Energy Harvesting Committee (EHC) Minutes
11st December 2019

Attendees	Apologies/Non attendees	
John Horzepa, PSMA Joe Horzepa, PSMA George Slama, Wurth (GUEST) Mohamed Jatlaoui, Murata Lorandt Foelkel, Wurth Thomas Becker, NTA- ISNY Sebastian Bader, MUIN (GUEST) **Brian Zahnstecher, PowerRox** **Mike Hayes, Tyndall**	Robert Andosca, AEI Francesco Carobolante, IoTissimo Steve Savulak, UTRC Johan Pederson, Sigma Design Mike Wingard, Amphenol Katherine Kim, UNIST Anthony Laviano, NRAIT Henrik Zessin, Fraunhofer IIS Justin Knott, FCI Jae-Do Park, Univ of Colorado Denver Nathan Jackson, Univ of New Mexico Warren Wambsganss, Astronics Jeffrey Jouper, Astronics Seshank Malap, Tektronix Ben LeNail, Alta Devices Denis Pasero, Ilika Marcus Taylor, Fleximatix Roberto la Rosa, ST Maeve Duffy, NUIG Aarohi Vijh, Alta Devices Peter Haigh, Tyndall	*Doug Osterhout, Google* Wensi Wang, BJUT Peter Zou, Huawei Ajinder Singh, TI Aaron Stein, Dartmouth Kevin Parmenter, TSC Guoqing Liu, Huawei (HiSilicon) Jochen Koszescha, Infineon Laili Wang, Xi'an Jiatong University David Newell, NUIG Dan Stieler, PowerFilm Sam Jones, PowerFilm Jamil Khan, Univ of Newcastle (AUS) Liubov Ebralidze, Silent Sensors Raj Budhabhatti, Alta Devices Alex Liu, Alta Devices Dusan Vuckovic, Ikea Gary Johnson, Ilika (for Denis) Baoxing Chen, Analog Devices Michalis Kiziroglou, Imperial College London Scott Thielman, Product Creation Studio

(Co-chairs in bold font)

Next meeting:- Thurs 16th Jan at 10:00 Central, Mike to chair, Brian to type.

Additional info for future reference: APEC face to face (F2F) meetings in March in New Orleans

i. **EH Committee Meeting** (Annual F2F) = Tue, 3/17/20, 12-2pm CST, Room TBD
ii. **EH Industry Session** = Wed, 3/18/20, 8:30-10:10am CST (PLUS DEMOS DURING BREAK IMMEDIATELY TO FOLLOW), Room TBD

Agenda

1. **Welcome any new members/guests.**
2. **EnerHarv 2020 planning.**
3. **APEC 2020.**
4. **White paper.**
5. **AOB, anything from 'treasure chest' at end of the minutes.**

1. Welcome New Members

2. EnerHarv 2020

- ***NCSU – North Carolina State* TUE-THU, JUNE 16-18, 2020**
- **Mehmet compiling hosting agreement (MOU) with PSMA help. ASSIST needs to hire temp. Almost there, need some budget clarifications. Joe & Brian talking offline.**

- **COMMITTEE**
  - Latest tentative table of chairs (most people willing to move around)

(# slots targeted)	**Chair**	**Co-chair**
Keynotes	*Host: Veena Misra* *Guest1: Sally Safwat, Intel* *Guest2: TBD, Analog Devices*	
Energy Transducers (NAME OK?)	Baoxing Chen	Medhi? (ASSIST Rep) flexible
Power Mgmt	Peter Spies (EnABLES Rep)	Maeve Duffy or Roberto La Rosa
Energy Storage	Mohamed Jatlaoui	James Rohan (EnABLES Rep)

System Integration The Italian quarter!	Francesco Carobolante (PELS Rep)	Francesco Cottone or Roberto La Rosa (EnABLES)
Low Power Loads (FINALISE NAME)	Shad and Mike investigating	Yang Yuan
Demos	Lorandt Foelkel	EnABLES Person?
Panels Sessions	1. Compare with the '5G experience' (panel style prep…smoother experience than '18) Prepare & assign carefully FRANCESCO CA. TO DRIVE 2. Bring together cluster leaders!! (ASSIST, EnABLES, EHN, Sheshank Pria, PowerMEMS)	
Posters	Jane Cornett	
Media	Julie Holder (supported by Carolin Lehmann of NCSU)	
Admin	Julie Holder (supported by Carolin Lehmann of NCSU)	
Treasurer	Steve Savulak	
Technical Chair	Mike Hayes	
Technical Chair	Shad Roundy	
General Chair	Mehmet Ozturk	
Co-General Chair	Brian Zahnstecher	
Industry liaison	Adam Curry	

