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World Sensors and MEMS Markets: Analysis and Trends

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Abstract: This world sensors market overview is based on both: available information from different market analytics and International Frequency Sensor Association (IFSA) market study. It includes different "hot" sensors types as well as micro electromechanical systems (MEMS)-based sensors and sensor interfaces. The main aim of this short review is to concentrate information from different printed and online sources and help make a right decision in very dynamics sensor market as well as let know what should we expect in the nearest future.

Keywords: world sensors market, MEMS market

1. Introduction

This world sensors market overview is based on both: available information from different market analytics and International Frequency Sensor Association (IFSA) market study. It includes different "hot" sensors types as well as micro electromechanical systems (MEMS)-based sensors and sensor interfaces. We will start from MEMS devices, go forward to types of sensors (according to most popular and perspective applications in the last and nearest next years) and continue to sensor interfaces and outputs.

Because industrial sectors are constantly looking for cutting-edge high performance at a lower cost, smart sensors using microcontrollers are adding intelligence and functionality to various sensor technologies and providing simpler, more intuitive set-up. Innovation will move industrial sensor markets into adopting new technologies including smart sensor capabilities, wireless communications, MEMS-based components, plug-and-play sensors, and increased precision. Many of these advanced technologies are available now [1].

The main aim of this short review is to concentrate information from different printed and online sources and help to make a right decision in very dynamics sensor market as well as let to know what should we expect in the nearest future.

2. MEMS Devices

According to NEXUS market analysis on 'MEMS and Microsystems III, 2005-2009'[2] markets for microsystems will double over the next five years from $12 billion in 2004 to $25 billion in 2009, resulting in a CAGR of 16%.

According to the Yole Development report [3], the MEMS device market was $3.84 billion and is forecasted to reach $5.6 billion at the end of 2005 and $7.0 billion in 2007, resulting in a 17% CAGR. However, growth rate will differ depending on the MEMS applications.

New developments of MEMS devices (from R&D to first production) take now 3 to 6 years and the development/adaptation of a new device on an existing process takes as usually 2 to 3 years (from R&D to first production).

The most popular and promised MEMS devices markets are the following: acceleration sensors, gyroscopes, pressure sensors, ink jet heads, optical MEMS (DLP, bar code readers, fiber optics components), silicon microphones, RF MEMS, and microbolometers [3]. Application areas are: consumer, space/military, automotive, medicine and telecommunications. However, one key point of optical MEMS is that the applications have very different characteristics and for the moment, only few are volume markets (display and bare code readers) [4].

The US and European automotive sensor industry is in a highly optimistic state. Automotive sensors are an attractive and still-growing multibillion-dollar market characterized by very high production volumes of sensors that must be extremely reliable and low cost. Microsystem sensor technologies meet these needs and thus, are widely accepted for automotive sensor applications. Market growth continues to be driven by increasing demands for more safety and comfort and greater reductions in emissions. Existing sensors will continue to find new applications, and new sensors will emerge to improve functionality [5].

The more than $10 billion worldwide automotive sensor market in 2005 will continue to increase at an average annual growth rate of 6% to $14.2 billion in 2010. During the period, position, speed and oxygen sensors will rise at an AAGR of 6.7 %; pressure and acceleration sensors, 5.6 %; and mass airflow, temperature and other sensors, 4.5%. Position, speed and oxygen sensors will remain the largest market segment, rising from $6.2 billion in 2005 to $8.6 billion in 2010 [5].

In European and US regions, the automotive sensor market will grow at an annual average growth rate of 9.95 percent from $5.66 billion in 2005 to $7.53 billion in 2008 [6].

Although the electronics content of vehicles continually increases, the vehicle market itself is expanding more slowly than in previous years. The net effect is a steady increase in the value of the automotive electronics market as more onboard systems are converted to electrical/electronic systems [5].

