

# MEMS/MST Based Systems Solutions: Think Outside the Chip

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## Introduction

I as well as many others have been guilty of writing and waxing on eloquently on the subject of microelectromechanical systems (MEMS) or Microsystems Technologies (MST), but in fact this has been a misnomer. The past dozen or so all-day sessions that I have organized at Sensors Expo has also followed this course of action. But this year was different indeed!!! The MEMS/MST that we have been addressing have ostensibly been MEMS/MST devices ...NOT systems. The Transducers'09, which I recently attended, took place in Denver, Colorado, in June, had over 600 technical papers and posters as part of its program. Based on my long history of attending these academic types of events, I think that it is safe to say that the majority of these papers dealt with MEMS/MST devices...not systems that utilize these devices. So if one were to ask if the "s" in MEMS and MST translate into "systems" what motivates MEMS people to devote most of their efforts developing and discussing devices?

## The problem

I believe that this is so because and with rare exception, universities teach students about devices and their physics, modeling, simulating, design and behavior and not how these devices can enable solutions. Ph.D. theses are typically about devices...and not practical solutions. It is assumed that industry can take care of this. As a result, graduating students are not armed with a toolbox of knowledge to create solutions. A welcomed departure of this academic approach exists at the University of Michigan through its Wireless Integrated Microsystems Laboratory (WIMS) and through the Fraunhofer ENAS Institute in Chemnitz, Germany. The good news is that key personnel from these organizations were the keynotes at the Sensors Expo June 8 all day session entitled... "MEMS Based Systems Solutions: Thinking Outside the Chip. Prof. Thomas Gessner of Fraunhofer

and Prof. Khalil Najafi from UMICH shared with the attendees of this session some of the exciting projects that their organizations are investigating to help create commercially viable MEMS/MST - based systems solutions. It is also interesting to note that Prof. Gessner was the Chairman of the Smart System Integration Conference, which was held on March 10-11, 2009, in Brussels. The conference is an activity of the European Platform on Smart Systems Integration (EPOSS). The European Union, unlike the US, has taken a decisive step to fund organizations to undertake work on this effort. This to me is a breath of fresh air.

## The solution ... think outside the chip

One may ask, "Why and how should I think outside the (MEMS/MST) chip" and what significance exists for "design for manufacturing/assembly and test". There are many reasons and the most significant is that to create an optimum solution for the customer, one needs to think about the customers' need for a function in their system and how to add the highest value to the suppliers' contribution to the customers' need. As a result, the supplier is enabled to provide more functionality, takes control and responsibility of all the interfaces and derives a higher profit margin to the solution while eliminating much of the work and trouble for the customers. While it is safe to say that the MEMS/MST chip is critical to the solution, many of these devices have reached the stage of commoditized components that are available at low cost and in high volumes from many suppliers, e.g. accelerometers.

The value added issues/elements to the basic MEMS/MST devices necessary to create a systems solution ap-

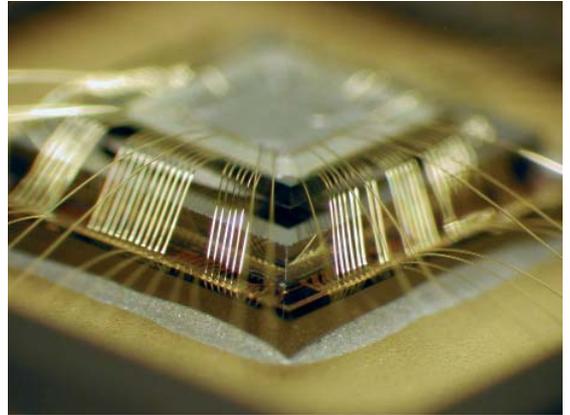


Figure 1: MEMS-based system for telecom applications shows a lower silicon die which supports an array of MEMS switches and has a wafer-level cap. On top of this is a CMOS controller die with wire bonding connecting the CMOS to the MEMS die. Courtesy: Aspen Technologies

proach are given below. I have expanded on some of the more critical issues/elements.

- Single or multiple device integration strategies...monolithic versus multi chip-based on numerous interviews with various device suppliers, it is apparent that the decision to use a monolithically functioning device versus that of a multiple chip solution is based on many parameters and is made on a case-by-case basis. Cost, performance, packaging and size are critical parameters of the tradeoff. It is interesting to note that Analog Devices has selected a monolithic approach for its accelerometer product line and a multi-chip approach of device and ASIC for its newly launched microphone product. MEMSIC has also taken the monolithic approach for its accelerometer. However, other major suppliers of accelerometers, including Freescale, Kionix and ST Microelectronics, have taken a multi-chip approach.
- Software co-design/system architecture development – various suppliers including Coventor and SoftMEMS provide software-based solutions to optimally integrate the MEMS/MST device with its associated ASIC signal conditioning circuitry.