Other committee members to date

- Denis Pasero
- Marcus Taylor
- Michalis Kiziroglou
- EPeas – Geoffroy Gosset
- Dusan considering….answer in Sept
- Johan also considering – Brian will stay in touch
- Brendan O' Flynn, Tyndall – subject to availability
- Julie Holder, ASSIST temp.
- Prof. Hengzhao Yang, New Mexico Institute of Mining and Technology- Brian in contact

Mike & Shad arranging meeting to start filling out the speaker tracker. Note invited speakers only, driven by the session chairs. There will be an open call for posters and demos.

- **Sponsors**
  - **TECH**
    - **EnABLES, PELS, ASSIST, CPSS**
      - Yang Yuan (CPSS) prepared write up on EH (& related) activities, lobbying for EnerHarv talk
  - **FINANCIAL**
    - PSMA
  - **COMMERCIAL** (more open this time, but MUST be related to program, content, etc.)
    - How2Power will circulate flyers – get preliminary one ASAP
      - PowerMEMS opportunity to promote EnerHarv, Mike, Shad, Michalis, Francesco Cottone planning to attend - DONE
      - Write-up prepared for PSMA Quarterly Newsletter, will be highly leveraged into press release for distribution in early-Dec. Brian has contacted Greg and will chase.
    - Adam has circulated targeted sponsorship invites - confirmations from ADI Wurth, now moving to 2nd wave.

KEYNOTES

COMMERCIAL SLOT – Katsu Nakamura, ADI fellow healthcare, low power, consumer projects. Not available, Boaxing or Jane will revert with alternative (probably Boaxing or Jane with some content provided by Katsu?.

ACADEMIC SLOT –

(Sally Safwat, ex UCSD now Intel) confirmed by Shad.

3. APEC 2020

- FOR APEC 2020, WILL BUMP RIGHT UP AGAINST ENERHARV 2020 SO SUGGEST TAKING A SLIGHTLY LESS INVASIVE ROLE IN APEC 2020 (I.E. – 4-SLOT INDUSTRY SESSION)
- **Session accepted, scheduled for Wed, 3/18/19, 8:30-10:15am CST!**
- **Ilika (Denis) has volunteered to step back to make room for new presenters**
- **We believe 10th Jan??? is drop dead date for presentations to be on APEC memory stick**
- Our working schedule is as follows –

- **12/20/19**: 1st Draft PPT Deadline for Comm Review (template circulated)
- **1/8/20**: 2nd Draft PPT Deadline for Comm Review
- **1/10/20**: Final PPT for USB Proceedings
- **3/9/20**: FINAL PPT Deadline for Comm Review
- **3/19/20**: APEC IS Presentation

- **Will be looking for demos**
- **The bio will be a short script to introduce the speaker**

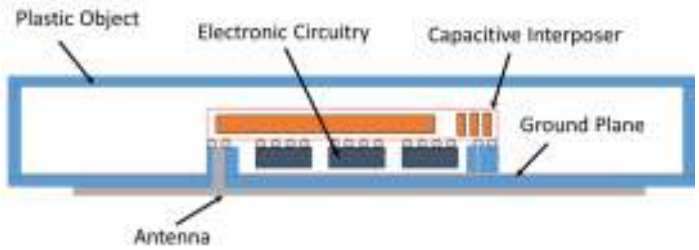
Presenters please **NOTE** draft PPTs are expected by the end of next week if you want to make it onto the APEC proceedings USB stick, which is far and away the best mechanism for getting your materials in front of attendees even if you have until the day of for final changes. If no PPT is provided in time for us to review (also potential iteration time), then we are listing only your abstract with the proceedings.

