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MEMS TECHNOLOGY SYMPOSIUM

Advancing MEMS and Sensors for Today's Exploding Demands

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MORNING AGENDA

7:45 am	**Registration Opens**
8:45 am – 9:00 am	**Welcome and Introduction**
9:00 am – 9:30 am	**OPENING KEYNOTE** **You Say Tomatoes, I Say Sensors** *Rob O'Reilly, Senior Technologist, Automation, Energy and Sensors Group, Analog Devices, Inc.*
9:30 am – 10:00 am	**Sensing System Symbiosis** *Peter G. Hartwell, Ph.D., Senior Director of Advanced Technology, InvenSense, Inc.*
10:00 am – 10:30 am	**Optimizing Device, Packaging, Test: The Art of Fast Tracking a Design to Production** *Matt Apanius, Managing Director, SMART Microsystems Ltd.*
10:30 am – 11:00 am	**Morning Break and Exhibits**
11:00 am - 11:30 am	**Applications Specific Electronic Packaging (ASEP):** **Electronics Packaging Leveraging High Speed Continuous Manufacturing** *Amrit Panda, Principal Engineer, Molex LLC*
11:30 am – 12:00 pm	**Fan-Out Wafer Level Packaging Enables MEMS and Sensors to Meet Future IoT Requirements** *Babak Jamshidi, Ph.D., Deputy Director, STATS ChipPAC*
12:00 pm – 12:30 pm	**Advanced WLP Platform for High Performance MEMS** *Dean Spicer, Director of Engineering, Micralyne, Inc.*
12:30 pm – 1:30 pm	**Lunch and Exhibits**

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AFTERNOON AGENDA

1:30 pm – 2:00 pm	**AFTERNOON KEYNOTE** **End-point Security in IoT from the Perspective of End-to-End Security** *Flavio Bonomi, Ph.D., Founder and CEO, Nebbiolo Technologies*
2:00 pm – 2:30 pm	**High Volume MEMS Testing: Evolution, Challenges and the Future** *Mårten Vrånes, Director, Consulting Services, MEMS Journal, Inc.*
2:30 pm – 3:00 pm	**Testing Approaches for Characterization and Selection of MEMS Inertial Sensors** *Dino Smajlovic, Business Development Manager, Acutronic USA Inc.*
3:00 pm – 3:30 pm	**Afternoon Break and Exhibits**
3:30 pm – 4:00 pm	**From Standard Processes (MUMPs® - Multi-User MEMS Processes) to Commercial Success** *Allen Cowen, MUMPs Program Lead, Test Department Manager, MEMSCAP Corporation*
4:00 pm – 4:30 pm	**Standardization of Packaging for the Internet of Things** *Adrian Arcedera, VP MEMS/Sensors, Amkor Technology*
4:30 pm – 5:00 pm	**CLOSING KEYNOTE** **Building the Future: NextFlex's Collaborative Environment to Advance the Flexible Hybrid Electronics Ecosystem** *Malcolm J. Thompson, Ph.D., Chief Technology Advisor, FlexTech Alliance and CEO, Nano-Bio Manufacturing Consortium (NBMC), Director of Commercialization, NextFlex*
5:00 pm – 6:30 pm	**Reception**

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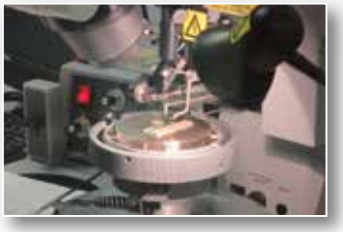

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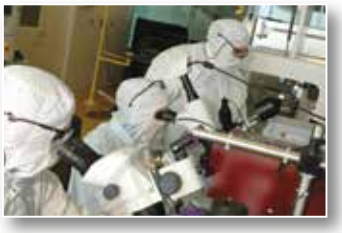

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BIOGRAPHIES

SYMPOSIUM CO-CHAIRS

Matthew Apanius is the President and Managing Director of SMART Microsystems. He has commercial MEMS product development experience working with applications that include telecommunications, aerospace, automotive, industrial controls, hand-held displays, biomedical devices, and life science. His work with academic and government research projects include state-change physics in microgravity, anisotropic thermal behavior of nanomaterials, and nanomechanical structures for switches and acoustic wave devices. Prior to launching SMART Microsystems, Matthew was the President of Microfabrication Solutions, Inc., a successful MEMS prototyping company located in Cleveland, Ohio since 2002. Matthew was also a co-founder of a medical device start-up company that utilized microsystem technology for the creation of home-care medical products. He enjoys guest teaching at Case Western Reserve University on topics of entrepreneurship, engineering management, and intellectual property.

