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Sensors are fundamental to new intelligent systems

Custom IC design

Executive summary

The evolution of intelligent electronic sensors is creating a revolution for IoT and Industrial IoT as companies bring new sensor-based, intelligent systems to market. These systems now incorporate processors and software and they include communication hardware in order to move data into the Cloud for analysis. While the sensor market continues to garner billions of dollars, the average selling price of a MEMS sensor, for example, is only 60 cents. How will vendors make money in the IoT intelligent systems market?

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Introduction

The evolution of the basic sensors to intelligent electronic sensors is creating a revolution in how we gather useful data from the world around us, analyze that data to make decisions, and connect together vast intelligence systems to enable new solutions and to accomplish tasks that we have never been able to perform before. This opens up the market to new ideas for existing companies and start-ups. Suddenly, sensor-based product development is exciting again and we see design teams tackling new challenges from IoT to Industrial IoT in order to deliver new solutions.

It is believed that first intelligent electronic sensor was proposed in 1980 (by S. Middelhoek and J.B. Angell). It consisted of a MEMS sensor, analog-to-digital (A to D) converter, with the new idea to connect to a processor.

However, MEMs and CMOS processor technology was not ready at that time to create this integrated device. But now, the technology is available and it is clear today that intelligent sensors are the key for the development for innovative IoT systems.

Most would agree that the intelligent sensor must contain these key elements (figure 1):

- A sensing device that measures physical parameters from the real world.
- A computational block, such as a processor or DSP, that analyzes the sensing device measurements.
- A communication block, such as a wireless transmitter, that exchanges information with the bigger intelligent system.

In addition, signal conditioning is required to transform the sensing device signal into data that the intelligent sensor can use. This conditioning can include amplification, or signal clean up or tuning. The A to D block converts the analog sensing signal to digital so that the processor and software can utilize the information and perform sensor calibration.

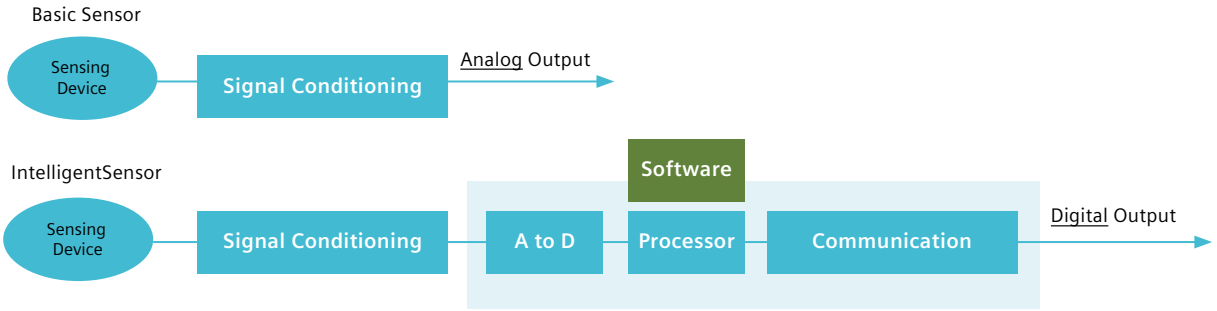

Figure 1: Comparing basic and intelligent sensors.

The Sensor Market

Designers can create electronic sensors using a variety of technologies including silicon photonics, CMOS, fluidic chips, and LEDs. But, MEMS sensors are the most interesting technology to explore due to their wide footprint in the intelligent sensor market. According to the Yole Développement's "Status of the MEMS Industry 2017" report, the MEMS sensor market in 2016 exceeded $11 billion in sales (Figure 2).

In 2003, Knowles Corporation® created the first MEMS microphone and due to its form-factor and resistance to heat that allows surface mounting, the product found its way into smartphones. Then in 2005, smartphones with accelerometers came into the market and accelerated the current MEMs sensor growth. In 2016, there was a big increase in the use of RF MEMS filters due to the complexities of 4G/5G communication, according to the Yole Développement report. But, the average selling price (ASP) of sensors has fallen to about $1 (more on that later). RF and microphones top the units shipped, followed by the top five MEMS sensors by type (Figure 3).