- **Confirmed presentations with revised abstracts**

1. "**3D Silicon Capacitive Interposer for RF Energy Harvesting device: Higher Efficiency, Higher Integration and Simplified Topology**

   Mohamed Mehdi Jatlaoui[1], Frederic Voiron[1], Bruno Allard[2], Nicolas Jeanniot[2]

   With emerging wireless Iot and IIoT devices during this past decade, many challenges have been raised in relation with functionalities such as sensing, communicating and more particularly harvested and supplied energy management efficiency [1-3]. This work presents the benefits of using a 3D Silicon Capacitive Interposer (3D SCI) for energy harvesting. This 3D SCI is composed of different type of capacitors: embedded 3D trench capacitors and an integrated supercapacitor. As shown in figure 1, the concept is applied to an RF harvesting device and could be extended to any energy harvester.
   Compared to battery based EH, the 3D SCI based EH presents a simplified harvested and supplied energy management building blocks. Indeed, compared to a battery, the supercapacitor can be charged with different voltages so there is no need for battery pre-charger blocks. Moreover, since the nominal voltage of an IoT (V_{IoT}) is lower than the battery nominal voltage (V_{IoT}< 3.6V), an LDO and a step-down DC-DC converter are necessary when using a battery. In the case of 3D SCI, the supercapacitor will be sized to have exactly the right output voltage needed for powering the device and since the supercapacitor can accept a highest peak current, the LDO is optional.
   From integration point view, it is undeniable that the 3D SCI allows an extreme device miniaturization [4]. The embedded 3D capacitors, as well as the supercapacitor, are ideally placed and connected to the rest of the electronic circuitry using thick copper RDL. Consequently, the power density is increased and the EH device exhibits a very interesting low profile.
   Finally, thanks to the miniaturization, the reduced number of building blocks and reduced voltage conversion steps, the EH device presents less energy dissipation and better efficiency. It can be activated more often thanks to the excellent cycling ability (>100 Kcycles) of the supercapacitor with very low input power (~ -20 dBm). Thanks to the silicon properties, 3D SCI solution presents outstanding lifetime (>10 years). All these advantages will be presented and discussed in details.



2. "*Large-Area Manufacturing Techniques for Reducing Energy Harvesting & MEMS Solution Costs*"
   Robert Andosca, AEI–Robert need to work on this and redcue to around 250 words

It has been long envisioned that MicroElectroMechanical (MEMS) devices and sensors could supplant existing non-microscale sensor technology and introduce micro-scale energy harvesting (EH) devices to enable the micro-sensors and wireless radio communication for various 'Internet of things' (IoT) markets. Yet, this has not yet come to pass broadly across the numerous IoT market segments. The question is why?

MEMS devices are ASSUMED to be low in production cost. Yet, many MEMS devices are area dependent, e.g. piezoelectric MEMS vibration energy harvesters power generation scales with its mechanically strained capacitance Cp2 ~ (width W * length L)2. So, it is difficult to scale these devices and sensors down in size to produce 1000's or more chips per 200 mm silicon (Si) substrate as is accomplished with an accelerometer or pressure sensor chip today. For instance, a 1 cm2 MEMS chip fabricated on a single 200 mm diameter silicon (Si) substrates produces approximately 216 unyielded die. In low volume, the chip with wafer-level packaging will cost $75-100 each; in high volume production these chips could be as low as $10-15 each. However, these levels of cost no matter high device performance and reliability is cost-prohibitive for market entry and widescale implementation without deep investment pockets. At the end of the day, the IoT needs an order of magnitude or two lower chip cost points for ubiquitous deployment.

This talk will cover all the commercialization barriers to market entry for MEMS sensors and EH devices to be adopted by price sensitive Connected Vehicle, Industrial IoT (IIoT) and consumer wearable markets. The speaker will suggest using large area fabrication techniques used to fabricate flat panel displays (FPD) to be exploited for MEMS manufacturing to lower production cost to make these devices worthy of market acceptance. Repurposing large area production equipment for large MEMS chips could be done tractably with minimal capital outlay. After converting GEN 2.0 FPD equipment to MEMS production a single 37 x 46 cm2 substrate can produce 6.5X more chips (1,404 total) than a single 200 mm wafer at only a 3X increase in overall fabrication cost. Just imagine manufacturing MEMS on GEN 4.0 (88 x 68 cm2) sized substrates or larger GEN 10.5 (3.1 x 3.1 m2) substrates in the future as adoption of low-cost chips produced in this manner becomes more and more pervasive. This could ultimately initiate a paradigm shift in the way MEMS chips are fabricated in general, even small chips sizes!