Sean Cahill is currently Director of MEMS Product Engineering at Maxim Integrated Products. Prior to that Sean was VP of R&D at BridgeWave Communications working on next generation millimeter-wave systems. Sean graduated with dual BS degrees in ECE/Signals and Systems and Biochemistry/Biophysics from UC Davis, and MSEE/Solid State Physics from UC Santa Barbara where he fabricated some of the first surface micromachined MOEMS. Over his many years in industry, Sean has worked for Exxon Research (flat panel displays), NovaSensor, Teknekron Sensor Development, and was a founder at three MEMS-based start-ups.

Mary Ann Maher, Ph.D. is the CEO of SoftMEMS LLC. She received her Ph.D. degree in 1989 from Caltech in the area of semiconductor device modeling. She then moved to the Swiss Center for Electronics and Microtechnology (CSEM) in Neuchatel, Switzerland. She joined Tanner Research in 1992 becoming the software architect for their IC design tools. She moved to MEMSCAP in 1999 as an Executive Vice President and became the company's CTO in 2001. She founded SoftMEMS LLC in 2004 to address the need for co-design tools for systems incorporating MEMS sensors, electronics and packaging.

Bettina Weiss is Vice President Product Management and Business Development at SEMI Global Headquarters, and is responsible for SEMI's global product management, as well as the association's engagement in new and emerging technology segments and geographies, to support the diverse needs of SEMI members and to assess opportunities for member company engagement in emerging markets. Weiss joined SEMI in 1996 and worked in several Standards positions in SEMI Europe in Brussels, Belgium and at SEMI's global headquarters in San Jose, CA. From 2005 to 2008, she was Director, International Standards, overseeing SEMI's International Standards Program operations. From 2008 to 2012, Weiss oversaw SEMI's global PV activities in PV Group, which later expanded into broader business development in new/emerging markets and technologies including strategic alliances and partnerships with other organizations. Prior to joining SEMI, Weiss worked in sales and marketing positions at Metron Semiconductor and Varian Semiconductors in Munich, Germany. She holds a B.A. in English from the International School for Applied Languages in Munich, Germany and is a certified translator for Anglo-American Law and Economics.

Steve Whalley is the Chief Strategy Officer, MEMS & Sensors Industry Group (MSIG), where he is leading efforts to scale the MEMS and Sensors ecosystem for the next decade of explosive growth. He is a former MSIG board member and 26 year veteran of Intel Corporation with over 30 years in the semiconductor and MEMS/Sensors industries. While at Intel, he directed strategy for cross platform efforts on sensors, multiple wired and wireless I/O technologies, power management and other initiatives. Moving to Chandler, Arizona in 1990 from the United Kingdom, Whalley has managed multiple product and technology development programs in various areas of Intel. He joined Intel in February 1988, working as a European

(continued)

Marketing Manager in Swindon, England. Whalley earned a Bachelors of Science Degree in Electrical Engineering, graduating with Honors from the University of Salford, England. He also received a Masters Degree in International Management from the American Graduate School of International Management ('Thunderbird'), Arizona.

KEYNOTE SPEAKERS

Flavio Bonomi, Ph.D. is a serial entrepreneur, technologist and industry visionary, who helped define a new computing paradigm – "Fog computing". Before founding Nebbiolo Technologies, Flavio Bonomi was the founder and the Chief Technology Officer at IoXWorks, Inc., involved in consulting and advisory roles with a number of large corporations and startups in the field of IoT. Prior to IoXWorks, Flavio was a Cisco Fellow, Vice President, and the Head of the Advanced Architecture and Research Organization at Cisco Systems, in San Jose, California. He was co-leading the vision and technology direction for Cisco's Internet of Things initiative. Before joining Cisco in 1999, Flavio Bonomi was at AT&T Bell Labs, with architecture and research responsibilities, mostly relating to the evolution of the ATM technology, and then was Principal Architect at two Silicon Valley startups, ZeitNet and StratumOne. He received an Electrical Engineering degree from Pavia University in Italy, and a Master's and Ph.D. in Electrical Engineering degrees in 1981 and 1985, respectively, from Cornell University in Ithaca, New York.

