ELECTRIC VEHICLES

FROM TRACK TO ROAD

Dave Priscak considers the opportunities and limitations that Formula E provides for on-road electric vehicles

Over the years, technologies developed in the high-performance, big-budget sporting arena of Formula One have later propagated to mass volume passenger vehicles. This knowledge transfer supports the evolution of better, safer, more efficient cars that everyone drives today.

The same potential now exists with Formula E as the proving ground for everyday electric vehicles (EVs). Innovations around battery technology, power management, charging and regenerative braking, for example, could all transfer across.

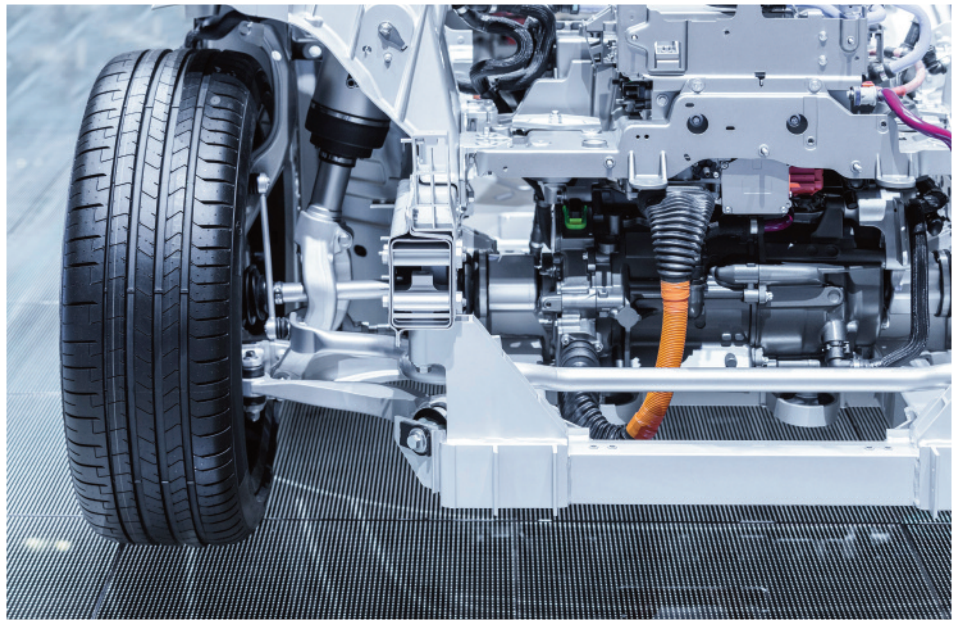
Battery

One of the main barriers to achieving large-scale adoption of EVs is consumer concern over how far they can travel on battery power alone; this is known as range anxiety, a fear of not being able to reach a destination on one charge. However, consider this, how long are most journeys in reality?

Thanks to modern battery technologies and efficient drivetrains, there are numerous production volume EVs available with ranges beyond 320km per full charge. This distance can comfortably accommodate most of our daily journeys, such as school runs, work commute and local shopping trips. Having said that, there is still plenty of scope and desire to improve battery performance.

Because battery design is an electrochemical science, it has the potential to be very volatile. Formula E works with companies that focus on architecting batteries that provide high power density, while at the same time making them safe to use in harsh racing environments.

Having a standard battery system reduces the hazards under extreme acceleration-regeneration and ensures a safe disconnect in case of a crash. Race car design teams also have a level playing field with a known battery impedance and characterised charge-discharge profiles.



Typical powertrain system in an electric vehicle

Powertrain

The powertrain, however, is not regulated. Each team adds its secret sauce to increase acceleration, improve the efficiency of regeneration, and manage the power budget to ensure the car finishes the race. It also allows each team to focus on the electro-mechanical powertrain, borrowing from the mechanical design of Formula One and the kinetic energy recovery systems used there.

Improvements

Due to the extreme nature of Formula E, race teams use many more embedded components than current production volume EVs for monitoring, controlling and optimising the car on the fly. During a race, the devices transmit real-time data to the control room for processing and analysis. Recorded data, such as power transfer efficiency, temperature rise, percentage of recaptured energy and more, enable the team to improve the software running the powertrain from the battery to the wheels.

After the race, teams share these data with industry partners to optimise how the powertrain operates and improve performance. These data also help with new product development, which, in turn, enhances the performance of components for the next powertrain design.

This continuous improvement process not only keeps race team partners competitive on the track, but EV designs benefit too from an ever-increasing level of knowhow and real-world application experience. Semiconductor manufacturers can

Formula E is pushing boundaries for EV design

then design better performing, higher efficiency and more reliable components for use throughout the powertrain.

