Notes from "Energy Harvesting for Wireless Automation" Conference

Munich, 24-25 March 2010, Alex Weddell

General comments about the conference

The conference provided delegates with a useful review of the state-of-the-art in energy harvesting and storage, with some notable exceptions (which are discussed later). The aggressive marketing strategy of Hanson Wade had clearly brought a number of people together who had varying levels of experience with energy harvesting technology. In particular, it was helpful to see presentations from customers of energy harvesting technology, along with updates from Perpetuum and Micropelt.

Approximately 55 people attended the conference, a significant proportion of which were speakers. The programme was decided by Hanson Wade, but apparently they spent some time speaking to other people in the sensing/energy harvesting community who recommended speakers for the conference. Feedback forms were provided with the ability to rate presentations and suggest improvements for future events.

Representatives from companies producing photovoltaic cells and supercapacitors were notably absent from the conference. Hanson Wade are planning another conference, entitled "Energy Harvesting 2010" (as opposed to "Energy Harvesting for Wireless Automation 2010") in October 2010, also in Munich. It was pointed out to the organisers that IDTechEx also had an event planned in Munich in May.

The conference was chaired by Richard Percival (Infinite Power Solutions).

Rob Van Schaijk – Micropower IMEC/Holst Centre

Gave a good overview of EH technologies. Regularly cited a review paper[1] on EH technologies. Exploiting MEMS technology for cost reduction, using 6-8" wafer processing on IC fabs. Expertise in harvesting sources (design, fabrication, testing), storage (characterisation, selection), management (IC design and testing). Not investigating EM VEH – not MEMS-compatible. Focussing on piezo, have fabricated MEMS piezo VEH devices (moved from PZT to AlN for improved properties). Latest device 85µW @ 325Hz ?g. Packaging of devices causes damping (by at least an order of magnitude), so package in a vacuum. Has $1cm^3$ demonstrator, 3 stacked PCBs (harvester, Li-ion battery, processor/xcvr), avg 10µW power consumption, all COTS components apart from VEH. Also has thermo demonstrator (WATS – medical applications, has been through several iterations, including energy harvesting shirt). Looking at using IC fab techniques for TEG (10µm high thermocouples), but contact R was too high on prototypes. Also looking at RF energy harvesting, in particular improving the antennae (conjugate matching rather than impedance matching) and other issues.

[1] Vullers et al., Micropower Energy Harvesting, Solid State Electronics 53(7) p684-693.

Thomas Kafta – GE Energy

Formerly Bently Nevada Asset Condition Monitoring. Expert in machine condition monitoring ($1.8Bn international market). Wants to use whatever power is available. Machine monitoring: vibration/temperature/oil sample. Targetted app: tank farm pumps – current monitoring 3wk walk-around, detection using case vibration/temperature. Presentation included graphs for barriers for wireless adoption. Typical vibration sensor lifetime 3yrs/battery pack. Customer uses $LiSOCl_2$ batteries (19Ah, 0.5mA avg, 3.6V, 4 yrs but uncertainty begins at 2-3yrs). Unpredictable maintenance logistics are a problem. Perpetuum PMG17 can give 0.5mA indefinitely. 75% machines gave >0.5mA across 3 user sites. Introduced concept of "Power Harvester Assisted Battery Life" – whenever vibration is present, device is working. $LiSOCl_2$ cannot be transported on passenger planes (leads to 2-week lead time for replacement batteries). Open to other EH sources (not wedded to Perpetuum) but want a standardised plug! Leads to ISA100 standard...

Fabrice Roudet – Schneider Electric

Thermal energy-powered ZigBee wireless sensors. Schneider now "energy management" expert – from production to usage. Mainly applied to industry. Use Micropelt TEGs, Green Peak wireless comms. Largest TEG - 126µW @ 3°C (across TEG, 6-8°C total). DC-DC converter 70% efficient at 100µW, using converter proposed by Micropelt. Uses ZigBee star architecture, can sustain measure and transmit every 5s. Most apps need transmissions every 5 mins – 98% of energy harvested would be wasted (obviously!).

