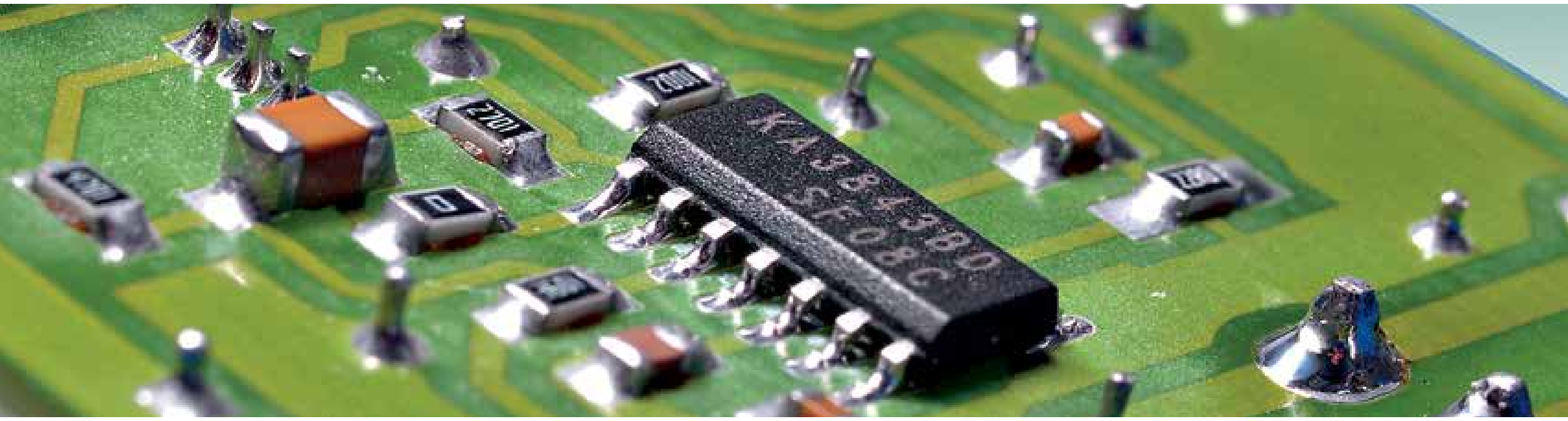


Winning share in automotive semiconductors

From self-parking cars to anticipatory braking, semiconductors have been important to automotive innovations in the past decade. And automotive-semiconductor revenues expanded quicker than those of both the automotive and broader semiconductor industries—but will this continue? Where will innovation come from?

Doug Parker and Christopher Thomas

Automotive semiconductors, a $24 billion business, have experienced one of the fastest growth rates of any large segment in the $300 billion worldwide chip market, averaging 8 percent annually between 2002 and 2012. An increasing number of powered systems requiring microcontrollers, sensors, and analog devices have led this growth (Exhibit 1). But there are signs of a slowdown. For example, the number of microcontrollers has leveled off in luxury cars at about 100 per automobile, and prices for those microcontrollers have dropped rapidly. Where will the next wave of growth come from for automotive semiconductors? We see three likely sources: further electrification of the drivetrain, "consumerization" of auto electronics, and vehicle intelligence (including active safety innovations and connectivity-enhanced driving).

Winning share in any automotive application is challenging, given carmakers' rigorous qualification process and strong risk aversion (for quality reasons), as well as the industry's need for long-term supply agreements and lengthy product cycles. However, we believe these sources of growth create opportunities for semiconductor companies, even those that are not traditional suppliers of automakers.

