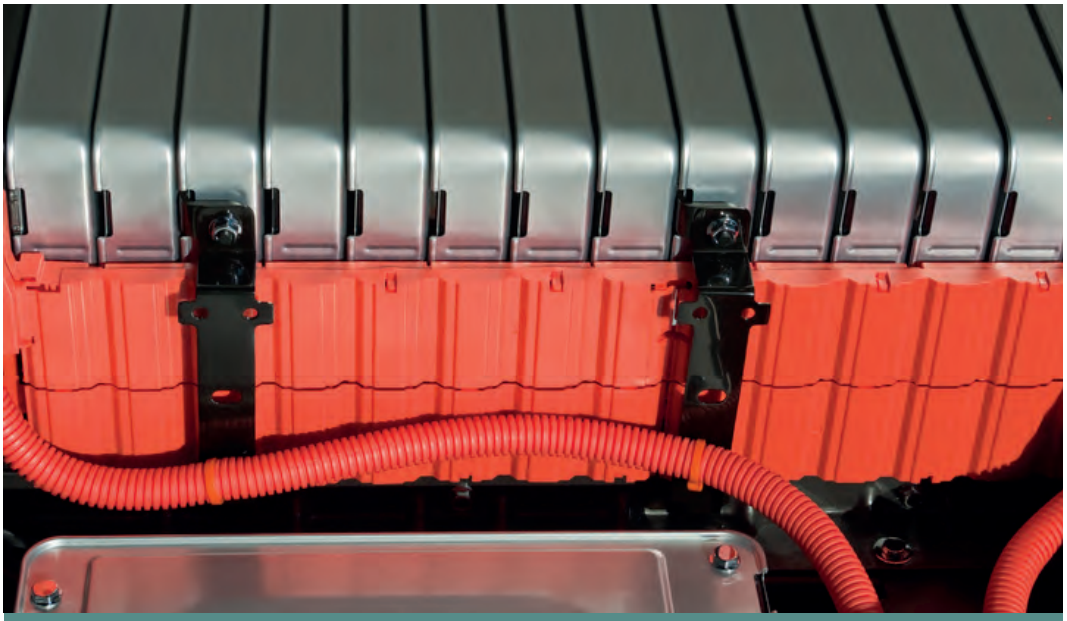
Different methods of balancing the cells within a battery pack must be evaluated to ensure the right solution maximizes performance in electric and hybrid vehicles

Engineers working with electric and hybrid-electric vehicles generally have to work with the available battery technologies, which are usually some variant of Li-ion-based chemistry. However, they do have a considerable challenge in managing the large assembly of cells that comprise the battery packs. The BMS has three major objectives: to protect the individual cells and the complete battery assembly from damage; to prolong battery life; and to maintain the battery assembly so it can meet the requirements of the application.

An unavoidable constant is that, in multi-cell battery chains, there will always be small differences between the cells due to production and operating conditions (especially temperature gradients, which can be significant for larger battery packs). These differences are magnified as a result of each charge/discharge cycle, with weaker cells becoming even weaker until they eventually fail, causing premature failure of the larger battery pack.

Cell balancing compensates for weaker cells by attempting to equalize, or balance, the charge on all the cells within the pack. Various methods of cell balancing have been developed to address this problem. The approach is also a function of the battery chemistry: lithium-based batteries are more tolerant of the 'micro' charge/discharge cycles associated with HEVs, but are more affected by cell-to-cell differences. In contrast, there is some natural cell balancing by increasing the charging time with lead acid and NiMH cells, since the fully charged cells will release energy by out-gassing until the weaker cells reach full charge.

The two most common cell-balancing techniques are active and passive – other approaches, such as charge shunting and lossless balancing are also used but, as always, there are trade-offs. Both techniques start by monitoring the state of charge (SOC) of each cell – measured by coulomb counting of current flow into and out of the battery, sometimes supplemented by a battery-impedance measurement. In some situations, only the voltage across each cell is measured. Switching circuits then control the charge applied to each individual cell in the chain during the charging process to equalize the charge on all the cells in the pack.



There are different approaches to battery cell balancing. Maximizing cell performance is vital to increasing BMS complexity

In active balancing, charge is removed from higher-charged cells and passed to lower-charged cells. This is a time-consuming process since it must be done by assessing each cell in what may be a very large number (hundreds and thousands). Some active cell-balancing schemes are designed to stop charging a cell that is fully charged and continue charging weaker cells until they reach full charge, thus maximizing the battery's charge capacity.

In passive balancing, excess energy in higher-charged cells is automatically drained through a bypass resistor until the voltage or charge matches the voltage on the weaker cells. It is a low-cost option, but wastes energy in the bypass resistors, and also limits battery-pack performance in line with the weakest cells.

Targeting this BMS and cell-balancing challenge, devices such as the Maxim Integrated MAX14920 accurately sample cell voltages for SOC and source-resistance determination. Accuracy is an issue with battery-cell monitoring, especially with chemistries that have fairly flat discharge curves, such as lithium-metal phosphate. All cell voltages are level-shifted to a ground reference at unity gain, which greatly eases the data-conversion process, and passive-cell balancing is supported by external FET drivers.

Regardless of the method used, squeezing out the last percentage points of capacity and performance can add to BMS system complexity and cost. Issues that would be minor in portable consumer devices are major ones in these applications, given the voltages and power levels, the operating environment, and user expectations. Furthermore, as in most engineering decisions, there is no single 'right' way to achieve a given goal. Each approach brings trade-offs that must be examined, reviewed and resolved from many perspectives, with a clear focus on design objectives, trade-offs, and the interplay between solutions.

EV cooling solutions

Advancement of electrified vehicle design requires highly effective cooling solutions that can reduce costs and deliver efficiency, ensuring consistent, high-performance operation

As OEMs design electrified vehicles that can compete with traditional passenger cars (and, in many cases, outperform them), the need for highly effective cooling solutions is growing. Electrified vehicles are adopting fast-charge capabilities resulting in extremely high current flow and, consequently, high levels of heat to manage. Today, Dana is exploring new ways to keep these vehicles moving forward safely and efficiently.

OEMs seek out next-generation thermal solutions that reduce costs and deliver efficiency, and they'll find them in insulated gate bipolar transistor (IGBT) cooling systems.

Dana's IGBT cooling system provides vehicle OEMs with a lightweight, package-friendly design that can be customized to meet specific needs

This Long technology innovation from Dana thermally protects the devices that power electrified vehicles, ensuring consistent operation and high performance.

Traditionally, these types of cooling systems have been made with copper. Since copper is both heavy and expensive, OEMs look to a lightweight, cost-effective alternative when possible.

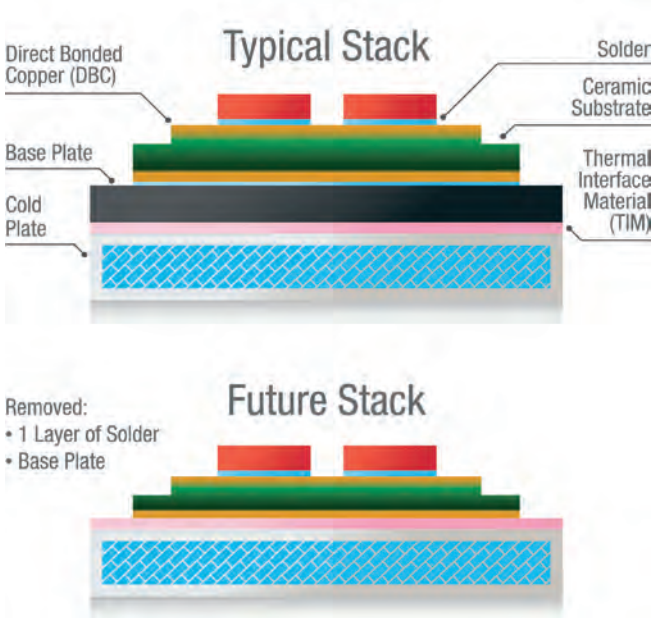
Leveraging Long's thermal management expertise, Dana is the first manufacturer to introduce a completely aluminum IGBT cooling system. Delivering reduced fuel consumption, aluminum is about 70% lighter than copper and is approximately 60% less expensive.

Dana's reliable sealing and fluxless brazing provide significant benefits. With the use of traditional flux brazing, contaminants and debris are common. Dana's proprietary fluxless continuous aluminum brazing process enables clean and precise cooling products, minimizing coolant contamination to maintain low conductivity in the power electronics cooling circuit.

Another point of difference in Dana's IGBT cooling solution is its superior flatness. Without this, the die can overheat. By reducing the contact resistance, Dana improves the heat transfer rate, which has a major impact on vehicle reliability.

Going forward, Dana will continue advancing dual-sided cooling and will explore innovations that utilize direct-bonded heat sinks. These highly integrated units will not require any thermal interface material, yielding even greater levels of efficiency.

Providing corrosion resistance and recyclability, Dana's aluminum IGBT cooling system is advancing thermal management technology to meet OEM needs. With full-scale manufacturing processes in place,



Dana's innovation provides customers with optimized cooling components to address the high-heat, high-power demands typical of electrified vehicles

Dana is an established supplier with the ability to take power electronics thermal solutions to market quickly.

Dana's IGBT technology is relied on by leading inverter and drive control manufacturers. In production now, this innovation can be custom designed in a compact, lightweight package. As the industry shifts toward fully integrated solutions, Dana's component downsizing and lightweighting efforts save critical underhood space.

"Dana enables cooling solutions that are helping the electrified vehicle industry to evolve and meet consumer expectations," explains Nick Kalman, technical business development manager, Dana Power Technologies Group. "The next generation of electrified vehicles demands sophisticated cooling solutions. With production-ready solutions such as IGBT cooling, Dana engineers discover unique methods that reduce components, while boosting efficiency."

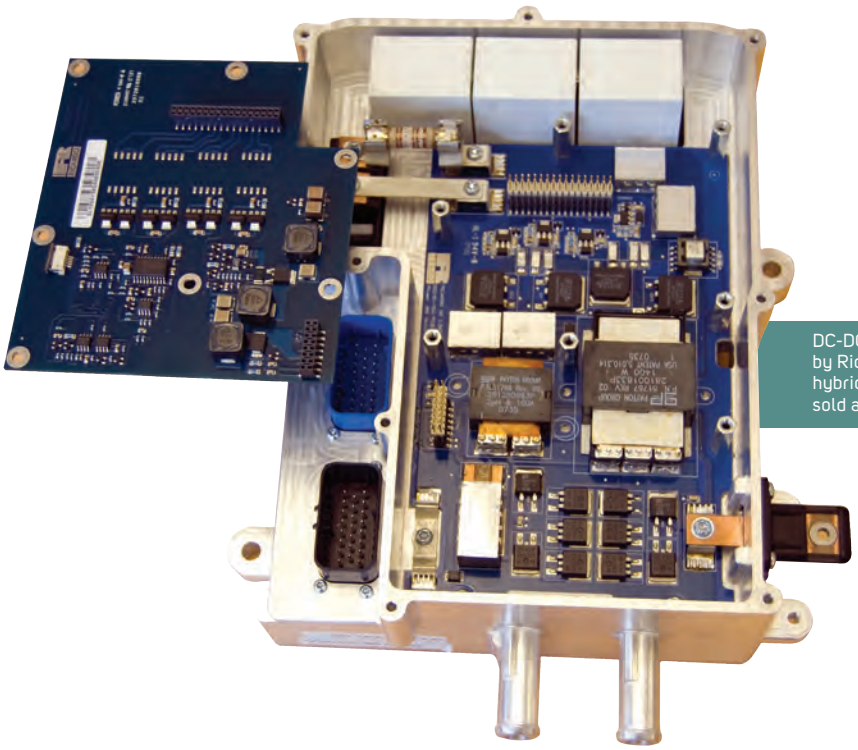
Dana has made great strides in terms of IGBT cooling technology. To reduce packaging size and improve lightweighting, Dana's engineers have devised a way to remove an entire layer of the IGBT cooling stack, which also serves to increase efficiency.

Unique innovations such as IGBT cooling technology position Dana at the forefront of the electrified vehicle industry segment. To meet this increasing market need, the company will continue to explore new ways to provide customized solutions for OEMs.

FREE READER INQUIRY SERVICE
To learn more about Dana, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 507

Semiconductor materials

New advances in semiconductor technologies are enabling designers to offer additional system benefits beyond those typical of standard power electronics



DC-DC converters developed by Ricardo are utilized in hybrid and electric vehicles sold across three continents

Power electronics are critical to the growth of the electric vehicle industry, in terms of both HEVs and BEVs. Ricardo is at the forefront of advances in technology – ranging from new ferrites for transformers and inductors used in line filters and DC-DC converters, to advances in thermal systems and high-profile development of semiconductor devices – leading a revolution in converter size.

The application of silicon as the semiconductor material of choice is here to stay, but the advances in gallium nitride (GaN) and silicon carbide (SiC) devices, and the improvement in yield from crystal growth, are making it possible for these materials to be more cost competitive in an increasing number of applications. The increase in the desired power density of converters (now looking to exceed peak capability of 25kW/l), and the desire for lighter solutions (some exceeding 11kW/kg) has provided the push to develop these technologies for real-world deployment.

The faster PWM frequency and higher dv/dt switching speeds of GaN and SiC, coupled with new advances in passive component base materials, enable considerable reduction in device size, weight and loss. A number of advances in wound components have been published and the drive for more planar technology in transformers and filters is well established, but faster switching speeds, increased power demands and the automotive desire to use film capacitors, have resulted in a need for further development. Furthermore, with sharper switching edges enabling the reduction of semiconductor switching losses, an understanding of the effect on electromagnetic radiation (and an increasingly detailed understanding of the effect on insulation layers within coupled components such as printed circuit boards, capacitors and wound components) is essential.

Through the development of GaN-based converters for passive air-cooled applications, Ricardo has experienced and risen to the challenges associated with using wide-band-gap (WBG) devices. The benefits of GaN enable high power density and high-efficiency power transfer through a galvanically isolated converter in a passively cooled aluminum enclosure. An understanding of the needs for parallel device gate drives and optimization of switching pattern enables Ricardo to design a compact and robust component with minimal in-validation failures.

Implementation of these new semiconductors, with appropriate design consideration, can provide system benefits beyond those of the power electronics converter alone. These include reduction of the load on cooling systems, more flexible design opportunities and the ability to apply higher power electronics to smaller spaces. The systems approach of vehicle design is paramount to maximizing the return on investment in WBG devices and assuring the system's behavior. For example, unexpected parasitic inductances becoming a bigger issue at higher switching speed is an ongoing area of investigation.

Multiphysics simulations are now providing an opportunity to improve pre-validation modeling, giving higher degrees of certainty of performance with a broadening of scope. This high-fidelity simulation, applicable to both silicon and WBG devices, reduces the development time, increases confidence and can produce a substantial downward trend in overall component cost.

The prevailing industry trends of cost reduction, range extension and package optimization are all met with these new devices, however care must be taken when applying them. Using advanced multiphysics design techniques enables a reduction in validation time and the time to market for new products, which requires expert engineering, adding value and deep knowledge of the whole process, from concept design through to manufacturing using high dv/dt devices.

Precision testing systems

Newly patented technology and improvements to existing equipment have led to the development of precise measurement tools that can reduce battery development cycles

Forecasting a battery's useful life requires test equipment that is capable of providing accurate current control, precise voltage measurements, fast datalogging, and stable temperature control. Arbin Instruments's new Precision series of hardware includes new technology developed from the company's successful ARPA-E project. Arbin, along with Ford and Sandia National Laboratories, successfully accomplished the goal of creating a new testing system capable of performing coulombic efficiency measurements with 50ppm precision at 200A. The new improvement in precision will dramatically reduce the development cycle for testing batteries and for evaluating new battery materials.

Derived from this project, Arbin's new Precision series incorporates much of the technology developed. Major improvements in the overall system design enable Arbin to provide precise test equipment for all applications, ranging from materials research up to grid storage testing. The addition of newly patented technology and improvements to existing equipment enables the Precision series to meet the demanding testing requirements of all energy-storage devices.

Measurement precision is more critical for long-term testing and long-term projections than accuracy alone. A number of other battery testing systems do not correctly specify (and/or have relatively poor) precision, which can hinder the conclusions that are drawn from results data. As a result, important trends and electrochemical indicators may remain unnoticed, lost in the measurement noise. Arbin's new technology provides users with 0.01% precision and 24-bit measurement resolution. Along with the ability to collect

Arbin has developed new technology, as well as improving existing equipment

2,000 data points per second with a time resolution of 100µs, the new Precision series hardware provides accurate capacity calculations to monitor long-term battery life. It is Arbin's hope that these higher degrees of measurement precision will lead to new discoveries and characterization metrics across the energy-storage industry for all organizations, not only those which are looking at coulombic efficiency as their key indicator.

As well as a number of major hardware improvements, Arbin's new Precision series equipment also provides important software advances. Additional processing power enables the new system to download complete test schedules to onboard microcontrollers for accurately timed profiles, provides customers with the ability to log large amounts of data, and download additional safety settings to ensure an even safer operating environment. Improvements to Arbin's MITS Pro Software enable flexible test scheduling, real-time control calculations using a library of over 90+ metavariables, and intuitive data analysis tools. Arbin's latest technology provides its users with a newly improved SQL database format to store large volumes of data, and provides tools that allow users to select only the data they want to export for smaller results files and faster investigation. The SQL database also provides users with an easy data backup solution for storing data over a network, and offers access to data from anywhere.