Fastest growing automotive sensor segment is crash avoidance, safety and security systems. The other important segments are drivetrain system, vehicle control and safety, passenger comfort and convenience, emission control and sensors for future vehicles such as hybrid and hydrogen fuel cell vehicles [6].

The MEMS market is enjoying a fresh spurt of growth as the technology finds innovative uses in the telecommunications industry [7]. So, the applications and markets for MEMS in mobile phone where close to 2 M$ in 2004 and will go up to 250 M$ in 2008 [8].

Silicon Microphone is another very fast growing applications of the MEMS markets. The market adoption from mobile phone suppliers has been very swift from 2004 up to the beginning of 2005 [9].

The overall market is forecasted to grow from 60+ millions units in 2005 to more than 350 in 2008, representing 50% of the mobile phone total available market.

Over the past two years, MEMS suppliers have also made great strides integrating a variety of MEMS devices into consumer electronics products of all kinds [10].

Fixed and durable medical sensors are gradually giving way to disposable ones that cost less and, at the same time, are more hygienic. This increasing demand for the throwaway sensors and sensor-based equipment is in turn boosting the medical sensor market. With the price of medical sensors ranging from $20-$25,000, low cost and high volume sales have become the key to remaining competitive in the disposable sensors market. Participants must also deal with challenges associated with the low cost of pre-owned medical devices. These equipment have lifetime warranties extending to the second user and therefore, prove to be a viable alternative to the more expensive new equipment. To solve this problem, participants need to provide better value propositions through technologically advanced and more intelligent new equipment [11].

The use of IC compatible process lines for MEMS production is growing. There are clearly high benefits in using CMOS or BiCMOS-compatible manufacturing lines to target high-volume MEMS markets such as automotive and IT devices. There is a general trend toward adoption of more integrated solutions. Some specific reasons to select monolithic integration as a solution: cost advantages, commercial imperatives, performance advantages, and pragmatism [12]. Nevertheless, hybrid solutions are still sometimes preferred as it offers distinct advantages (more flexible manufacturing strategy, shorter development time, simpler and more easily available manufacturing process...). Integrated MEMS market share is expected to grow in the future. However there are today still bottlenecks to be overcame (process standardization, MEMS is not always a large volume market ...).

One of success attempt to overcome the mentioned bottlenecks was developed by IFSA and SWP, Inc. (Toronto, Canada) the IC of Universal Frequency-to-Digital Converter (UFDC-1) compatible with MEMS-based time-domain output sensors [13]. The UFDC-1 provides the technologies that both reduce the cost and

time of sensor application development and improve digital sensor performance. It is a multi sensor data acquisition and signal processing system with three popular sensor interfaces: SPI, I^2C and RS-232.

The MEMS on IC technologies are taking a very important market share compared to total MEMS activities.

3. Sensors Market

3.1. Pressure Sensors

New analysis from Frost & Sullivan (www.sensors.frost.com), World Pressure Sensors and Transmitters Market, reveals that the market earned revenue of $4,018.8 million in 2004 and projects to reach $5,545.1 million in 2011 [14].

The pressure sensors market also has progressed towards digital electronics, which are in demand for multiple end-user applications. More developments in the high-end pressure sensors are also expected. There has been a demand for the software integration, which includes software programs to collect and assess data. This provides higher control of the process, as the data received by the operator is a sort of recommendation to help improve the process. End-users prefer buying pressure transmitters with software integration and hence manufacturers are forced to address these needs.

As a result, to help manufacturers and customers to design digital output pressure sensors and transducers very quickly, the UFDC-1 also can be used in order to reduce time-to-market and production cost [15].

"Manufacturers are now forced to offer pressure sensors and transmitters that are compatible with the fieldbus systems," says Frost & Sullivan Industry Analyst Dr. Rajender Thusu. "This is due to the increase in demand towards highly accurate and compatible pressure measurements. Manufacturers who fail to offer such technologies in certain markets are bound to lose their market presence as the manufacturers who provide a total solution have a definite edge over the rest." [14].

