Bill Fleming
Senior Editor

Smarter Cars: Incredible Infotainment, Wireless Device Charging, Satellite-Based Road Taxes, and Better EV Batteries

Chevrolet Offers New Infotainment Systems

Chevrolet (Detroit) has developed a next-generation infotainment system called MyLink. There are two systems with the MyLink name—one is in the 2014 Impala, and the other is in the 2013 Chevrolet Spark and Sonic [1], [2]. Like all General Motors cars, these models also come with OnStar (a subscription-based service that includes communications, in-vehicle security, hands-free calling, turn-by-turn navigation, and remote diagnostics).

Low-Cost System in Spark and Sonic Vehicles

The version of the new MyLink system in 2013 Spark and Sonic vehicles is low cost. For navigation, it utilizes a US$50 smartphone app called BringGo. (An "app" is an abbreviation for "application"—it is a specialized software program that can run on a smartphone or on other electronic devices). These cars will also be the first to have Siri, Apple's voice-recognition system that functions as a personal "answer woman" and also works with an iPhone. Siri additionally works with Google Android and RIM Blackberry smartphones, plus Windows Mobile and phones with the Nokia Symbian operating system. An iPhone or iPod can be plugged in and can be paired with Bluetooth [1].

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The BringGo app loads maps into the phone memory, so the system does not use a cellular data plan, even for turn-by-turn directions. (Data plans allow smartphones to access the Internet through cell phone services rather than Wi-Fi connections.) BringGo uses data plans for live traffic, points of interest, and three-dimensional (3-D) maps. The MyLink radio on Spark and Sonic vehicles is available with a 7-in (18-cm) touch screen and includes Pandora and Stitcher as embedded apps, along with Siri. (Pandora provides music and Stitcher provides news and information.)

The Eyes Free mode in a Siri-equipped Spark vehicle is activated by pressing a push-to-talk button on the steering wheel. The Siri system exhibits good voice recognition and an easy interface with a smartphone. Siri could, for example, tell you the score of a football game, the weather forecast, and similar information. Through voice recognition, Siri also makes voice-activated calls, checks the driver's calendar (and adds appointments), and composes/sends text messages. For driver safety, it declines questions that would require reading a Web page, even when the car is parked. For example, the question "What is a data plan?" elicits a refusal [1].

Upscale System in Impala

The MyLink system in the 2014 Impala is more upscale, with a standard 4.2-in (10.7-cm) or an optional 8.0-in (20-cm) touch-and-sweep screen that looks and performs like a smartphone. The driver first pairs the phone (pairing a phone establishes and maintains the connection between the phone and the MyLink system). The driver can then put the phone away and does not have to use it while driving because the MyLink touch screen functions as an in-car replacement for the phone. But it is not just a display—the MyLink system also draws everything from a well-apped smartphone, which, in fact, is what the Spark–Sonic system really is.

Impala MyLink intelligence is embedded in the infotainment system, including navigation. The voice-command function is provided by Nuance's Naturally Speaking. (Naturally Speaking is a speech-recognition software package developed and sold by Nuance Communications Inc., Burlington, Massachusetts.) The Naturally Speaking choices are navigation with 3-D city maps, phone, audio, and weather. It will read text messages and stream audio from the smartphone when updates arrive. All Nuance voice-control features work while the car is moving [1]. There is a choice of home screens, each with different styles of icons, to match a mood and/or a particular driver. A home screen selection is shown in Figure 1.

In-Vehicle Infotainment Evolution

An increasing demand to link smartphone apps to vehicles is forcing

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Figure 1 One of several home screen choices for the MyLink system in the 2014 Impala [1], [2]. (Figure courtesy of Chevrolet.)

developers to plan for apps that may become more complex with time. "A lot of apps don't take much computing power, but CPU bandwidth will become an issue in the future as apps get more complicated and people want to run many at once," said Mark Peters, director of engineering for car multimedia at Robert Bosch LLC (Farmington, Michigan) [3].

Automotive software developers must also figure out how to connect other consumer products to vehicles. Automakers may have to add another link, one that is popular in homes: the high-definition multimedia interface (HDMI) connector. "Many newer phones and portable media players support HDMI output. This now puts some pressure on the vehicle industry to support the HDMI standard for streaming audio and video to the vehicle," said T.C. Wingrove, senior manager, Global Electronics Innovation at Visteon.

