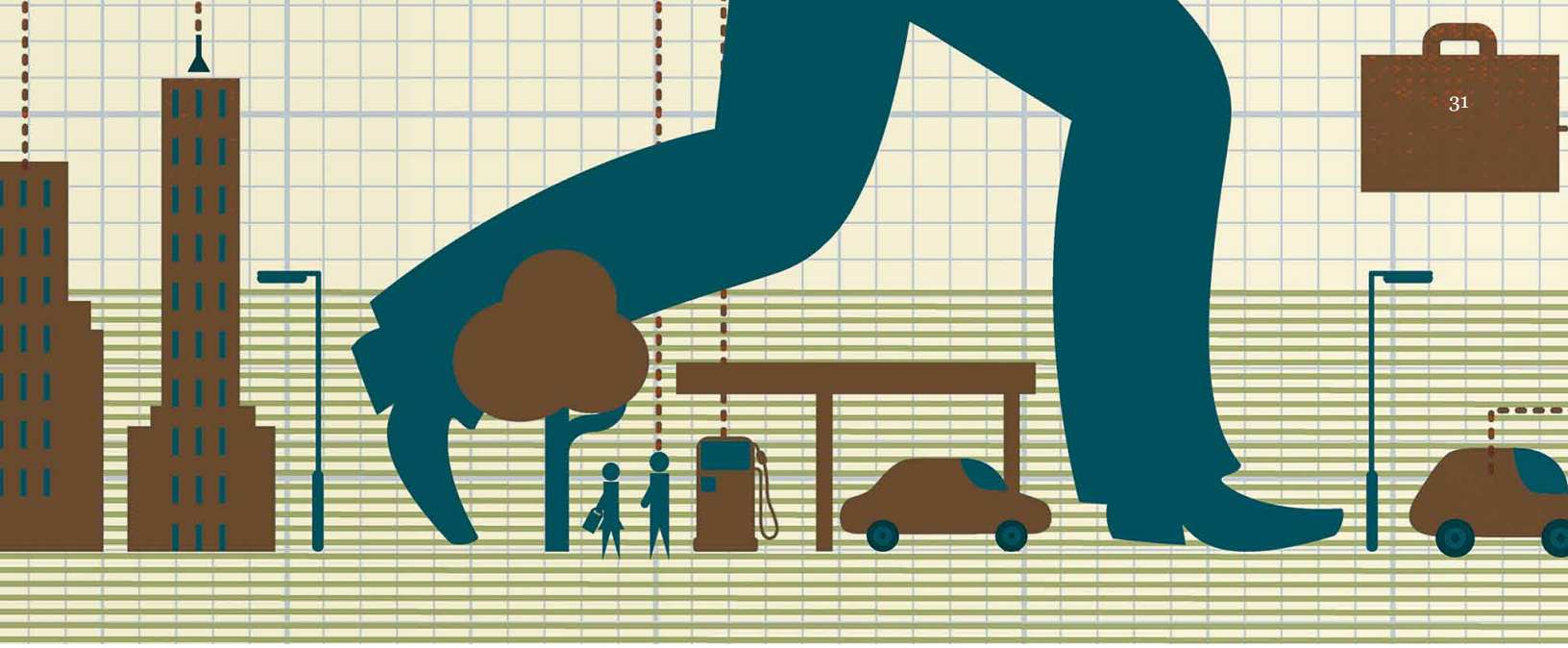


Andrew Baker

# How big data and connected consumer products could boost the market for MEMS technology

**MEMS technology continues to thrive in familiar markets, but with the advent of the Internet of Things, a significant new opportunity is emerging for industry players.**