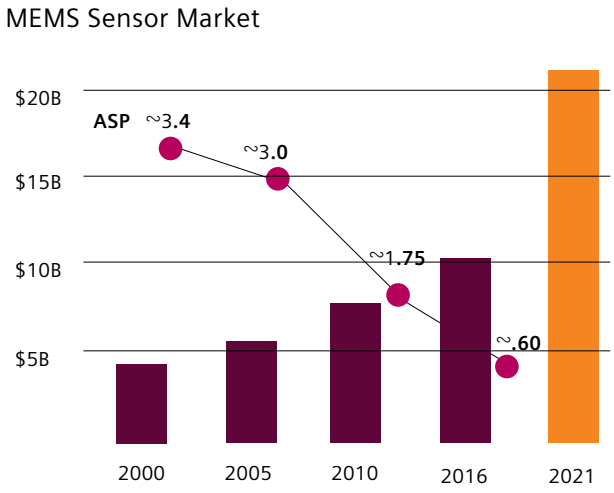

Figure 2: The MEMS sensor market with falling ASP.

Data Source: Yole Déeveloppement

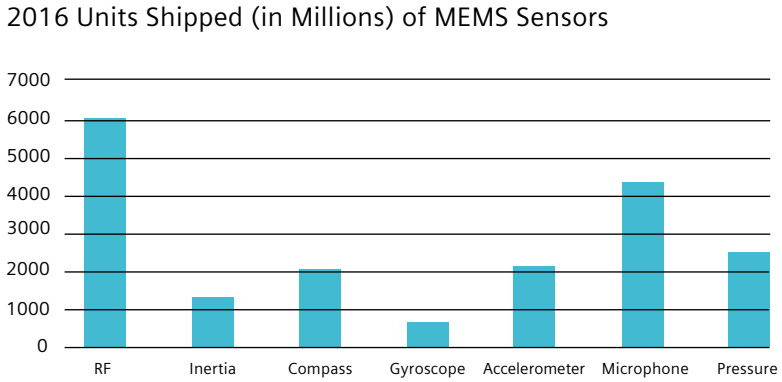

Figure 3: The most popular MEMS sensors sold by type.

Data Source: Yole Déeveloppement

If we examine overall MEMS and sensor sales, the consumer market, which includes smartphones, drones, smart home devices, and wearables, is by far the biggest market for combined MEMS and sensors. The automotive market comes in second with driver assistance, safety, and self-driving technology that are laden with sensors. The industrial market is driving sensor purchases for the Industrial IoT (figure 4).

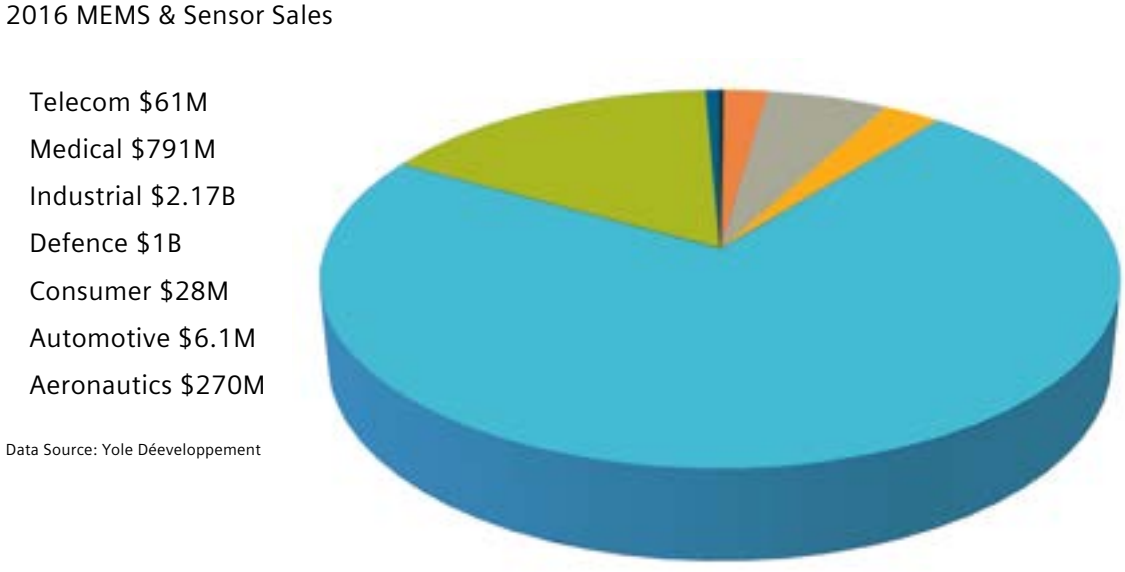

Figure 4: MEMS and sensor sales by market segments.