Rob O'Reilly, a former Flight Engineer in the US Navy, joined Raytheon Company in 1982 and managed one of the largest Environmental test labs in the country specializing in shock and vibration input and analysis. Rob began his MEMS career with Analog Devices in 1991, first as a consultant, followed by joining the company in a full time capacity in 1995. Developing the first production Shake test systems enabled ADI to take on sensing challenges initially in automotive, but ultimately spanned to the full sensing ecosystem. Currently Rob is exploring Smart Ag as a sensor to cloud strategy which has led to the IoTomato project. While at ADI he has led many groups within the MEMS division including MEMS Applications, Advanced Test, Production Test, Trim and Probe, and Characterization groups. He holds several patents in MEMS test technologies for accelerometer and gyro and combo test platforms. In 2012, Rob was inducted into the MEMS Industry Group's Hall of Fame and continues to serve on their Technical Advisory, Test Standards and the Accelerated Innovations Subcommittees.

Malcolm J. Thompson, Ph.D., is the Chief Technology Advisor for FlexTech Alliance, where he has shared responsibility for FlexTech's technical program, and serves as the CEO of the Nano-Bio Manufacturing Consortium (NBMC), a FlexTech managed organization. Dr. Thompson has over 40 years of experience in the semiconductor, telecom and display industries and was a founder of FlexTech (then called USDC) in 1993. Dr. Thompson has served as CEO of several electronics companies, including, dPix, RPO, Vitex Systems and Novalux. He has received multiple recognitions over his illustrious career, including that of Tech Pioneer for the World Economic Forum, and has held numerous advisory roles for both industry and government. He is and has served as a director on several corporate boards, including CDT, LBO, UniPixel and Photon Dynamics, Inc. Dr. Thompson received his Ph.D. degree at the University of Brighton, Sussex, where he studied semiconductors.

PRESENTERS

Matthew Apanius is the President and Managing Director of SMART Microsystems. He has commercial MEMS product development experience working with applications that include telecommunications, aerospace, automotive, industrial controls, hand-held displays, biomedical devices, and life science. His work with academic and government research projects include state-change physics in microgravity, anisotropic thermal behavior of nanomaterials, and nanomechanical structures for switches and acoustic wave devices. Prior to launching SMART Microsystems, Matthew was the President of Microfabrication Solutions, Inc., a successful MEMS prototyping company located in Cleveland, Ohio since 2002. Matthew was also a co-founder of a medical device start-up company that utilized microsystem technology for the creation of home-care medical products. He enjoys guest teaching at Case Western Reserve University on topics of entrepreneurship, engineering management, and intellectual property.

Adrian Arcedera joined Amkor in 1997, and has served in various positions in engineering, package platform development, supplier and material development, business development and product management of Amkor's Chip Scale Products -- Chip Array® BGA, Tape Array BGA and Stacked CSP. He has worked on various interconnect and packaging technologies to reduce package sizes, reduce package thickness, improve package cost, and improve thermal performance of chip scale products. Adrian has been granted 2 U.S. patents. Currently, Adrian is responsible for the business and platform development of MEMS, sensors, and PBGA products that service automotive, industrial and consumer markets/applications. Prior to joining Amkor, Adrian worked as Materials Engineer for Motorola Philippines, and earned his degree in Chemical Engineering from the University of the Philippines.

Allen Cowen received the BSCEE degree in electrical and computer engineering from Purdue University and the MSEE degree from Carnegie Mellon University in 1986 and 1989, respectively. After school he began working with MCNC on a process simulator. In 1991, he switched to the field of MEMS and began working on the MUMPs Processes circa 1993. He was a member of the successful startup MEMS company, Cronos, followed by JDS Uniphase and finally MEMSCAP, INC. He currently leads the MUMPs programs at MEMSCAP and manages the test department.