Recent collaboration with EIS system manufacturers means Arbin is able to offer turnkey, high-value solutions that offer the best of both worlds to researchers doing full- or half-cell characterization. Now, the company has combined the feature-loaded, high-precision cycling capabilities of the Arbin LBT and the high-accuracy EIS and AC Impedance scanning capabilities of Gamry. This combined solution improves the EIS unit's duty cycle by multiplexing across multiple Arbin channels, improving testing value.

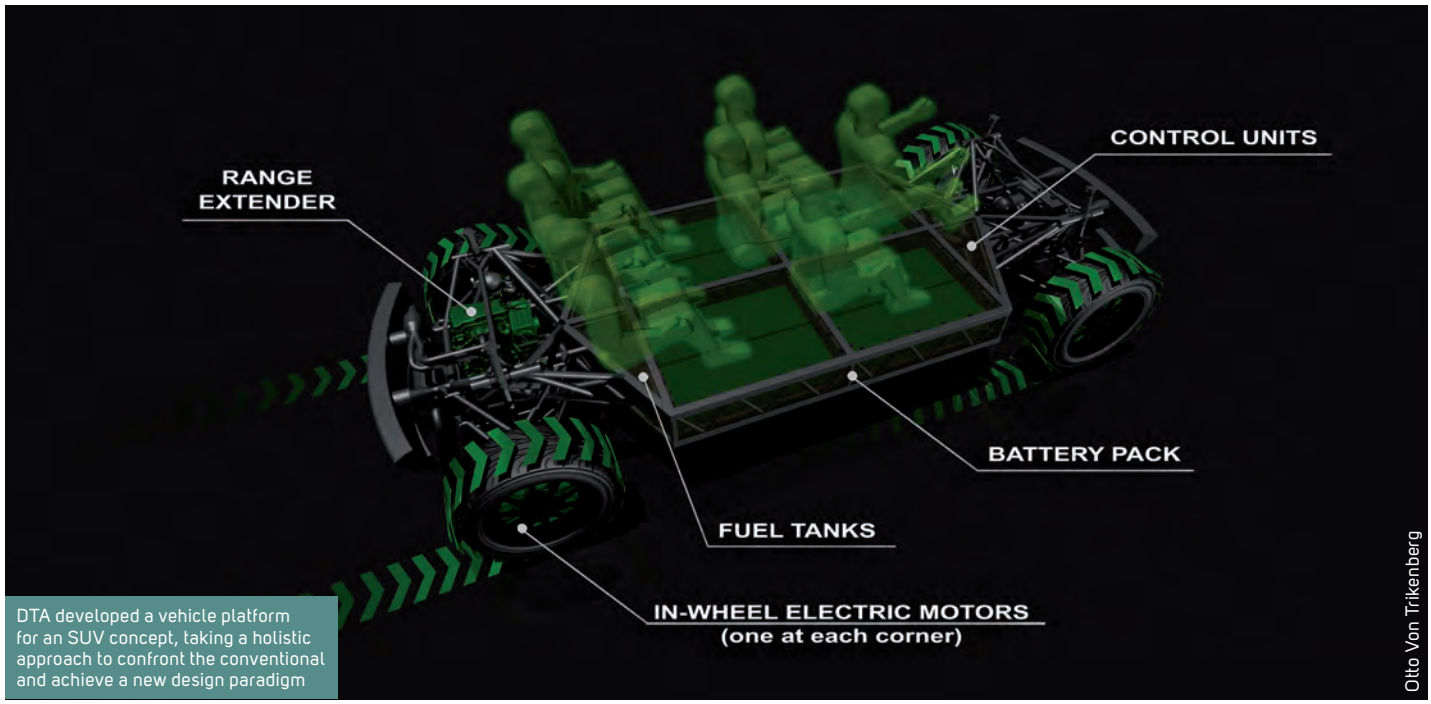
These major hardware and software improvements can be paired with Arbin's new Life Cycle Chamber, which has been designed to provide an accurate and stable temperature. Regulating cell temperature fluctuation is an important factor for accurately measuring coulombic efficiency. The Life Cycle Chamber provides an integrated solution to control the temperature of cells from 10-60°C.

Arbin Instruments understands the vital role energy storage plays in everyday life and its importance to the future. The hope is that these higher degrees of measurement precision will subsequently lead to new discoveries and characterization metrics across the energy-storage industry, and that these will be particularly impactful for the electric vehicle market.

FREE READER INQUIRY SERVICE
To learn more about Arbin Instruments, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 509

Rolling SUV platform

A revolutionary new SUV concept is said to offer a unique marriage of emerging but well-proven technologies, facilitating flexibility in superstructure designs



DTA developed a vehicle platform for an SUV concept, taking a holistic approach to confront the conventional and achieve a new design paradigm

Otto Von Trikenberg

Dynamik Technological Alliance (DTA) has introduced an innovative rolling platform as the solid base for a revolutionary luxury SUV concept. The new creation, which represents near-future vehicle architecture, features well-proven technology and is backed by a number of key industry partners.

The project's brief was simple: create a seven-seater luxury SUV of the future. In order to break the hegemony of existing SUV designs, a holistic approach was deliberately adopted. One that required foresight from the project client, addressed commercial viability, social needs and environmental concerns.

DTA's philosophy is based on the maxim that design perfection is achieved, not when there is nothing left to add, but when there is nothing to take away.

"Once you remove a conventional engine, transmissions, differentials and driveline components, it's surprising how much space you can give back to the people," says Iván Platas, technical manager at DTA.

With an in-wheel motor at each corner providing the drive, and a longer wheelbase, ample space is made available to accommodate the underfloor batteries and range extender fuel tanks.

The design involves an interesting synergy of existing and well-proven technologies, concentrating on efficiency. "We recover up to 90% of braking energy and with intelligent use of the range extender engine, an 800km range is possible," says Karl Niklass, vehicle architect. DTA is working toward an ultimate goal of a 1,000km range.

Pedro Mari Olaeta, the CEO of DTA

DTA's concept is for a plug-in serial hybrid plus range extender. The company's reasoning is that this gives the optimal marriage of existing technologies based upon their energy equation simulations. "In pursuit of the luxury SUV theme, it was felt that the quiet four-wheel electric motor drive and the vehicle's interconnected suspension system, providing a magic carpet ride, were top of the list of our requirements," adds Platas.

The vehicle has a 300mm range in ride height available, with minimal camber change due to the design's ingenious double wishbone suspension. The wheel loads are kept constant regardless of the terrain. "We are able to steer all four wheels while controlling the torque to each," continues vehicle architect Niklass. "That, coupled with an underbody absent of any driveline components, gives it unprecedented off-road capabilities."

The DTA REEV chassis platform is intended to spawn a myriad of alternative superstructure designs and possibilities. The increased passenger space facilitates several autonomous layouts and provides increased passenger safety. "This exciting and challenging project proves the technical capacity of DTA," explains CEO Pedro Mari Olaeta, "and also opens up future business opportunities."

FREE READER INQUIRY SERVICE
To learn more about Dynamik Technological Alliance, visit:
www.ukipme.com/info/ev
INQUIRY NO. 510

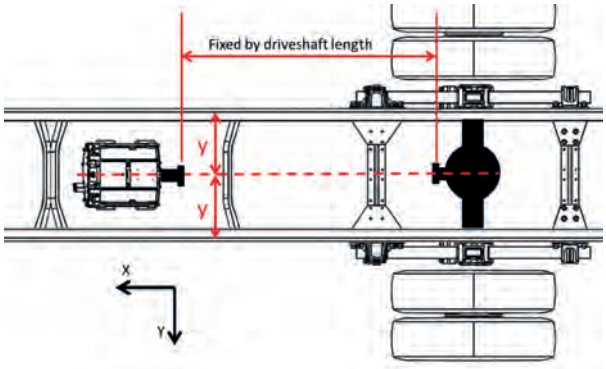
Direct-drive motors

The elimination of the transmission from commercial EVs, in favor of direct-drive technology, can improve efficiency, reliability and installation, reduce maintenance and maximize ROI

The Sumo line of direct-drive electric powertrains, offered by TM4 for the bus and commercial vehicle markets, are high-torque permanent magnet motors that are designed to interface directly with a standard rear differential, without the need for an intermediate gearbox. This design offers a range of key advantages, such as higher efficiency and reliability, ease of installation, lower maintenance and faster ROI.

The vehicle transmission can be responsible for approximately 5-10% of energy losses inside a powertrain as a result of mechanical friction. Considering that the battery pack remains the most expensive and important component inside an electric vehicle, making the most of the available energy is critical. Multispeed gearboxes can, in some situations, be part of the solution when it comes to increasing the efficiency of a vehicle's powertrain. This is especially true for traditional gasoline cars, but is also the case for electric powertrains using AC induction motors. Although the peak efficiency of these motors can be as high as that of permanent magnet motors, it can only be attained in a small speed range – outside of this, efficiency falls quickly. TM4's permanent magnet and reluctance-assisted PMAC motors not only have high peak efficiency, but also maintain a >94% efficiency over the majority of the operating range, which surpasses any potential efficiency gain that could be achieved with a transmission.

Most bus and truck OEMs are unwilling to make major changes to their vehicles or production lines for the purpose of incorporating a new powertrain. The TM4 Sumo motor and power electronic components easily fit within the H-beam of a truck or in the engine bay of a city bus, keeping the same type of driveshaft arrangement. A direct-drive single motor is easier to install and integrate with the existing bus and truck axles available today.

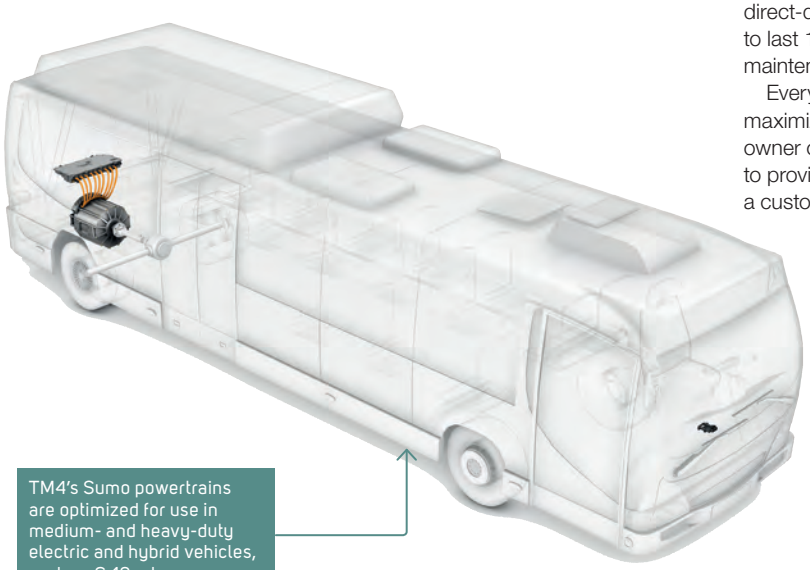


A schematic demonstrating the typical layout of a truck or high-floor bus chassis

One way to maximize reliability is to minimize the number of parts within a drive system. Removing the gearbox means removing the most mechanically complex and maintenance-intensive part of an electric vehicle. With a direct-drive motor connected to the axle, the only mechanical wear taking place in the powertrain is to the driveshaft bearing and the axle itself. Both these components are designed to last the lifespan of the vehicle. TM4 direct-drive motors are designed to last 1,000,000km without any maintenance being required.

Everything comes down to maximizing the ROI for the vehicle owner or fleet operator. TM4 aims to provide the best torque density a customer can get for their money (both in terms of initial investment and long-term expense), while also maximizing system efficiency, which can also be translated into cost savings. To that end, a simple powertrain architecture that is based on direct-drive motors offers the best compromise. TM4 has not only validated this hypothesis theoretically during the design of the Sumo product line, but has proven it through the tens of millions of on-road kilometers achieved by buses and trucks using these products since their 2012 launch.

TM4 is currently supplying its powertrains to a number of OEMs and technical centers in North America, Europe and Asia. Production takes place at TM4's Canadian facilities in Boucherville and at its Chinese joint venture, Prestolite E-Propulsion Systems in Beijing. Both are equipped with high-volume, flexible, automated production lines, and a large range of dynamometers and test cells, making it possible to conduct full validation and certification of electric and hybrid powertrains.



TM4's Sumo powertrains are optimized for use in medium- and heavy-duty electric and hybrid vehicles, such as 6-18m buses

FREE READER INQUIRY SERVICE
To learn more about TM4, visit:
www.ukipme.com/info/ev
INQUIRY NO. 511

E-drive goes wireless

A unique project has seen the delivery of what is claimed to be an industry first – a downsized e-drive for small car hybridization with no bulky cabling

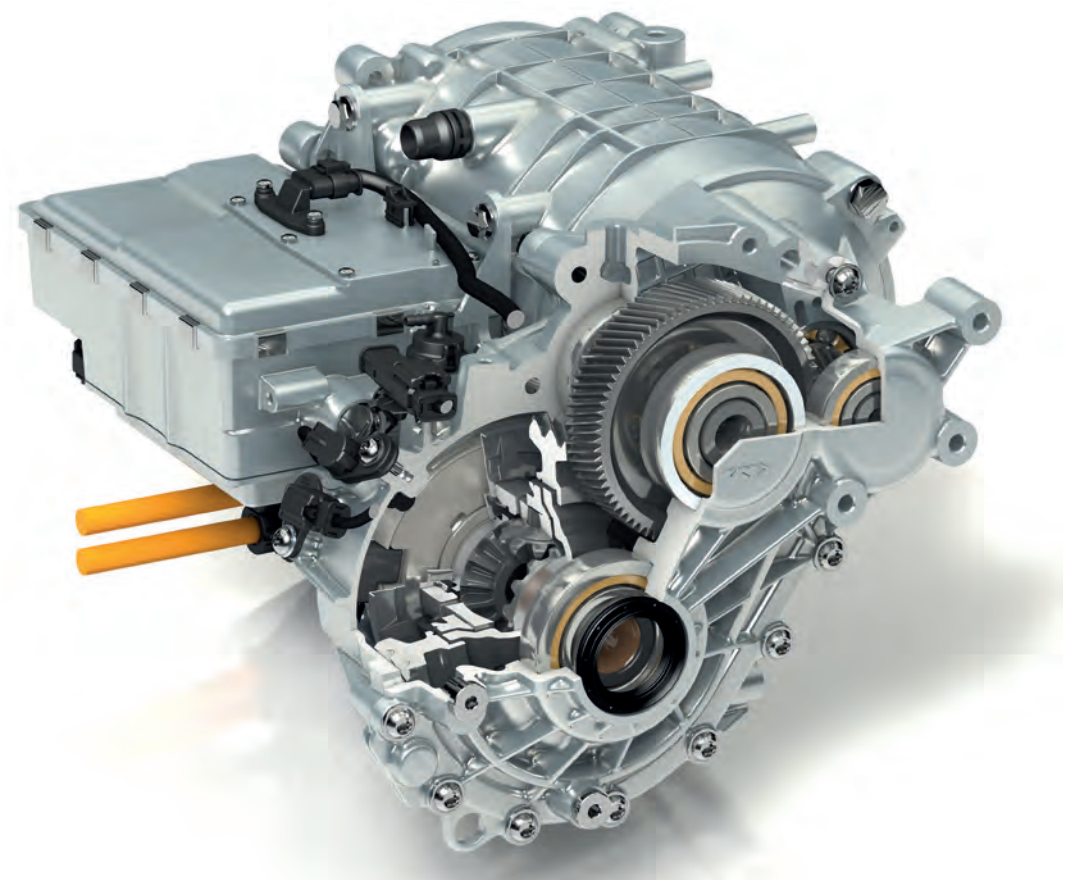
Future vehicle models need to offer plug-in hybrids as an integral part of the range, and driveline strategies are changing. For small car platforms in particular, the focus is now on electric drivelines that are highly integrated, making the e-motor and electric axle (e-axle) reduction gearbox much simpler to package and assemble.

Following a series of high-profile hybridization programs for Porsche, BMW, Volvo and Mitsubishi, GKN Driveline is continuing to make e-drive and electric all-wheel drive (AWD) more mainstream. The latest development is a highly integrated system that will provide the electric drive to a global car platform when it starts production in 2019.

While many competitor systems essentially connect standard motors, inverter and reduction gearboxes, GKN's compact module integrates the three into a single unit. This approach not only makes packaging and production simpler, it also helps improve system efficiency.

"All of GKN Driveline's decades of driveline integration experience with all-wheel-drive systems, as well as our long-term investment in e-axles, go into delivering an e-drive system this compact," says Peter Moelgg, chief executive of GKN Driveline's e-drive and AWD business. "Our technologies make offering plug-in hybrids to consumers simpler. GKN engineers are helping more and more auto makers turn electric propulsion into exciting new hybrid all-wheel-drive experiences."

The new module integrates a water-cooled electric motor and inverter with a single speed e-axle reduction gearbox. The all-in-one e-drive system even replaces external wiring with a bus bar to eliminate unnecessary mechanical interfaces – an industry first. The result is an e-drive system with higher power density that is simpler to install.



GKN Driveline's new highly integrated and compact e-drive module simplifies hybridization for small car platforms

The new system generates a maximum 65kW of power and can deliver up to 2,000Nm of torque to the rear wheels. The complete e-drive module is only 300mm high and 325mm wide and weighs just 54kg, making it approximately 20mm narrower and 2.5kg lighter than comparable systems.

