MEMS sensor testing challenges and requirements

By Andreas Bursian [Xcerra]

Industry 4.0 and the Internet of Things (IoT) may be the most utilized expressions currently being used to describe the change going on in the world. But Industry 4.0 and IoT are small components of a rapid global change that experts tend to call the 4th Industrial Revolution. This revolution will change all aspects of today's living, such as cash flow, data handling, job structure, and the political and social structures of society and the industrial production of goods.

Before answering the question of what the test requirements for MEMS sensor devices will be in the future, you have to answer the question of what our world will look like in the future. Such a discussion can give a rough indication on how the semiconductor industry has to evolve to keep pace with this revolution. Some aspects of MEMS sensors need to be examined first before you can start to think about how the requirements for MEMS sensors will change in the future.

If you take a look at today's market size, the annual volume of MEMS sensors can be roughly estimated to be 14 billion devices per year. Some forecasts have the annual growth rate estimated to be up to 20% until 2020. This would translate to 30 billion MEMS sensor devices. Scientists, however, expect, that the number of connected devices will go up to 1 trillion in 2025, which suggests an even larger growth rate than we are experiencing today. Whichever projections are proven out, they tell us that we will see a large trend in smaller and cheaper devices. This trend in turn will lead to advanced packaging and production technologies that will enable the industry to stay on trend.

Taking a look at sensor functions today, we see a large number of inertial sensors being used in mobile applications. The market is saturated and the main goal is to make these sensors cheaper and less power consuming. Nevertheless, there is a growth potential, because the mobile market is still growing and the lifetime of mobile devices is limited.

New trends for MEMS sensors can be observed in environmental sensing, such as barometric pressure, humidity, gas and sound. Sensor abilities and technology are driven by an army of engineers and obey the rules of the 4th Industrial Revolution. New technologies may be disruptive, e.g., replacing existing technology in a very short period of time. More than that, there will be new requirements for testing, which cannot be achieved with test equipment that is available today. This disruptiveness may find its path into final test as well.

Quality has always been an important factor, but there is a trend to 0ppm test quality requirements that have only been seen so far in automotive applications. There are a couple of reasons for this. On the consumer side, there is the pure cost factor and the fact that one bad device on a board can only be detected on a system-level test. Once detected, the whole board will be scrapped, no repair is possible. For industrial, medical and automotive applications, quality is determined by safe operation. Many of the sensors are used to maintain lifesaving systems or systems for human interaction, where a fail function of a sensor can cause serious injuries to human beings.

The market for MEMS sensors is becoming more and more volatile and disruptive. Large global manufacturers in the sensor market acquire smaller companies, or mergers create new super companies with new portfolios. Even larger companies disappear or give up on MEMS product. Demanding product ramps require a fast time-to-market and the ability to ramp production from zero to ultra-high volumes, maintaining this volume for a couple of months, and then running the same cycle for different product with potential different test requirements. Suppliers that cannot keep track with the demanding market requirements may disappear in a very short period of time.

MEMS test equipment requirements

Keeping the above outlook on the MEMS sensor market in the 4th Industrial Revolution in mind, there are a few key factors that MEMS test equipment has to fulfill: 1) fast time-to-production; 2) highly parallel; and 3) modular, scalable, and easily convertible.

Fast time-to-production has become a key factor over the past several years with consumer applications having been the main driver. The product cycle for consumer products is no longer than one year. It can be observed that the ramp-up and qualification period of a new MEMS sensor can be down to three months. A typical test setup for a MEMS device comprises a handler, tester, test program, a stimulus, a contactor solution, and last, but not least, the integration of everything. In a classical test environment, the integrated device manufacturer (IDM) or outsourced semiconductor assembly and test supplier (OSAT) would select all parts and drive the integration on site. There is a big risk that parts may not fit, or you may see interfacing problems due to the fact that every piece was built by a different supplier. This is unavoidable and you can account for it, if time margins are large enough. Besides timing issues, incompatibilities produce costs that usually do not appear in any planning.

A very convenient way for the customer to overcome such issues is to push the integration part of the job out to the vendor. If the vendor acts like the customer, there will be no big improvement on the whole process. If the vendor, however, can supply all parts from its own portfolio, the process becomes lean and safe. The vendor typically can build and integrate the whole system in its factory. Once the vendor produces all parts and sub-systems on its own, there is a seamless communication and knowledge of every little piece under the umbrella of one company. In such an environment, the customer's duty is limited to a requirement list. Pre-qualification can be done at the supplier and final qualification can be done on site. The customer saves cost in terms of work that has to be done in engineering and development and can focus on the core competency, which is production. Following this model, there is a huge cost saving potential in supply chain management and spare parts management.