Many observers also note that wired connections can be problematic for automakers because they will never be able to keep up with the rapid changes that occur in consumer products. For example, Apple changed from a 30-pin connection to its new eight-pin Lightning connector, creating an incompatibility issue in existing vehicles. "A lot of car makers who built iPhone docks got caught when Apple changed its connector," said Andy Gryc, automotive product marketing manager for QNX Software Systems. (Ottawa, Ontario, Canada) "That shows how vulnerable automakers are. Anything they can do wirelessly gives them more flexibility" [3].

Design teams are tackling the compatibility challenge by employing wireless technologies both in-vehicle and with connections to the cloud. They are using standards such as Bluetooth and, possibly, Wi-Fi to link handhelds in a car to communicate with the vehicle's radio head unit. Currently, a problem with these technologies is that users must still attach a cable to recharge smartphones or tablets. However, advances in wireless charging technologies (see the section "In-Vehicle Mobile-Phone Battery Wireless Charging") may eventually change that, allowing users to enjoy a completely cord-free connectivity.

"We're also moving towards putting apps in the cloud, not on the smartphone or the radio head unit," said Frank Hirschenberger, senior director of innovation at Agero (Medford, Massachusetts). "Then, you have the opportunity to modify apps on the server instead of on the radio head unit" [3].

Infotainment System with Gesture Control

Harman International (Stamford, Connecticut) supplies infotainment systems to automakers. Augmented navigation, gesture control, high-speed networking, brilliant graphics, and smart connectivity are being combined in an infotainment concept system, which Harman claims, "will be the ultimate in-car premium infotainment experience" [4]. This car infotainment concept system runs a virtualized platform that keeps vital car functions running on QNX with an Android-based interface (QNX is a mobile operating system for embedded systems and Android is an operating system designed primarily for touch-screen mobile devices).

In Harman's concept system, drivers will have access to Android's usual app suite as well as automaker-run app stores. The system features integration with mobile devices (including Apple's Siri and Google Voice Search) as well as an interface that expands touch-select targets when the users fingers get close [4].

At Harman, a potentially distraction-free interface is being developed. Its prototype includes an infotainment display (Figure 2) and a built-in pair of gesture-control image-recognition camera-based sensors mounted on the console display surface. The driver simply swipes his or her hand to play a song and sweeps twice to pause. To change the volume, he or she raises his or her hand from a low position to turn it up and drops it from a high position to turn it down.

Long-term evolution (LTE) data and a possible smart grid tie-in that shows messages only when the car is stopped at a red light are also included. (LTE is a standard for mobile phones designed for wireless communication of high-speed data.) Harman will further minimize driver distractions by integrating icons in its new infotainment system that grow in size as the driver's finger approaches the touch screen. This ensures that the touch targets are big enough for users to find quickly the first time [4].

Gesture Recognition and Eye Tracking

Commonly used clusters of buttons and knobs were mostly eliminated in Hyundai Motor's HCD-14 Genesis concept vehicle (shown at the North American International Auto Show, Detroit, 14–27 January 2013). Eye tracking and 3-D hand-gesture recognition are employed to input driver commands [5]. To adjust the climate control temperature, a driver would take one hand off the wheel and move it slightly upward. The car then responds by increasing the temperature by a few degrees.

The technology behind the Hyundai HCD-14 is based on eye tracking, gesture recognition, and smart software. The gesture-recognition/eye-tracking control system works as follows [5]:

- The Hyundai HCD-14 concept vehicle includes four displays: a free-form stack display located above the center console, a head-up windshield display, an instrument panel digital display, and a driver information display to the left of the instrument panel.
- A pair of cameras in the steering wheel tracks the driver's eyes. Once the car sees the driver's eyes glance at a specific area in the center stack—with its climate control, infotainment, phone, and navigation areas—it determines which control is selected and illuminates a confirmation on the display.
- A second set of cameras in the headliner look down on the driver and track the driver's hand movement. The field view of these cameras is approximately 1 ft^2 (0.1 m^2).
- Detected hand gestures include pointing, raising, or lowering the hand, pinching or spreading, swiping left or right, or rotating clockwise or counterclockwise. Hand gestures provide input signals that adjust the desired operating level of the control function selected via eye tracking.
- Available adjustable controls include volume, zooming in on a display, flicking to a new page, adjusting the speed of the fan, scrolling through a phone contact list, etc.
- A head-up display on the windshield allows the driver to keep his eyes straight ahead while using the eye-tracking and gesture-recognition control functions.