"Auto makers increasingly want complete e-drive systems from suppliers, rather than sourcing the different elements from different companies," explains Moelgg. "Having experienced, specialist development partners support the program frees in-house teams to focus on other challenges."

GKN Driveline's systems expertise ensures that, despite significant differences in the acoustic signatures of the inverter, motor and gearbox, the overall system delivers an extremely smooth, near-silent electric driving experience.

The company has been advancing the development of e-axle technology since 2002 and has produced more than 300,000 units at its manufacturing facilities, which are located in Europe and Japan. Awarded official Porsche technology partner status for its contribution to the plug-in hybrid Porsche 918 Spyder program, GKN has also launched what is claimed to be the world's first 2-speed e-axle in the plug-in hybrid BMW i8. The company supplies the e-axle on the Volvo XC90 T8 Twin engine PHEV program, too.

FREE READER INQUIRY SERVICE
To learn more about GKN Driveline, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 512

Battery module connectors

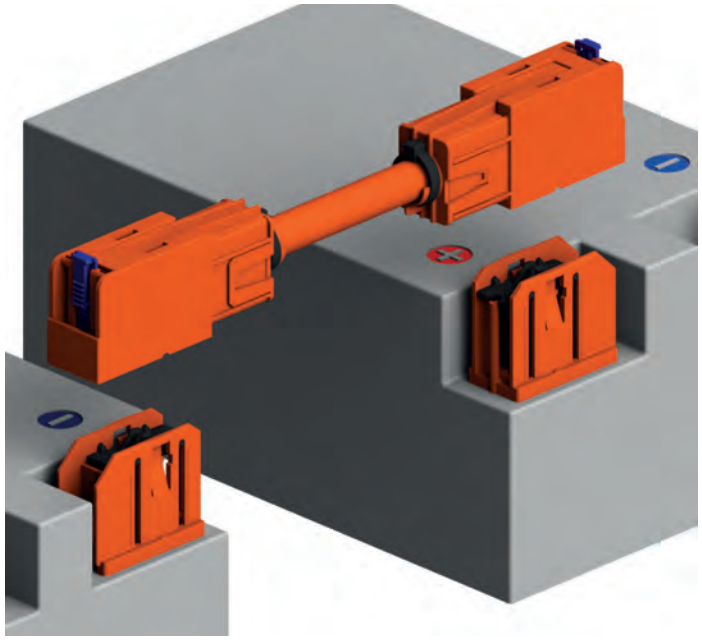
Connection technology for automotive high-voltage battery applications can deliver high levels of performance, and is flexible enough to suit a wide range of system uses

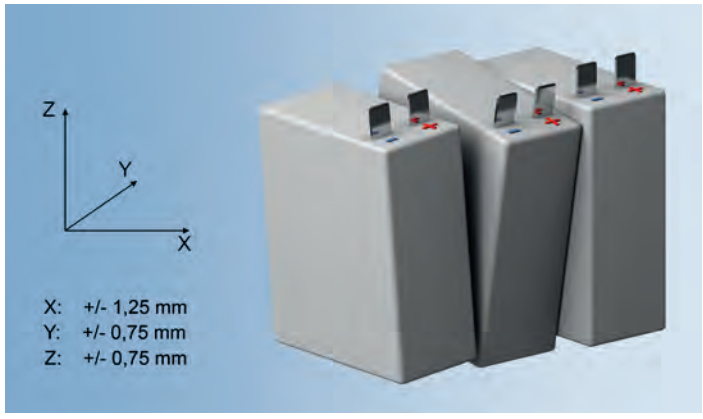
A member of the Kostal Group, Kostal Kontakt Systeme specializes in the development, manufacture and sale of electromechanical components, with an emphasis on connectors. It deals mainly with application-specific products for the automotive industry. For its customers, the added value arises from the company's systems expertise, supported by the wide range of technologies within the Kostal Group.

Kostal Kontakt Systeme has gained extensive experience in the development and production of connection technology for use in the electric and hybrid vehicles produced by leading international automotive manufacturers.

Having developed a wealth of connector system expertise for the first generation of high-voltage batteries, Kostal Kontakt Systeme will start production of its series of optimized and smaller housing families for new high-voltage battery module connection systems. The basis for this development is the PLK 14,5 contact system that can handle copper and aluminum cables, which can be ultrasonically welded or crimped in a cross-section range from 16-70mm².

Kostal Kontakt Systeme has extensive battery connection system experience





Left: High-voltage connections can be tailored to suit the requirements of a wide range of automotive applications

Left, below: Module tolerances for the Kostal Kontakt Systeme products

Kostal Kontakt Systeme's 14,5 x 1,8mm blade connector is integrated into the unit with touch protection. In addition, the company provides a standardized and assembly-friendly connection system. The overall design allows a continuous current up to 250A in uncooled conditions. In DC quick-charge mode, currents from 350-400A can be realized over a period of 10 to 20 minutes. With additional cooling these currents can be considerably increased.

The requirements for every application can be met due to the associated housings, resulting in a patent-registered cost-effective cable-free connection system or a cable connection, mountable at either 90° or 180°.

Thanks to the uniformity of the tab-header design, both versions of the connector can be plugged in. The modular concept solution can flexibly cover the grid dimensions of two plugs from 35-120mm. Cable connections are recommended starting from 120mm.

All housings are easy to install without the need to use any tools. Therefore, they can also be easily unmated and mated in the event of service requirements.

An important advantage of module connectors is compensation for the tolerances in the individual arrangement of battery modules. Existing nut-and-bolt solutions are suitable up to a limited extension tolerance. The module connector ensures an optimal alignment and space-saving configuration for the entire battery system.

"This new technology has been successfully created and designed based on customer needs out of the battery manufacturer segment," explains Dirk Kloske, the product marketing manager at Power and Signal Group, Kostal Kontakt Systeme's distribution partner.

Due to the specific requirements of high-voltage batteries, Kostal Kontakt Systeme, or Power and Signal Group, should be consulted for every implementation.

FREE READER INQUIRY SERVICE
To learn more about Power and Signal Group, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 513

Specialist power solutions

Experience in the automotive connector industry makes a UK distributor ideally suited to provide customers with support for hybrid and electric vehicle applications

In the continuously evolving hybrid and electric vehicle industry, TE Connectivity (TE) has established a global reputation for innovation through collaboration, creating high-quality systems and components for the efficient, reliable and safe distribution of power, both in-vehicle and at the roadside.

Dalroad has worked in the UK's automotive connector business for more than 20 years, and is a TE-authorized distributor, providing the experience, knowledge and commitment to provide customers with skilled design-in, technical, sales and aftersales support.

With the promise of many new, exciting high-performance products due to arrive in 2017, current TE hybrid and EV components available off-the-shelf from Dalroad include connectors, relays, harnesses, contactors and disconnects.

Conforming to the certification requirements of major world markets and proven to withstand up to 10,000 mating cycles, the TE AMP+ charging coupler cable assembly Type 2 comes in a range of colors and labels to suit customers' needs.

The TE AMP+ modular charging inlet Type 2 (EU version) is certified to IEC 62196-1 and IEC 62196-2. This ergonomic and flexible modular system can be configured to suit different package spaces and positions across a multitude of applications. Options include a connector locking device and 90° wire exit.

TE's AMP+ HVA 280 connector/header system is a finger-proof, touch-safe low-medium connector/header system. With over 3,000 combinations, multiple latching options and an integrated HVIL, the system provides optimum flexibility for device and wire harness applications such as battery pack, DC/DC converter, onboard charger, electric header and high-voltage power distribution.

Designed to AK 4.3.3, LV215-1 specifications, the TE AMP+ HVA 630 is a two-position low-medium current connector and header system. It is finger-proof, touch-safe and features internal HVIL for advanced shielding performance.

The TE AMP+ HVP 800 high-current connector/header system is touch-proof and watertight, and features integral HVIL and EMI shielding. The system is designed to safely deliver high currents and voltages from the battery to the inverter and e-motor. Featuring wide wire and temperature ranges, plus multiple keying options, systems are available in two- or three-position with either 90° or 180° lever-assist (low insertion force) plugs.

Designed for harsh environments with screwed aggregate connections to withstand high levels of vibration, the super-tough AMP+ IPT shielded ring tongue is available in ratings up to 500A/1,000V. Applications include e-motors, inverters or batteries for hybrid and EVs.

The TE AMP+ HVP 1100 high-current connector/header system is finger-proof, touch-safe and has built-in HVIL. The one-position, high-current system has a common header footprint to accept 90° or 180° plugs. The system is designed for flexibility with a wide range of options for hybrid and electric vehicle device applications.

TE high-voltage DC relays and EVC contactors provide reliable and resilient battery switching and backup, power control, and circuit protection in hybrid and electric vehicles. Mini K HV pre-charge relays support the connection and disconnection of the traction battery in switching assemblies – even under fault conditions – while EVC 135, EVC 250 and EVC 500 main contactors provide rapid switching of the high-voltage battery to the vehicle system.

Dalroad is an authorized distributor of TE Connectivity's range of systems and components for safe, efficient power distribution

TE AMP+ high-power disconnect solutions prevent the battery pack HV cables from short-circuiting and also provide protection for the technicians and emergency response teams working with high-voltage electric vehicles.

FREE READER INQUIRY SERVICE
To learn more about Dalroad, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 514

Electric camshaft phasing

A compact electromechanical camshaft phasing unit can adjust quickly and accurately to the operating conditions of a vehicle's engine, independently of the oil volume flow

The development of energy-efficient drive concepts will become increasingly important in the future. Continuous increases in efficiency and high levels of electrification will define the technological path of the drive architecture. The ICE will therefore have an important part to play in the future of the overall efficiency of the drivetrain. One of the main approaches is to replace hydraulic systems with electromechanical systems. A key element here is the electromechanical camshaft phasing unit, which adjusts the camshaft more quickly and accurately to the engine's current operating conditions. A further advantage is that electromechanical camshaft phasing units can operate independently of the oil supply.

Complete independence from the oil volume flow can be achieved with the use of electromechanical camshaft phasing units. As a result of this technology, it is possible to adjust the camshaft timing before the engine is started or, alternatively, during starting before the first firing event. This capability is of special importance for electrified drivetrains, particularly where these allow for a coasting function that decouples the engine from the drivetrain during travel and shuts the engine down. Having started volume production in 2015, Schaeffler is the first European supplier to manufacture an electromechanical camshaft phasing unit in large volumes.

One of the development's primary requirements was for a compact design that permits the engine manufacturer to pursue a modular component strategy. The electric camshaft phasing unit must fit within the same design envelope as a hydraulic system. The decisive factor in achieving a compact design is matching the size of the electric motor to the transmission ratio of the gearbox.

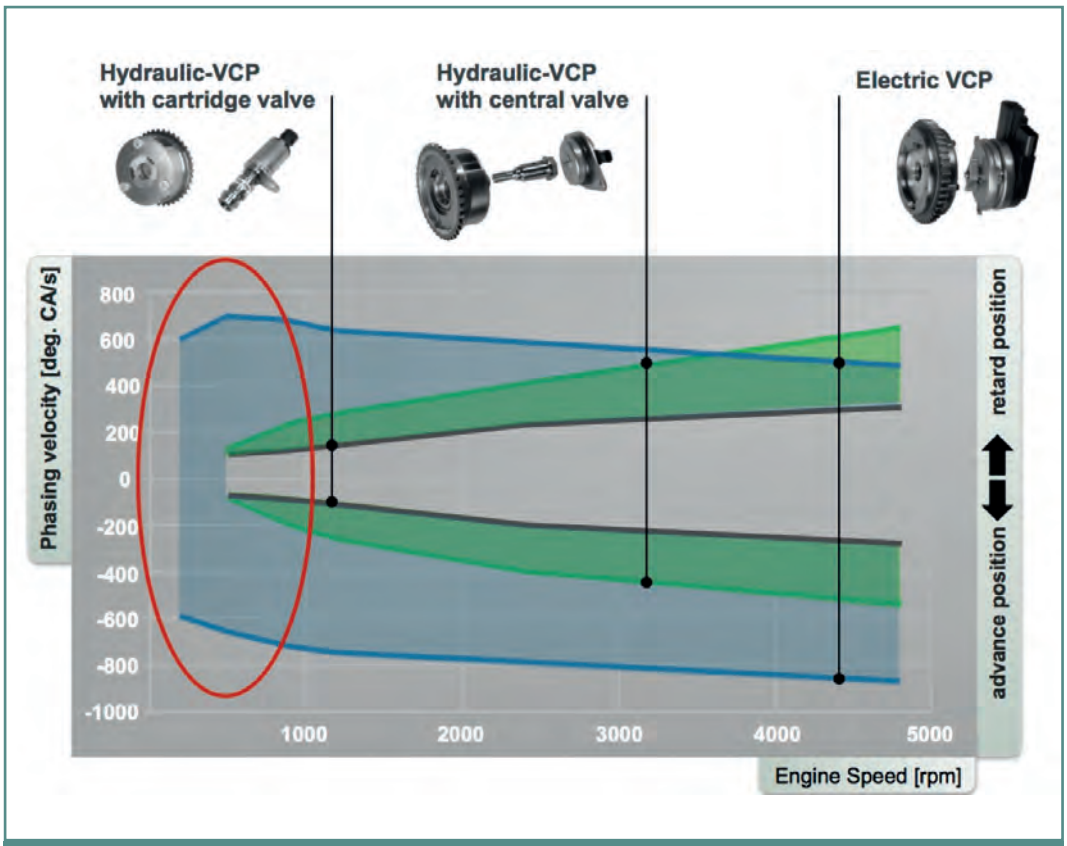


Figure 1: a representation of the shifting speeds of various camshaft adjustment systems as a function of engine speed

Schaeffler uses the combination of a compact brushless direct-current motor with a gearbox that was specifically developed in-house for the electric camshaft phasing unit that gives a high transmission ratio of 1:66.

One notable component of the current volume-produced system is a separate control unit that drives and controls the electric motor of the camshaft phasing system. Positioned in a suitable mounting location within the vehicle engine compartment, this component is adequately protected and operation is therefore not affected by the high operating temperatures of the ICE. As an alternative to a separate controller, the controller functions can also be fully integrated into the engine control unit.

The primary advantage of the electromechanical phasing system is that it is capable of extremely high adjustment speeds irrespective of the oil temperature and speed, as shown in Figure 1.

Schaeffler has demonstrated that this rapid adjustment is also possible during engine starting events by conducting engine tests. It is possible to shift the camshaft by 80° of crankshaft rotation in approximately 300ms – and thus before the first firing event of the vehicle's IC engine. Perhaps even more impressively, the system first moves to the end stop position for initialization purposes and then makes the actual phase adjustment as demanded by the drivetrain's engine control unit within this 300ms start sequence.

FREE READER INQUIRY SERVICE
To learn more about Schaeffler, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 515

Increases in vehicle range

Common perception is that an electric motor does not need a transmission, however this overlooks the efficiency and performance improvements possible, particularly with a CVT

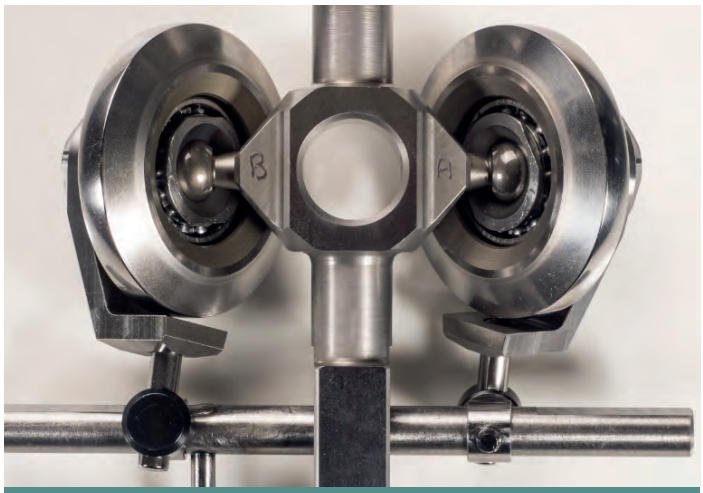
To increase EV sales, the industry must close the gap with fossil-fueled vehicles in terms of range, performance and cost. According to John Fuller, director of concepts and IP for Torotrak Group, all these factors can be improved by incorporating an appropriate transmission in combination with the traction motor.

The challenges of incorporating a transmission into an EV include torque interruption during gear shifting, and driveline refinement. Occupants of EVs are particularly sensitive to both these issues because the available low speed torque is often very high and the ambient cabin noise levels very low. Autonomous driving, increasingly on OEMs' roadmaps, will require a smooth driving experience as a 'passive' driver will not expect or accept torque interrupts. The toroidal CVT also overcomes torque interruption by providing seamless power delivery during ratio shifting.

"There is an inherent mismatch between the rotational speed and effort at a vehicle's road wheels and the ideal operating speed of an electric motor," explains Fuller. "Although an electric motor generates maximum torque from zero RPM, the efficiency is poor at such low speed. Much of the time, the motor in a typical EV is operating below its optimal efficiency. The motor efficiency could be increased considerably with a suitable transmission, and the benefit taken as increased vehicle range. A second option is to multiply up the maximum available motor torque at low vehicle speed in order to increase acceleration performance and gradeability. As a third option, increased maximum vehicle speed is also possible by offering an increased over-drive ratio, which is attractive in EVs whose top speed is often limited by need for 'short' fixed ratio gearing to achieve acceptable wheel torque at low vehicle speed. The CVT opens up all of these possibilities to the OEM."