Nico Gotthardt – Thermokon

Use enOcean technologies, building automation application. 150-200k properties equipped with their devices (including thermostats in conference hotel!). Building automation gives substantial savings, illustrated by graphs. "EasySens" module – uses sun, movement (finger press, window handle, etc.). Requires min 140lx daylight 2hrs/day. 50-60hrs op in complete darkness. Battery expansion is possible. Wakes up every 100s, checks sensors. Sends basic telegram every 1000s if nothing to report in this time. Also some powered sensors e.g. CO_2 for air quality monitoring. Commissioned study: radio emissions 100x lower than conventional light switches, 1500x lower than DECT phones. Gateway interface to wired building management systems (KNX, Bacnet, Lanmark, ModBus etc.). Case studies of equipping facilities with wireless tech, ROI ~ 1 yr.

Roy Freeland – Perpetuum

NASA say that complex wired systems typically have at least 2 wiring faults, showed picture of wired system. Biggest problem in wireless systems is knowing when the batteries are going to expire. Perpetuum tech: ATEX Zone 0 cert, MTTF 440yrs. Pruftechnik – Vibnode RFA wireless condition monitoring system. Freestanding generator produces constant current. Showed table of energy usage of 0.5mA sensor. Introduced concept of "Integrated Power Unit" – battery plus harvester (primary or secondary battery).

Harry Ostaffe – Powercast

RF power has 3 types: intentional/anticipated/unknown. They develop RF power transmission technology, their transmitter uses ~15W. RF matching techniques... Rectenna (rectifying antenna): no matching network, no matching loss, difficult to measure diode complex Z, requires specialist antenna design. Standard Impedance (Powercast): matched to 50Ω. Developed drop-in modules for RF power e.g. P1110 PowerHarvester receiver – 915MHz, 3V load. Showed AVX Bestcap among

other caps – worth looking at. Also showed Cymbet and Infinite Power Solutions batteries. P1110: battery charging, inc o/v protection (user-config); P2110: battery-free systems inc. o/p regulation. Has 850MHz bandwidth sensitivity with ±20% efficiency. Intended for building automation/zone control.

Buckhard Habbe – Micropelt

Harvesting efficiency doesn't matter – the energy is free! (his generators are only 2% efficient)... Showed range of prototype products including EGO – wireless cooking sensor. "Full Pilot" production line is now running – up to 10k units/yr, setting up volume production for 3Q 2010. 540 thermocouples on 11mm^2 = 140mV/K (400x more than conventional TEG. 1W thermal -> 2mW electrical (~2.5mA). TEG is fragile and sensitive to mechanical impact, so has to be protected by rigid cover. Evaluation modules: TE-Power ONE – gross harvesting power sources, TE-Power PLUS – net harvesting, 1.6-5Vdc, adjustable V and capacitor extension. Being sold by Mouser. Starts operating at 0.3V ~2.2K dT. >70% electrical efficiency from Pin >300µW at dT>4K. Have developed own PM cct, but hoping to shrink size using new PM products. TE-Power Scope – evaluation software. TE-Power Probe – energy harvesting bolt. Applications in central heating control. Live demo with candle.

Roger Hazelden – TRW Conekt

Spoke about WiTNESSS project (3yrs, started Oct 2008). Target: aircraft health management and prognostics (HMaP). Developing generic system framework for use of wireless tech to collect data. Demo platforms: engine test bed (Rolls-Royce), Helicopter (Agusta-Westland), composite wing structure (Bombardier/Airbus/Qinetiq). Will not develop EH devices. Sensing temperature/pressure/strain/vibration. Classified: low data rate <1Mbps, medium <10Mbps, high >10Mbps. EH used as main power source, or life extender for batteries. Ideal size of data gathering modules <1cm^3. WiTNESSS aiming for demo Q4 2010-Summer 2011. Looking to develop proposals for collaborative R&D for UK National Aerospace Tech Strategy. Proposed projects to raise TRL of EH for aircraft applications. Question from Roy Freeland about whether Roger had checked fundamental laws of physics, as roger wants large amount of power from matchbox-sized generator.