Peter G. Hartwell, Ph.D. is Senior Director of Advanced Technology at InvenSense. Peter has extensive experience in commercializing silicon MEMS products, working on advanced sensors and actuators, and specializes in MEMS testing techniques. Prior to joining InvenSense, Peter spent four years as Architect of Motion Sensing Hardware at Apple. Peter also worked as a Distinguished Technologist at Hewlett-Packard Laboratories. At HP, he was the MEMS lead on HP's 10 nano-g/rt Hz MEMS accelerometer forming the basis of HP's Central Nervous System for the Earth (CeNSE), an early vision of what has become the Internet of Things. Peter has over 40 worldwide patents on MEMS and sensor applications. He has a B.S. in Materials Science from the University of Michigan and a Ph.D. in Electrical Engineering from Cornell University.

Babak Jamshidi, Ph.D. is currently Associate Director of Product Technology Marketing at STATS ChipPAC, leading the MEMS and Sensor Product business development for the Company. Before joining STATS ChipPAC, he was a Senior Principal at FormFactor Inc., managing the development of advanced MEMS based wafer probe card solutions. He has over 10 years of experience in semiconductor design and manufacturing, including extensive experience in the field of microfabrication and wafer processing. Dr. Jamshidi received his Ph.D. in Mechanical Engineering from University of California, Berkeley and has several journal and conference publications as well as patented inventions in the field of MEMS.

Amrit Panda is Principal Materials Engineer at Molex LLC. Molex is a provider of total electronic solutions, headquartered in Lisle, IL. At Molex, he helps define the materials roadmap, and is actively engaged in exploring and implementing technologies that help enable new applications. In addition he helps in improving the efficiency of existing high volume manufacturing processes. Prior to Molex, Amrit was part of Altera's Power Business Unit (now part of Intel Corp.). While at Altera he helped introduce the first commercial integrated planar magnetic MEMS inductor for power management applications. In his various positions he has worked closely with device and system designers, to fully leverage process advantages while developing and defining product specifications. He holds a Ph.D. in Chemical Engineering, is co-author of a book chapter on electroplated materials in the CRC handbook of nanomaterials and several technical papers. He is actively involved in the intellectual property community as an agent registered to practice before the USPTO.

Dino Smajlovic is the Business Development Manager for ACUTRONIC USA Inc. He is the company expert for inertial sensors testing, including MEMS sensors, and is responsible for developing new and maintaining key existing business opportunities, pricing and sales budgets, specifically in MEMS, commercial and industrial markets. Dino has been with ACUTRONIC USA Inc since 2013. Prior to joining ACUTRONIC, Dino was an Engineering Test Manager for Systron Donner Inertial, a California based manufacturer of quartz MEMS inertial sensors and systems. His duties included engineering team development, NPI, high performance inertial sensors, hardware/software testing, and overseeing verification and validation test-

(continued)

ing approaches and execution. Dino holds a B.A. in Mathematics from Bethel College, Indiana, Master's in Physics from Bowling Green State University, Ohio, and Master's in Aeronautical and Astronautical Engineering from Purdue University.

Dean Spicer joined Micralyne in 2006 as a Research and Development Engineer, specializing in Advanced Wafer Bonding processes (eutectic, fusion and anodic). Following a series of leadership roles and responsibilities, Dean currently serves as Director of Engineering. The emphasis of Dean's current role is enabling the development engineers to bring new customer projects efficiently through to manufacturing. He is also the internal champion of developing process platforms that enable multiple projects to be fabricated from the same processes, saving customers' time and money. Dean earned a Bachelor of Science in Engineering Physics and a Masters of Science in Electrical and Computer Engineering from the University of Alberta.

Mårten Vrånes is the Director, Consulting Services at MEMS Journal, Inc. where he leads activities for strategic planning, market intelligence, marketing and business development. Mårten has spent over 13 years in the MEMS industry and has a significant track record as an engineer, manager and founder of a VC-backed startup. His career began in Norway, at SensoNor ASA, where he focused on production ramp-up for automotive sensors. At the Bay Area start-up, LV sensors, Inc., Mårten was responsible for sourcing the entire multi-million dollar custom final test production line for TPMS sensors. In 2009, he founded Consensic, Inc. and personally developed several test platforms for MEMS die and final packaged parts. Mårten holds a Bachelor's Degree in Electrical Engineering (EE) from Agder University, Norway, a Master's Degree in Computer Integrated Manufacture (CIM) from Swinburne University of Technology, Australia and an MBA from the University of Queensland, Australia.