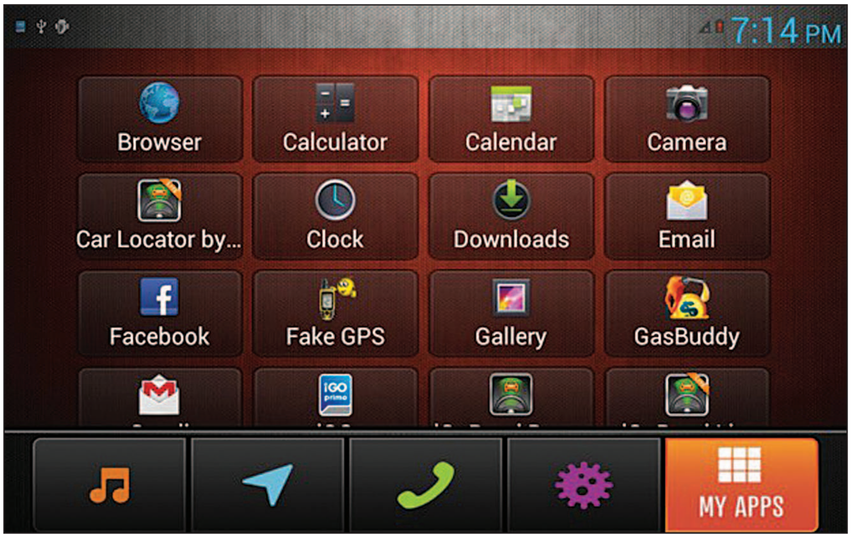


FIGURE 2 Drivers or passengers can select interface display/control options using touch-free hand-gesture control. One of the selectable displays is shown here [4]. (Figure courtesy of Harman International.)

Both the eye-tracking system and the gesture-recognition system were developed from commercially available consumer electronics products [5].

- The eye-tracking system was developed by Tobii Technology AB (Stockholm, Sweden). Tobii had previously released Tobii REX, which enabled users to control a Windows 8 PC by combining their eye gazes with other input controls, such as touch, mouse, and keyboard.
- The gesture-recognition system uses a technology called Soft Connect that uses sensors placed on the headliner to detect hand gestures. The software is basically an extension of gesture-based recognition software used in Xbox Kinect (used in a Microsoft Xbox 360 video game).

As the hand-gesture detection zone becomes the control area for the car, as seen in Figure 3, an instrument panel space need not be allocated for clusters of buttons and knobs. The driver selects a function with eye tracking and then sets its control/output level through hand-gesture recognition. The driver can also choose to further refine a selection through steering wheel buttons or voice controls.

When asked about the installation of eye-tracking and gesture-recognition software in a production vehicle, Hyundai said it has not talked with government regulators about safety aspects. Hyundai says it is not clear whether the government has to be involved; if regulation is needed, it likely will fall under the broad heading of driver distraction. As Hyundai sees it, everything that its tracking-and-recognition tools do, drivers already do with traditional knobs or with voice-recognition control inputs [5].

In-Vehicle Mobile-Phone Battery Wireless Charging

When creating an in-vehicle mobile-phone battery wireless-charging system, it is important for the system to be capable of charging a broad range

Figure 3 The Hyundai HCD-14 Genesis concept vehicle is shown without clusters of buttons and knobs. Instead, eye tracking and hand-gesture recognition systems are used to select and control specific features [5]. (Figure courtesy of Hyundai Motors USA, Fountain Valley, California.)

of mobile devices—regardless of brand, manufacturer, or type of device. This is a key design consideration for vehicular infrastructures, wherein the diversity of user devices is high [6].

In the 2013 Toyota Avalon Limited (Figure 4), smartphone charging while driving is enabled by an in-vehicle wireless charging system using Qi and RF-identification (RFID) technology. (Qi is an accepted standard for wireless charging [7] that enables electrical power transfer over distances of up to 40 mm.) Avalon drivers are also given the option of conventional wired charging.

