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Driving the green revolution: Technology advancements enable new efficiencies in electric cars

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Summary

Automotive transportation is undergoing a revolution, as advanced electronics enable the electrification of vehicle engines, as well as increasing automation, safety, comfort and convenience. As a result, these changes make the future of driving look very different from our experiences today. Vehicles will be custom-designed for their applications and loaded with communications for occupants (just passengers, no drivers) to work or entertain themselves. The levels of electrification may vary, but one thing is certain: integrated circuits (ICs) and their very technical role in these autos of the future are key.

Keywords: Components, batteries, high-voltage power, HEV/EV, hybrid

1 Advanced electronics enable automotive innovations

Worldwide emission standards drive a paradigm shift in today's powertrain architectures towards higher efficiency, better drivability and safer and smarter vehicles enabling highly automated to autonomous driving. Car sharing models and mobility services will continue to grow and call into question the future need of car ownership in general. Cities will be filled with self-driven, zero-emission electric vehicles (EVs) that communicate among themselves and with roadway infrastructure. Electrical grid stability and efficiency will greatly benefit from smart usage of the vehicle's energy storage capabilities and the second life reuse of car batteries in residential storage.

Imagine cars delivering passengers, and then directing themselves to parking spaces with inductive pads to quickly recharge until they are summoned again. Traffic intersections and other places where cars are forced to stop will also have recharging pads for battery top-ups. Vehicles will be custom-designed for their applications and loaded with communications for occupants (just passengers, no drivers) to work or entertain themselves. Cars like these will not only be more comfortable to ride in but will also be in use a much higher percentage of the time than most cars today, using roads and energy more efficiently for a greener urban environment.

Whether or not this vision describes the future precisely, the fact is that advanced electronics are enabling any changes in automobiles, beginning with the engines themselves. Auto manufacturers and customers alike are increasingly turning to various forms of EVs, hybrid-electric vehicles (HEVs) and electronically assisted combustion engines to improve gas mileage and lower emissions cost-effectively.

The market for HEVs and EVs will continue to grow, with demand for systems in these vehicles reaching $64.1 billion in 2023, up from $23.9 billion in 2017, according to market analyst firm Strategy Analytics. Meanwhile, annual production of HEVs and EVs will rise to 19.8 million vehicles in 2024, representing 18% of all vehicle sales worldwide, and an increase from 4.8 million in 2016 [1]. HEVs are popular because, in addition to reducing fuel consumption and emissions, they offer manufacturers a chance to develop step by step the supporting technologies necessary or electrification and give consumers time to become accustomed to them. Governmental mandates, as well as market demand will determine how rapidly this transition moves.

The changeover to HEVs and EVs, plus more limited options such as automatic start/stop and regenerative braking, is made possible by innovations in electronics, which also serve as enablers for new benefits in automotive efficiency, safety, comfort, convenience and automation.

Increasingly, cars rely on integrated circuits (ICs) that sense conditions, drive actuators, convert signals, communicate among vehicle systems and decide what to do—often without intervention by the driver. ICs that function in vehicles must operate under extreme conditions of voltage, current, temperature and vibration, and they must operate reliably to keep the equipment and occupants safe.

2 A wide range of electrical/combustion configurations

In the market today, a small, dedicated group of consumers seek EVs, while a larger minority is motivated to buy HEVs due to their decade of success. The great majority of buyers look for new electronic features that promote efficiency and performance in combustion engines. The full range of these configurations is summarized in Table 1, which shows the levels of engine assistance and/or propulsion and the amount of fuel savings in ordinary driving over a standard, baseline car today. Below is a quick breakdown of the various electrified vehicle classification.

2.1 Start/stop and micro-hybrids

To begin with, an engine can simply be stopped when it idles, and then restarted to move again, saving a small amount of fuel in city driving. Adding regenerative braking (recuperation) and coasting creates a micro-hybrid, with a bit more fuel savings because of the reduction in battery recharge demanded from the engine. In addition, some safety and convenience automation features that are becoming common, such as adaptive cruise control, save fuel by making driving more efficient. These forms of assistance, though seemingly simple, can be quite involved and require electronic management. There are also weight-saving measures such as drive by wire, shift by wire and brake by wire that help reduce fuel consumption and prepare the way for greater electrification. Start/stop, energy regeneration and various other forms of electrical assistance will be introduced into vast numbers of cars in upcoming years, increasing overall fleet fuel efficiencies and preparing car buyers for the more extensive innovations of HEVs and EVs.

2.2 Mild hybrids

Further improvements in fuel efficiency depend on increasing the battery size. Light electrical functions such as the lights and windshield wipers are already run directly from the battery, but heavier functions such as pumps must be assisted from the alternator or belt-driven directly from the engine. A number of auto makers are working to introduce a dual-voltage electrical system that combines a 12-V battery for compatibility with existing systems with a 48-V battery that will run the starter/generator, supercharger or turbocharger, fuel pump, water pump, cooling fan and other power-hungry systems.