**Harald Bauer, Sebastian Schink, and Florian Thalmayr**

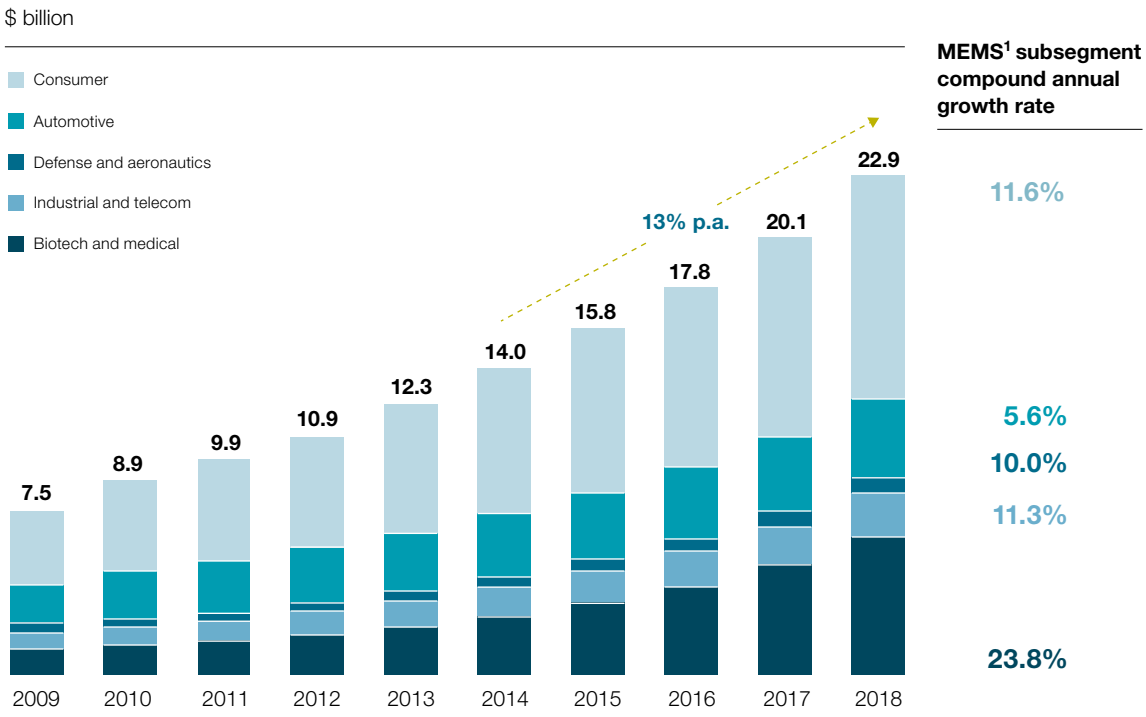
The overall market for microelectromechanical-systems (MEMS) technology—a category of devices that includes, for instance, inertial measurement units, gyroscopes, accelerometers, and pressure sensors—is projected to grow from about $11 billion in 2012 to approximately $23 billion by 2018 (exhibit).[1] While mobile phones, automobiles, and healthcare will continue to make up a large share of the MEMS applications market, there is another, potentially higher-margin use of the technology emerging within the next five years: as a critical enabler of the Internet of Things.

For more than a decade, as information has become increasingly digitized and computing power more robust, researchers, governments, and businesspeople have talked (in varying terms) about the emergence of smart, global, "object to object" communications. We define the Internet of Things as a universe of uniquely identifiable objects that are connected to a common network (public or proprietary) through which information about them can be exchanged (actively or passively) and analyzed.

In this universe, sensor-enabled equipment could facilitate the monitoring of production activities in a chemical plant. Sensor-enabled equipment in an automotive plant could allow managers to better predict which machines need maintenance, thereby decreasing production downtime. In the consumer world, connected objects might include

Exhibit

## The MEMS market is projected to grow.




[1]Microelectromechanical systems.

Source: iSuppli; Yole Développement; McKinsey analysis

cars, fitness bands, washing machines, or home security systems.

MEMS sensors, already a proven technology in the mobile-telephony market, will provide the critical backbone for the Internet of Things simply because they enable the generation and collection of all the "small data" required to accumulate the big data that feeds the network and can then be analyzed to inform a range of business activities. MEMS-based infrared sensors and vibration and temperature sensors will help industrial-plant managers pinpoint root causes of production problems—for instance, detecting increased vibrations ahead of a machine's failure or diagnosing cracks in equipment. And building-management professionals are exploring the use of MEMS-based sensors to monitor and control ventilation systems and energy usage, room by room. Real-time climate and lighting conditions, as well as meteorological information, can be captured through these sensors and fed into a control system to allow for predictive heating and cooling—a smart building.

At the point where MEMS technology and the Internet of Things intersect, there is an opportunity for semiconductor companies and other industry