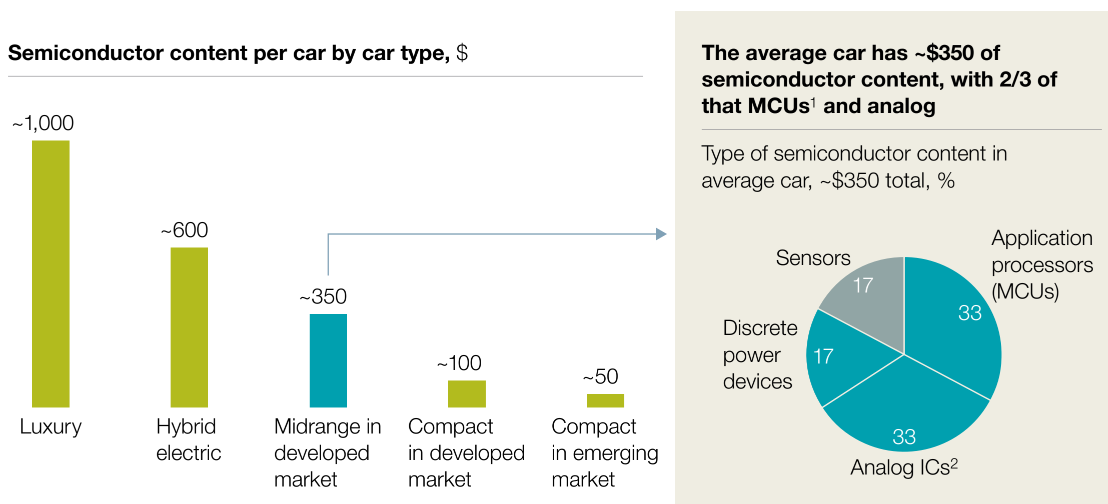
Further electrification of drivetrains

The electrification of the drivetrain, due to the rise of hybrid and full electric vehicles, may lead to the largest expansion of semiconductor usage in automobiles over the next ten years. The drivetrain now accounts for 30 percent of all semiconductor content in an automobile, or a market of about $7 billion a year. While the average internal-combustion drivetrain uses less than $100 of semiconductor content, hybrid drivetrains contain more than $1,000 of electronics, much of which is in power circuits. Such circuits route power from batteries to the motor; in this case, semiconductor content comprises isolated-gate bipolar transistors (IGBT) and power metal oxide semiconductor field-effect transistors (MOSFETs). Toyota has highlighted the efficiency and fast switching rates of the IGBT in the Prius's drivetrain as a distinct advantage, "tuned at the level of the crystal" (Exhibit 2).

Automakers rarely change suppliers of the electronics controlling the power and drivetrains of their vehicles. There are four reasons for this: the complexity of installed systems makes consistency valuable; strong relationships exist between semiconductor companies and automakers in various regions; the installed base of designers using proprietary tools and programming languages favors consistency; and high risk exists in making significant changes in established platforms. As such, the costs and risks of switching would be high.

Exhibit 1

The average automobile has about $350 of semiconductor content, with nearly 80% of that in microcontroller units, analog, and power.



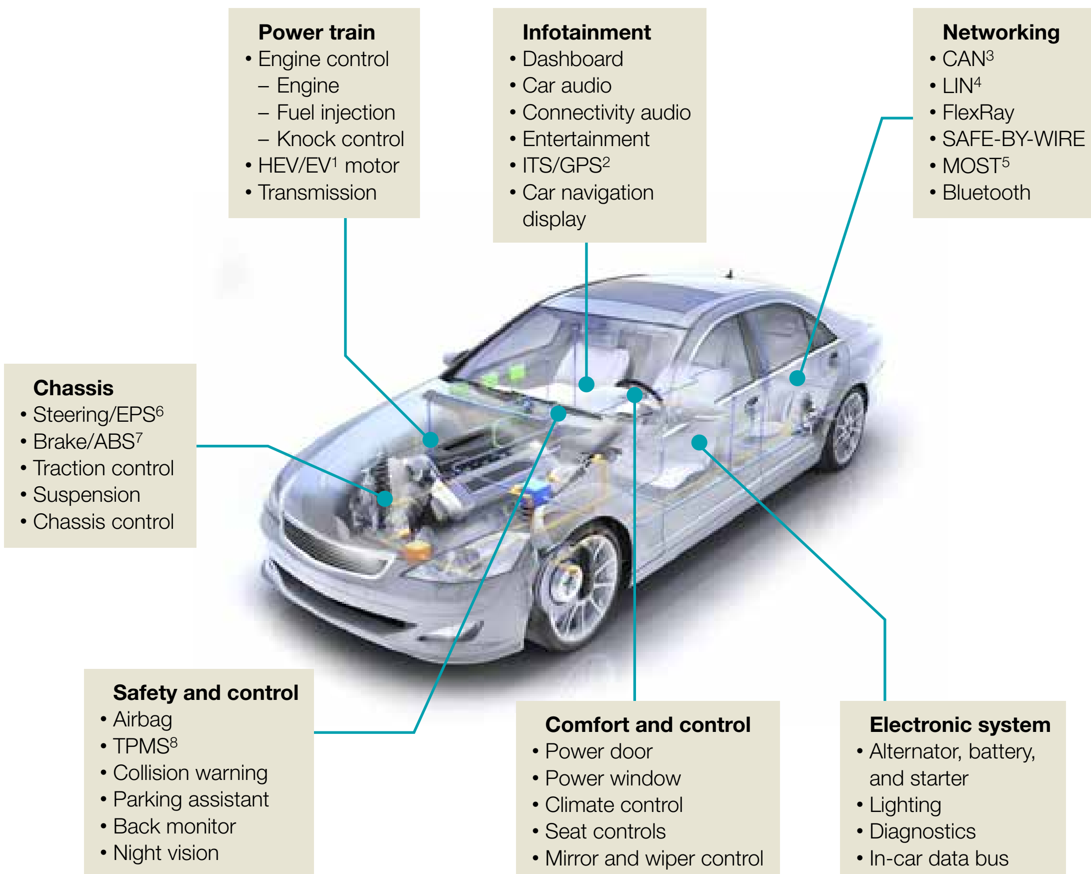
[1]Microcontroller units.
[2]Integrated circuits.