MORNING KEYNOTE

You Say Tomatoes, I Say Sensors

Rob O'Reilly
Senior Technologist, Automation, Energy and Sensors Group
Analog Devices, Inc.

This presentation will provide a description of the "IoTomatoes" effort conceived by Experience Co-Creation Partnership (ECCP), Analog Devices, Inc. and the MEMS and Sensors Industry Group (MSIG). In addressing the four pillars of earth (Air, Water, Health and Energy), MSIG hosted an event where the keynote speaker (Francis Gouillart of ECCP) "challenged" the MEMS component suppliers, "Why isn't the sensor industry more focused on providing global solutions to help with clean energy, hunger, health, or clean water?". The project entails working with local farmers, chefs and supermarkets to better define the problem and identify areas where MEMS and technology could benefit the growing process. ADI created a reference design that utilizes an ultra-low power approach for a battery operated edge mote connected to the cloud. The focus isn't just on productivity, yield or margin optimization, but equally on taste. Data, analytics, predictive algorithms, work flows and harvest schedules all benefit from a small amount of environmental and physical data. Saving tomatoes from a certain ketchup or pasta sauce death requires farmers to understand the quality/chemistry of the tomato and in turn convince the distributors that the tomato meets a certain quality standard. An overview/update of the IoTomato project reference platform, gateway approaches and cloud service including the path towards reconciling productivity and taste will be presented.

Sensing System Symbiosis

Peter G. Hartwell, Ph.D.
Senior Director of Advanced Technology
InvenSense, Inc.

The MEMS industry has experienced tremendous growth in the past 5 years, driven primarily by the inclusion of motion tracking devices, among a variety of MEMS-based sensors, in smart phones and other consumer electronic devices. Growth is expected to accelerate as Internet of Things (IoT) devices proliferate enabling the cloud to connect with, and sense, the ambient world in order to make intelligent real time decisions. The IoT promises a new economy built on services created by analyzing the data collected from up to 1 trillion smart, sensing "things". An inherent assumption is that because silicon integrated circuits are small, low cost, power efficient, and reliable, MEMS sensors can be the same – after all MEMS are built from the same materials and processes in the same factories. But a mechanical transducer must interact with the physical world it is sensing and it is this simple principle that forces a significantly different approach to creating reliable systems. The system developer must deliver "things" with compelling features as payment to the owner for taking it to interesting locations to be sensed, keeping it powered, and ensuring its connectivity to the cloud. And those who intend to profit from the new economy must realize that unless those rewards are returned to the roots of the data, to the system and component creators, innovation will stop and technology will plateau preventing the true potential of the IoT from being realized. The internet of things, poised to be the next layer on the internet, must be a symbiotic system created to benefit all whom it touches, from the supply chain, to the users, to the financiers, to the very planet that it covers.

Optimizing Device, Packaging, Test: The Art of Fast Tracking a Design to Production

Matt Apanius
Managing Director
SMART Microsystems Ltd.

The exploding new demands for MEMS sensors are resulting in new applications that are emerging every day. Organizations that intend to exploit this market potential will need to mobilize their program quickly and execute it without making mistakes. This presentation will discuss how companies who do not necessarily have internal know-how can gain the knowledge to get the job done properly. Process technologies and solutions, when addressed early on, can ensure successful integration of design, packaging and testing of MEMS sensors.

MEMS sensors require microelectronics packaging. This is a critical part of the manufacturing process that has to be developed and, without careful consideration, can create cost over-runs that can kill a program before it gets completed. Additionally there tends to be at least one element of the design that requires a custom manufacturing process. Therefore any and all of the custom design elements need to be quickly evaluated and understood.

Innovative product development strategies can be used to avoid the pitfalls of traditional methods. 1) A "test early, test often" approach to product development creates quicker learning so that more design iterations can be done in less time. This shortens the overall design cycle. 2) Concurrent engineering, where design efforts are coupled with process expertise, reduces the cost of product development. This can be leveraged during scale-up in order to optimize tooling and equipment utilization without excessive cost.

Launching a new MEMS sensor product is expensive and risky. Process expertise in microelectronic packaging is a "must have" requirement for success. This presentation will highlight some examples of this new approach in a case study where the first prototypes were built in 90 days and put on test with zero failures. These examples will feature key learning, best known methods, and a call to action. The lowest overall development time and cost is a necessity for any organization.