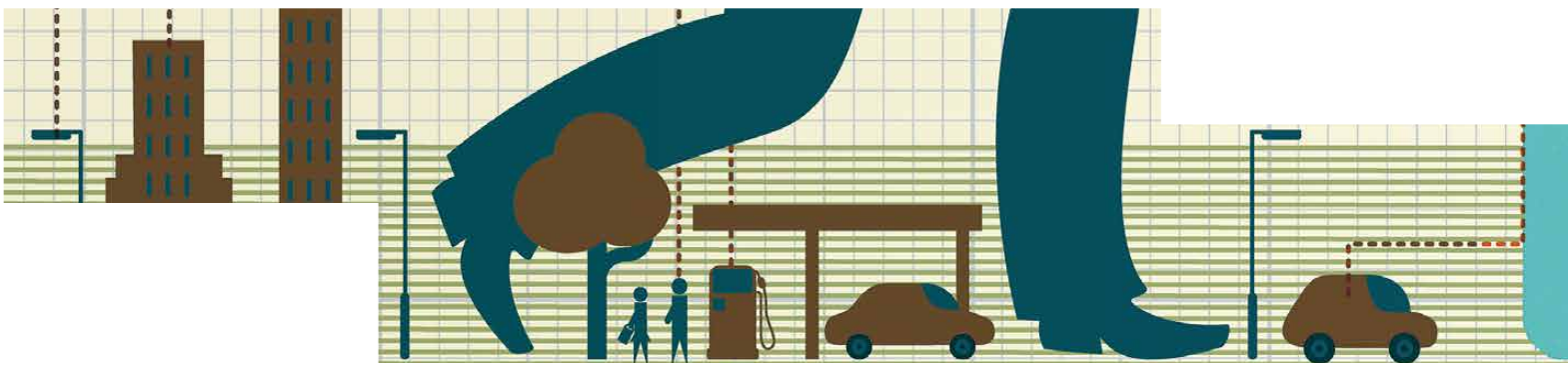
players to innovate, increase revenues, and reach new customers. In this article, we consider how MEMS technology is evolving and how fabs, integrated-device manufacturers (IDMs), and foundries can manage emerging trends—specifically, anticipating a shift toward technology acquisitions, player consolidation, and operational changes.

## The technology advances

Over the next several years, the global MEMS market is expected to expand at a compound annual growth rate of about 12 percent, compared with only 3 to 4 percent growth in the semiconductor industry overall, according to the technology consultancy Yole Développement. Low-cost, low-power, small-footprint sensors built from MEMS technology can already be found in many mobile phones, cameras, and tablets on the market, as well as in every automobile and in some healthcare devices. These sensors enable the automatic rotation and adjustment of images on iPhone screens and support navigation functionality. Increasingly, MEMS-based microphones are replacing the condenser microphones embedded in cell phones, headsets, and laptops.

But the demand for MEMS-based sensors will increase exponentially not only because of the ubiquity of smartphones but also because of the rising popularity of connected consumer lifestyle products. Examples of the latter include glasses, watches, wristbands, and other wearables that allow individuals to monitor their heart rate, activity level, calories consumed, or sleep patterns, as well as smart appliances that allow consumers to optimize their home energy consumption or ensure home safety through the use of remote controls.

MEMS production is inherently scalable, enabling continuous improvements in chip performance, size, and cost (manufacturers' costs can drop 10 percent or more each year). A good example of such scalability is MEMS-based bulk-acoustic-



wave (BAW) filters and duplexers for radio-frequency front ends in mobile devices. If one looks at the bill of materials associated with today's high-end 4G smartphones, one would see that the cost contribution of BAW filters and duplexers is comparable to what it might have been when these devices were embedded in early-generation mobile products such as a Samsung CDMA watch phone in 2001. However, the number of duplexers in today's smartphones (for instance, the iPhone 6) has quadrupled while the size of a single duplexer has been reduced by a factor of 30. Performance increases have helped mobile users realize significantly improved cell-phone reception and battery life.

The innovation cycle for MEMS technologies is decreasing as developers improve on previous MEMS releases. As a result, many newer types of MEMS-based technologies are making their way into products. In the market for mobile handsets, for instance, MEMS-shutter-based display technologies could replace LCD screens. And MEMS-based micromirror technologies are gaining favor in the burgeoning market for projectors and head-mounted display products (think Google Glass and Oculus Rift).

Some chip makers, specifically in the mobile and sensor areas, are exploring the economic and operational benefits of developing integrated MEMS modules, which constitute a sensor or timing component, a logic component, and connectivity capabilities. The MEMS chip maker Sand 9 and Intel recently demonstrated an integrated transceiver for cellular phones, including frequency reference. Sand 9 is providing MEMS-based timing devices that are 50 percent smaller than conventional timing devices. Thus they can be copackaged with Intel's transceiver chip through overmolding.[2] Such MEMS-based stacks can provide enhanced functionality at lower cost, with a smaller footprint (which is critical for use in more compact, connected consumer electronics, such as smartphones and fitness bands) and with relatively low power consumption.

## How will the market respond?

The trend toward MEMS integration suggests that a substantial part of the market will be served by a few big players that can offer "many in one" chips. Companies that produce single-device chips (with only an accelerometer or only a gyroscope, for instance) will still be able to thrive but mostly in niche areas outside of consumer electronics—for instance, providing chips for certain automotive and military applications, both of which represent the traditional customer base for components manufacturers. We expect the MEMS market to follow a typical "hogs' cycle" over the next few years, with pronounced periods of overcapacity followed by periods of price erosion, investment cutbacks, and shortages, followed by a wave of consolidation.