Source: *Auto Semiconductors Report*, Sanford C. Bernstein, September 2012; iSuppli

Hybrids and full electric vehicles present a unique opportunity for semiconductor companies to win share in the next generation of the automobile engine. Electric drivetrains change substantially in each vehicle generation. The basic design of the drivetrain itself is still evolving, with pure electric vehicles (EVs), EVs with internal-combustion-engine charging, and EVs with internal-combustion-engine assistance (hybrid electric vehicles, or HEVs) competing for

Exhibit 2

Semiconductors are used pervasively in modern automobiles.



[1]Hybrid electric vehicle/electric vehicle.
[2]Intelligent transportation system/global positioning system.
[3]Controller area network.
[4]Local interconnect network.
[5]Media-oriented systems transport.
[6]Electric power steering.
[7]Antilock brake system.
[8]Tire-pressure monitoring system.

market share and the option to be the next dominant engine type.

The innovation cycle for electronic components in electric vehicles is much faster than it is in internal combustion engines. For example, the bipolar transistors, sensors, and microcontrollers serving one generation of vehicles may be deemed insufficient for the next one. In fact, automobile executives tell us that designs for these elements are leapfrogging previous generations, not just offering incremental improvement.

While the pace of innovation is fast, automakers and their tier-one suppliers have been conservative in choosing vendors for the core electronic functions such as powertrain and drivetrain management. These functions favor large incumbents, as established companies usually have both financial stability and a reputation for quality. A number of winners have emerged as this landscape evolves, just one example of which is Mitsubishi Electric. When the company spun off its semiconductor business to Renesas, it notably retained its IGBT business, which now captures roughly a third of that market. Given the rate of development in IGBTs and in high-voltage gallium nitride MOSFETs, we expect to see semiconductor players that don't currently serve the auto industry supplying chips to hybrid makers, especially auto manufacturers that have not released a successful hybrid offering yet. These players must be strong financially, meet high quality standards, and most important, offer significant performance improvements over current offerings while understanding vehicle usage or specific systems-usage patterns very well. Developing a less expensive alternative to IGBTs would be one way to accomplish this; another would be to offer kits of sensors and microcontrollers that could be used to extend the range of the car through better assisted-driving technology or more efficient power management, for example. A third opportunity for semiconductor companies would be to offer products to improve the driving experience, covering the wider field of driving dynamics and handling—for example, continuous tuning technology, which aims to reduce engine vibration in the types of smaller engines used in hybrids.

Consumerization of auto electronics

Infotainment—a market of about $6 billion—accounts for almost a quarter of the semiconductor content in automobiles, up from 20 percent ten years ago. Consumers' tastes

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have changed considerably in that period; they now enter cars with smartphones in hand and expect a similar user experience from automotive electronics. If the car's electronics are not up to their expectations, they could simply use smartphones for communication, entertainment, navigation, and other information-access services.