3. "*Optimizing Piezoelectric Synchronized-Discharge Harvesters*" Siyu Yang, Georgia Tech
Recommendation (senior PhD sudent) from GABRIEL RINCON-MORA given to Michalis

Piezoelectric energy-harvesting transducers can draw power from motion that can be used to energize a host of wireless microsystems that sense, process, and share vital information across a network. Since these tiny devices draw little power, maximizing the power they transfer is critical. Synchronized-discharge circuits are popular in this space because they can draw up to four times more power than an ideal full bridge can. Pre-charging the transducer can draw even more, but only as much as voltage-breakdown limits allow. Output power is the fraction of drawn power that the system doesn't consume. This talk will discuss how synchronized-discharge circuits can output the most power possible from tiny difficult-to-overdamp piezoelectric transducers. Measurements will show how pre-charge symmetry and energy-transfer schemes alter the power drawn from the transducer and the power lost in the system. When a 10 x 50 x 1-mm^3 15-nF transducer generates up to 10 uA at 100 Hz and the breakdown voltage of the harvester circuit is 3 V, for example, indirect and direct transfers with asymmetric/symmetric pre-charges output 17%/21% and 29%/43% more power with the same inductor than the 4.2 uW that indirect transfers without pre-charge can generate. Generating the highest output power possible is important because, with more power, tiny piezoelectric transducers can power and avail wireless microsensors with greater functionality.

4. Demo Session (as standalone, "speaking" slot), TEAM

4. White paper

Michalis Kiziroglou & Thomas Becker separately expressed interest in participating in a white paper – ref next page for strawman, we shall discuss this on the Jan call.

White Paper Energy Harvesting (Title...)

Authors:
PSMA EHC, template…?

Summary
(Purpose…)
Abstract
(Content…)

State of the Art and Users Perspectives

(What)
Methods and Technologies
(Short! summary {copyrights}, tables, technical limitations, classification against renewable energy)
Acceptance Limits
(Users expectations and typical deployment methods, power management and storage issues [batteries])

Opportunities

(How and why)
Implementation Strategies
(Technical excellence, energy balance harvester vs consumer, lifetime)
Exploitation of Results
(Economic excellence, Cost Benefit Analysis, compared to wires, batteries, best sensor is no sensor…)
Environmental Impacts
(Ecological excellence, Life Cycle Assessment, GWP, CO2eq, SO2eq)

Beyond State of the Art

(Next Steps)
Reconsideration of the Application Scenario
(Know what to know, not to what to measure, Virtual Sensing…)
Future Harvesting Research Needs
(Expectations to funding bodies, EU, US, China…)
Standardisation
(Current situation, suitable organisation)
Everything else why we want to write the White Paper

About

TREASURE CHEST

Approach these items one at a time in future meetings as people raise them.

5. Updated goals

- Open to suggestions.
- Consider a white paper? (Who will co-write and when?) – **REMINDER** can members please give Mike & Brian inputs offline
- Mike & Brian to revert with proposal for doing a white paper if so approved
    - OR other dedicated champion from EH Comm, **will put call out**
- We should try to forge links with other groups/sessions, e.g. capacitor, magnetics, packaging. – addressing this via "Tiger Team" effort within PSMA (multiple focused initiatives with small teams from various committees)
- **BZ INITIATIVE**: working on feasibility for an official, IEEE Future Directions initiative on Energy Harvesting (a 1-6yr process)
    - JOE notes PSMA would be happy to support such an initiative, **BZ to figure out if/how**
    - BZ has obtained process detail (https://cmte.ieee.org/futuredirections/fd-opportunities/), **BZ to pitch initial proposal to PELS TC6 at ECCE on 10/1/19…WILL SHARE FINAL PPT WITH TEAM**