Fuller believes a high-efficiency toroidal CVT using Torotrak's variator technology offers many advantages. "By increasing the wheel torque at low vehicle speeds, a toroidal CVT can improve gradeability and performance, or be an enabler for a downsized electric powertrain that is lower in cost and weight," he says. "With the CVT configured to achieve efficiencies over 95%, there is also the potential to increase EV range."

The discs and rollers in Torotrak Group's toroidal traction drive, which offer ultra-quiet operation and seamless shifting



A toroidal CVT transmission with variator technology offers many advantages

An EV transmission may only require a ratio range of between 2 and 4, but the wide ratio spread of the variator – up to 12 – enables highly efficient 'power splitting' whereby only a fraction of the motive power is transferred by the variator, the remainder being transmitted by a direct mechanical path. This enables vehicle efficiency to be improved in various ways: firstly, by reducing the amount of energy dissipation when pulling away from stationary and, secondly, by enabling the motor to run at optimum efficiency when cruising.

"By improving hill climbing and pull-away performance, a CVT can increase the load-carrying capacity of an electric delivery vehicle without resorting to a large and expensive motor," says Fuller. "The higher ratios in the transmission can then be specified to provide more efficient and extended high-speed cruising, enabling EVs to mix more easily with other vehicles on highways."

The traction drive variator in the Torotrak CVT operates in almost complete silence, avoiding the NVH challenges that are typical of geared transmissions, because power is transmitted between discs and rollers via a traction fluid.

Unlike more conventional CVT technology, the Torotrak system can be readily applied to both front- and rear-drive platforms thanks to its high torque capability and extremely compact package. A version has already been demonstrated with power capacity in excess of 300kW.

To help minimize the cost of the toroidal CVT, Torotrak drew on experience that was gained with variable speed transmissions for accessory drives which are highly cost-sensitive, as Fuller explains: "We developed a low-cost actuation system for ratio control called PitchSteer that uses a simple 10W linear actuator in place of hydraulics. Once the variator ratio has been adjusted, the power requirement drops almost to zero."

Smart transducer setup

A new smartphone app saves time by automating the process of placing and integrating each test transducer into the analysis software using sensors from any manufacturer

Setting up a noise or vibration test can take a long time – far longer than the measurement itself. The person setting up must place each transducer, record its position and orientation, trace the cable to the data acquisition hardware, then manually type the data into the right fields in the software – for every transducer. Not only is this process time-consuming, it is also complex and repetitive. This makes it prone to human errors, such as assigning the wrong transducer to the wrong channel, or incorrectly entering an accelerometer's alignment. Added together, small errors like these can waste days.

A new concept from Brüel & Kjær simplifies and automates this process, speeding it up while also reducing errors. The Transducer Smart Setup concept is centered around a smartphone app that allows testers to simply scan a data matrix code on the side of the transducer. The app retrieves the transducer's identity and calibration information from the data matrix. For accelerometer measurements, scanning the data matrix code also gives the essential DOF alignment. The app works with transducers without data matrix codes.

Once the tester has cataloged all of the transducers on a test object, the complete setup is then uploaded to the cloud, directly from the smartphone. The setup is then retrieved from the cloud by the PULSE Reflex analysis software platform. Here, the transducers are all automatically recognized and have the necessary information automatically assigned to them. This avoids considerable time spent on manual inputs: with a modal test using 40 accelerometers, this can save hours. Critically, the shortcut through the cloud removes the importance of knowing which transducer's cable goes into which port. Testers can even unplug the cables and plug them back into a different port, and the software figures out which one goes where – no need to trace one cable through the spaghetti-like mass.

Scanning the data matrix code gives transducer orientation and identity, which is then tagged and integrated into the software

But what about transducers without data matrix codes, like older Brüel & Kjær transducers or those from other manufacturers? Instead of recognizing a transducer from the data matrix code, the tester scrolls through the options to select it from a list, within the app, and then adds alignment information (for accelerometers) by rotating an interactive diagram until visually matching it to the accelerometer.

As well as making ad hoc testing setups simpler, the smart setup concept also helps with planned tests. Prior to the placement and integration of the transducers, the tester pre-defines the test in PULSE Reflex. Transducers without data matrix codes are normally added at this stage as well, but only once – the software then remembers them forever. With the test setup defined in PULSE Reflex, instead of writing down the test setup and then setting up manually, the tester simply uploads the setup into the cloud – from where the smartphone app then retrieves it.

So when it comes to the messy business of setting up, for example, a microphone by the left front wheel, the tester simply scrolls through the smartphone app and selects that location from a list of options. It does not matter which transducer is used at which location; they are only paired when the tester sets up that particular transducer, and not before. This automated matching between transducer and software removes opportunities for errors to creep in during the setup process by automating as much as possible and limiting the choices of anything that can't be automated.

Overall, time is shaved off transducer setup procedures by reducing manual input tasks. For large, planned tests, the setup tasks that remain are moved to earlier in the workflow, back to when the test setup is defined. Here, a single test engineer can perform more of the test definition on a single PC running PULSE Reflex, before even touching the test object. And once the test object becomes available, the team needs far less time with it before the testing begins.

Optimizing transmissions

As development of EVs and HEVs continues, CAE design, analysis and simulation are key to ensuring complex transmission systems meet the automotive industry's requirements

For a long time, CAE software has played a vital role in an engineer's ability to achieve levels of innovation beyond those obtainable through manufacturing and testing prototype systems. Requirements are significantly increasing year on year, and CAE software has had to keep up with the demands presented by the automotive sector.

The challenges facing today's automotive transmission engineers include ever-rising expectations of the performance and characteristics of complex modern transmissions, where electric and hybrid are fast becoming king.

As the noise that combustion engines generate is eliminated by electric drive modes, the vehicle driveline's contribution to overall noise is an increasingly significant factor. The tell-tale high-pitch whine of a vehicle's transmission is a common characteristic of EVs and hybrids during electric drive modes and has become an issue across the industry.

Software such as SMT's MASTA can considerably reduce the time it takes to design and analyze these advanced transmission systems. Engineers are able to predict key performance characteristics and identify the root cause of failures or weaknesses at the design phase of the development cycle.

MASTA's detailed gear geometry analysis features enable a user to quickly generate virtual contact patches, simulate transmission error and perform advanced durability analysis such as predicting tooth interior fatigue fracture, and much more. Most importantly in terms of gear whine, NVH analysis can be performed to identify audible frequencies and the sources of excitation in a full driveline system.

Furthermore, with finite element analysis (FEA) features, casing meshes can be imported and analyzed to minimize resonance and response to frequencies generated by the components of the internal gearbox.

SMT's MASTA software program can significantly reduce the time needed to design and analyze advanced transmission systems

These noise characteristics were traditionally picked up during the project's physical prototype phase and analyzed under rig and test track conditions. The cost and time associated with this has led engineers to use FEA packages to help deduce the sources of excitations and frequencies by looking at individual components. Performing FEA in this manner doesn't take into account the full system and the nature of multiple components acting on one another. This is where a full system analysis CAE package such as MASTA can save a substantial number of man hours, enabling a user to analyze components such as gearsets, bearings and electric motor excitations in the context of the components around them.

Another prominent feature is MASTA's parametric study tool. This enables the user to calculate an array of multidimensional results by providing a simple parameter input range. An example would be performing a Monte Carlo study to simulate manufacturing tolerances on a system's microgeometry and see how these variances would impact transmission error.

Complex, flexible multibody dynamic analysis has also posed a challenge for automotive engineers. A series of CAE modules called Driva can simulate dynamic events within the time domain, for example, allowing hybrid vehicle engineers to simulate the switchover between the combustion engine and the electric motor, which could result in unwanted excitation that is felt through the gearbox.

With the sustained push toward electric and hybrid vehicles and an increasing trend toward fully integrated systems such as hub drives, CAE design, analysis and optimization will continue to play an integral role in the transmission innovations of tomorrow.

Integrating simulation

Linking the modeling of different vehicle systems is key to the successful development of next-generation electric and hybrid-electric powertrains

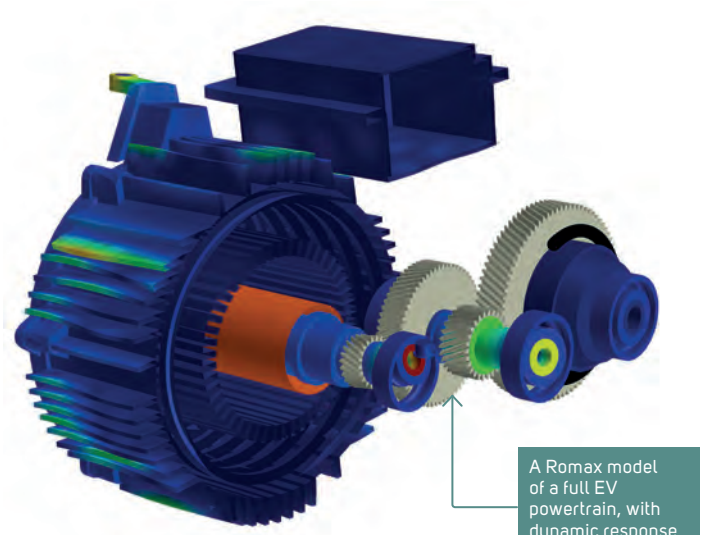
The automotive industry is now into its second century, and for much of that time it has supplied vehicles with an ICE as the prime mover and a gearbox to match engine and vehicle speeds. Operational efficiency drove vehicle manufacturers to set up specialist departments to develop subsystems, which are then assembled into the vehicle. Processes and tools were equally specialized and segmented.

Romax Technology has grown up within this industry paradigm. The company's software package, RomaxDesigner, was the first to simulate the whole gearbox system in terms of engineering performance, accounting for the interactions between all the components. Since its introduction, OEMs have consistently reported productivity improvements of 80-90% compared with previous methods.

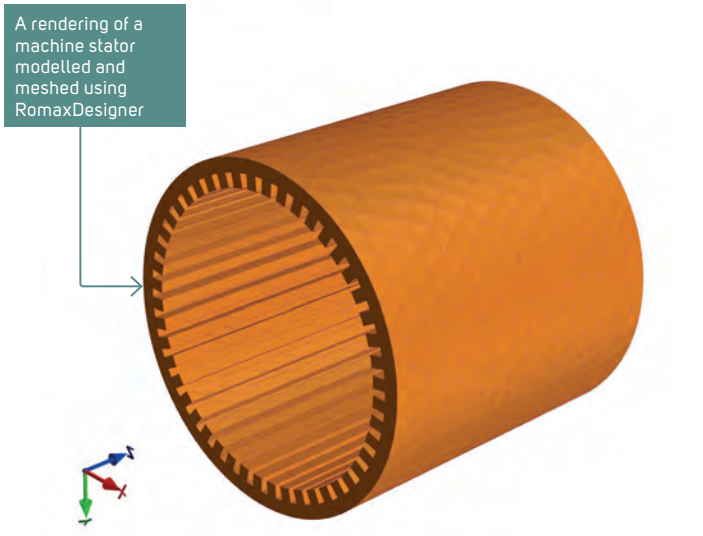
However, times change. The car of the future will rely to some degree on electrical motive power, and the demands of power density and packaging mean that there will be close integration between the different functional systems – power transmission, combustion power, electrical power, and others.

In anticipation of this trend, several years ago Romax set out to build links to other systems. Engine-gearbox interactions have been demonstrated in links with AVL Excite, and recent work for Ford linked Romax with GT-Suite and ADAMS for full engine-gearbox-vehicle interactions.

One area of particular interest is the interaction between the electric machine and the gearbox, in either EVs or HEVs. The habitual approach is for a vehicle company to develop subsystems separately and then assemble them within the vehicle. However, this approach can often prove to be unsatisfactory. Various interactions take place between the machine and gearbox, yet are not accounted for in traditional design processes and tools deployed for the separate subsystems. As a result, when the prototype vehicle is tested, unacceptable performance is experienced in terms of thermal behavior, efficiency, or noise and vibration. To a large extent, the CAE process, intended to avoid failure modes and optimize performance, has failed.



A Romax model of a full EV powertrain, with dynamic response to torque ripple



A rendering of a machine stator modelled and meshed using RomaxDesigner

In collaboration with leading universities, software vendors and OEMs, RomaxDesigner has been extended beyond the gearbox to include models of the electric machine that are analyzed within the same environment as the gearbox, fully accounting for interactions between the two.

The latest RomaxDesigner release enables the stator to be modeled and meshed directly, mounted within the powertrain model and subject to dynamic excitation. Romax's electrification team has substantial experience in the use of the machine simulation tools for standalone electromagnetic simulation – Maxwell, Flux, Opera, JMag, and others – and data from these tools can be imported and used directly in dynamic simulation of the powertrain.

The electrification team studies further aspects in its commercial design and simulation projects. Analytical models of the machine are created for efficiency and allow trade-off studies to be carried out during the concept design stage, sometimes including thousands of potential variants. Thermal models study the flow of heat from the machine to the gearbox, including innovative integrated cooling/lubrication systems. Details of the motor control can be combined with the driveline dynamics to facilitate smooth vehicle launch.

Challenges still remain, however. "Our clients wish to develop low-carbon powertrains and yet when we visit them we find that the gearbox and motor teams are in separate buildings, with no agreed processes or tools," says Romax CTO Barry James. However, the direction of travel is clear – the next generation of Romax tools look set to revolutionize working methods in the same way as the last.

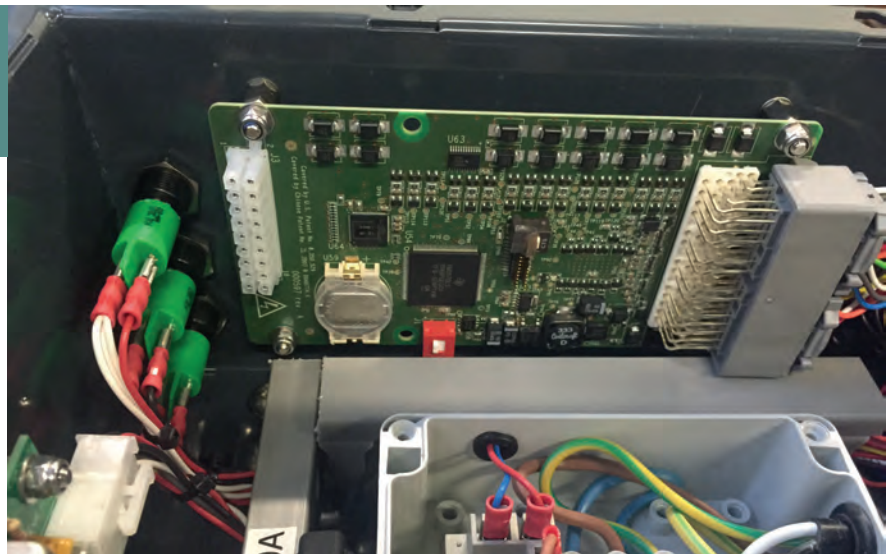
Integrated circuits for BMS

A new battery-monitoring application-specific integrated circuit (ASIC) supports up to 16 cells, offering an ideal, standardized solution suitable for use in all 48V battery systems

Battery management systems play a fundamental role in optimizing lithium-ion batteries in terms of endurance, performance and reliability, and represent up to 15% of the battery cost. The cost of battery management systems will decrease only when standardized solutions start to become available, thus allowing for economies of scale.

The new integrated circuit for battery voltage and temperature monitoring from Lithium Balance represents such a standardization, as it reduces the high component count and overall price of battery management systems through the use of ASIC technology. The solution leverages the incorporation of premium technologies in higher-volume (lower-cost) products. The specification of the battery management ASIC has been performed by Lithium Balance in close cooperation with leading automotive manufacturers located in Europe and North America.

The main innovation behind this design is the ability to monitor up to 16 battery cells per ASIC – ranging from 0-5V per cell to a maximum of 80V for all 16 cells (it is also possible to support the maximum voltage of 16 cobalt-based lithium-ion cells). Up to 24 temperature sensors are also monitored by the ASIC, which is fully compliant with ISO 26262 (Functional Safety – Road Vehicles) at ASIL C-level.



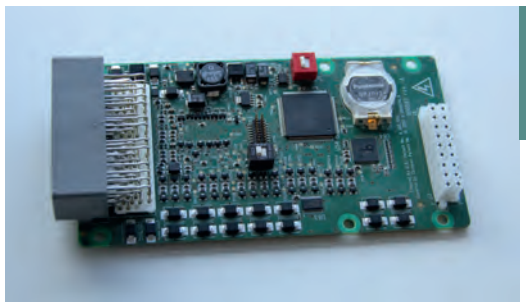
A new integrated circuit from Lithium Balance can reduce high component count and lower overall BMS cost

The new Lithium Balance battery management ASIC implements the required cell voltage and temperature monitoring functions on the slave modules in modular battery management systems. The slave board is either accessed directly from the master module using a serial peripheral interface (SPI) bus or via a microcontroller on the slave board (in this case typically using a CANbus).