While 48 V represents a new standard that will provide up to about 15 kilowatts (kW) of power for driving the systems in Figure 1. Latest developments enable 48-V systems to reach power levels up to 30 kW. , In either case, the auto-configuration, a mild hybrid, saves additional fuel, increases drivability, and provides limited independent electrical propulsion or drive for the vehicle.

2.3 Full and plug-in hybrids

In a full hybrid, which propels the car electrically with a load of up to ~80 kW, a battery rated in the hundreds of volts is required. City cars might rely on the more cost efficient, less powerful 48-V architecture to power full and plug-in hybrid vehicles. Fuel efficiency depends on how long the car drives electrically versus by combustion. In the absence of a breakthrough in battery technology or some way of rapidly replacing batteries, fuel consumption can be further reduced only by recharging the battery from an outside source such as a wired connection or inductive pad. Plug-in hybrids, projected to be the fastest growing configuration of those listed in Table 1, representing approximately a third of the 19.8 million units selling in 2024 [1], increase fuel efficiency to the extent that the owner regularly recharges the vehicle from a wall socket.

2.4 Fully electric vehicles

At the final level, full EVs diminish gas consumption to zero, though they lose the flexibility of a combustion engine for taking longer trips and refilling quickly. Low range and long charge times are the greatest drawbacks in acceptance of EVs. Although most of the time people drive their cars for only short distances and have plenty of time to recharge overnight, they still want the option of driving across the country for a comparable distance that a tank of gas would take them, then recharging in little more time than a gas fill-up requires. The long-term success of zero emissions vehicles appears to depend on technological advances in battery capacity and fast charging cycles, the latter possibly being supplied wirelessly by induction coils beneath the car, instead of or in addition to a power cord.

2.5 Self-driving and Advanced Driver Assistance Systems (ADAS)

An additional factor weighing into fuel savings is automated driving. Strictly speaking, automatic operation is not an HEV/EV issue and can be introduced in any car. However, vehicles capable of self-operation include numerous sensing and actuation systems that parallel the systems required for electric engines. Cars can also be designed to operate automatically with greater fuel efficiency than most human drivers can achieve, especially in city driving where maintaining as constant a speed as possible is difficult. For these reasons, it seems likely that HEV/EV development for auto makers will be closely aligned with development of advanced driver assistance systems (ADAS) and self-driving capabilities, for reasons of safety as well as fuel economy and emissions.

3 Technical challenges facing development of HEVs and EVs

For car designers and electronics suppliers, the central issue in electrifying automobiles lies in dealing with high voltages safely. High voltages bring stringent requirements for materials, processes, designs, packages, qualification—the whole gamut of IC technology. Meeting these challenges is important not only for reliable functioning but also for safety in operating the starter/generator, power steering, traction control, battery management, bidirectional DC/DC conversion and many other areas. These systems must be protected against overvoltages, overcurrents, power spikes, signal feedback to other systems, electromagnetic noise from outside sources and a variety of other destructive or contaminating influences. Above all, there must be no risk whatsoever that people will be exposed to high voltages and currents.

Aside from the IC technology factors already mentioned, safety depends heavily on circuit isolation, which may be internal to a chip die, between chip dies in a single package, among IC devices that function together, or some combination of these. To ensure safety, automotive specifications call for twice the isolation required for simple functioning. Automotive ICs are manufactured to provide this level of protection, known as reinforced isolation.

High voltages in hybrids permit downscaling the combustion engine, which reduces fuel consumption but also reduces the power delivered. To compensate for the smaller engine, the electric starter motor needs to deliver torque to the engine, and the conventional turbo/supercharger needs to be replaced or complemented by an electric one that adds torque during operation. Providing overvoltage transient protection for these functions that complies with industry standards for 48-V supply rails, such asVDA320, requires IC process technology characterized for up to 100 V. For propelling the car and charging it from an external source, such as a wall socket or induction coil, even higher levels of characterization are required, measuring as high as 1,000 V (1 kV) to support fast charging cycles.

In some applications, support for extremely high-frequency switching is required, too. Providing FETs capable of achieving these high voltages and frequencies is another challenge in automotive electronics. Silicon power FETs are characterized for voltages high enough to handle the loads on traditional 12-V and many loads on 48-V batteries. However, a different material is needed for characterization approaching and beyond 100 V. Recent advances in gallium-nitride (GaN) and Silicon Carbide (SiC) technologies make these materials excellent options for high-voltage power switches. Theoretically capable of switching 1 kV and more at megahertz frequencies, SiC and GaN are useful not only in simple on-off high-power switches but also in ultra-high-frequency switching power supplies. Wide bandgap technologies like GaN and SiC are expected to increase the power density by a factor of three to four and enable efficiency gains extending driving range by 10%.