Avalon's charging system consists of a center-console-mounted base station with a power transmitter utilizing a transmitting coil, and the mobile device should have a power receiver with a receiving coil. The transmitter is packaged in the sliding lid of the center-console storage bin. The lid is designed specifically for docking electronic devices. Toyota calls it an eBin. To begin wireless charging, the driver places a cell phone on top of the eBin lid. An engineering challenge for Toyota was to maintain full functionality of the sliding lid even when a cell phone was placed on top of it. In addition to packaging the transmitter inside the lid, an important consideration was the selection of a material for the lid so cell phones do not slide around too much.

Wireless charging capability will be made available in Avalon models to be released later in 2013. Qi-wireless charging will initially be programmed to accommodate 34 mobile phone models. Here, the backward compatibility of the Qi standard is critical, as it will ensure that the seamless charging experience is maintained as Qi technology evolves. (A product designed for a new standard is said to be backward-compatible if it can receive, read, view, or play older standards or formats.)

In 2008, the Wireless Power Consortium (WPC) signed an agreement for an open standard for wireless power. (WPC is an open-membership cooperation of Asian, European, and American companies that work toward the global standardization of wireless charging technology.) The Qi standard is based on inductive/wireless-charging technology that involves transmitting energy via a magnetic field. Specifically, devices that operate with the Qi standard rely on magnetic induction between planar coils [6]. Two components involved are

- in-vehicle base stations that provide inductive/wireless power
- mobile devices that consume inductive power.

The base station has a power-transmitting coil. The mobile device has a power receiver that contains a receiving coil. Close spacing of the two coils, as well as shielding on their surfaces, ensures efficient inductive power transfer. The use of appropriate shielding is important because it reduces the driver's long-term exposure to the electromagnetic field.

Power transfer efficiency of the wireless charger is claimed to be typically 70%. However, efficiency

Figure 4 The 2013 Toyota Avalon Limited can be ordered with an optional wireless mobile-phone charging system. To charge a phone, all the driver needs to do is place his or her Qi-protocol-enabled phone onto a center-console eBin lid [6]. (Figure courtesy of Toyota Motor Sales, Torrance, California.)

can drop to 40%, depending on the distances involved in the power transfer. In general, inductive charging has faced challenges due to lack of efficiency and increased resistive heating. In comparison to direct-contact wired charging methods, it is more expensive in terms of equipment because it requires additional electronics and coils both in the device and charger [6].

Typically, inductive systems are also criticized because the device being charged has to stay positioned on the charging mat. When it comes to the in-vehicle use of wireless charging, however, this limitation actually offers a benefit, unlike cable-connected recharging methods, it prevents drivers from using the phone while driving.

Toyota's wireless-charging system is supplied by Denso (Kariya, Japan) and based on the technology developed by Hong Kong–based ConvenientPower and Philips Lite-On Digital Solutions. ConvenientPower is a specialist in wireless power charging and has codesigned Qi and cofounded the WPC, which now has about 100 members, including Samsung, Nokia, HTC, Motorola Mobility, and Sony. For its part, Philips Lite-On Digital Solutions designs and develops optical-disk-drive products for automotive applications. Its major research center is based in Germany [6].

An important element in the continuing implementation of wireless charging is to ensure that systems can recognize different products and how much charge they need. Israeli company Powermat uses RFID tags to identify what is being placed in the charging position. The RFID tags are mounted in a case made to fit around popular gadgets like iPods, laptops, and mobile phones. As shown in Figure 5, the mobile phone is positioned on an eBin lid. Then, the Powermat reads the phone's RFID tag to identify the device and ensures that it receives only the required amount of charge [6].

Intelligent Driver-Assist Research

Audi AG (Ingolstadt, Germany) unveiled new ideas for urban automotive intelligent assists at the Los Angeles auto show (30 November–9 December 2012). It introduced new technologies aimed at improving drivers' information and decision-making capabilities. Audi's Urban Intelligent Assist project is a three-year joint effort between Audi AG, the Volkswagen Group Electronics Research Laboratory in Belmont, California, the University of Southern California (USC), the University of California (UC) at Berkeley, and UC San Diego [8].