However, as the new solution supports up to 16 cells on a single ASIC, it is an excellent fit for all 48V systems. Lithium Balance is therefore launching the c-BMS, a new 16-cell battery management system. Aside from utilizing the new ASIC, the new c-BMS uses safety-rated automotive components to ensure the highest possible levels of functional safety.

In order for the ASIC, as well as the c-BMS, to achieve ISO 26262 compliance, the development process entails the creation of an item definition, hazard analysis, risk assessment and functional safety concept, as well as a technical safety concept for a rechargeable energy storage system. These documents specify a safety architecture that can be used in conjunction with a safety-rated battery management system to achieve functional safety in a rechargeable energy storage system for a hybrid, plug-in hybrid or pure-electric vehicle intended for public road traffic. Software and hardware development are both strictly regulated by ISO 26262, with requirements being imposed on development procedures, verification procedures and tools. The stringency of the requirements depends on the highest ASIL level allocated to the software function or hardware part. In all cases simplicity, robust design patterns and usage of highly reliable components are advocated – for high ASIL levels it is functionally mandated by the reliability metric targets specified by the standard.

From an engineering perspective, it has also been important to build a compact battery management system. The c-BMS measures just 7 x 15cm and, in spite of its compactness, the c-BMS offers more functionality at ISO 26262 ASIL C level, at a competitive price. The c-BMS therefore supports industrial and automotive 12V, 24V, 36V or 48V applications, such as forklift, AGV, cleaning machines, and stop/start systems. The c-BMS is also a perfect fit for 48V home energy storage systems.



The integrated circuit supports up to 16 cells, making it suitable for all 48V applications

FREE READER INQUIRY SERVICE
To learn more about Lithium Balance, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 520

Cooled vehicle charging

Newly developed cooled cable and connector technology can enable the super-fast charging of electric vehicles, and reduce the impact of a common barrier to purchase

The problem that many car buyers have with electric vehicles is the time that it takes to recharge after a long journey. You can't just go to the petrol station to fill up the tank; you need to charge your vehicle for anything up to eight hours. With the release of the next generation of long-range electric vehicles, fast-charging stations with power levels of 50kW and a current of 120A can result in charging times of only one hour. When compared with eight hours, this is a great improvement – but it is still not fast enough, not when compared to the short amount of time it takes to refuel a traditional vehicle.

However, Huber+Suhner – a leading international manufacturer of components and systems for electrical and optical connectivity – has developed a cooled cable and connector that looks set to put the super-fast charging of electric vehicles within reach.

This development can multiply the power throughput of a charging cable and keep vehicle charging times below 20 minutes, even with the big battery packs that are typical of new electric cars and trucks. In addition, currents of up to 500A (and higher) are possible, while still providing a flexible, small-diameter, low-weight cable solution. These capabilities perfectly match the high-power charging stations currently under development, which are said to provide 400kW with charging currents of 400A.

Compared with traditional high-current cables, cooled cables are highly flexible, lightweight and easy to handle. However, when creating such a cable, technical challenges present themselves. For example, the lower the diameter of the conductor, the higher the resistance and temperature – as the size of the conductor is reduced, the resistance of the cable increases, leading to an increase in temperature.

Newly developed technology from Huber+Suhner has the potential to make charging times of less than 20 minutes feasible

The hottest area in the system is where the cable is connected to the connector pin (whether welded, crimped, or soldered) – the cable needs to be cooled at every spot under each and every working and environmental condition. This means that more heat needs to be dissipated. To achieve this, coolant is led to the hottest spot of the system first, and then back to the radiator. This enables the coolant to cool the conductor in a defined and controlled way.

Huber+Suhner's cooled cable and connector technology for super-fast charging

Thanks to this integrated cooling circuit, cooled cables also offer a much smaller cable cross-section than the traditional option. This cooled cable is unique because the cross-section can be reduced from 95mm² to 10mm² in extreme circumstances, thus reducing the weight from 2.8kg/m to 0.9kg/m. The reduced weight, together with the ergonomic design of the connector, enables easy handling of the system, even for smaller people.

As long charge times can be a key negative influencing factor in a person's decision to purchase an EV, the industry is hopeful that this sort of technology will support and accelerate the public demand for electric vehicles.

FREE READER INQUIRY SERVICE
To learn more about Huber+Suhner, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 521

Reliable solid-state storage

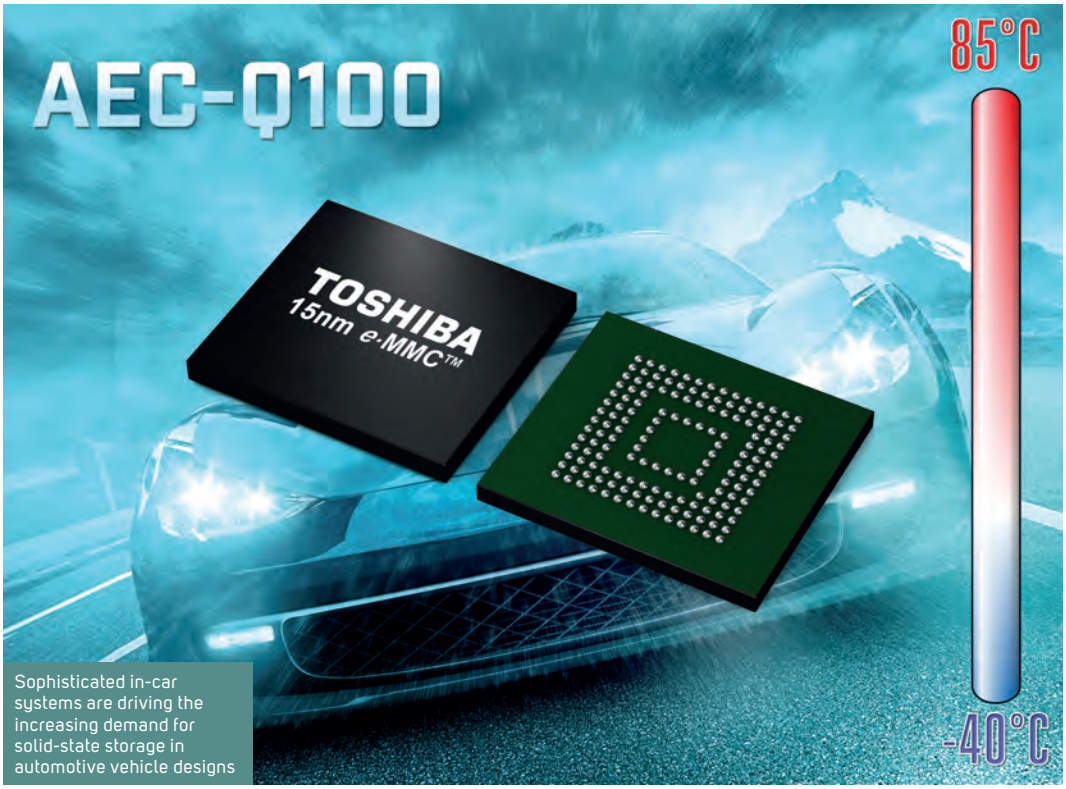
A wide range of advanced in-car applications is making reliable, low-power data storage a fundamental requirement for new and emerging automotive designs

Mapping and media data now account for 70-80% of all data storage requirements in cars, and the need for capacity is increasing as navigation with 3D graphics, extensive point of interest data and satellite images become increasingly commonplace. Other applications driving the demand for automotive storage are voice recognition and speech synthesis and the move to connected vehicles – it is expected that in the next two years, 60% of all new cars will be connected through mobile technology.

As a result of this, average vehicle memory capacity is estimated to increase from 15-35GB in 2018, to above 60GB by 2025. Much of this growth will be satisfied by reliable, low-power NAND flash memory, not least in entry-level and mid-range vehicles where infotainment and navigation systems tend to include between 4GB and 32GB of storage. At these capacities, NAND flash is particularly cost-effective.

For such applications, e•MMC NAND is proving increasingly popular. The technology combines the NAND host controller and an array of memory management tools within the chip itself – making it easy to design in. Many modern vehicle navigation systems use dedicated automotive HDDs with up to 320GB capacity for map and media data, plus 16-32GB of e•MMC capacity for application data.

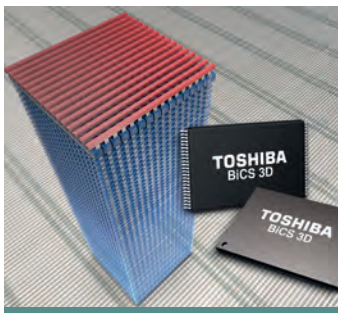
The memory devices installed in electric and hybrid vehicles need to function in a range of environmental conditions while also withstanding constant vibrations and shocks. Solid-state memory provides a clear advantage over mechanical HDDs. Some manufacturers have already replaced these HDDs with SSDs integrating 60-200GB of NAND memory – while others have moved directly from HDDs to solutions with 64-128GB of e•MMC. It is expected that projects scheduled to enter production from 2020 will use one form or other of solid-state storage.



Sophisticated in-car systems are driving the increasing demand for solid-state storage in automotive vehicle designs

NAND memory is also important for instrument clusters, where the erosion of color TFT prices is driving the popularity of hybrid clusters in mainstream vehicles and helping premium cars move toward fully digital clusters. Both require more memory for advanced graphics. Today, such systems may use external SLC raw NAND, but this will quickly move to e•MMC.

Toshiba currently supplies automotive memory solutions based on 19nm and 15nm NAND flash, with a number of manufacturers starting to specify these increased bit density solutions.



Toshiba's 3D stacked cell structure further improves storage capabilities

In the longer term, 3D NAND will also become of interest as its higher bit densities keep pace with the demand for higher capacities. Toshiba has recently announced its new generation of BiCS Flash, a 3D stacked cell structure flash memory capable of surpassing the capacity of mainstream 2D NAND flash memory while enhancing write/erase reliability endurance and boosting write speeds.

The company also offers NAND flash solutions with a UFS interface that support requirements for maximum bandwidths of up to 11.6Gbps. Sequential read speeds can reach up to 600MB/s and write speeds can be as fast as 180MB/s. UFS technology also provides increased random read and write performance and very low standby power consumption.

FREE READER INQUIRY SERVICE
To learn more about Toshiba, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 522

GDO AC inverter design

Gate-driver-only technology, based on a proven product line, is an integral part of inverter design that overcomes interface mismatches and offers the best possible system integration

The concept is ready. Motor, battery, safety system – almost everything is there. Only the inverter needs to be chosen. That is where it becomes difficult. You are looking for a MOSFET-based AC inverter that can neatly integrate into your plans, but you are confronted with a lot of different offers that deliver a completed box with a predefined interface and functionality – nice, but not what is needed.

MOSFET-based AC inverters have been around for more than 20 years and have evolved gradually, together with their lead applications, into the ready-to-use products that they are today. However, new application fields and new requirements for safety lead to a wide range of application system designs that are not easily aligned with existing AC inverter designs – in terms of requirements regarding interface, functionality and safety. At the same time, MOSFET-based AC inverters do not typically leverage unique selling points for the end application, limiting the resources and money that can be spent on system integration, and later, series prices.

There is a mismatch between the physical interface of the inverter and the hardware and software interfaces that are required by the application system. Off-the-shelf inverters today have a fixed installed control-board, often including the software. From an application system design perspective, the controller and software should preferably be part of the control and safety system design.

What are the options for a product that meets the requirements? Even if the control part of the inverter can be designed in-house to perfectly match the application system, the development of a new customized power inverter is difficult. The high currents require a dedicated power technology for the switches and an attached bus capacitance with a very low inductive connection to them. Alternatively, the design process can be turned around – by choosing a freely available inverter and building the rest of the application system around it. This will always be a compromise at best. Finally, a customer-specific design can be requested from a suitable supplier, resulting in a customer-specific product, albeit at considerable development cost and investment of resources.

What are missing are building block concepts that overcome the mismatch of the interfaces – a concept for the power stage of the inverter, comprised of MOSFET modules, gate driver, and bus capacitance and sensors, that is free to be connected to a control system that is specifically designed to achieve the best integration of the AC inverter system in the overall application system.

Semikron has designed a gate-driver-only (GDO) derivative, based on the company's SKAI2 LV product family, to meet the demand for flexibility of the control section. GDO technology can deliver a powerful MOSFET inverter stage with an easy-to-connect gate driver, current sensors and temperature sensors, and sufficient space under the protective cover to mount a customer-specific control board side-by-side with the gate driver board. The complete gate driver requires only a single 12V supply and signals are already scaled for direct connection to the processor.

Semikron's SKAI2 LV product family supports battery voltages with an extensive range of robust inverters, traditionally rated for 36V/48V and 80V batteries and maximum supply voltages of up to 72V and 115V respectively.

SKAI2 LV inverters have a very low resistance – down to 0.3mΩ (typical) per switch in 48V systems and 0.8mΩ (typical) per switch in 80V systems – and excellent thermal resistances, combined with low switching losses.

Semikron's SKAI2 low-voltage single inverter has a very low resistance – down to 0.3μΩ (typical) per switch in a 48V system

FREE READER INQUIRY SERVICE
To learn more about Semikron, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 523

Powering mild hybrids

Hybridization using 48V technology provides a cost-effective near-term alternative to full hybrids and pure electric vehicles, which are currently expensive to produce

Electrification of the powertrain is one of the primary methods being used to meet future vehicle emissions and fuel consumption targets. In addition to high-voltage (plug-in) hybrid concepts, 48V mild hybridization in particular enables increases in efficiency at financially low overheads, since a complete overhaul of the drivetrain is not necessary. The FEV ECObrid is an example of a 48V mild hybrid concept, which has an integrated 12V/48V dual-battery electrical system. The third generation of the FEV HECS 1.6-liter four-cylinder diesel basic engine with variable turbine geometry charger, as well as high and low pressure EGR, is extended by an additional electric compressor and a belt-driven starter generator (BSG) to a voltage of 48V and via a bidirectional DC/DC converter coupled to the 12V power supply system.

The 48V system with BSG and powerful LTO battery enables high recuperation rates and provides additional degrees of freedom in the design of power management. The regenerated brake energy can be fed to the drive via the electric compressor or BSG as well as to the electrical power supply in the conventional onboard network. The pilot is used to explore and optimize the interaction taking place between the model-based FEV engine control and the mild hybrid operating strategy. The focus of the investigations is on low-end torque compensation of the downsizing concept with simultaneous emission reduction, as well as optimization of the electrical energy management. In order to accomplish this, the torque path of the motor control is expanded by providing interfaces and functionalities for the optimum operation of the concept's electrical compressor and BSG.

The Voltabox 48V energy-storage system is configured from the company's modular kit

Voltabox's facility in the German town of Delbrück

The required 48V energy-storage system is developed by Voltabox and configured from the modular Voltabox system kit. The system integrates the prismatic LTO cells in a battery module. The BMS and the CAN interface are fully integrated.

The Voltabox central control unit provides CAN communication and manages the precharging function, as well as control of the battery contactors. The high cycle and electrical strength of the LTO cell, combined with the exceptional cold-start performance, adhere to the most stringent automotive requirements. Furthermore, the comparatively high thermal strength, as well as the integrated protective devices, ensure a high level of operating safety. The voltage range of 36-54V, which is required for safety reasons for the 48V electrical system, can be achieved by scaling the variable length battery module.

The housings made of extruded sections, as well as cell connectors and electronic components, enable integration of up to 36 cells within a module, which can be connected in parallel and in series for high-voltage applications. The energy output of the 48V battery is 960Wh at a peak power of 14kW. To ensure safe functionality, it has integrated air cooling. In the event of an accident, special gas diversion elements, such as a local short-circuit due to an accident, prevent overlapping of adjacent battery modules.

Collaborative software

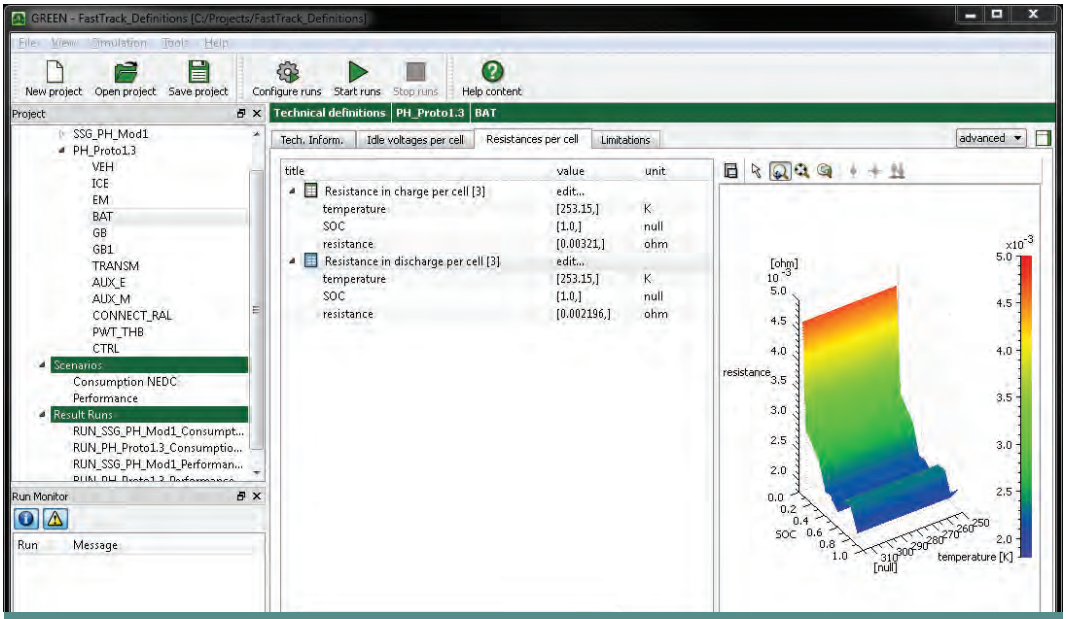
An advanced software solution has enabled a major OEM to create a collaborative platform for assessing the energetic synthesis of any hybrid configuration, streamlining development

Hybrid powertrains are much more complex than internal combustion engines or all-electric powertrains, mainly because of the multitude of possible combinations of architectures. For example, in parallel hybrid applications, multiple propulsion sources can be combined or used independently. In series hybrid vehicles, the sole propulsion is done by the electric motor, while the electric energy comes from another onboard source, such as a combustion engine.