Many manufacturers have set up their production centers in Asia Pacific regions due to the lower production and labor costs [14]. It is also expediently to draw manufacturers' attention to Former Soviet Union countries, from labor and production costs point of view, for example, Russia and Ukraine. Due to an economy of these countries is in an initial market stage development, they will be also very promised customers in a few next years.

3.2. Image Sensors

The image sensor and module market will exceed $4 billion in 2005, led by the camera phone application, according to market research firm Strategies Unlimited. Four Japanese companies continue to lead in market share Sharp, Sony, Toshiba and Matsushita, in that order. However, the analysts note that Japanese companies are no longer producing only CCDs. Two of them are now among the largest producers of CMOS arrays [16].

According to Research and Markets (http://www.researchandmarkets.com/reports/c27583) the image sensor market has continued to show sharp growth over the past year. CMOS sensors have ridden the camera phone wave to surpass CCDs in 2004. Camera phones shipped well over three times the volume of the next most successful image sensor application, digital still cameras. CMOS sensors have also been successful in low-end digital still cameras and web cameras.

CCDs have been successful as well, especially in traditional point-and-shoot digital still cameras, camcorders, and security cameras. However, none of these applications are growing at nearly the rate of camera phones, leaving CCDs behind CMOS in shipments.

3.3 Fiber Optic Sensors

Global revenues for fiber optic sensors are projected to rise to $304.3 million in 2006, from a current estimate of $288.1 million, according to a report from Business Communications Co. Inc. of Norwalk, Conn. The updated document, "RG-116N Fiber Optic Sensors," suggests that revenues will increase at an average annual growth rate of 4.1 percent to $371.8 million by 2011. It further indicates that, to move beyond the status of niche applications, the sensors must drop in price significantly [17].

Estimated at $214.8 million in 2005, the market for extrinsic sensors, which are used in the telecommunications industry, is expected to grow at a rate of 4.1 percent until 2011, reaching a revenue value of $274.4 million. Forecast to grow at a rate of 4 percent to $97.4 million, the intrinsic sensor market is lagging in some application markets. Intrinsic sensors are primarily used in military applications, which are often specialized and seldom lead to mainstream markets.

Promise exists in the medical market for the sensors, which may be used in minimally invasive treatment applications. Current revenues in this area are modest, however, because of the challenges facing the technology.

3.4 Biosensors

Biosensors sometimes are broadly defined as any device designed to gather biological information, such as the presence of a particular biomolecule, and convert it into an analytical signal. A stricter definition of biosensors used by the National Research Council (NRC), part of the U.S. National Academy of Sciences. The NRC has defined a biosensor as *a detection device that incorporates a) a living organism or product derived from living systems (e.g., an enzyme or an antibody) and b) a transducer to provide an indication, signal, or other form of recognition*

of the presence of a specific substance in the environment [18].

New markets for biosensors and other bioelectronics devices are developing. For example, heightened security concerns in the wake of the 9/11 terrorist attacks have focused attention on the development of new sensors to detect dangerous chemical and biological agents. The first protein-based optical memory media have begun appearing on the market [18].

Rapid technological advances in the field of biosensors are allowing this technology to cater to an extensive range of applications. Apart from home diagnostics, medical and bio-defense applications hold immense potential for biosensors. In order to make the most of these emerging applications, researchers worldwide are hiking up investment in research and development (R&D) activities. Biosensors are moving beyond detection of biological threats such as anthrax and are finding use in a number of non-biological applications. Emerging biosensor technologies that can sense toxic agents and avert related illnesses in a timelier manner, especially during wars, hold huge growth potential. According to experts, the army can network thousands of sensors to detect these agents. With the move toward miniaturization and developments in lab-on-a-chip technologies, participants that can offer refined products to meet the expanding biosensor applications are set to gain a competitive edge [19].