- Functionality tradeoffs when selecting ASIC/interfacing IC-ASICs have become a major differentiator in creating optimum system solutions. Current ASICs provide a myriad of electronic functions including interfacing with multiple sensors, temperature compensation using E2PROM, analog-to-digital conversion. While some companies have the ability to design and produce the ASIC in-house, e.g. Austria Microsystems, some vendors design both the ASIC and MEMS/MST devices but contract out the production of the ASIC, e.g. Kionix. Companies including Si-Ware Systems and Triad Semiconductor design and develop ASICs specifically suited for MEMS/MST applications. The role of embedded software in optimizing system performance over temperature and through manufacturing variances is critical and can play a key role in product differentiation.
- Energy harvesting and energy storage devices
- Network ICs either wireless or non-wireless
- Packaging and interconnects – truly this area is receiving a great deal of interest by many suppliers because it is a major part of the total cost of the solution. Our research has shown that between 50% and 70% of the total solution cost is attributed to packaging and interconnects. Here especially the packaging team needs to be involved from the onset of the design to achieve a truly robust, reproducible and low cost approach. With the adoption of wafer-level packaging, chip stacking (Fig. 1) and through-silicon via approaches many MEMS/MST-based system solutions are finding their way into high volume and low cost applications. Additionally, the use of “mechanical” packages, i.e. packages that have been specifically designed to shield the sensor and its signal conditioning electronics from harsh environments are specific to the application. Unlike the packages for typical ICs, e.g. DRAMs, these packages must survive extreme shock, moisture, and especially harsh media that they must measure (Figure 2).
- System integration design for

manufacturing and test

It is critical in the development of the MEMS/MST-based system solution that all of the members of the design, manufacturing and test team all work together from day one of the development project to create a solution that optimizes a high regard for high volume manufacturing, assembly and test. Software co-design activities need to be firmly in place to optimize the interface between the device and its signal conditioning circuitry.

**Application examples**

In my recent conducting of market research, it is becoming apparent that the MEMS/MST based systems solutions approach is gaining favor and momentum in the industry. Numerous companies, including Acuity, asept, Crossbow, LV Sensors, and Tronics Microsystems, are pursuing this direction. A “poster child” of successful application of this approach is the tire pressure monitoring systems (TPMS) that are currently invading the automotive market. Our market research has established this market to exceed 50 million units in 2009 despite the significant downturn of the automotive sector. A typical TPMS system similar to the one produced by TRW has multiple sensors, i.e. pressure sensor, motion sensor to control when the device is turned on to save battery life, and temperature sensor to be used in temperature compensation: a full functioning ASIC including power management, stored calibration coefficients; a Tx/Rx chip to communicate the data to the passenger cabin display, battery and antenna. This is all housed in a robust plastic package that serves as the tire valve stem. Cost = \$5.00 US. It took a great deal of “thinking outside the chip” and the collaboration of many engineering teams early on embracing a co-

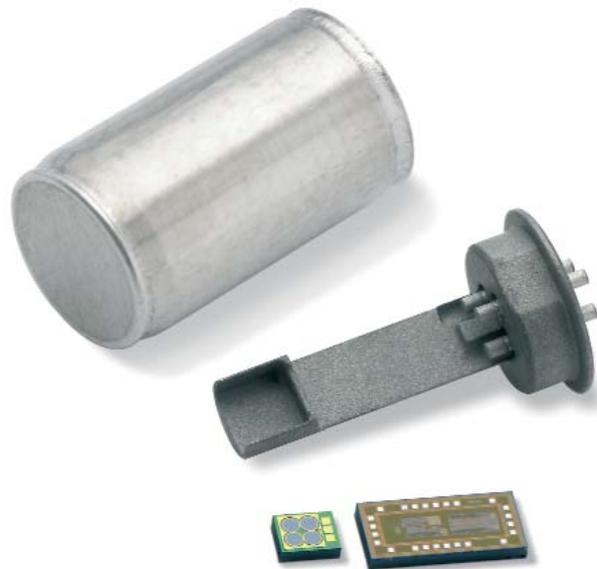


Figure2: Ultra miniature medical implantable MEMS pressure sensor is housed in a 3.5 x 6.5 mm hermetic Titanium package. The MEMS sensor (right ) and the ASIC (left) are mounted on a ceramic substrate. Courtesy: Tronics Microsystems

design process to come up with this winning approach.

**Conclusions**

I believe that MEMS/MST-based systems solutions’ “time has come” especially with the current economically trying market conditions. Also MEMS/MST developers have received higher grades in the 2008 MEMS/MST Commercialization Report Card in the area of “Design for Manufacturing/Assembly and Test” (Ref. 1) over the past few years. I expect that the adoption of these approaches by suppliers will help them differentiate their products from the current commoditization of MEMS/MST devices. It should also provide the user of the product with a “plug and play” solution in their application that should help reduce the level of in-house system integration efforts. The expected outcome results in a “win-win” approach between customer and supplier to doing business.

Ref. 1 R. Grace, 2008 MEMS/MST Industry Commercialization Report Card, Sensors Expo 2008, www.rgrace.com

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