The project, which wraps up at the end of 2013, aims to find technologies that can help reduce traffic congestion, improve safety, and reduce stress on drivers, according to Mario Tippelhoffer, Audi's lead engineer. Development efforts focus on two primary areas:

- the Driver-Centric Urban Navigation application
- the Urban Assistance app.

"We are developing smartphone apps that help you plan your trips before you get into your vehicle," Tippelhoffer explained. The USC team collects data from multiple sources to provide predictive information to drivers using Audi's Driver-Centric Urban Navigation application suite [8].

Driver-Centric Urban Navigation Applications

- The Time-2-Start app runs on drivers' mobile devices and lets them know the expected duration of a planned drive so that they know when to start. It uses real-time traffic data along with historical traffic information for the location and time of day.
- The Smart Parking app recognizes drivers' parking preferences and habits and searches for available spots in the destination area, automatically providing routing information to the space.
- Predictive Traffic forecasts traffic conditions using current traffic information, historical data, weather, and event information. For example, if the home team has a playoff game, drivers are warned to avoid trying to drive through that part of town.
- The Predictive Destination app guesses drivers' intended destination based on their history, location, and the time of day to provide information about the route the app expects the driver to take. "Most people go to places on a regular basis," said Tippelhoffer. "That is a really repetitive pattern we see. Most of the time drivers go to only five different locations."
- Naturalistic Guidance recognizes that a robotic voice saying "turn left in 400 m" is not terrifically helpful to many drivers, but a navigation system telling them to turn left after an upcoming landmark—say,

FIGURE 5 Toyota announced that its 2013 Avalon Limited will be the first vehicle to offer in-console wireless charging for Qi-enabled cell phones and devices [6]. (Figure courtesy of Toyota Motor Sales, Torrance, California.)

FIGURE 6 An engineer calibrates image-recognition software and its facial-mapping camera (mounted above the rearview mirror). Facial images are used in an app called Attention Guard to regain the driver's attention if he or she is not focused on driving [8]. (Figure courtesy of Audi AG, Ingolstadt, Germany.)

a McDonalds' restaurant—is much better. So that is what naturalistic guidance aims to provide. "A person giving directions would say, 'Take a right after the Starbucks'," Tippelhoffer explained. "We want to use prominent landmarks like churches and restaurants to make route guidance more natural."

- The Seamless Navigation app addresses the fact that we can sometimes reach our parking space for a destination but still need some help finding the actual destination building's entryway, so it gives drivers walking guidance all the way to the door.

Urban Assistance Applications

Another category of applications, Audi's Urban Assistance, looks at scanning around the car to provide information about tactical driving conditions. USC, UC San Diego, and UC Berkeley teams are contributing to these applications [8].

- Merge Assist is a new application designed to help drivers attain the speed and timing needed to merge smoothly with the surrounding traffic by giving them a target speed on the instrument panel and green LEDs in the side mirror when it is time to merge. It acquires the necessary information about the surrounding vehicles using a combination of video cameras and radar, said Tippelhoffer. We have some really sophisticated sensors that can monitor 360° around the vehicle, he said.
- Lane Change Assist is a more advanced version of today's blind-spot warning technology. It improves on current products by detecting fast-moving vehicles approaching in the adjoining lane, not just vehicles currently in the car's blind spot.
- Attention Guard addresses the problem of driver distraction by using cameras to watch the driver and alerting him to regain his attention if he was not focusing on driving (Figure 6). "We want to keep you safe if you are not paying attention," said Tippelhoffer. "We want to bring you back to your driving task." How to do that is under discussion. "We are looking at human–machine interface solutions for different ways of telling drivers that they're distracted." In a worst-case scenario, the car could even determine that the driver is not going to respond to a crisis and intervene automatically, he added.

"Some of the applications we are developing could be applied rather soon to an automotive environment, and some applications will require infrastructure such as traffic and parking sensors," Tippelhoffer said [8].

Satellite-Based Vehicle Road-Tax Assessment

Intelligent transport systems satellite applications for road transport cover much more than in-car navigation. They potentially include [9]

- road-use charging with satellite-based tax collection systems
- in-vehicle dynamic route guidance for drivers
- intelligent speed adaptation to control the speed of vehicles externally
- traveler information systems
- fleet-tracking systems for better management of freight movements and goods delivery.