Ideal biosensors should be fast, easy to use, specific, and inexpensive. However, the significant upfront investment required for developing biosensors is a key challenge faced by manufacturers. In addition, prolonged R&D timelines make it difficult to justify the high costs in the absence of huge volume markets. Smaller suppliers in particular are less likely to obtain sufficient funding "Numerous participants earmark millions of dollars every year to develop new biosensors and improve the existing ones so that they can stay ahead of competition," says the analyst of the research [19].

Researchers are also struggling to gain support from financial agencies for biosensor R&D projects due to long gestation periods and low success rates. Given the current scenario, manufacturers need to be more selective and ensure that only sound research projects with greater potential for success receive funding [19].

Developing biosensors that meet accurate technical standards is a crucial issue that manufacturers need to address immediately. At the commercial scale, a series of associated problems such as sterilization, selectivity, reproducibility, reliability, and cost of manufacture also exist. These techno-commercial considerations delay product launches and also prevent mass production of many newly developed biosensors. As demand for various biosensors continues to increase and investors streamline the commercial manufacturing aspects ensuring higher long-term growth, the impact of this challenge is likely to reduce [19].

Rapid miniaturization is going to be a key consideration while developing biosensors. High performance miniature biosensors are not only expected to quicken commercialization but also allow biosensors to penetrate several untapped markets. Many North American and European manufacturers have deployed their financial and intellectual resources and successfully developed biosensor-based miniature monitoring instruments, especially in the home diagnostics applications. Manufacturers have also successfully integrated biosensor technology with leading-edge IC and wireless technology in some high-end applications [19].

3.5 North American Markets for Proximity, Photoelectric, Linear Displacement Sensors

Shipments of proximity and photoelectric sensors to North American markets totaled $617.2 million in 2004. The market is forecast to increase at a compound annual growth rate (CAGR) of 4.7% through 2007, exceeding $708 million. The market for photoelectric sensors is expected to be the fastest-growing segment during this period. Shipments of linear displacement sensors to North American markets totaled $334.9 million in 2004. The market is forecast to increase at a CAGR of 4.3% through 2007, reaching approximately $380 million. The market for triangulation laser sensors is expected to be the fastest growing product segment during this time. Increasingly, sensors will have bus/network interfaces. Our research indicates a trend toward greater use of Ethernet. The relative use of other networks and buses, including standard serial, DeviceNet and Profibus, is expected to remain fairly constant. The most important criteria to user respondents in selecting sensors include: accuracy and reliability for linear displacement sensors, and reliability and durability/ruggedness for proximity and photoelectric sensors. Respondents want assurance that their sensors provide a correct reading, and will continue to do so over time [20].

3.6 Nanosensors

Nanotechnology generally is defined as *the creation and use of materials, devices and systems through the manipulation of matter at scales of less than 100 nanometers or 0.0000001 of a meter (i.e., about the size of three atoms).* At this scale, the properties that characterize larger systems do not necessarily apply. Nanostructured metals are generally harder than macroscale metals, nanoceramics are softer, etc. Nanoscale materials light absorption properties also differ from macroscale materials, e.g., some materials become transparent if the particles are small enough [21].

Since many of the properties that sensors are supposed to measure are formed on the molecular or atomic level, nanotechnology has obvious sensing applications. Sensors constructed at the molecular scale would be extremely sensitive, selective, and responsive and thus, the impact of nanotechnology on sensors potentially is huge.

According to the BCC report [20] total global nanosensor sales are expected to rise at an average annual growth rate (AAGR) of 25.5% to $592 million by 2009. Nanochemical and nonbiosensors will grow significantly through 2009, at AAGRs of 53.1% and 32.9%, respectively. Nanomotion and nanoradiation sensors are not expected to account for a large portion of the market while nanothermal sensors are not projected to achieve any commercial sales during the period.

4. Sensor Buses, Interfaces and Outputs

According to IFSA study (2005) most popular sensor interfaces and buses are RS-232/422/485, SMBus, IEEE-1451, CANbus, I^2C and SPI (Figure 1).