Applications Specific Electronic Packaging (ASEP): Electronics Packaging Leveraging High Speed Continuous Manufacturing

Amrit Panda
Principal Engineer
Molex LLC

The need to integrate higher functionality and integration into smaller packages continues to be driven by the addition of electronic components to every facet of our daily lives. This presentation introduces ASEP – Application Specific Electronics Packaging. ASEP is a continuous and flexible processing platform capable of integrating different substrates, functional devices, and features into an interconnected multi-layered, three dimensional packaged solution as defined by the final application.

This presentation will demonstrate a programmable LED module for automotive lighting with the drive electronics integrated into a connector. This light module uses 20 fewer process steps, and has the associated benefits of better component integration, ease of design and lower costs. Continuous manufacturing methods provide cost, and high volume manufacturing advantages from the outset. Key process technology nodes and custom design elements can be introduced into existing high reliability manufacturing flows. This mitigates risk by being able to focus on a few key challenges instead of an all new process flow and minimizes capital outlay constraints.

ASEP aims to address issues such as thermal management, current requirements, shielding, for wireless power, sensors, MEMS, LEDs and other active/passive devices in a single unified solution. Process expertise is not just a desirable attribute at the design stage – it is a requirement for successful product introduction. Designing and developing electronic solutions requires vision, and an innovative product development strategy. Our strategy is to concurrently design both product and process to best leverage existing manufacturing methods to shorten the time to market.

Fan-Out Wafer Level Packaging Enables MEMS and Sensors to Meet Future IoT Requirements

Babak Jamshidi, Ph.D.
Deputy Director
STATS ChipPAC

The semiconductor industry has an essential role in realizing the promise of a global network of people and devices connected through Internet of Things (IoT). Micro-Electro-Mechanical Systems (MEMS) and sensors devices, which enable the "Thing" sub-segment of IoT, are expected to exceed in performance while remain cost competitive in the face of exponential volume growth. Packaging and silicon fabrication account for more than half of device cost and have a significant impact on footprint and performance.

In recent years, the scale and performance demanded by the mobile and handheld market have driven advanced packaging technologies to re-invent themselves to meet aggressive specifications while enabling cost reduction roadmaps. As a result, new trends in advanced packaging technologies are emerging to meet MEMS and sensors requirements for IoT, where incumbent technologies have been stretched thin.

Although a majority of MEMS and sensor devices will continue to be in mainstream leaded or laminate types of packages, the disruptive cost and footprint reduction offered by advanced technologies will be quite attractive. In this presentation, we will review fan-out wafer level packaging (FOWLP) and how it can enable additional values for IoT devices in the areas of cost reduction and signal integrity that are quite suitable for RF sensors. In addition, we will review how FOWLP can take miniaturization to the next level and offer footprint reduction for a two-chip sensor solution in IoT consumer applications.

Advanced WLP Platform for High Performance MEMS

Dean Spicer
Director of Engineering
Micralyne, Inc.

High performance inertial sensors often require expensive packaging materials to achieve a resonator with high quality factor. To reduce environmental damping, the MEMS die must be hermetically sealed under vacuum using a ceramic package. A discrete getter is often added to ensure the reliability of the device over its lifetime. Presented here is an advanced wafer level packaging platform that utilizes an integrated thin film getter and hermetic wafer bond to eliminate the need for costly packaging materials and die level processing, while significantly reducing the size of the final component. The process platform also includes through silicon vias, enabling electrical connections to the hermetically sealed device and wafer level placement of a lead-free solder BGA (ball grid array). The end result is a high performance MEMS die that is ready for direct bonding once singulated.

AFTERNOON KEYNOTE

End-point Security in IoT from the Perspective of End-to-End Security

Flavio Bonomi, Ph.D.
Founder and CEO
Nebbiolo Technologies

The success of the Internet of Things will be predicated, to a large extent, on the evolution and deployment of a horizontal networking, computing, storage and services platform, supporting and enabling multiple vertical applications and use cases. Key elements of this platform will be a widely distributed and networked set of computing and storage resources, manifesting as Cloud, Fog, and Endpoint resources.