European toll-road operators have outlined how they plan to employ the two European Global Navigation Satellite Systems. They are the Geostationary Navigation Overlay Service (EGNOS) and Galileo (the European global navigation satellite system). They plan to use these satellite systems to provide new vehicle road-tolling/tax solutions.

Luigi Giacalone is the managing director of Autostrade Tech (which holds European rights for toll motorway management). Autostrade Tech provides the technology for the French Ecomouv association (which collects Ecotax/Ecological taxes). Giacalone said EGNOS will help to reliably collect taxes on heavy trucks using a road charging scheme [9]. Giacalone said, "This will be a tax not a toll. It aims to collect a new tax reliably and fairly according to distance travelled, while dissuading fraud."

The Ecomouv association covers 600,000 French lorries/trucks and 200,000 foreign ones, and it will run for 11.5 years, beginning in July 2013. Giacalone said its performance target was 99.75% accuracy of the entire collection chain, and the trials have already demonstrated 99.8% accuracy [9].

Hybrid Lead-Acid/ Lithium-Ion Battery

Johnson Controls' new 48-V dc micro-hybrid battery module, part of its full spectrum of advanced energy-storage solutions for automobiles, was demonstrated at the North American International Auto Show (14–27 January 2013) in Detroit. Leveraging dual-voltage architecture, Johnson Controls' battery system (shown in Figure 7) is comprised of a traditional 12-V dc low-voltage lead-acid battery together with a 48-V lithium-ion (Li-ion) battery. Its function is to enable optimization of vehicle energy generation and consumption, thus saving fuel [10].

The 48-V battery, which is still being developed, could support higher power loads, such as electric air conditioning, active chassis technologies, and the capture of regenerative power energy during vehicle braking. The 12-V battery would continue to provide 12-V dc power to the vehicle starter, interior and exterior lights, and entertainment systems such as radios and DVD players.

"The micro-hybrid battery facilitates the development of evolutionary energy-storage systems that offer more fuel efficiency than a start–stop system at less cost than that of a hybrid or electric vehicle," says Alex Molinaroli, president, Johnson Controls Power Solutions [10]. (A micro-hybrid is a start–stop system that includes a modified starter motor that also works as a generator for the car. A start–stop system automatically shuts down and restarts a vehicle's engine to reduce fuel consumption. A hybrid refers to a vehicle that combines an internal combustion engine and electric motors to power the vehicle. An electric vehicle is solely powered by electric motors.)

FIGURE 7 The micro-hybrid battery pairs a traditional 12-V low-voltage lead-acid battery with a 48-V Li-ion battery [10]. (Figure courtesy of Johnson Controls, Milwaukee, Wisconsin.)

Micro-hybrid technology has the potential to deliver additional fuel efficiency, reaching improvements of up to 15–20% in fuel economy. "Due to their more stringent fuel economy and emissions standards, we expect this technology to be adopted in Europe first," said Molinaroli [10]. "It will then quickly move to U.S. markets in the next few years, with mass adoption by 2020."

New Standard Cuts Time to Charge Electrified Vehicle Batteries

In 2012, the Society of Automotive Engineers (SAE) approved a revised standard that will let electrified vehicles (EVs) charge their batteries much quicker, in as little as 10 min for plug-in hybrids or 20 min for battery electric cars [11]. (A plug-in hybrid is a hybrid vehicle that has high-capacity batteries that can be recharged by plugging into normal household current as well as using on-board charging capabilities. A battery electric vehicle uses only batteries for energy storage.)

The standard brings new technology to public charging stations and parking garages but not to homes. "Before, it was a matter of hours to charge an electric vehicle battery," Andrew Smart, director of SAE International, said. "Now it can be a matter of minutes [11]."

The new SAE J1772 standard calls for fast-charging, using dc voltages that range from 200 to 500 V and currents of up to 200 A. Using the new technology, plug-in hybrids will be able to charge from 0 to 80% in 10 min and battery electrics could charge from 20 to 80% in 20 min. As seen in Figure 8, the new SAE J1772 combo connector includes a two-pin dc plug underneath the currently used ac plug.