Automakers have tried to improve the user experience, for example, by shortening the software-development cycle to keep graphical user interfaces fresher and more intuitively user-friendly. However, it is hard to compete with leading consumer-electronics players. Apple and Samsung release updated products on a 9- to 12-month cycle, while automakers are making purchase decisions now for their electronics on a four- to five-year cycle with a potential midcycle upgrade option. In fact, some automakers have just announced user interfaces with the familiar tile layout of Apple's products—six years after the first iPhone was released. This puts pressure on a critical high-margin product for automakers: the in-dash infotainment system. They charge up to $3,000 for infotainment and navigation packages, while a new smartphone can be purchased for less than $200 with a service plan.

Car manufacturers have made efforts to integrate consumer electronics into vehicles. Premium carmakers, for example, have incorporated a search function into navigation systems and have developed apps that allow users to control parts of their infotainment systems with their smartphones.

To keep pace with consumer-electronics development, automakers must find a way to accelerate their product development and allow a broader range and more frequent upgrade of application installations in the infotainment system while maintaining control over the in-dash offering. On the one hand, if they cannot keep up with the consumer experience, there is a risk that auto buyers will not opt for their navigation systems (or for a lower-end offering at best) and will instead rely on smartphones and other devices. But if they give up too much access to their onboard systems—for example, adding an in-dash iPad docking station—there is a risk that profits could erode as their own infotainment systems become commoditized. One important aspect to note is safety while using the infotainment features in order to minimize driver distraction: this could ultimately lead to a continued preference for embedded solutions in the infotainment system.

One way automakers can compete is to create a limited connection between a user's smartphone and their car's in-dash navigation system. MirrorLink is a standard system established to help automakers and smartphone makers connect their devices. It mirrors the driver's smartphone screen on the navigation system. To keep the customer experience current, automakers could push operating-system and user-interface updates to vehicles through Wi-Fi or other device-based upgrades.

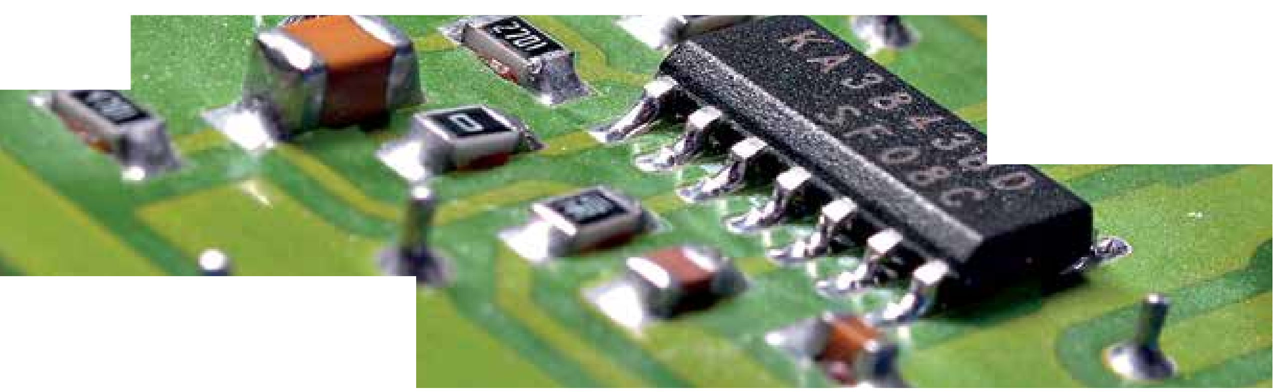
Another way to maintain competitiveness is for automakers to allow for easier upgrades of their infotainment features or capabilities. They could do this in a number of ways, including focusing their upgrade efforts more on software (either operating-system or feature-based software), installing sufficient memory and microprocessor capabilities, or creating easily exchangeable hardware elements to enable these new capabilities (for example, memory chips). Maintaining high reliability standards is critical while pursuing these opportunities.

Infotainment is also the most likely place for ARM-based products to penetrate the auto market. ARM-based processors have been gaining share rapidly in the broader microcontroller market but have not made significant inroads in automobiles because of concerns about reliability, the large installed base of proprietary products and instruction sets already in use, and long product cycles. Entering into the smart-phone ecosystem would have many benefits. Automakers could tap software and hardware designers from consumer applications. They could also benefit from the R&D being invested in semiconductors and in user experience for cell phones, which operates at a different order of magnitude. While Toyota sold almost ten million cars in 2012, only a fraction had infotainment systems. In that same year, Apple sold about 200 million iPhones and other devices using its A-series processors. It will likely take years for ARM chips to penetrate deeply into auto powertrains, but the shift in infotainment could happen if reliability can be proved to match the very high quality standards of both auto manufacturers and buyers. Ultimately, to make this happen, it would be important that automotive, consumer-electronics, and semiconductor players collaborate to tackle these issues and develop high-quality and user-friendly product solutions.