Fog Computing extends the Cloud Computing paradigm to the edge of the network, thus enabling a new breed of applications and services. It will also provide rich resources complementing both the Cloud and the embedded Endpoints in functionality dimensions such as authentication, security and privacy, storage, data management and analytics, and application support.

The ultimate applications, solving useful use cases for various verticals, will be distributed, and use resources across the path between Endpoints and Clouds, and will often share the common underlying infrastructure. This distribution of resources will enable the optimization of where certain functions will be performed, and this task distribution will depend on the physical, cost, energy, latency, reliability constraints characterizing each end to end application.

Within this architectural perspective, the hardware design of Endpoints, and the software functionality associated to Endpoints, should be defined with close consideration of the overall end to end architecture, and of the end to end applications the end point will support. In particular, security is a fundamental end to end attribute of the future IoT platform. The support of Security has to be defined and implemented as an end to end function.

In this keynote we will discuss IoT security in this broader, distributed perspective, and focus on the role of the Endpoints in the support of this critical end to end attribute, presenting a number of innovative technologies which may contribute to the overall security of IoT solutions.

High Volume MEMS Testing: Evolution, Challenges and the Future

Mårten Vrånes
Director, Consulting Services
MEMS Journal, Inc.

High volume MEMS testing, including calibration and verification of sensor functions, has long been considered costly, complex and a major barrier to scale. A paradigm shift was needed to cost efficiently test increasing volumes of lower-cost MEMS devices. The rapid adoption and commoditization of sensors in consumer electronics, and in particular smartphones, has driven major innovations in MEMS production test equipment and technology. Some are subtle, like finding the appropriate clamping force for motion sensors to avoid biasing the calibration as a function of exerted mechanical stress. Others have been more obvious, like increasing parallelism in the form of additional test sites. Many of these advancements were developed by leading MEMS component providers in close collaboration with test automation companies. After a period of exclusivity for leading customers, new test solutions are being released to the general market. There are now readily available systems for high-volume testing of inertial sensors (accelerometer, gyroscope and magnetometer), environmental sensors (pressure, humidity and ambient light), audio sensors (microphones) and combo-solutions. Multiple vendors are providing competitive turnkey systems, either as a one-stop-shop or through partnerships. This presentation will discuss some of the key lessons learned during the evolution of MEMS testing, what the current challenges are and the implications of a futuristic trillion sensor market.

Testing Approaches for Characterization and Selection of MEMS Inertial Sensors

Dino Smajlovic
Business Development Manager
Acutronic USA Inc.

Since 2007, the year first iPhone was released, we have seen an ever increasing utilization of the MEMS sensors in all kinds of smart devices. Over time, the MEMS technology advancement allowed for utilization of the MEMS sensors for several different roles, including inertial, pressure, humidity, and temperature sensing, as well as audio and video applications. At the same time, the complexity of the sensors has gone up as well, in particular with the inertial MEMS sensors. From the single axis accelerometers and gyroscopes through sensor triads in a single chip, to "combo" sensors with 6 or 9 degrees of freedom (including 3-axis accelerometers, gyroscopes and magnetometers), today's integrator is faced with many choices, in price, size, performance, energy utilization and packaging. Adding to that a large number of manufacturers of the inertial MEMS sensors it becomes obvious selection process is more complicated than ever before.

While some of the characteristics of the sensors are easily compared (price, size, number of axes, etc.), performance parameters are typically only partially defined by the manufacturers, and can vary greatly from one to another and over different environments.

Because the expected use of the products with the embedded inertial sensors (smartphones, wearables, smart helmets, VR sets, etc.) can vary greatly the best approach to select MEMS inertial sensors is by conducting characterization tests for a defined set of parameters.

In this presentation we are describing the process of testing inertial MEMS sensors (accelerometers and gyroscopes), selection of the parameters and choosing test procedures to collect relevant data. Once the data is collected and the product application is considered selection of the appropriate sensors can be made.

To illustrate these steps we will present a comparison of the 3-axis gyroscopes ACUTRONIC has conducted in our iTS Lab located in Pittsburgh, PA. The tests were performed over the temperature, to fully characterize performance of the sensors, and parameter definitions were based on the IEEE 2700 Standard for Sensor Performance Parameter Definitions by the IEEE Standards Association.