Non-MEMS players may attempt to acquire MEMS suppliers to integrate their devices into their own silicon and improve their competitive positions. That was the case when ROHM targeted Kionix for acquisition in 2009. The Japanese wireless-communications company wanted to add sensor technologies to its portfolio, and Kionix was one of the market leaders at the time for MEMS accelerometers. Rather than take the time to build MEMS capabilities in-house, ROHM acquired Kionix's proven platform, design expertise, and manufacturing capacity. In part because of this acquired technology, ROHM was later able to partner with the German

tech firm EnOcean to establish EnOcean's energy-harvesting wireless technology in the Japanese market.[3]

In-house development of integrated MEMS can be difficult, because it is time consuming and because many of the device and process technologies associated with MEMS are already patented. So even the leaders in the MEMS market will likely turn to acquisitions to build the combination devices that will further strengthen their portfolios, although incorporating rivals' technologies into their stacks may prove to be difficult given the specific production processes associated with various MEMS devices. One company that produces resonators, for instance, may rely on a process whose core element is deposition of a piezoelectric layer, while another company producing a device for the same application may rely on a process whose core elements are creating a tiny air gap and controlling oxidation levels.

Partnerships with or strategic investments in MEMS providers may prove to be the most effective way for semiconductor companies to quickly gain access to emerging MEMS devices. The components maker Alps Electric, for instance, was able to tap into Qualtré's MEMS expertise by making a $3 million strategic investment in the company in June 2013. The companies are aiming to codevelop and bring to market three-axis inertial sensors based on Qualtré's BAW technology and supported by Alps Electric's manufacturing capabilities and global sales resources.[4]

## The stakes for MEMS players

These trends are likely to have direct implications for individual players within the MEMS market. Among them, fabless design companies will probably have an advantage because of their role as small but critical contributors to innovation in the MEMS market and their ability to react quickly to swings in demand (the latter due to their low overhead). The fabless chip designer InvenSense is now one of the fastest-growing MEMS companies, with a cost structure that is 15 to 20 percent lower than its competitors among IDMs, according to Yole Développement.

For their part, IDMs should not need to replace much of their existing equipment to capitalize on the growing demand for MEMS devices, because many single-function MEMS devices do not require bleeding-edge resolution or lithography. Older fabrication plants should work fine. However, the IDMs that want to explore MEMS integration (producing stacked devices with many functions) will need to take the time and find the resources required to harmonize their manufacturing processes, since many of them will have multiple process-technology platforms in place as a result of legacy acquisitions. These semiconductor players may also need to adapt their sales and marketing processes to reflect their new offerings—MEMS modules rather than components.

Meanwhile, the symbiotic relationship between foundries and fabless companies is expected to evolve to accommodate MEMS. For certain manufacturing technologies, such as complementary metal-oxide semiconductor, or CMOS (a technology for constructing integrated circuits), foundries have been able to offer standard design libraries to their fab clients, creating flexibility for customers that want to, say, design a single chip that supports two different operating voltages. One family of recipes can be used to make thousands of different products. Previously, most foundries supported proprietary MEMS development but did

not offer a common MEMS design library. However, more and more foundries, such as X-FAB Semiconductor Foundries and GLOBALFOUNDRIES, are starting to own and offer "open" processing modules for the production of MEMS devices—providing, for example, a module comprising silicon-on-insulator wafers with pre-etched cavities, poly through silicon via for interconnects, and hermetic sealing. In this way, foundries are able to help remove barriers to entry for small fabless players, which could fuel innovation within the start-up scene.

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The mobile market has already lit a fire under MEMS chip producers; innovation cycles are getting shorter and costs are coming down. That flame will grow as consumers find value in interconnected objects, and as industrial clients see the advantages in adopting new Internet of Things applications to complement their existing capabilities. Producers and suppliers of MEMS-based technologies must recognize the effects that the move toward integrated MEMS devices will have on their operations and in the marketplace. Those that adapt can seize significant opportunities for growth; those that don't risk falling far behind. ○

[1] R. Colin Johnson, "MEMS market to top $22 billion by 2018," *EE Times*, November 8, 2013, eetimes.com.
[2] R. Colin Johnson, "Sand 9 MEMS cracks cellphone market," *EE Times*, September 3, 2013, eetimes.com, and "Integrated MEMS Oscillator for Cellular Transceivers," presentation at 2014 IEEE International Frequency Control Symposium, Taipei, May 19–22, 2014, ifcs2014.org.
[3] "EnOcean and ROHM announce strategic partnership at electronica 2012," November 12, 2012, enocean.com.
[4] "Alps Electric and Qualtré, Inc. announce partnership for next generation inertial sensors; strengthen relationship with strategic investment," June 7, 2013, qualtre.com.

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