Due to the interdisciplinary nature of hybrid powertrains, engineers must balance the power required from each energy source, study the impact of other system choices (such as transmissions and cooling systems) on the vehicle's energy performance and validate optimal configurations. These tasks require that engineers investigate a number of different vehicle and powertrain combinations together with the appropriate control strategies.

At Renault-Nissan, one of the current differentiators is the ability to deliver eco-friendly vehicles at reasonable costs. The Renault-Nissan Alliance Group is committed to reducing the environmental impact of its activities and products throughout their lifetime, from design to recycling. The Alliance already claims about 70% of the worldwide electric vehicle market, with fully electric vehicles such as the Renault Zoe and Nissan Leaf, and aims to further expand its vehicle range by developing advanced hybrid architectures.

The EOLAB concept vehicle is a first step. Compact and affordable, the EOLAB is a new plug-in hybrid vehicle delivering ultra-low fuel consumption with zero-emission mobility on journeys of under 60km (37 miles) at speeds of up to 120km/h (74.6mph). In order to develop this future technology, the Renault-Nissan Alliance is teaming up with Siemens PLM Software and uses its Simcenter products and services to assess the energetic synthesis of any hybrid configuration. Renault introduced a new simulation platform, called GREEN (Global and Rational Energy EfficieNcy), which is an application-specific graphical user interface linked to LMS Imagine.Lab Amesim software, the MATLAB environment, the Simulink environment and Excel spreadsheet software file repository. The new simulation platform makes it possible for engineers to quickly parameterize models, run simulations and post process results. It includes a pre-built, comprehensive hybrid vehicle configurator that enables users to choose between a number of different hybrid architectures.



The GUI for the new GREEN simulation platform is built on top of LMS Amesim, which was developed by Siemens PLM Software

The GREEN simulation platform enables engineers to define and validate a new hybrid vehicle architecture, its selected subsystems and the energy management control laws, in a matter of hours.

"The GREEN platform developed with LMS Amesim will be used by the Renault-Nissan Alliance to support the virtual design and energy management analyses of future hybrid vehicles, which is one of our major engineering challenges," explains Eric Chauvelier, method and simulation manager for hybrid and electric systems in the Test and Digital department. Results provided by the platform are fuel and energy consumption, performance, operating points of the powertrain, and energy flow throughout the driveline. In addition to these results, sensitivity studies on physical characteristics or control parameters can be easily managed with the tool.

The graphical user interface for the GREEN simulation solution was developed on top of LMS Amesim. "The mechatronic system simulation platform from Siemens PLM Software provides off-the-shelf but customizable, validated components [with which] to build complete vehicle architectures, from subsystems to systems integration," explains Chauvelier. "LMS Amesim is a flexible but robust backbone. Its multilevel approach provides components that fit to any design stage. Thanks to its multidomain nature, it not only enables modeling of different drivetrain components such as electric motors, combustion engines and transmission systems, but it also enables us to balance vehicle attributes such as fuel consumption, emissions, performance and driveability."

FREE READER INQUIRY SERVICE
To learn more about Siemens, visit: www.ukipme.com/info/ev
INQUIRY NO. 525

Propulsion solutions

Building on a wealth of experience across motorsport and other industries, a leading developer of advanced power electronics can create solutions for a range of applications

Rinehart Motion's range of inverter products includes (clockwise from above): the PM100 and PM150; the RM300; the RM100

A leading developer and manufacturer of advanced power electronics for road cars, trucks, race cars, and ruggedized ground vehicles of different kinds, Rinehart Motion offers two standard lines of propulsion inverter for the EV and HEV markets. The company also provides design services and custom product development for OEMs and Tier 1 companies in ISG inverters, turbo-compounding for performance enhancement and energy harvesting, e-supercharger applications, high-power DC/DC converters, and a variety of other high-power, high-voltage electronics components and subsystems ruggedized for ground vehicles.

Rinehart Motion grew from a background in power semiconductor packaging, and has been gaining experience in supplying Formula 1 KERS/ERS system inverters and components since the start of the 2009 race season (serving four F1 teams today), as well as experience with Formula E, Le Mans prototype hybrid race cars, hillclimb cars, race motorcycles, land-speed record vehicles, military ground vehicles, stationary generation systems, experimental aircraft, and many other quality-conscious applications. The company fabricates, inspects and tests to IPC Class III+ and 'Mars Rover' quality to support the F1 grid – without recording a hard failure on track since 2009.

Rinehart Motion has leveraged its extensive experience in motorsport and has successfully penetrated the road-certified hypercar propulsion market, in addition to specialty niche markets in mining vehicle electrification, delivery and fleet trucks, and a host of applications where small size, low weight, and ease of use are critical.

Rinehart's standard products include the PM family of 100kW, 150kW and 250kW inverters, in production since 2010 and capable of delivering up to 350kW$_{pk}$ with a suitable motor.

The newest Rinehart Motion family of high-volume production inverters, tooled and validated for road car application worldwide, will span 50-500kW power ratings at automotive production pricing in high volumes.

Rinehart Motion's power products are the smallest, lightest solutions available today – inside and outside of professional motorsport – and are designed to meet ISO 16750 and OEM standards. The company's products are rated for commercial vehicle operating environments (and beyond), and its customers have successfully completed full vehicle certification in various world markets for cars, trucks and motorcycles.

If it moves, Rinehart Motion has a propulsion solution suited to fit a customer's application, or its team of experts can design one.

FREE READER INQUIRY SERVICE
To learn more about Rinehart Motion, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 526

Advanced BMS technology

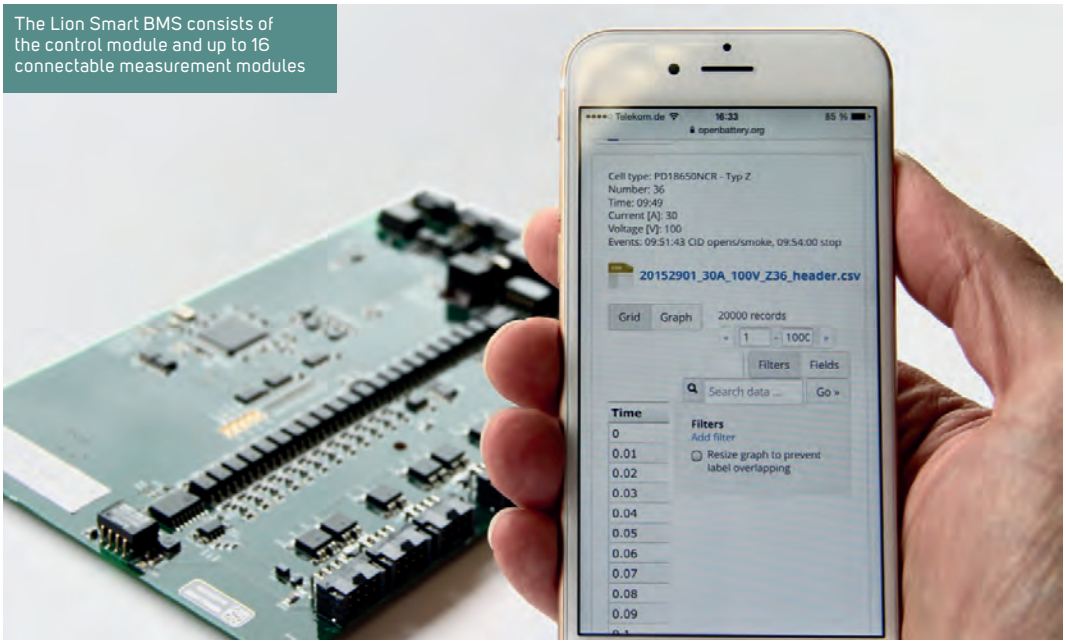
A line of battery management system products that use passive balancing can reduce space and cost, while wireless developments also promote battery capacity expansion

The Lion Smart BMS is a universal measuring, monitoring and control system for lithium-ion energy storage devices. The BMS consists of the Lion Control Module (LCM) and up to 16 connectable Lion Measurement Modules (LMM) via a daisy-chained serial bus system. The total current consumption of both modules is typically 160mA, with an external operating voltage of 9-18V. The LMMs are mounted at the cells and normally powered over the particular cell stack. In this case, the operating voltage range is between 10V and 70V. The LCM performs the SoC calculation for the connected cells (depending on all measured physical values) and creates an average over the full calculation span.

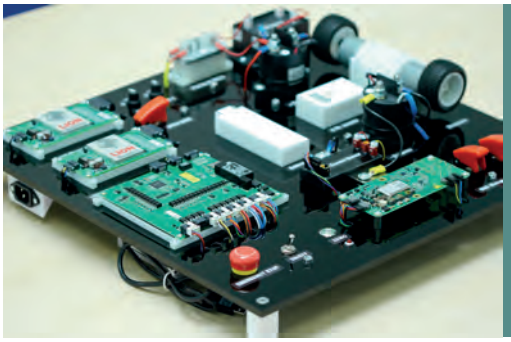
Through cooperation with Linear Technology, it is possible to carry out cell monitoring with the latest measurement chips. This features a fast and precise measurement that permits cells to operate at their limits without exceeding them. The cell voltage measuring range is 0.7-5V with an absolute accuracy of ±1.2mV. Cell temperature measuring range is -40°C to 125°C with an absolute accuracy of ±1.5°C. To observe the cell operating limits, the Lion BMS uses the passive balancing method. Thus, the system ensures safe and gentle charge equalization of the individual cells.

The BMS is space saving and cheaper than the active balancing solution. If the BMS detects an imbalance between cells, energy is drawn from the most loaded cell and transferred to the least. The compensating current via the discharge resistor may amount to between 50mA and 4A per cell and is dissipated via an additional board.

Internal module communication utilizes isoSPI, and all measured values can be stored to a microSD.



The Lion Smart BMS consists of the control module and up to 16 connectable measurement modules



The Lion Smart BMS utilizes passive cell balancing, ensuring the safe and gentle equalization of the individual cells

Minimum and maximum values are stored to the 128KiB EEPROM. Therefore, it is possible to check faulty conditions of the battery pack that have occurred in the past. Special features include the open and flexible software architecture and the web-based user interface enabling the configuration of control parameters; and the graphical representation and logging of measured values into a database.

One of the latest developments is wireless communication between LMMs and LCM. The omission of wiring connections makes the LMM a standalone system. As a result, the modules can be mounted to the cell stacks and operate in the early production phase. In the face of Industry 4.0, the wireless BMS can provide accurate data acquisition of the individual cells during manufacturing. These cell characteristics are locally stored in the measuring module and offer insight into possible process tolerances. Thanks to the wireless solution, it is possible to connect an unlimited number of measurement modules and still obtain the data in real time. In contrast to the wired BMS, each LMM in the wireless BMS performs SoC calculations separately, and their network connection is fully synchronized. This means the measured values of LMMs are clearly marked with a time stamp, and it is not necessary to determine the reference time of data transmission. Fully networked manufacturing makes it possible to perform early sorting, improving the quantity of cells with equal capacity in battery modules. With regards to stationary energy storage in particular, this makes it possible for the wireless BMS to easily expand battery capacity without any changes to the wiring harness.

FREE READER INQUIRY SERVICE
To learn more about Lion Smart visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 527


SIEMENS
Ingenuity for life
Discover better designs, faster.
STAR-CCM+ and Battery Design Studio charging Electro-mobility.
Don't just simulate, innovate! Analyze complex battery systems with simultaneous resolution of flow, heat transfer and electrochemistry.
siemens.com/mdx

Semiconductor power module

The 2016 Paris Motor Show indicated to the public that the automotive industry is currently subject to a fundamental change – electric and hybrid vehicles are soon to become mainstream and the internal combustion engine is under threat.

The range of new all-electric cars, which will go on sale in a few years, support this conclusion. This change in the state of mind can also be found in prototypes and showcases: large batteries are safeguarding sufficient range. New architectures of passenger compartment and drivetrain packaging have led to extremely large cabin space and usability, in a small vehicle footprint.

Meanwhile, the challenge for engineers continues. Increased power density and effective packaging of power electronics components, cooling, battery and drivetrain are an ongoing requirement.

For future-generation electric cars, Danfoss offers a range of novel technologies for IGBT and MOSFET power modules. In addition to its long-lasting and high-rel sintered and mold-encapsulated module blocks, Danfoss has improved its ShowerPower cooling. A three-dimensional cooling plate now even further increases thermal transfer. Finally, efficient cooling is the key lever to make the most out of precious silicon components. This enables excellent power density in new traction drive inverters – more than 50kW/liter is possible. The inverter power stage can now be mechatronically integrated into electric machines, gearboxes and axles.

Additionally, the new technology can be applied to onboard chargers and power-supply components. Danfoss can develop customer-specific solutions according to the most stringent industrial standards in volume production for every possible demand.

FREE READER INQUIRY SERVICE
To learn more about Danfoss, visit:
www.ukipme.com/info/ev
INQUIRY NO. 528

High-powered laboratory testing system

A leader in the battery charging and testing industry, Bitrode Corporation is once again expanding its FTF-HP high-power product line. Most recently, Bitrode designed, built and shipped a 650kW FTF-HP for testing automotive pack batteries.

This machine is capable of charge or discharge cycles up to 650kW with precise control of up to 900A and 1,000V. Parallel functionality means four interconnected systems can operate at an impressive 2.6MW of power for large-scale testing applications.

The FTF-HP is designed to switch from charge to discharge seamlessly and has current rise times of less than 10ms for zero to full current of the unit. This enables the FTF-HP to meet the rapidly changing testing demands in EV/HEV systems. Discharge power recycling to the AC line makes the FTF-HP more energy efficient to operate. Additionally, the battery simulation function can program constant voltage, maximum current and internal impedance for motor and DC inverter testing applications.

Bitrode Corporation's FTF-HP is available in both single- and dual-circuit configurations.

"The FTF-HP product line has been available in the market for over two years now, but recently we have been receiving customer inquiries for higher and higher power levels," states Craig Brunk, director of sales and marketing of Bitrode. "Applications in automotive racing, train and ship industries are really pushing the envelope toward 1MW of power and voltages over 1,000V."

FREE READER INQUIRY SERVICE
To learn more about Bitrode Corporation, visit:
www.ukipme.com/info/ev
INQUIRY NO. 529

Advanced electrification

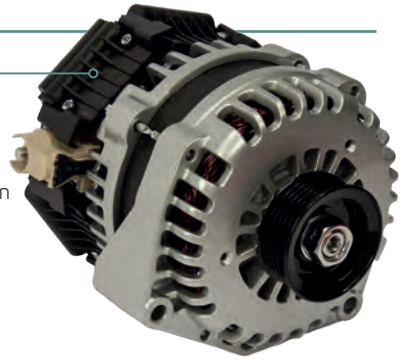
Advanced electrification technologies, working in harmony with combustion engines and new powertrain designs, are the game-changers the industry needs now, as BorgWarner is aiming to prove.

"Customers need electrification systems that can be used with existing combustion engine platforms," says Dave Fulton, director, advanced engineering at BorgWarner. "That's why BorgWarner acquired Remy International. Remy added significant strength in electrification engineering and manufacturing, for hybrid and full-electric systems.

"Our latest 48V iBAS [Integrated Belt Alternator Starter] design with integrated power electronics will be the most widely adopted," says Fulton. "It can fit into existing platforms and serve as the electrification centerpiece in vehicles using stop/start, regenerative braking, sailing/coasting, and torque assist functions."

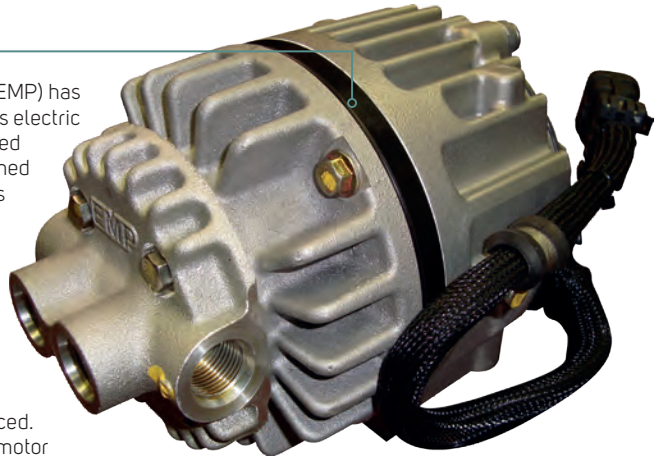
Vehicle electrification designs reduce fuel consumption and emissions, but Fulton stresses they also enhance the driving experience. "Our high-voltage drive motors such as the HVH250 can deliver more than 400bhp [405ps]. Our technology is invisible to the driver, but the power definitely is not."