6. Organise webinars for PSMA & PELS (FOCUS STARTING APRIL 2020 MTG ONWARDS, after APEC, discuss also briefly at the face to face at APEC for the March monthly meeting face to face)

- We are ok for PSMA webinars (did 1 in Nov) for now but need to discuss PELS et al.
    - Dan Stieler, PowerFilm was considering one (will be chased by way of Sam)
        - Sample abstract suggested per existing blog (https://www.powerfilmsolar.com/about-us/the-horizon-blog/2018/08/10/outdoor-vs-indoor-solar-the-key-differences), BZ reviewed/supports, **need Committee input. Worth reviewing seeing as Powerfilm's abstract did well in voting but was not in top 2.**
    - Lorandt willing to do 1 – getting back up to speed (in your own time Lorandt) – Q1/2 2019? Also depends on whether Lorandt/delegate does APEC paper. **BZ TO FOLLOW-UP WITH LORANDT**
- Dan & Dusan willing to revert with suggestions – no commitment yet – Dusan thinking about an applications orientated presentation but no commitment yet.
- Brian and Raj (GeorgiaTech) gave IEEE EPS webinar on IoT with Dushan, Marc & Denis – Went very well. Can do a variant for PSMA later in the year.
- Would be good to do 1-2 on 'practical real life performance' of parts and systems – comparison of technologies. Saw some good examples at EnerHarv e.g. Ilika & ARM presentations

7. Sponsorship of a program where students build demonstrators.

- Lorandt has a budget to supply kits
- Help with education links – Qualcomm 'High Tech High'. Francesco will follow up.
- Green story. International dimension. Technology and applications dimensions.
- Wurth running design challenge.
- Keep simple, easy to use
- Competition or roadshow?
- PSMA has money to support.
- Action:- Catherine and Mike met at EnerHarv & discussed, She will write ½ page strawman for student engagement mechanism. Mike will ping again. **NEED A CHAMPION TO LEAD EFFORT FOR COMM Maeve willing to help but does not have bandwidth to lead.**

"Here are Katherine's thoughts on the competition:

There are two main styles of the competition that could be developed:

1. Engineering-Style Competition

- planning committee chooses specific EH devices that can be used and the target load
- planning committee also specifies energy input conditions (lighting setup, vibrational input, etc) for testing
- specifications are announced and teams would develop the power converter solution based on the specification
- teams can submit videos and/or reports on their team and proposed idea
- final teams are selected and they test their prototypes on site at an event competition (could be a conference)
- judging is based on technical criteria measured during the test (size, weight, efficiency, etc.)
- implementation is the most important aspect for this style of competition
- over different years, the specification and scenarios would focus on different technologies with the same basic format
- more similar to the International Future Energy Challenge run by PELS

2. Design-Style Competition

- planning committee could choose a theme based on a technology or application (e.g. smart homes, wearables, building monitoring, etc.)
- planning committee may want to specify some constraints or scenarios for the competition
- teams come up with complete EH design ideas (transducers, circuitry, load) and develop a prototype
- teams can submit videos and/or reports on their team and proposed idea
- final teams are selected and they present and demonstrate their prototypes on site at an event competition (could be a conference)
- judging is based on mostly qualitative and some quantitative judging criteria (so balanced judge selection will be important)
- this style of competition is more focused on the idea and design, but implementation is also important

There should probably be some discussion on which style the committee would like to see. The engineering-style requires a lot of prep work before even announcing the competition, while the design-style is more work for the judging and evaluation. I could see either being good for students. I hope someone can take these basics ideas and further development them into a competition."

7. Technical forum (links, list of forthcoming events, etc.)

- Johan will review and update the list of events when he gets a chance but EnABLES project is creating a calendar of events, Mike should be able to share this (edited version) in July/Aug
  - Johan delivered updated list on 7/23/18, which MH & BZ will digest and share with group.
- Any volunteer(s) for white papers, weblinks, use cases, etc.
- Reach out to other societies/groups and cross link? – Mike & Brian to discuss.
- Note activities underway separately to re-vamp PSMA website.
- Does this add any value, should we remove??

8. AOB, actions, next meeting, etc.

- Software? Packaging/industrial design? Modelling?

Mike Hayes & Brian Zahnstecher,
11th December 2019.