Show me the money

Given that the ASP of MEMS sensors is approximately 60 cents a unit, how will vendors make money in the IoT marketplace? If you are a market leader and you ship billions of sensors, then volume is a revenue factor. Or mergers and acquisitions can broaden the market. However, there are other approaches that vendors are taking to bring in revenue. One approach is sensor fusion.

Sensor fusion means developing a product that combines multiple sensors and intelligent software to create a high-value system that is more accurate than using the individual sensors. A good example is the InvenSense (TDK®) ICM-20728, the world's first integrated 7-axis MotionTracking™ device (figure 5). This device contains a 3-axis gyroscope, 3-axis accelerometer, and a pressure sensor in a single-chip platform solution with an onboard digital motion processor and firmware algorithms.

Software opens the gate to new revenue paths. For example, vendors can offer a portfolio of application-specific products at different price points where the hardware remains the same, but the intelligent sensor functionality is solely controlled by the software. Because the sensor is connected to other sensors and the Internet, the vendor can move into services. These services can include data fusion to optimize systems or to calibrate sensor systems remotely, providing data analysis, or performing remote diagnostics and maintenance.

Figure 5: The TDK sensor system on a chip (Source: TDK).

Tanner leads the way

From hobbyists, to small and large companies, designers are taking their new IoT ideas to market by taking advantage of intelligent sensors. A new breed of designers has arrived and they are making hardware design trendy again.

This new breed of designers are reshaping design flows and they have new expectations. They typically work in small teams and require integrated design flows to quickly and easily produce a functioning device while spending as little money as possible. They require the capability to develop a proof-of-concept for system validation in order to capitalize on the opportunity of the IoT market. Design teams need to rapidly implement products using integrated design flows that allow them to quickly develop all the pieces needed for the sensor-driven IoT edge device, including: sensing elements, analog circuit interfaces, analog-to-digital logic, digital logic, and RF, all at a low cost compared to traditional IC and systems design.

Many design teams employ the integrated IC design and verification solution from Tanner to create intelligent sensor-based IoT systems, including Knowles (see the case study here) and InvenSense (TDK). Why? Creating a sensor-based IoT edge device (figure 6) is challenging, due to the multiple design domains involved. But, creating an edge device that combines the electronics using the traditional CMOS IC flow and MEMS sensors on the same silicon die can seem impossible. In fact, many IoT edge devices combine multiple dies in a single package, separating electronics from the MEMS design. The Tanner AMS IC design flow accommodates single or multiple die techniques for successful IoT edge device design and verification.

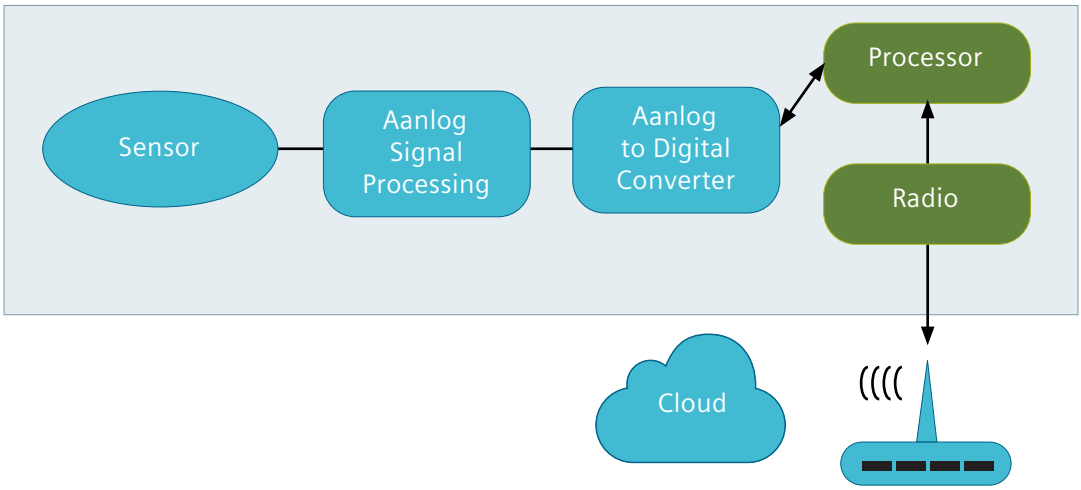

Figure 6: A typical IoT edge device showing multiple domain design.