Thus, both ac and dc charging options are available, which means that current EVs, such as the 2012 Nissan Leaf and 2013 Chevrolet Volt, equipped with the older SAE J1772 ac-plug-only couplings can still use the new SAE J1772 combo plug [12].

FIGURE 8 The new SAE J1772 combo connector allows for both slower ac charging and faster dc charging of plug-in and battery EVs [12]. (Figure courtesy and SAE International, Warrendale, Pennsylvania.)

The original SAE J1772 standard was created in 1996. It was revised in 2001 for use with a paddle-type connector and again in 2010 with a continued focus on ac charging. The new 2012 version is the first to address dc fast charging and the first to accommodate voltages as high as 500 V and currents as high as 200 A. The new standard reflects a consensus of 190 global experts representing makers of automobiles and charging equipment as well as utilities, national laboratories, and municipalities. The experts had to consider the effects of temperature, humidity, and moisture, as well as mechanical aspects [11].

FIGURE 9 The 2014 Chevrolet Spark EV includes the new SAE J1772 combo connector that allows fast dc battery charging [13]. (Figure courtesy of General Motors, Detroit.)

"You have people who are constantly plugging and unplugging EVs," Smart said. "We needed to know everything, including the fatigue levels of the wires, connectors, and plastics. We also needed to get input from people on the infrastructure side—people who write building codes, and representatives from municipalities—not just the auto companies." Automakers say the new SAE J1772 standard fast-charge technology could have a profound effect on the sale of pure electric vehicles. Thus far, however, not a single fast-charge station using the new standard is open to the public in the United States, but they will come and are expected sooner rather than later [11].

Electric vehicles and plug-in hybrids already on the road, such as the Chevrolet Volt, will not be able to use the new technology immediately, since they do not have the new fast dc-charge hardware and software. However, Kevin Kelly, a spokesman for General Motors, said its forthcoming 2014 Spark battery electric vehicle will have the new SAE connector, interface, and software. "It's less important to do this on the Chevrolet Volt, because the Volt already has extended range on board," he said. "But it makes a lot of sense for the Spark EV."

When it goes on the market in mid-2013, the General Motors 2014 Spark EV, shown in Figure 9, is expected to have one of the best EV battery ranges in its segment and be the first electric vehicle to offer SAE combo dc fast-charging capability that will enable the Spark to reach 80% battery charge in just 20 min [13]. Two other major domestic automakers (Chrysler and Ford) and the five major automakers from Germany (Audi, BMW, Daimler, Porsche, and Volkswagen) are also planning to include the new SAE J1772 combo connector to allow dc fast charge on their upcoming EV models [12].

Magnetic-Coupling Wireless EV Battery Charger

The least-favorite component for EV owners is probably the battery-charging cord. After all, no one is fond of having to remember to plug in their car every evening and fumbling around with the power cord each time. Several companies have either developed or tested wireless technology that requires motorists merely to park their EVs over a device that is embedded in a garage floor or parking space, enabling them to power up without even leaving their seats.

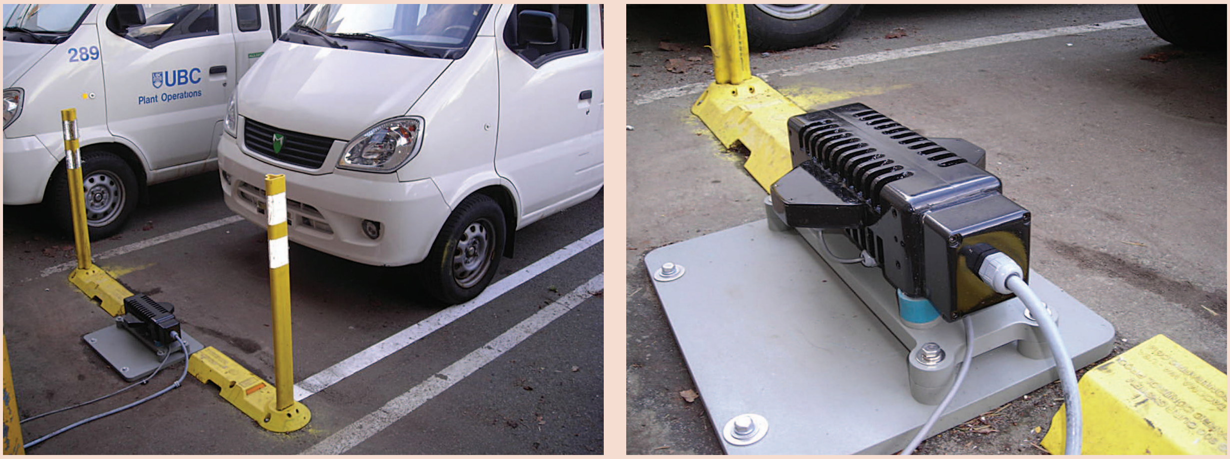
Many marketing experts from automotive industry believe that wireless battery charging is likely needed for widespread adoption of EVs in the United States. Leading-edge automakers are designing so-called plug-less hybrid EVs with wireless battery charging, which will be produced and introduced in the period 2015–2017.