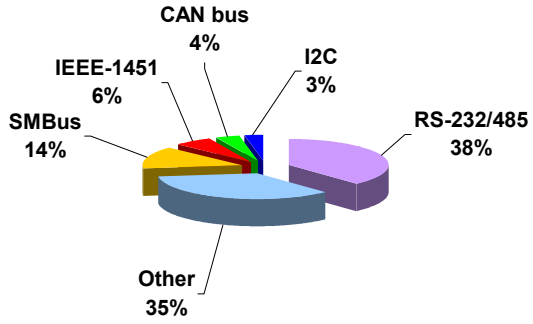

Fig. 1. Market shares of sensor interfaces and buses (studied by IFSA, 2005)

Due to an IFSA effort to simplify the IEEE 1451 standards family extension for adding smart, plug-and-play and self-adaptation capabilities to frequency output sensors the level of commercial adoption of the standard in industry and smart sensors market may be increased up to 20 % in the next years and gives strong benefits to both: customer and manufacturers [22].

In the last years frequency-time domain or so called quasi-digital sensors (with frequency, period, duty-cycle, time-interval, PWM or phase-shift output) become more and more popular and widely distributed among manufacturers, customers and system integrators. This sector will be growth up in the next years because of not only analog but also frequency output sensors will be used as a basis for creation of different plug-and-play (TEDS) smart sensors.

According to IFSA study (2004), the sensors market in term of sensors' outputs is divided into the following: voltage output sensors - 46 %; current output sensors - 19 %; digital output sensors - 16 %; frequency output sensors 12 %; duty-cycle output sensors 2 % and other - 5 % (Figure 2). The last one includes phase-shift output sensors, charge output sensors and other outputs.

Smart sensors will also have a good market niche due to sensors price reduction. The best modern approach for smart sensors creation will be to use both modern technologies and advanced methods for signal processing and conversion. Moving from traditional analog (voltage and current) signal domain to the frequency-time signal domain lets achieve many benefits due to properties of frequency as informative parameters.

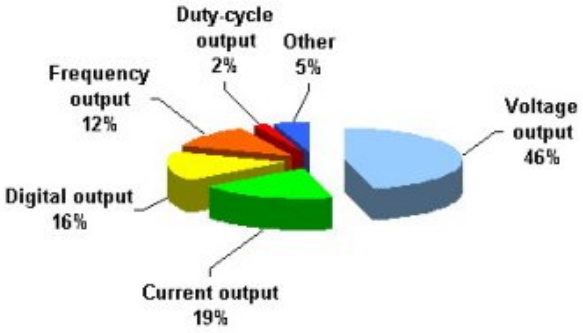

Fig. 2. Sensor Market in term of output signals (studied by IFSA, 2004).

Today's intensive development of quasi-digital group of sensors and its growth in the nearest future will also increased the digital sensors market share in the sensors world market. Because of many digital sensors will be made based on quasi-digital sensors. The market shares of quasi-digital sensors are shown in Figure 3.

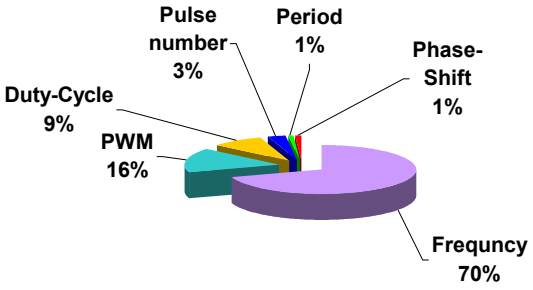

Fig. 3. Market shares of quasi-digital sensors (studied by IFSA, 2005)

Today many manufacturers produce sensors and transducers with analog, and frequency or digital output, and sometimes, with several interfaces in the same device. This tendency will be continued in the next years due to standard solution like the UFDC-1 and MEMS on IC technologies.

