Sensor-based systems solutions

To be successful, sensor-based systems designers must adopt a DFM/DFT approach with a broad view of requirements

BY ROGER H. GRACE
Roger Grace Associates
Naples, FL
http://www.rgrace.com

One of the major barriers to commercialization of sensor-based systems has been the inability of the industry to adopt adequate design for manufacturing and test (DFM/DFT) strategies. As previously reported in the "MEMS Commercialization Report Card" (*www.rgrace.com/documents/MEMSReportCard_2007.pdf*), DFM/DFT is one of the most critical success factors for MEMS commercialization. If one is to create an optimum sensor-based system, one needs to take a "30,000-ft view" at sensor-based system requirements, and then develop a solution that embraces interfacing with signal conditioning electronics, embedded intelligence (software), networking, and power supplies. In addition, interconnects, packaging, and testing all need to be considered.

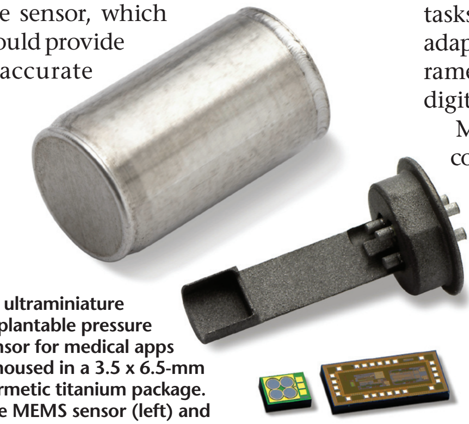
For a design to succeed, all these factors have to be addressed in unison, at the very onset of the design process. Some call this process co-design or concurrent engineering or, in the case of electromechanical systems, mechatronics. Also, the sensor-based system designers/architects must understand the implication of the design from a manufacturing perspective so they can integrate basic strategies to minimize the manufacturing cost of the resultant solution while providing a very robust product.

The following addresses some of the specific design challenges that both providers and users of sensor-based systems face, as well as some applied examples of the concept.

Packaging

Sensor packaging is unique, because a sensor cannot be essentially isolated from the medium in which the measurement parameter needs to be assessed. Quite frequently, this medium is harsh, from a chemical (for example, engine oil, blood), thermal, shock, vibration, humidity, and/or EMC perspective. The package must thus be considered an integral part of the sensor design (and typically proves to be a major portion on the bill-of-material cost of the final solution.

Ironically, the package can frequently impart mechanical stresses to the sensor, which would provide inaccurate measurements unless the sensor is adequately isolated from those package effects. To minimize such effects, many sensor–in-package designs use finite element analysis to model and characterize the mechanical interaction between the sensor and its package. To overcome these effects, a common approach is to mechanically isolate the sensor from its package through intervening materials and barriers, for example, by using glass "frits" and silicone. Organizations that specialize in sensor packaging include Aspen Technologies, Engent, ePack, and Microassembly Technologies.



An ultraminiature implantable pressure sensor for medical apps is housed in a 3.5 x 6.5-mm hermetic titanium package. The MEMS sensor (left) and ASIC (right) are mounted on a ceramic substrate. (Courtesy of Tronics Microsystems)

Interface circuits

Another major issue in creating an optimized sensor-based system solution is the sensor-interfacing circuit. Most sensors have low-level, millivolt outputs that are analog in nature and are affected by numerous factors, including nonlinearities, hysteresis, and temperature sensitivity.

A now-popular approach to overcome these inherent problems is to use an ASIC. Popular ASIC functionalities include the ability to handle multiple varieties of signal manipulation tasks. Fundamental versions include adaptation for different measured parameters, amplification, analog-to-digital conversion, and filtering.

More advanced versions include compensation/embedded intelligence circuits to overcome temperature variations using look-up tables and E^2PROM networking circuits both wireless and wired. Sensor solutions using ASICs are provided by a number of companies, including Austria Microsystems, Sensor Platforms, Si-Ware Systems, and ZMD.

Interconnects

When it comes to integrating the various elements of sensor-based system solutions, interconnects are a major factor. A popular approach is to use the "system-in-a-package" (SIP) solution where system elements are arranged on a substrate that either forms the complete system or is subsequently embedded into a mechanical package. Another approach is the system-on-a-chip (SoC) where the circuit elements are integrated monolithically on one chip, such as in Analog Devices' ADXL accelerometers.

An exciting new approach of chip stacking is becoming popular in both the integrated circuit as well as MEMS areas. Here, individual chips are layered one atop each other, and the connections are made using either external bond wires or an approach called "through-hole-vias." An excellent example of the chip-stacking approach is VTI's MEMS accelerometer.

Testing

Testing is a critical and quite frequently overlooked but necessary function. Unlike semiconductors that are tested in a pure electronic environment, sensors need to be tested using their appropriate stimulus — for example, vibration or pressure. This has created major but not insurmountable problems. To move away from testing sensors on a "one-at-a-time" fashion — a major issue — people have taken to creating complex fixtures/manifolds.

In the case of micro electromechanical systems, MEMS manufactures attempt to create testing strategies that can be implemented on a wafer level, before the devices are sawed and integrated into system-level solutions. Earlier determination of "known-good die" minimizes total cost of manufacture and "weeds out" non-spec-compliant devices before then can move to their next level of integration. An organization called MEMUNITY (*www.memunity.org*) has been formed to educate producers of MEMS devices on strategies that will create cost-effective and accurate approaches to measurements for their products.

System examples

As the previous paragraphs indicate, the sensor is only a portion (albeit and important one) of an overall solution. If an optimum approach is to be created, one needs to address all the issues.

A number of excellent examples of this approach exist today. One of the most popular is tire pressure-monitoring systems such as those from TRW. In these systems, designers have integrated pressure, temperature, and motion sensors with an ASIC chip to form the heart of the system. In addition, a Tx/Rx chip, antenna and power supply (battery) complete the sensor system that is introduced into a low-cost and robust tire valve stem package. Over 50 million of these systems will be produced in 2009.

Many other opportunities that exist for sensor-based systems are being pursued by such organizations as Acuity, Axept, LV Sensors, and Tronics Microsystems. The complex nature of these systems' requirements cry out for the adoption of an integrated design approach. This is a win-win approach, since it provides the user with a complete solution (versus a fragmented one which has been popular in the past) and it provides suppliers with the opportunity to better differentiate their product. It's time to think outside the sensor.

More information about this approach, with details on its application to microelectromechanical systems, can be found at *www.rgrace.com*, and at this year's Sensors Expo (*www.sensorsexpo.com*), an all day pre-conference session devoted to the topic of MEMS-based systems solutions will be held on June 8. ■

Strategic marketing consultant Roger Grace has over 40 years in the electronics industry, holding positions as a circuit designer, project engineer, and applications engineer. His focus has been on sensors and especially MEMS. He co-founded and is a past president of the Micro and Nanotechnology Commercialization Education Foundation and was named Northeastern University's Engineer of the Year in 2004.