Software

Electronics in both hardware and software form dominate new vehicle innovation nowadays and software is a significant element of the powertrain. There are already numerous software configurations operating in today's EVs.

Traction control algorithms, for example, adjust and balance drive to the wheels to make for safe progress in icy road conditions or to trigger regenerative braking when drivers lift their foot off the accelerator.

Modern EVs are becoming more complex, with additional drive motors and higher levels of autonomous operation. Drivers can select their preferred drive modes, such as opting for performance over range for their daily commute or all-wheel drive (AWD) for off-road or wintery weather conditions.

Performance selection technologies transferred from Formula E include slip during cornering controlled by acceleration profiles. The transfer of these software algorithms will continue to customise, differentiate and improve EV characteristics.

Similarities

While Formula E cars can reach speeds of up to 280kmph, the race itself lasts for just 45 minutes – they are optimised for speed, not range. On the other hand, consumer EVs are designed for maximum range and a much lower speed. However, both powertrain applications are much the same.

The similarities are that both powertrains strive for the highest power transfer efficiency and use regenerative braking to feed power back to the battery to extend range. They also use motor algorithms, which are essential for different modes of operation.

Formula E pushes the boundaries in terms of power conversion, thermal dynamics and control software. EVs will undoubtedly benefit from what has been learned and tested on the circuit.

Using silicon carbide (SiC) elements in the powertrain, designers are meeting the heights of efficiency, safety and reliability in the harsh environments of Formula E. The use of SiC components, in turn, will enable EVs to travel further, be safer and more reliable.

Bus voltages

Today's EV main power bus is typically 400V, but there are 800V powertrains in development, which is fast approaching Formula E's own 900V bus. High voltage, wide bandgap components, such as SiC, increase power density and allow smaller motors to be used; this will speed up the realisation and adoption of higher voltage busses.

Higher battery voltages also help in the volt-amp problem of fast charging. However, for the installed base of EV chargers, changing battery voltages may be problematic. Future chargers will likely be digitally controlled to accommodate multiple voltages. Also, EVs will have to be flexible on charging rates, as it will be based on the charger's output capabilities.

The 12V bus system will be around for the foreseeable future for both Formula E and EVs. This is because 12V provides power to everything from sensors to infotainment systems to comfort and convenience. However, this does not necessarily imply a need for 12V batteries. High voltage DC-DC converters, such as 400 or 800V to 12V and 48V to 12V can solve this problem.

The 48V bus systems are becoming more of a requirement. Many motors, such as those driving the park assist and e-turbo, need a higher voltage to satisfy increased torque requirements. One way to get to 48V is to use two 12V batteries and then boosting one to 48V. In the future, there is a likelihood there will be one high voltage battery with multiple voltage rails to support the different requirements of each of the electronic loads around the vehicle.

Fast charging

Consumers have expectations that commercial EVs should have a similar charging time to that which it takes to fill a regular petrol-powered car at the pump. Although Formula E charging for third-generation cars will be 600kW, delivering 4kWh in 30s, it is unlikely these speeds will be available to consumers in the foreseeable future.

Most electrical grids are not designed for massive power

Range anxiety: How far will the car go on one charge?

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Designing for Formula E makes the learning curve steep and rapid

transfers such as this. Other limiting factors to the charging speed include the current capacity of the charger and cable, the impedance of the battery, and battery balancing.

As higher voltages reduce the charge currents and transmission loss, there will likely be higher battery voltages in the future. It is reasonable to envisage charging stations, similar to petrol stations or collocated with petrol stations, connected to 1200V mains capable of delivering a full charge in minutes and therefore replicating the traditional petrol vehicle experience.

Regenerative braking

The driving style in Formula E requires fast acceleration and exceptionally hard braking as the cars travel around winding circuits. This environment is ideal for regeneration as the ratio of brake to run is high. However, the time it takes to generate energy from a hard brake is not long enough to store back into the battery, which is an issue.

Using technologies such as Li-ion capacitors or supercapacitors can temporarily store the recovered energy and transfer it to the battery or be consumed upon the next acceleration. This methodology can be expensive to implement, however, and the return on investment may not justify the expense if the brake to run ratio is low.

Regeneration, therefore, is a critical differentiator between Formula E and consumer EVs. However, with continued research into the best ways to capture and reuse regenerative energy, this knowledge will eventually transfer into more effective and cost-optimised systems for consumer EVs.

Summary

Racing environments continue to be an invaluable proving ground for consumer vehicle developments. The benefits and knowledge gained help both car manufacturers and component developers alike. There is no better way to understand how devices and systems will work than in the real world – not lab-based environments. And when that environment is as challenging and extreme as Formula E, then the learning curve can be steep and rapid.

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