Managing the batteries of HEVs and EVs is a key area for innovative high-voltage technologies. Dual-voltage systems, combining 12-V and 48-V batteries, need bidirectional DC/DC conversion, to both protect the circuitry and enable functionality. Even higher voltages, associated with propulsion and external charging, will come from large numbers of cells connected in series. Battery management needs advanced control intelligence that can monitor charging, discharging and recharging with sensing for temperature, voltage and current in each cell. Synergetic with control of individual electrical systems is communication among them, as well as with vehicle control systems that are sensing external road conditions and automatically managing some or all operation of the car. Auto makers rely on the CAN bus and other recognized network standards; however, there is still much innovation on the horizon in automotive network communications. Car makers expect IC suppliers to be able to adapt to the varying communication requirements of different car models.

4 Meeting the challenges of automotive electronics

The technical requirements for safety and operational integrity using high voltages demand innovative technology on the part of IC suppliers. Recognizing the specialized requirements of the automotive market, IC suppliers devote a large portion of technology expertise to the development of automotive solutions.

Concern with safety has led to the development of leading isolation techniques that enable, for instance, the integration of high- and low-voltage and high and low-frequency functions in the same package.
Reinforced isolation is a regular feature of chip dies and packages certified for automotive and industrial use, as are higher temperature, voltage, current and vibration qualification.

For safe control of electrical systems, microcontrollers (MCUs) provide dual lockstep CPUs, error correction and self-testing as well as MCU cores and peripherals optimized for high-speed, real-time motor control.

Process technology advances also continue to push silicon to perform at higher voltage levels, such as those used in the new automotive electronics. In adding new high-voltage systems to their products, auto manufacturers are opening new territory, and they need the flexibility to adapt, which is best done by leveraging a broad portfolio of IC solutions, including battery charging and management, voltage conversion and regulation, power drivers and other functions in the electrical system.

5 Electrifying transportation in the future

As the revolution in transportation continues, new introductions in automotive electronics are continuing to make cars more fuel-efficient, safer and convenient. Electrically assisted combustion engines, hybrids at various levels, and full EVs are all making a change in emissions that cut down on pollution locally and greenhouse gases globally. Automated driving and EVs will change the operation of vehicles, especially in cities, bringing new business models that help provide low or zero emissions and customized transportation for millions.

6 Referencing

[1] Ian Riches, "Automotive Electronics System Demand Forecast 2015 to 2024: Electrification Drives," Strategy Analytics, April 2017, pp. 96-100, accessed June 1, 2017.

7 Figures and Tables

7.1 Figures

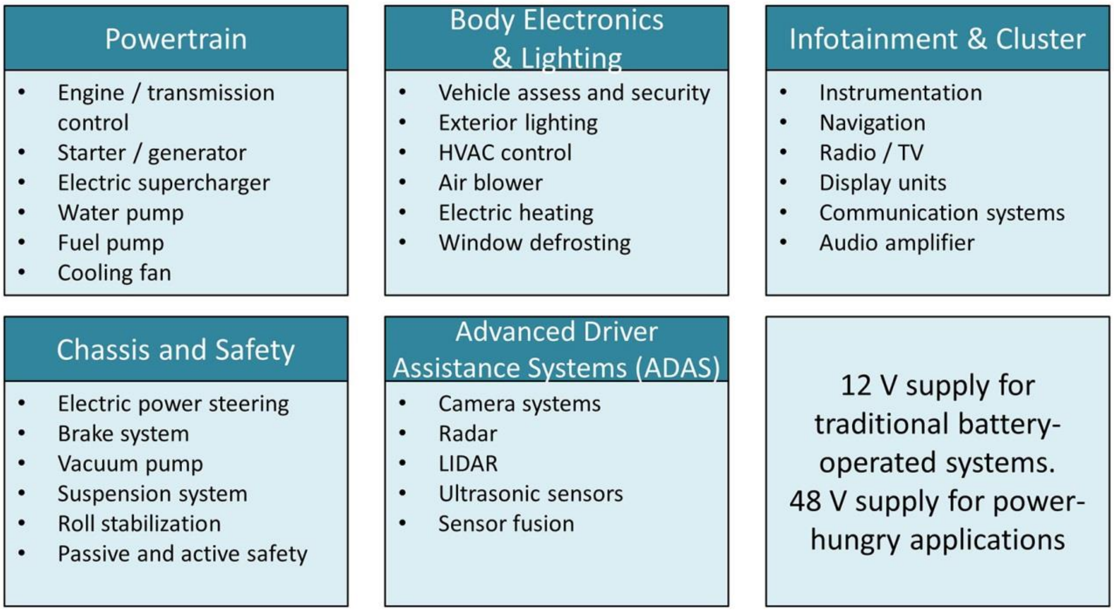

Figure 1: Dual 12-/48-V architecture.

7.2 Tables

Table 1: Electric-combustion vehicle configurations.

Electrified Vehicle Technology			**CO2 Reduction**
Micro Hybrid	12V	<5kW	3-10%
Mild Hybrid	48V	5-12kW(30kW)	8->20%
Full Hybrid	100V-400V (48V)	20-80kW (30kW)	20-50%
Plug-in Hybrid	100V-800V, (48V)	>50kW (30kW)	40-80%
Pure Electric	100V-800V, (48V)	>50kW (30kW)	100%

Author

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