BorgWarner is reimagining propulsion systems for passenger, commercial and off-highway vehicles across the full range of hybrid and electric drive architectures. "Every vehicle class can benefit from electrification, and we are dedicated to innovating in every part of it."



FREE READER INQUIRY SERVICE
To learn more about BorgWarner, visit:
www.ukipme.com/info/ev
INQUIRY NO. 530

Electric oil pumps



Engineered Machined Products (EMP) has introduced several new models of its electric oil pump technology, which are based off of the company's recently launched OP40 electric oil pump. The line has also been expanded to include a higher flow capacity model, which doubles the flow capacity of the OP40 pump up to 8.0 gal/min.

A higher fluid temperature rated model of each pump, which will increase the continuous fluid temperature operating range from 100°C to 130°C, will also be introduced. Meanwhile a new integrated BLDC motor drive controller option is available for each model to support CAN (SAE J1939) communication and control.

All EMP oil pumps are equipped with high efficiency, long-life BLDC motor and drive technology, available in both 12V DC and 24V DC. The pumps are positive displacement type utilizing gerotor pumping element technology for quieter, more efficient operation. With discharge pressures up to 100psi, the pumps can handle a variety of fluid transfer applications including lubrication, cooling, scavenge, and general fluid management.

FREE READER INQUIRY SERVICE
To learn more about EMP, visit:
www.ukipme.com/info/ev
INQUIRY NO. 531

Safety first

When handling batteries, there are two main safety hazards. These relate to the high voltages (U > 60V) and the potential leakage of flammable or toxic gases caused by thermal runaway, particularly in the case of Li-ion-based battery cells (hazard level ≥ 4).

Battery testing conducted by the supplier, as well as mandatory risk assessments, ensure the highest levels of safety. This risk assessment involves the calculation of the hazard rating number (HRN; range of 1 to 1,000 by ISO 12100), which is devised as a product of the likelihood of occurrence (LO), the frequency of exposure (FE), the degree of possible harm (DPH) and the number of persons (NP): HRN = LO x FE x DPH x NP.

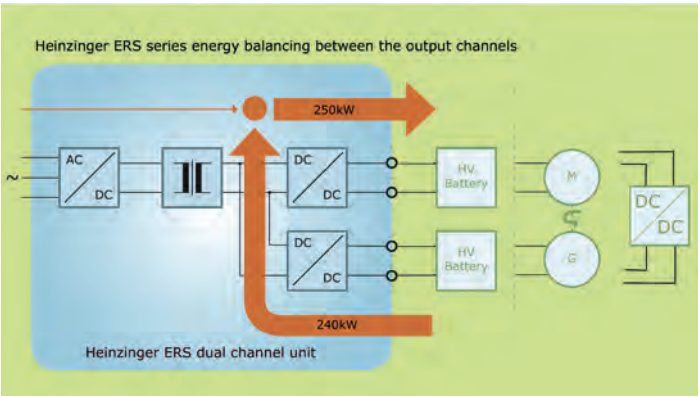
For an HRN higher than 10, safety measures that reduce potential danger according to ISO 13849 are necessary. Voltages higher than 60V, for example with HRN > 300, require constructive safety measures (such as protection against contact), technical measures (such as insulation monitoring devices) and warning and indications (such as lights or symbols on the cabin).

Furthermore, safety control with redundant measurements, a double-checked execution of the emergency shutdown (DC stop and DC on) as well as a conformity declaration and documentation, are also essential requirements. According to the risk graph evaluation (ISO 13849 1), safety-related components of category 3 or higher are compulsory in this example.

Suppliers often know these facts, but trivialize the hazardous potential to lower costs and push the risk responsibility onto the customer by declaring the test station as a single device. FuelCon is an expert in battery testing in order to ensure the utmost level of safety.

FREE READER INQUIRY SERVICE
To learn more about FuelCon, visit:
www.ukipme.com/info/ev
INQUIRY NO. 532

Testing high-power applications



When testing components inside an electric drivetrain, the power demand continues to increase; however mains supplies of test labs remain limited. Heinzinger Electronic has developed a solution to address this particular issue. In an example test scenario designed to assess the lifecycle of the batteries, which alternate in charge and discharge mode, a high-capacity mains and recovery supply is required. Similar conditions can be found when testing DC/DC converters or testing power inverters back to back.

Within its ERS series, Heinzinger offers a bidirectional highly dynamic test bench system with active energy recovery – the ideal solution for these types of applications. Every output channel is designed to handle up to 250kW, independent of the mains supply power.

Through an intelligent combination of the test run, energy balancing between the two channels of the ERS system can be achieved. Input power of one channel is used to enforce the output power of the other channel and reverse. Energy circles in the DC link of the ERS system and power dissipation only are taken out of the mains supply.

The advantage is that no loss arises from the setup insulation level-DC/AC-grid-AC/DC-insulation level, as is the case with two separate units. This results in noticeable savings by reducing the energy demand and enables high-power applications with a limited infrastructure.

As an option to simulate real conditions, isolation between the two channels is also available.

FREE READER INQUIRY SERVICE
To learn more about Heinzinger Electronic, visit:
www.ukipme.com/info/ev
INQUIRY NO. 533

Integrated current transducer

There are three main applications for current transducers in electric vehicles. These are: battery management applications where current transducers are used to monitor the capacity remaining in the battery and the resulting autonomy;. electric motor three AC phase applications where current transducers are involved in speed regulation inside the inverter; and DC/DC converters (400V/12V) where the transducer monitors current switching at high frequency.

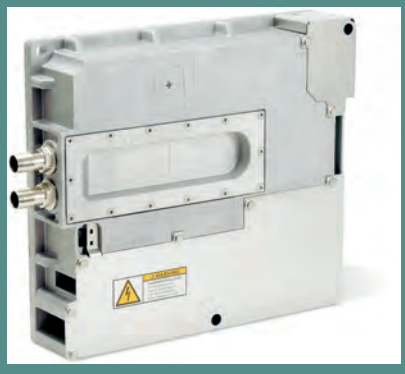
Trends in the development of current transducers for EV applications are focused on miniaturization, ease of mechanical integration with high-current measurement capability, and improved accuracy. LEM's new HSN family of current transducers integrates a primary current bus bar as an additional feature in a Hall-effect open-loop sensor. This integration provides the opportunity for a local size reduction of the over molded bus bar, in order to optimize the shape of the magnetic core and global size of the sensor.

The improved shape of the magnetic core provides optimal management of the magnetic field around the hall cells LEM ASIC and enables extremely high levels of accuracy in the current measurement. The integrated bus bar creates a plug-and-play solution for integration in battery junction boxes, battery disconnection units, inverters and DC/DC controllers.

With the HSN family, LEM offers a complete portfolio for battery management (HSN BV) as well as drive/motor control and inverter applications (HSN DR) from 50A to ±1,200A. Systems with dual output measuring capability in two current ranges, or used for ISO 26266 redundancy requirement are also available. A connector version (pictured), or a version with integrated harness interface, offer additional ease of integration.

FREE READER INQUIRY SERVICE
To learn more about LEM, visit:
www.ukipme.com/info/ev
INQUIRY NO. 534

Flexible drive solutions



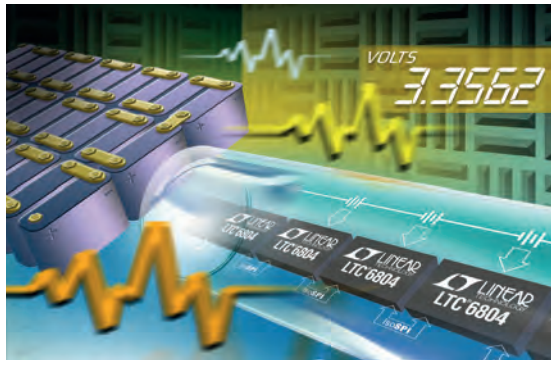
Lenze Schmidhauser, a leading manufacturer of drive solutions for mobile use, recently presented its new systems for commercial vehicles and mobile machines. This includes its Mobile modular system, as well as solutions for numerous sample applications. The modular unit comprises a double inverter (DCU), DC/DC converter (PSU) and various combi modules designed especially for use in commercial vehicles. The double inverters are each equipped with two motors or generator outputs in the power range of between 7.5kWp to 60kWp.

Manufacturers can simply use the catalog to quickly and easily put together a customized system to suit their individual applications for drive control in auxiliary equipment and power supply for onboard supply systems.

This also enables users to economically and efficiently cover a wide range of applications with just one product family and react flexibly to new requirements. The modular systems – designed as catalog products – can be used in both large-scale production and customized solutions. An ECE Declaration of Conformity is available for the entire Mobile family in accordance with ECE R10 regulations.

FREE READER INQUIRY SERVICE
To learn more about Lenze, visit:
www.ukipme.com/info/ev
INQUIRY NO. 535

Accurate hybrid/electric battery monitor



The LTC6804 was designed to surpass the environmental, reliability and safety demands of automotive and industrial applications. It is fully specified for operation from -40°C to 125°C. It has been engineered for ISO 26262 (ASIL) compliant systems and a full set of self-tests ensure that there are no latent fault conditions. To accomplish this, the LTC6804 includes a redundant voltage reference, extensive logic test circuitry, open wire detection capability, a watchdog timer and packet error checking on the serial interface. The LTC6804 combines 30 years of analog experience with hard-earned lessons in automotive battery management. On the bench, or on the road, this part delivers outstanding performance.

Along with the LTC6804, Linear Technology offers the LTC6820 isoSPI transceiver. The LTC6820 enables bidirectional transmission of the serial peripheral interface bus (SPI) across an isolated barrier up to 100m. The LTC6820 supports SPI data rates up to 1MHz, using matched source and sink currents to eliminate the need for a transformer center tap and to reduce EMI. The drive currents and the comparator thresholds are set with two resistors, allowing the system to be optimized for cable length and signal to-noise performance. Battery management systems using the LTC6804 can interface to external components, such as microcontrollers, via the LTC6820. The LTC6804 is packaged in a small 8 x 12mm surface-mount device and priced at US$10.95 each in 1,000-piece quantities. Samples, demonstration boards and the data sheet are now available.

FREE READER INQUIRY SERVICE
To learn more about Linear Technology, visit:
www.ukipme.com/info/ev
INQUIRY NO. 536

High-performance, reliable connectors

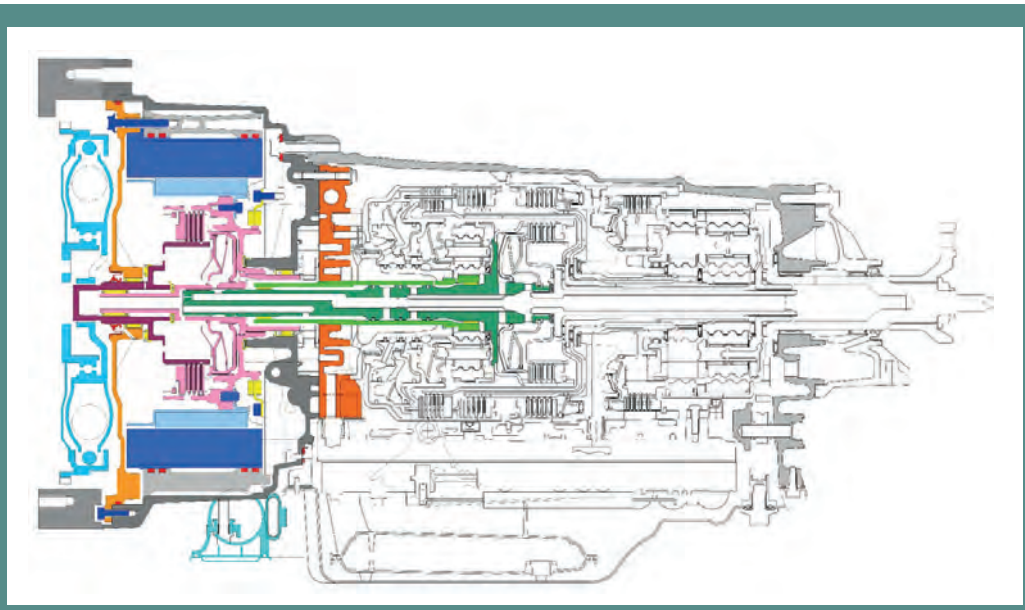
ODU's contact systems are efficient and reliable. They are both temperature and vibration resistant and can meet the challenging requirements for many mating cycles and high current carrying capacity in hybrid and EVs.

ODU has the expertise to create and produce connector technology for the e-mobility requirements of today and tomorrow – whether that is connectors built into vehicles or special contacts used in charging plugs, for high driving power or ultra-fast charging.

Through intelligent designs and the use of innovative materials, ODU's connector solutions are high-quality and sustainable, particularly for reliable transfer of high power currents under complex conditions. The ODU GEN2 guarantees the stable transfer of high currents and is designed as a simple assembly in standard processes. Combined with the ODU LAMTAC high-voltage contact, it is an ideal connector solution with durably high current-carrying capacity.

Plug-in and electric vehicles can benefit from the unique features of ODU contact systems – notably by the guaranteed 10,000+ mating cycles for battery charging. Well-known industry customers have relied on ODU technology for many years. The company continues to focus on application-specific custom developments, not just in e-vehicles, but in all application areas.

FREE READER INQUIRY SERVICE
To learn more about ODU, visit:
www.ukipme.com/info/ev
INQUIRY NO. 537



Hybrid automatic transmission

The increasingly stringent fuel regulations and the rise in automation and electrification of the powertrain have underpinned the interest in using a proven transmission in a P2 configuration, such as the Punch Powerglide 6L50 automatic, a longitudinal 6-speed transmission based on the Lepelletier powerflow, jointly developed with General Motors.

A step-by-step approach for further electrification has been adopted in developing this new driveline solution. The first step was the implementation of an optional module of a hydraulic accumulator that can generate the necessary pressure on the oil pump as soon as the engine switches on again. The expected fuel economy that can be achieved is up to 6.5% (standard NEDC cycle) depending on the application.

The next step toward electrification will be hybridization with an electrical motor. This will provide a turnkey hybrid solution for OEMs that have already integrated the conventional 6L50. The target is to install a 45kW (continuous power) electric machine, in order to pass the full NEDC cycle in purely electric drive, and thus be compliant with a PHEV configuration. This hybrid module integration will have a limited impact on the installation space. Also, in order to minimize the cost, engineering effort and risk, the technical changes compared with the standard 6L50 will be limited to the surrounding area of the hybrid module, as shown in color on the cross-section (above).

FREE READER INQUIRY SERVICE
To learn more about Punch Powerglide, visit: ***www.ukipme.com/info/ev***
INQUIRY NO. 538

Advanced piston dosing system

The current requirements for electronic building blocks and components are clear: new products are becoming smaller and often carry considerable loads. To protect sensitive electronics and ensure efficient heat dissipation, thermally conductive adhesives or gap fillers are increasingly being used. However, due to their high viscosity and the substantial amount of abrasive fillers used, these materials place tough demands on the dispensing equipment used. Especially in industrial production processes, where cycle times are short, the correct and accurate dosing of thermal conductive materials often presents a challenge.

To ensure rapid and efficient application for difficult to work with thermal conductive materials, Scheugenpflug has made innovative changes to its proven piston dosing system, Dos P016. These enable fast dispensing with consistent application accuracy and low maintenance. Also thanks to these improvements, the material volume can be increased by 200% with an extremely high level of accuracy.

This proven technology offers high-precision application, 100% consistent mixing ratio, and can be supplied with a dispensing head customized to the requirements. It provides optimal dispensing results, the highest repeatable accuracy, outstanding wear resistance and maximum process safety.

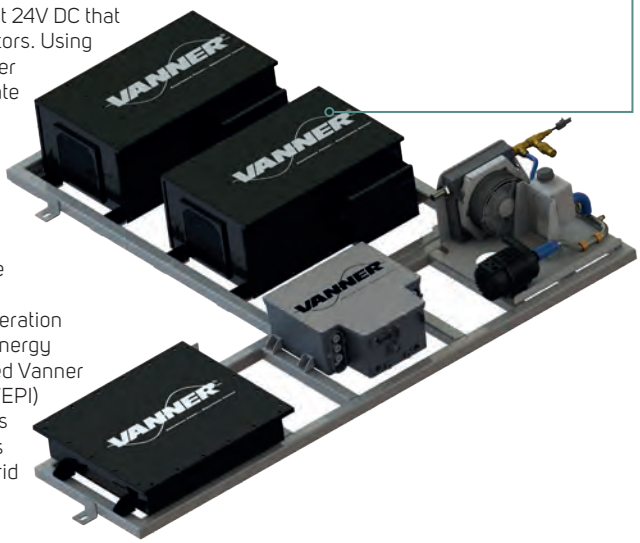
FREE READER INQUIRY SERVICE
To learn more about Scheugenpflug, visit:
www.ukipme.com/info/ev
INQUIRY NO. 539

Full accessory electrification for buses

Philadelphia is known for many great things. Ben Franklin, Independence Hall, the Liberty Bell, not to mention the Philly cheesesteak sandwich. Now the City of Brotherly Love has another claim to fame. The Southeastern Pennsylvania Transportation Authority (SEPTA) has ordered 525 hybrid buses and they will have Vanner's full accessory electrification.