Haydn Thompson – Rolls Royce University Technology Centre

Rolls Royce sells "power by the hour" – power generation products and maintenance. Sample rate up to 30kHz for vibration in aerospace apps. Projects include Airbus WICAS (wireless nervous systems for future aircraft using 60GHz RF), Airbus SWIFT (skin friction reduction for aircraft, equipment health/nervous system/airflow), Network Rail. Has developed range of wireless sensors, thermocouples for jet engines. 3-axis G, T, P integrated sensor – for blade monitoring. Also thrusters monitoring, gear/cog/big end. Can't use batteries in engines due to thermal range. Weight of heatsink is problem for TEGs in aircraft. Used Micropelt device for aircraft engine, marine diesel. On ships, transmit through rubber door seals and through cable runs.

Thomas Becker – EADS Innovation Works

Wireless infrastructure for new aircraft services – EADS IW (wireless backbones). Today: fixed maintenance intervals, but trying to move away from this. Concept: wireless strain gauge using Micropelt TEG (between inner and outer skin of aircraft). Roy Freeland agreed VEH not suitable in fixed-wing aircraft. Also has worked on container monitoring with PV cells. Vibration harvesters in helicopters – rotor head monitoring.

Dieter Wagner – Continental Automotive

Developing energy harvesting for TPMS. TPMS functionality will increase (2002: first devices, 2008: wheel-speed info, 2012: EU TPMS legislation, 2015: friction/tread, 2020: chassis functions for stability control). Existing sys measures P, T, acc. Future will have data storage: logistics, depth of tread, summer/winter, mileage of run-flats, ABS/rollover protection etc.). 17M systems sold worldwide, rising to 50M worldwide by 2015. Idea: replace battery with EH. ASYMOF project: collaboration inc Siemens, Helmut Schmidt Uni, Daimler, Intek – developing piezo and EM, plus power management. Aim: increase reliability and reduce cost. 2 possible locations: rim valve hole or inner liner of tyre. Max 20s delay for reading from stationary to 15km/h, survive 270km/h. Target: 100µWs/telegram (existing 250-500µWs). Useful table of available energy. Acceleration due to deformation of tyre: also allows length of tyre footprint to be measured (can see how loaded tyre is – useful for ESP). Use PZT directly on lining of tyre. ASYMOF looking at electrostatic, EM, PZT macroscopic, PZT microscopic (acoustic). Test system is 17grams but this is too heavy! Siemens have developed MEMS piezo stripe to generate energy from tyre deformation. Target is to be cheaper than 90cents battery systems! Roy Freeland commented that in this case he wouldn't bother developing a product; Roger Hazelden commented that TRW Conekt would happily develop a cheaper battery-powered device to undercut the EH unit.

Richard Percival – Infinite Power Solutions

Thinergy solid-state thin-film batteries/micro energy cells. 4V "capacitor with a flat voltage" –(0.5, 0.7, 1.0mAh), decades of operation. In excess of 20yrs/45,000 charges (proven with 100% depth of discharge and <20% irreversible capacity loss). Used by Siemens, Microstrain (top link of helicopter), EPFL (EH with piezo and carrier wave), Virginia Tech (avionics in UAVs). Virginia Tech self-charging concept: uses Midé piezo structure. Charging: DC – Schottky diode, AC – bridge. Has "sneak circuit" for overvoltage protection (uses 1nA). Starts charging at 300nA. Leakage 1%/annum. Infinergy D-MPM101 is ASIC with overvoltage and undervoltage protection capable of 60mA discharge. Integrated switching converter? Live demo with Ixys solar bits, battery, ez430-rf2500. Runs node for 30hrs from stored energy in 1 cell (full charge: solar 30 mins, office 10 hrs). Available from Arrow. Shipped 1/3 charged – to prolong life of battery. Note: short-circuit destroys "cell-only" devices.