From Standard Processes (MUMPs® - Multi-User MEMS Processes) to Commercial Success

Allen Cowen
MUMPs Program Lead, Test Department Manager
MEMSCAP Corporation

Since 2003, MEMSCAP has offered four unique integrated MEMS standard processes in PolyMUMPs, SOIMUMPs, PiezoMUMPs and MetalMUMPs, the only MEMS company in the world who can boast such a variety of low-cost MPW services and easy, fast, and an inexpensive pathway to volume production. MUMPs has delivered over hundreds of thousands of devices to different user groups from the academic, commercial and government sectors worldwide. Results from these devices have provided detailed proof-of-concept data for use in graduate theses, published conference papers and, most importantly, advanced commercial product development. Results from these devices have provided detailed proof-of-concept data for use in graduate theses, published conference papers and, most importantly, advanced commercial product development.

Standardization of Packaging for the Internet of Things

Adrian Arcedera
VP MEMS/Sensors
Amkor Technology, Inc.

The basic building blocks for the Internet of Things have been around for more than two decades. Connectivity, memory, microprocessors and microcontrollers have all benefited from using standard IC packaging platforms, except for MEMS Sensor/Devices. MEMS devices are not standard integrated circuits. The creative wafer fabrication techniques gave birth to Si-based transducers and actuators that respond to or interact with external or environmental stimulus. At the onset of MEMS packaging, cost and package form were not primary considerations in solving end market applications. This created a broad variety of package form factors for almost every application and end market.

As the IoT market grows and transitions into high volume production, the drive towards sensor fusion, integration and IoT module assembly will become more critical. Assembly packaging and test standardization will be needed to offer cost competitive solutions without sacrificing performance. Among all of the devices necessary for the IoT to be successful, none is more "sensitive" than the MEMS/Sensor device. The requirement of "controlling stress to the MEMS structure, while allowing stimulus to pass through" remains the same whether the packaging solution is a discrete package like MicroLeadFrame® (MLF®), a Land Grid Array (LGA) or an IoT module.

A standard platform will open opportunities to combine MEMS/Sensor devices with microcontrollers, memory and connectivity at the package level instead of at the silicon level. The resulting IoT/Sensor module can be delivered with a shorter design to manufacturing cycle time, smaller footprint and lower packaging cost than the current discrete packaging solutions. Additionally, the standard platform provides the necessary flexibility and customization to support multi-MEMS/Sensors on the inside, while keeping a standard footprint outside to maintain maximum compatibility during assembly, final test and surface board mount.

The discrete MEMS/Sensor devices are aligning to standard packaging platforms, and the same action needs to happen in the IoT/Sensor module in order to achieved successful commercialization. What will you integrate in your IoT module? Will you need a shield or an antenna or both? These questions and more will be addressed during this presentation.

CLOSING KEYNOTE

Building the Future: NextFlex's Collaborative Environment to Advance the Flexible Hybrid Electronics Ecosystem

Malcolm J. Thompson, Ph.D.
Chief Technology Advisor, FlexTech Alliance
and
CEO, Nano-Bio Manufacturing Consortium (NBMC)
Director of Commercialization, NextFlex

Flexible Hybrid Electronics (FHE) products are growing dramatically over an incredibly diverse range of applications, such as medical patches continuously monitoring chronically ill patients, soldiers in combat, firefighters, pilots, and premature babies, as well as structural health monitors, soft robotics, prosthetics, and more. The technology and processes are reaching advanced levels of maturity. The biggest challenge going forward is advancing the manufacturing readiness of these materials and processes. This presentation describes the status of NextFlex and how it is developing the FHE manufacturing ecosystem through collaboration among companies, academic institutions, nonprofits, and state and local governments.

About MEPTEC

MEPTEC is a trade association of semiconductor companies and professionals involved in the manufacturing, packaging, assembling and testing of integrated circuits. Since its inception over 30 years ago, MEPTEC has provided a forum for the semiconductor industry to learn and exchange ideas through our monthly luncheons, conferences, and our quarterly publication, the MEPTEC Report. With the support of an Advisory Board consisting of individuals from all segments of the industry, MEPTEC has, over the years, kept current not just with semiconductor industry developments, but has expanded its scope to cover relevant industry segments such as MEMS and medical electronics. For more information about MEPTEC events and membership please visit www.meptec.org.

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