Vanner's full accessory electrification is a customizable electric distribution platform that delivers electric propulsion power to accessory components such as electric air-conditioning, electric air compressors, and power-steering systems. Included are DC/DC converters delivering efficient 24V DC that eliminate belt-driven alternators. Using the electric propulsion's power enables accessories to operate more efficiently and reduce parasitic loads. Reduced accessory maintenance and fuel consumption, and the elimination of rubber drive belts is achieved. It enables a reduction in engine strain and high idle time.

This is Vanner's latest generation in electrical propulsion bus energy management. A water-cooled Vanner Exportable Power Inverter (VEPI) is now included and produces 230V AC 3-phase for full bus electrification. Vanner's Hybrid Beltless Alternator (HBA), in either a single or dual HBA configuration, provides up to 600A-at-idle 24V DC charging. A high-voltage distribution module (HVDM) acts as a smart electrical grid for the bus. Vanner's 80-Series Equalizer or Battery Monitor with model-based battery monitoring (MBBM) provides dynamic charging based on battery SOC and SOH.



FREE READER INQUIRY SERVICE
To learn more about Vanner, visit:
www.ukipme.com/info/ev
INQUIRY NO. 540

FOR ELECTRIC CAR BATTERIES
SMART JUST GOT REAL

The next generation EV battery is filled with thousands of smart Tanktwo String Cells. Packed at random, they can be swapped, serviced or upgraded in under three minutes.

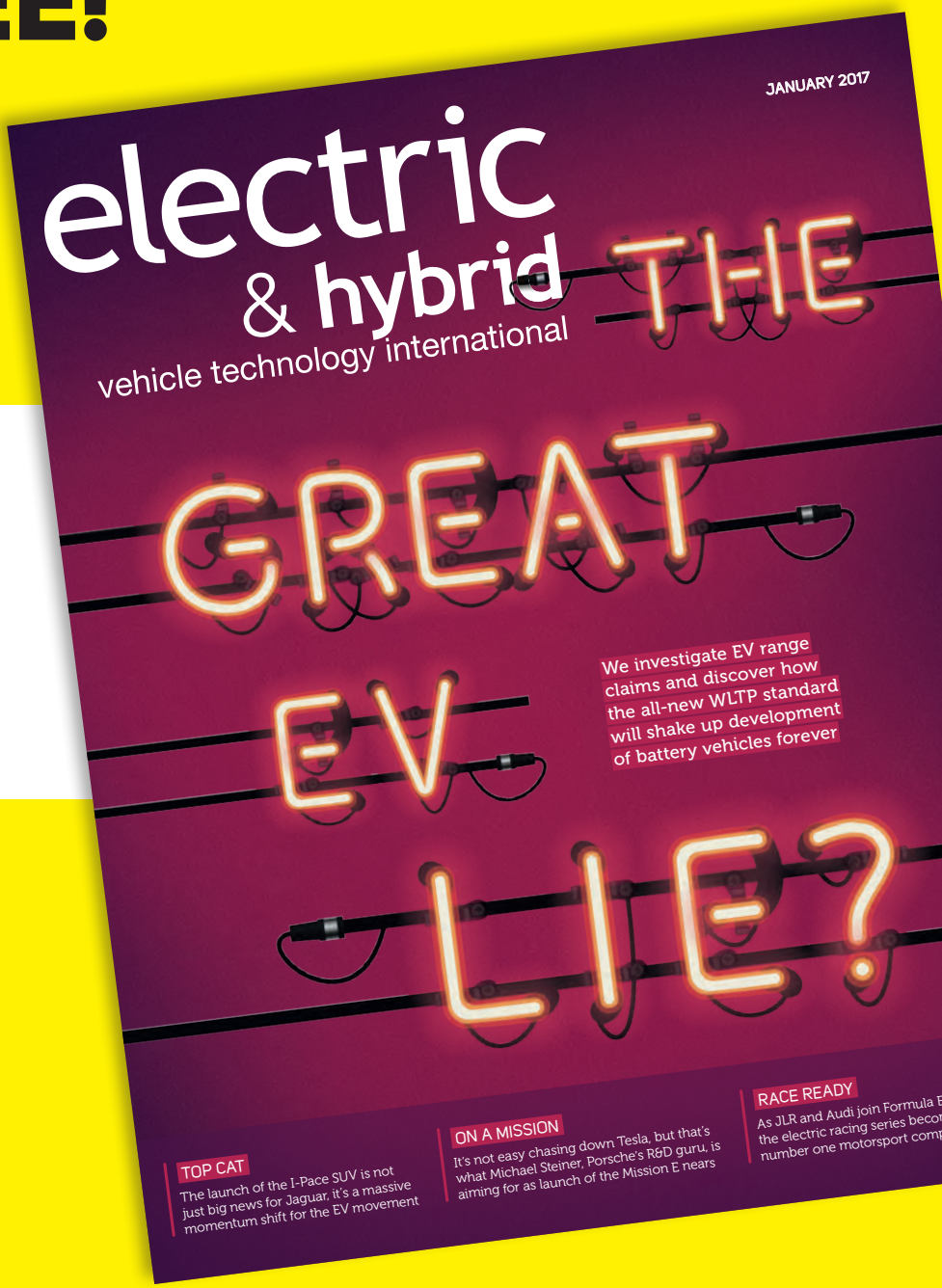
Yet, a Tanktwo String Battery costs less than a regular pack.

TANKTWO

Tanktwo Inc., 48 Wall St., 5th fl., New York, NY 10005

b@tanktwo.com
tanktwo.com
+1-973-TANKTWO
+1-212-321-0630

SUBSCRIBE TODAY: REGISTER ONLINE TO RECEIVE THE NEXT ISSUE **FREE!**



To receive future copies of *Electric & Hybrid Vehicle Technology International* free of charge, or to register a friend or colleague, please sign up online now!

Register free online at:

www.ukipme.com/ev

WORDS: **DEAN SLAVNICH**

Pace setters

The stunning I-Pace is a prime example of next-gen BEVs potentially replacing HEVs/PHEVs. The Jaguar crossover boasts a driving range in excess of 500km

Back in 2010, I was invited to an early tech workshop to better understand the powertrain that PSA Peugeot Citroën was pinning its future hopes on: Hybrid4. Unlike Toyota and Honda with their HSD and IMA gasoline-electric creations, which were finding favor with early tech adopters, environmentalists and even Hollywood stars the world over, PSA was going down its own path: diesel-electric.

Wow, I thought. Brave, not just because it was the first car maker to wade into this commercially unknown pool, but because Hybrid4 also represented a lifetime investment of over US$532m. That might be small fry for, say, Volkswagen Group with its large flexing muscles, but for PSA, at that time, this was a lot of chips at the table. Some 300 patents were filed for the world's first diesel hybrid system; 1,500 engineers worked on the project and the technology was tested to the equivalent of 5,000,000km.

Two years later PSA launched it, first in the Peugeot 3008 and 508 and then Citroën DS5. The hope was to shift more than 40,000 units per year by 2013.

In short, they didn't. And by 2015, PSA announced plans to kill off Hybrid4, as a change in strategy meant it would pursue gasoline hybrids and plug-ins that replace e-TDi. Shame really, because, on paper at least, a diesel hybrid makes much sense. Match one efficient, low-torque, long-lasting engine with another instant torque, zero local emissions powertrain. It was like 1 + 1 equaling 10. Except there were a few problems.

Firstly, in the real world Hybrid4 wasn't anywhere near as refined, sophisticated or as good as HSD and IMA. And unlike those other two operating systems, this really was a powertrain just for Europe. The other pressing issue was with the technology as a whole. "The problem with diesel hybrid is you're putting one really expensive engine technology on top of another really expensive engine technology. It's not easy to make margins from that," Fritz Henderson said to me back in 2008 when he was vice chairman of GM.

Since Hybrid4, a number of other car makers have dipped their toe into this pool. Volvo launched a diesel plug-in, which I was rather impressed with, but that has since been overtaken by the brilliant gasoline-hybrid Twin Engine. Mercedes-Benz also offers a diesel-hybrid option, albeit a different system to Volvo's, in the E-Class.

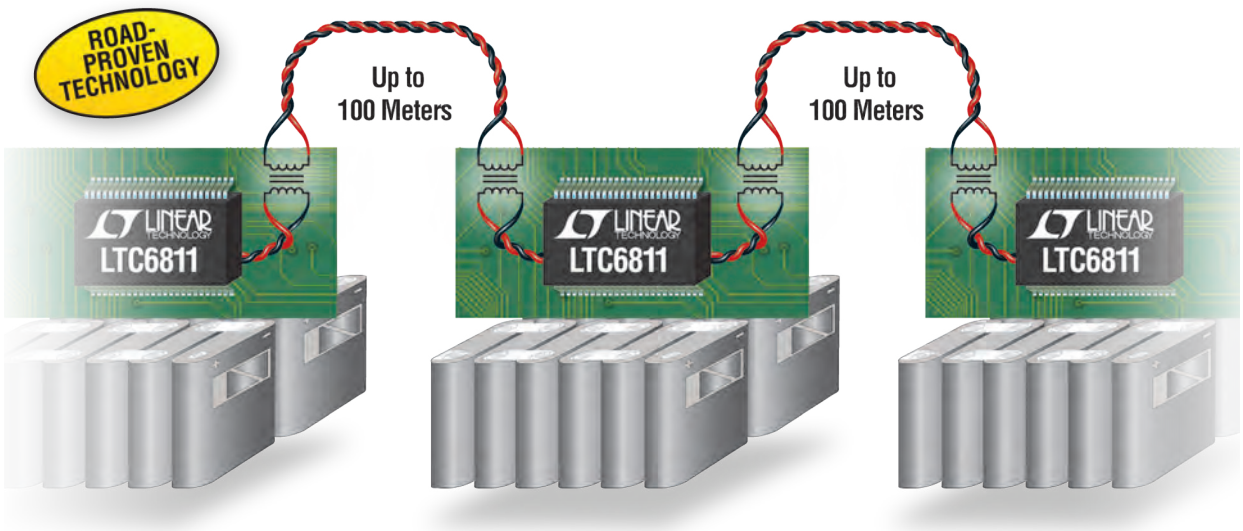
It's a shame, but I'm skeptical as to just how many more diesel powertrain developments we'll see going forward. There are just too many (better) competing technologies that are cheaper to develop and produce.

And that leads me on to the next point. For me, this year has been a real turning point for battery electric vehicles. Car makers are now openly discussing realistic driving ranges of 480-640km (300-400 miles) for next-gen BEVs. And that's not some sort of future vision for the rich and wealthy: the Jaguar I-Pace might boast that kind of mileage from one charge, but look at the numbers associated with, say, the revised Renault Zoe and VW e-Golf.

We're finally entering an age where range anxiety, a term I never really grasped, shouldn't be a thing, and where a BEV can be the main family car, not a second or third runner to the IC models also on the drive.

And this all ultimately means hybrids, in general, not just the diesel ones, could be on their way out. The 400-mile-plus BEV is here, at last, and you just know that range will get even better with time.

1.2mV Accurate, Noise Immune Battery Stack Monitor



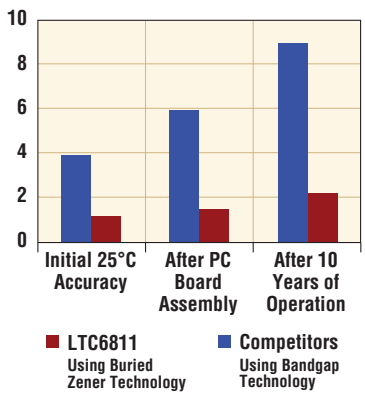
Maximize Battery Pack Safety, Life, Capacity & Driving Range

Safely extract the potential of large battery packs via precise monitoring of every cell. The LTC®6811 Battery Monitor measures cell voltage with less than 0.04% error, guaranteed. Measurement stability over time, temperature and operating conditions is achieved with a buried Zener voltage reference, similar to those in precision instrumentation. A programmable 3rd order noise filter keeps noise from corrupting cell measurements, and a 2-wire isoSPI™ interface provides a cost-effective, noise immune, 100 meter interconnection for multiple LTC6811s.

Features

- Total Measurement Error <1.2mV
- Long Term Stability Assured with Laboratory-Grade Voltage Reference
- isoSPI, Isolated 2-Wire Interconnection up to 100 Meters
- 290µs to Measure All Cells
- Passive Cell Balancing
- 4µA Sleep Mode Supply Current
- AEC-Q100
- Engineered for ISO 26262 Compliance

Measurement Error (mV) when Measuring a 3.3V Cell



Info & Free Samples

www.linear.com/product/LTC6811

1-800-4-LINEAR

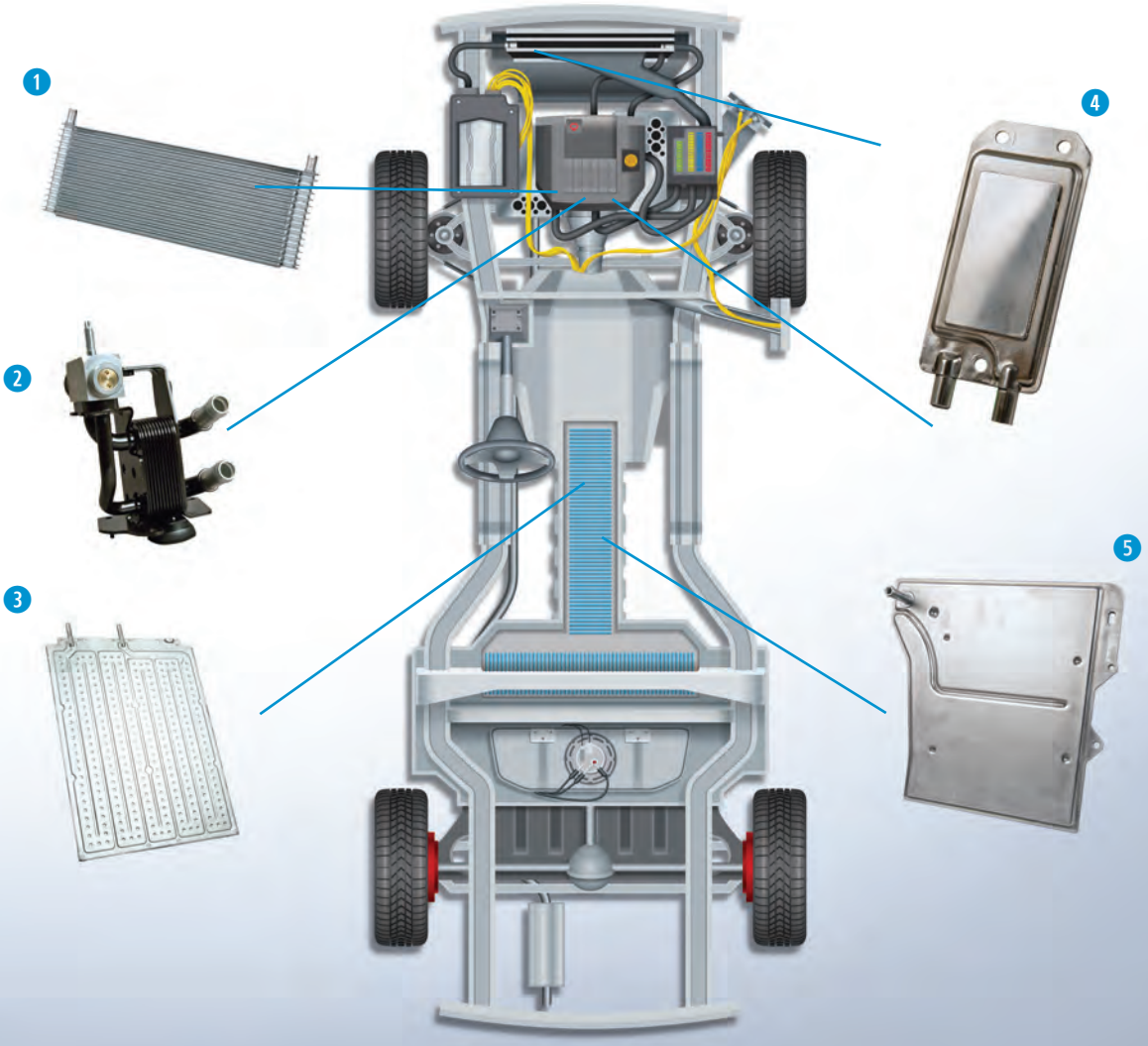
Download White Paper

"Battery Stack Management Makes Another Leap Forward"

www.linear.com/docs/52618

Innovation Through Every Part.

Thermal Solutions for Hybrid and Electric Vehicles



1. **Sub-Cooled Loop Radiator**
2. **Hybrid and Electric Vehicle Battery Cooling Chiller**
3. **Battery Interelement Cooling Plate**
4. **Power Electronics Cooling Plate**
5. **Battery Cold Plate**

TAILORED PRODUCTS FOR EACH APPLICATION As a leader in thermal technologies, Dana collaborates with global automakers and electronics manufacturers to create superior cooling solutions that meet the unique needs of today's battery systems and power electronics. Our cooling technologies are precision engineered to include advanced features that enable high thermal performance. Through a strong pursuit of innovation, our parts also effectively minimize overall vehicle weight and reduce manufacturing costs. For more information, visit **danacontactus.com/EH.**

DANA LONG® Thermal Products