Tanner provides a single, top-down design flow (figure 7) for IoT design, unifying the analog, digital, RF, and MEMS design domains. Whether you are designing a single die or multiple die IoT device, you can use the Tanner design flow for design, simulation, layout and verification.

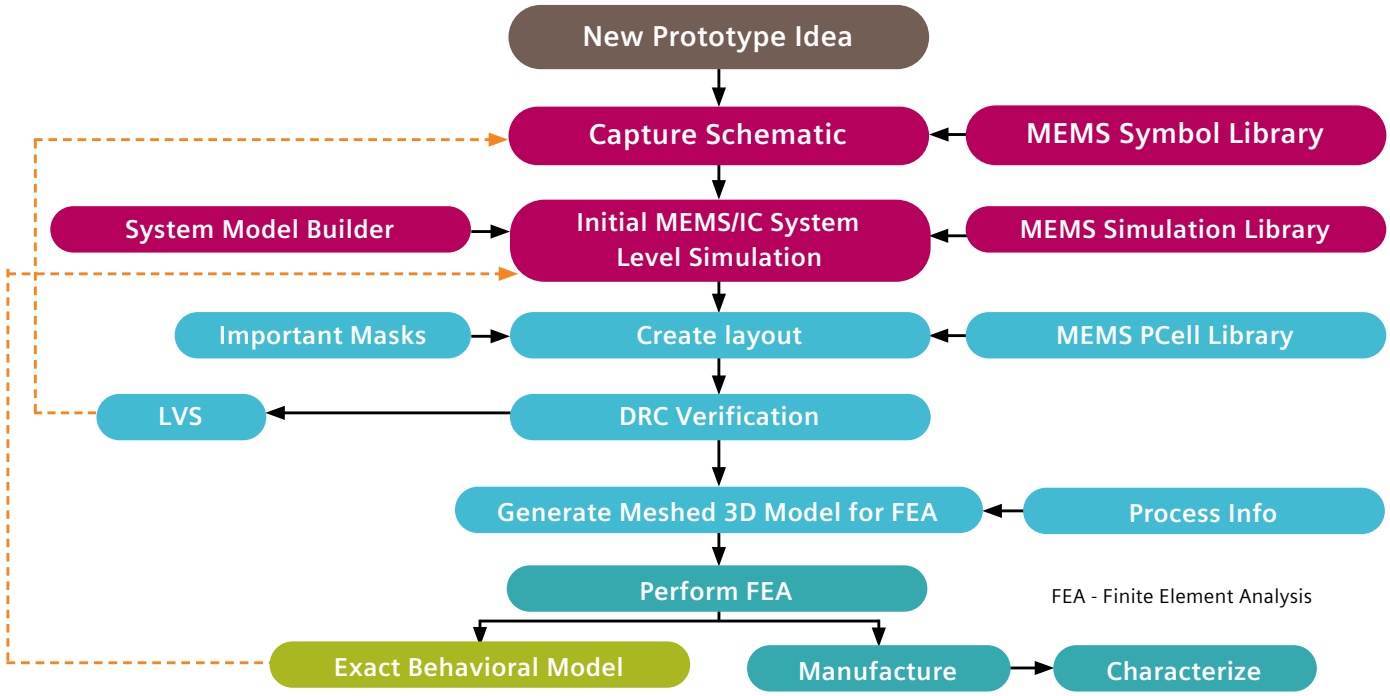

Figure 7: A single top-down design flow for multi-domain design and verification.

Siemens recognized early the opportunities that the IoT edge opens up to the new breed of designers and offers them a unique solution, tailored to their requirements.

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