5. Conclusions

The accuracy of output achieved in MEMS based sensors and transmitters is high and has prompted their growth in multiple end-user markets. Trends towards digital electronics, software integration and networking systems compel manufacturers of sensors and transmitters to

enhance their product offerings based on modern achievements in signal processing.

The intensive development of quasi-digital group of sensors and its growth in the nearest future will also increased the digital and smart sensors (including TEDS plug-and-play transducers) market shares in the sensors world market.

References

[1].Randy Ray, What's next in sensor technologies ? *Control Engineering*, October 1, 2005
[2]. MEMS and Microsystems III, 2005-2009, NEXUS
[3]. Ultimate MEMS market Analysis, April 2005 (http://www.the-infoshop.com/study/yd27263_mems.html)
[4]. Analysis of Optical MEMS Applications for Non Telecom Markets, January 2005 http://www.the-infoshop.com/study/yd26292_optical_mems.html
[5]. Automotive Sensors, November 2005 http://www.the-infoshop.com/study/bc34281-automotive-sensors.html
[6]. Automotive Sensors Market Emerging & Current Sensors Update Now and Future Fuji-Keizai USA, Inc., September 2005 http://www.researchandmarkets.com/reportinfo.asp?report_id=307920
[7].World MEMS Based Tunable and Dynamic Component Markets for Telecom Applications, February 2005 http://www.the-infoshop.com/study/fs27021_mems_component.html
[8]. Mems4Mobile: Analysis of the applications and markets of MEMS in mobile communications, January 2005. http://www.the-infoshop.com/study/yd26293_mems_mobile.html
[9]. Silicon Microphone Market 2005, September 2005 http://www.the-infoshop.com/study/yd32516-silicon-microphone.html
[10]. MEMS and Consumer Electronics: Growing Up Fast, July 2004. (http://www.the-infoshop.com/study/cg22697_mems.html)
[11]. World Market for Sensor Opportunities in Medical Applications, June 2005 http://www.the-infoshop.com/study/fs32120-medical-sensor.html
[12]. MEMS on IC: Analysis of the Applications and Technology Trends**,** November 2004 http://www.the-infoshop.com/study/yd25077_mems_ic.html
[13]. Universal Frequency-to-Code Converter (UFDC-1). Specification and Application Notes http://www.sensorsportal.com/DOWNLOADS/UFDC_1.pdf
[14].World Pressure Sensors and Transmitters Market, F545-32, Frost & Sullivan, http://www.sensors.frost.com
[15].Yurish S.Y., Intelligent Digital Pressure Sensors and Transducers Based on Universal Frequency-to-Digital Converter (UFDC-1), *Sensors & Transducers Magazine*, Vol.60, Issue 10, October 2005, pp.432-438. http://www.sensorsportal.com/HTML/DIGEST/P_50.htm
[16]. Image Sensor Market Review and Forecast, 2005 http://www.tekrati.com/T2/Analyst_Research/ResearchAnnouncementsDetails.asp?Newsid=6127
[17].http://www.photonics.com/spectra/business/XQ/ASP/businessid.1456/QX/read.htm
[18].Biosensors and Bioelectronics, April 2005 http://www.the-infoshop.com/study/bc29282_bioelectronics.html
[19]. World Biosensors Markets, April 2005 http://www.the-infoshop.com/study/fs29639_biosensors_market.html
[20].North American Markets for Proximity, Photoelectric, and Linear Displacement Sensors: February 2005 http://www.the-infoshop.com/study/vd29181_displacement_sensor.html
[21]. Nanosensors, December 2004 http://www.the-infoshop.com/study/bc26155_nanosensors.html
[22]. Yurish S.Y**.,** IEEE 1451 Standard and Frequency Output Sensors: How to Obtain a Broad-Based Industry Adoption ? *Sensors & Transducers Magazine*, Vol.59, Issue 9, September 2005, pp.412-418. http://www.sensorsportal.com/HTML/DIGEST/P_52.htm