Currently available EV battery-charging systems are based on electromagnetic induction. An ac electric current in a conducting wire coil (transmitter) placed in a road bed produces an alternating magnetic flux coupled to a coil (receiver) mounted in the vehicle underbody. Operated in resonance, an ac current is induced in the vehicle's receiver coil. In this way, the vehicle receives ac power that is rectified and converted to dc power, thereby recharging the EV battery.

There are issues associated with using ac electromagnetic induction that evoke perceived public safety concerns. It can emit stray radio waves or heat up nearby metal objects (via ohmic heating) unless engineered correctly. However, developers of this charging method believe that ac power transfer technology has been fully tested and shown to be completely safe.

However, researchers at the University of British Columbia (UBC) in Vancouver, Canada, believe that they have developed a better, simpler way to wirelessly charge EVs. They believe that they have produced a safe, high-efficiency method that employs what inventor Lorne Whitehead, an applied physicist, calls remote magnetic gears [14].

UBC's noncontact power-transfer approach, Whitehead says, relies on magnetodynamic coupling (MDC); i.e., a magnetic field interaction between two rotating permanent magnets that are separated by an air gap of 4–6 in (10–15 cm). The system consists of a rotating magnet assembly in a road-embedded transmitter, separated by an air gap and another rotating receiver magnet assembly in the underbody of a car. When an electric motor rotates the lower magnets, the upper magnet assembly is also caused to rotate. The in-car magnet assembly then drives a small generator that



(a) (b)

FIGURE 10 (a) The magnetic-coupling-based wireless EV charger system has operated for more than a year at the UBC campus. (b) The wireless charger is mounted on a simulated street curb [14]. (Figures courtesy of University of British Columbia, Vancouver, Canada.)

charges the car battery. "The magnetic field between them," he continued, "essentially acts as a mechanical coupling—but it requires no direct contact and is claimed to be energy-efficient" [14].

Whitehead added that relatively low-cost ferrite magnets can be employed rather than more costly and potentially supply-challenged rare-earth permanent magnets. Tests show the system is up to 90% efficient as compared with a cable-connected EV charging. Perfect alignment of the car with the device is not needed. It is envisioned that the UBC EV-charging technology could be incorporated into low street curbs, over which the car would drive and then position its receiver magnets adjacent to the road-embedded transmitter magnet (Figure 10).

Last year, four demonstration MDC systems were operated successfully at UBC, wirelessly charging electrically powered campus-service vehicles that have been retrofitted with an MDC receiver [14].

"One of the major challenges of electric vehicles is the need to connect electrical cords and sockets in often cramped conditions and in bad weather," said David Woodson, managing director of UBC Building Operations. "Since we began testing the system, the feedback from drivers has been overwhelmingly positive—all they have to do is park the car and EV charging begins automatically."

However, other experts on wireless EV-charging technology doubt the ultimate practicality of the UBC development. "It's really nothing new," said John M. Miller, center director in the Power Electronics and Electric Machinery Research Group at Oak Ridge National Laboratory in Tennessee. "Too many moving parts—it all comes down to the number of energy conversions that are involved. Here, the energy transfer goes from electrical to mechanical to magnetic field coupling and back to mechanical and then to electrical. Each step entails a loss in energy efficiency that adds up" [14].

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