Vehicle intelligence and connectivity-enhanced driving

Perhaps no other trends offer greater growth opportunities than vehicle intelligence (including active safety) and connectivity. Many of the most impressive innovations in automobiles in the last few years have been collision-avoidance braking, lane-change sensors, and automatic-parking functions. This has driven the market for sensors in automobiles to grow at a 14 percent annual rate over the last decade. Last year it was a $3 billion market. We expect there to be significant additional growth in this market as features in luxury cars migrate to midrange cars and new connectivity-enhanced driving features enter the marketplace.

While fully autonomous driving may be ten or more years away, we expect to see a continuous increase in driving assistance and related



Efforts to monetize the data stream collected by automobiles may be driven by automobile makers or by big-data players and tech start-ups.

semiconductor content. Tires embedded with microelectromechanical systems can monitor road traction and adjust braking. Enhanced night vision is another intriguing area. With the increase in these types of driver support and assistance comes a spike in the amount of data sensed, processed, and collected.

The new generation of premium automobiles collects not only physical data (for example, road resistance, temperature, and speed data) but also visual data (posted speed limits in assisted-driving modes) and even audio data (the sound of the road to sense ice and other hazardous conditions). While automakers use this to create a smoother, safer ride for their customers, the data collected by automobiles create opportunities of potentially significant value. Cameras in automobiles could continuously feed road conditions to navigational-software programs that will learn to not only report current traffic but also accurately predict traffic levels and suggest better routing. Highway operators could tap these data to predict likely accident spots and to automatically drop speed limits in that area and position safety crews. High-tech traffic lights could feed timing information to driving-assistance systems (and vice versa) to help reduce congestion and improve gas mileage. In the future, road-maintenance crews could know the size of every pothole in their city with a precise GPS position—before any citizen called to complain. Of course, the collection and use of such data must be balanced against privacy concerns, but many benefits are readily apparent.

In the short run, connectivity-enhanced driving innovations will likely be led by various players in the existing auto value chain such as original-equipment manufacturers and suppliers. (Most premium automakers already have self-driving and assisted-driving prototypes.) New entrants to the auto value chain are currently exploring their role within it, as well (such as big-data players like Google).

Efforts to monetize the data stream collected by automobiles may be driven by automobile makers or by big-data players and tech start-ups. The payback on innovations tapping these data streams likely will take longer, and all players in the auto value chain still need to develop business models to address how to use the vast trove of data they could create and tap. The real question is how to develop scalable business models.

Deployment outside the automobile (for example, in the systems that power traffic lights or parking-space locators at parking garages) is also attractive and will likely appeal to a larger set of systems providers and start-ups. However, it will be important for players to understand end-consumer preferences and willingness to pay, as well as the required technical infrastructure. In the parking-space-locator arena alone there are numerous start-ups, with a few notable players including Parking Panda, SpotHero, Parking Spotter, and Parker. These systems will prompt increased semiconductor demand for sensors, basebands, and microcontrollers, to assess the area and communicate with users, alerting them to conveniences like open parking spaces. Still, consumers will likely use their handsets to gain access to these improvements, rather than the onboard systems in their dashboards. Therefore the biggest challenge for broader use will be defining system standards to make efficient large-scale systems work (the types of systems that could work with traffic lights across multiple municipalities, cellular providers, and automaker systems) and take advantage of embedded systems with regard to safety and user-friendly, intuitive interfaces.

Given the rapid pace of change, automakers, current suppliers, and newcomers to the space need to move quickly and further adapt their business models to capture these ideas, including potential alliances and collaborations. Whoever develops a good understanding of end consumers' true preferences and willingness to pay, together with a viable plan for developing scalable solutions, may gain competitive advantage.

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The recent growth in automotive semiconductors has made the segment one of the most attractive spaces for designers and manufacturers to target. However, companies should carefully assess application areas, including the three discussed in this article, before investing in development.

Doug Parker (Doug_Parker@McKinsey.com) is a consultant in McKinsey's Seattle office, and **Christopher Thomas** (Christopher_Thomas@McKinsey.com) is an associate principal in the Beijing office.