Panel Session – Standards

Graham Martin – enOcean, enOcean Alliance

Range of products already developed including mechanical EH from lightswitch (not peizo – EM is better for endurance), photovoltaic, thermal. Energy stored in 'gold cap'; device uses 20nA sleeping, 80nA with timers running. Used in >100k buildings. enOcean streetlamps used in Vancouver 2010 with proximity sensors that only activate lights when people nearby. enOcean/Siemens have lots of patents – invited people to "talk to them" if developing products in these areas. 30-100x less energy used for enOcean packet than ZigBee. 150 companies involved in Alliance.

Gilles Theonet – Schneider Electric, ZigBee for Very Low Power Communications

Based on 802.15.4 (90% products use 2.4GHz, 330 companies in ZigBee alliance). 4M ZigBee smart meters deployed worldwide. Same radio as ISA100 (Wireless HART) PHY layer. Proposing amendments to ZigBee standard – green power group has been formed. Allow EH devices to

communicate with existing ZigBee wireless infrastructure – e.g. using shorter frames. “Employees steal batteries”.

Roy Freeland – Perpetuum, ISA100

ISA100 Power Source Working Group (TBC – proposal to form WG currently out for ballot). Encouraging single power source standard. ISA so no fee to join, all meetings are public. Not attached to ISA100 wireless standards. Aims: permit interchangeability of power modules for WSNs, develop and publish standards for specifying performance of power/energy devices. Includes energy harvesting, storage (inc. batteries), mains powered sources (inc transmitted). Requirements of LP wireless e.g. ISA100.11A, ZigBee, etc. Standards on how to write: power source o/p performance, power source i/p required by nodes. Prescriptive standards documents to promote interchangeability. Inc. connectors, power mgmt systems, hazardous area issues, energy storage. 3-wire interface (or more to be able to identify/manage power sources). If WG status granted, will be able to start writing standards.

Panel Discussion

Third generation enOcean technology – “Dolphin” – has encryption possibilities but energy implications. Discussion re. enOcean/patents/prior art. ZigBee is focussing on building automation, energy management and healthcare.

Peter Spies – Fraunhofer IIS (Institute for Integrated Circuits)

Integrated energy supplies. Polarity switch and boost converter (needs ± supply) – uses charge pump, power used by comparator is low. Start-up at 150mV, drop off at 40mV, later 5mV; good for VEH. Also DC-DC converters for TEGs: low-threshold conversion, coupled-inductor DC-DC converter (small transformer and JFET). Uses inductor/transformer to control switching of JFET. Just use JFET on start-up then MOSFET does switching (improves performance). Works with 20mV, boosting up to >3V. 50-75% efficient. Integrated into ASIC (except transformer and o/p C). Works with Micropelt TEG. MPPT for TEGs: Vmpp = 0.5*Voc. Match R, duty cycle controlled by Voc. MPPT measures o/p I of DC-DC converter; uses op-amp integrator cct to control duty cycle. AC/DC converter for piezo generator has been developed: shifts V and I into phase (normally 90° out of phase) SSHI (sync. switch harvesting on inductor) challenge is control cct., uses Mide harvester and delivers large improvement in harvesting efficiency. DC-DC converter chip is available for purchase in sample quantities.

Cees Links – Greenpeak

802.15.4 2.4GHz “extreme low power” module with 30-50m range. Working towards “dashboard for the home” (home has no central control network like a car). RF4CE could be standard comms interface, use remote to control the house. Showed picture of TED (The Energy Detective) – prototype energy dashboard. Cees likes ZigBee but doesn’t think meshing makes any sense (in practicality it makes networks difficult to manage; most networks are star and only successful mesh network is the internet itself). All homes now have backbones (wi-fi router). Having 2 flavours of wireless standard are stalling market for industrial monitoring (ISA100/Wireless Hart). EH currently constrained to niches where batteries are forbidden.