Test parallelism is a key factor for volume production, ramp capability and cost-of-test. There are two very specific constraints for MEMS sensor testing: 1) The major fraction of these devices are being tested after saw and packaging. The silicon sensors are extremely sensitive to mechanical force, which can influence the calibration of the sensors. And 2) The test times are short, but the calibration process usually lasts for seconds. Supplying the stimulus at a high accurate level may also significantly contribute to the process time.

The ability to test singulated devices in a highly parallel manner is the basis for running in high-volume with a reasonable amount of equipment. Test parallelism of 144 devices under test (DUTs) is widespread in the market, going up to by 256 DUTs. Such equipment can run millions of devices per month and enable ramp ups from engineering to production lost within days.

Systems that can test millions of devices per month used to be dedicated in the early days of the semiconductor industry. They were built to run one product for one life cycle, which had been acceptable because the depreciation period was shorter than the life cycle. This is no longer acceptable because MEMS test systems have to be able to test many different generations of sensor types. The nature of such systems is the ability to be converted easily. This goes beyond the simple change of some mechanical parts, but requires the ability of the base system to handle a large variety of different package types and sizes. Starting with classical molded devices, going to automotive packages, metal cap, and finally, chip-scale packaged devices, all package types have to be handled in a reliable way, guaranteeing the highest QA standards and fulfilling all relevant safety standards.

The discussion above aside, not only packages are changing. Stimuli change completely or develop over time. A good example is the environmental combo sensor that started with the requirement for obtaining a highly accurate temperature. The requirements for barometric pressure, relative humidity and gas tests were added step-by-step, now being able to provide only one port hole for four different kinds of sensing. So it can be seen that just as packaging technologies develop, so must test requirements (i.e., stimuli). Being modular means that handling and MEMS testing must be separated, so that you can keep the handler as a base system and exchange the MEMS module if required. The same is true for the tester: it has to be flexible to support all MEMS applications. Having this flexibility in place, it is possible to assign test cells to special production processes that can be limited to a short period of time and may change in test requirements. The modularity enables the customer to keep most of the equipment and adjust the test cell to the new requirements by simply using a new conversion kit and, if required, exchanging the MEMS test module. After an initial investment, the customer can react to changing production requirements in terms of volume and MEMS stimulus by a resource management of existing production resources. Additional investment is limited to new or improved MEMS stimuli.

There is another aspect of scalability that is often not considered. Coming out of standard singulated test handling, loading of devices, testing and unloading of devices are part of one single handling system. This is the classic pick-and-place (P&P), or gravity handler. Taking a look at the large and rapidly changing number of device types, the pure handling process becomes challenging. Devices become smaller and smaller, not being able to be handled on a gravity system. Chip-scale devices finding their way into MEMS applications may even exclude P&P handlers as appropriate handling systems. Every jam that occurs in such a combined handling system will impact the load of the tester and the output of the system. Furthermore, long test times may cause the loading and unloading areas of these handlers to be idle. Therefore, it can be an advantage to separate loading and unloading from the test process. If, for example, the test process is very long, one loading and unloading unit can serve more than one test unit or vice versa. Such an arrangement makes best use of the handling system units and enables the customer to add capacity to its fleet of handlers by adding the required units only, instead of adding systems, thereby delivering the entire loading and testing capability. Such a production environment can be optimized by planning and needs less investment once it is established.

The 4th Industrial Revolution will dramatically change our lives. The changes take place everywhere and will affect our private lives as well as our professional lives. It will make our lives better, it will increase the health and living standard for billions of people, but it will also make our lives more volatile, demanding more flexibility from everybody.

The 4th Industrial Revolution with Industry 4.0 and IoT will also dramatically change the MEMS sensor testing requirements. A static production environment cannot fulfill the requirements of the MEMS sensor market. The production process will have to provide flexible answers to the marked requirements. Traditional test handling systems may not be able to provide the required solutions. New MEMS sensor handling systems need to provide good ramp capability, high test parallelism and modularity to be able to react flexibly to these market requirements. We have described a number of paths on how such test systems can look and which preconditions have to be fulfilled to be successful.

Biography

Andreas Bursian received his Masters degree in Electrical Engineering at the U. of Applied Sciences and Arts, Dortmund and is a Director of InStrip and InMEMS products at Xcerra. He started his career as a pioneer in SPICE and FEM simulation; email andreas.bursian@xcerra.com