gefördert vom Bundesministerium für Bildung und Forschung

VDI|VDE|IT

Prozessintegriertes autonomes Überwachungssystem für die Verfahrenstechnik auf Basis vernetzter, multifunktionaler MST-Funksensoren

(**PAC4PT**)

Ressourcen-effiziente, robuste Sensor- und Funksignalverarbeitung für autonome vernetzte Systeme in fluiden Medien

(**ROSIG,** Fkz. 16SV3604)

ROSIG Project 2012/2013 Final Phase

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Motivation

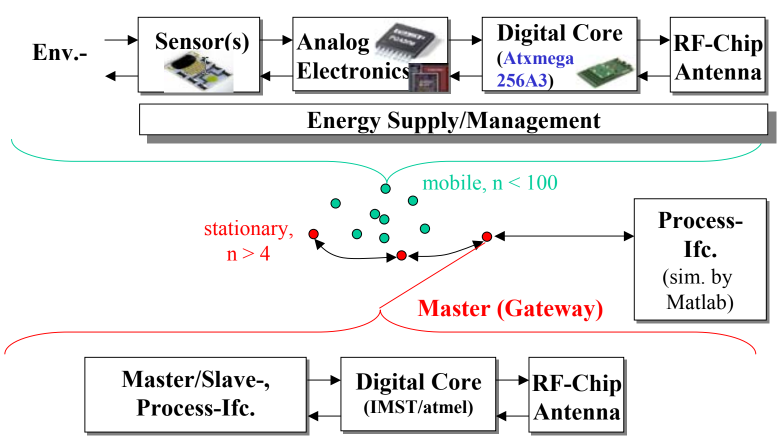
- WSN becoming ubiquitous in Automation, Agriculture, AmI/AAL etc.
- Cyber-Physical-Systems and the Internet of things add momentum
- Limitation of existing implementations technologies require access to advanced packaging and MEMS technologies in addition to mainstream chip technologies (CMOS, BiCMOS, SOI etc.)

- ISE goal (project proposal) for research & exploitation: Get training in and access to packaging/MEMS technologies for inclusion in RLP research centers, e.g., Ambient Systems, Commercial Vehicles etc. and indidual initiatives, e.g., Driver Assistance Systems (DeCaDrive) or SmartKitchen

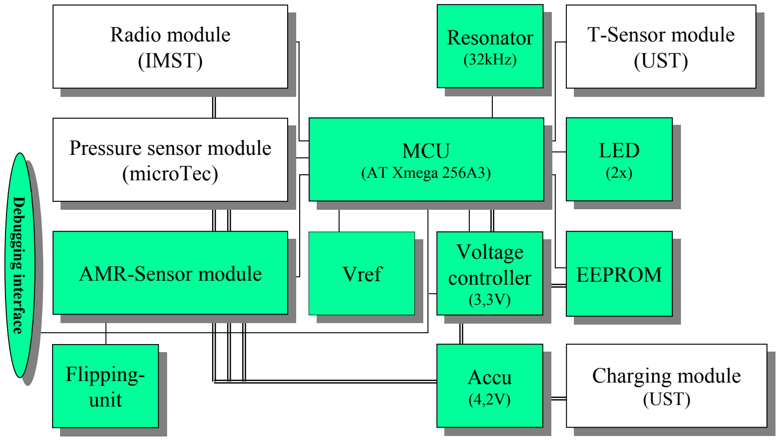
- Important issues in WSN besides the communication and technology:
  - Localization
  - Synchronization
  - Self-X and Low-power

Sensor Node Prototype and Test Issues

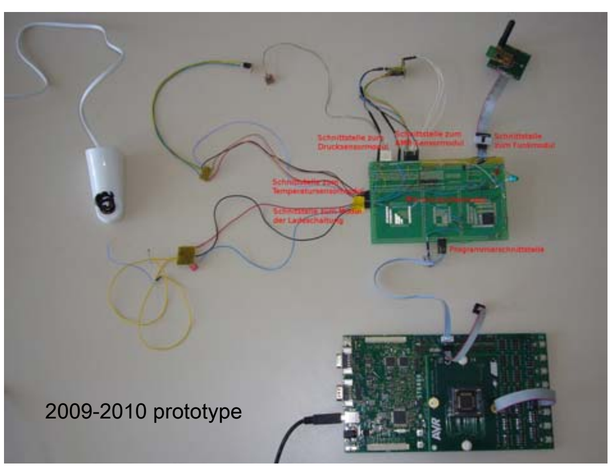
- **Coarse System Architecture (adapted from 2009):**



Sensor Node Prototype and Test Issues

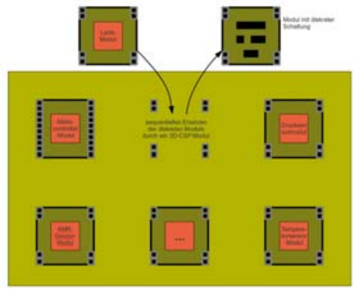


Sensor Node Prototype and Test Issues

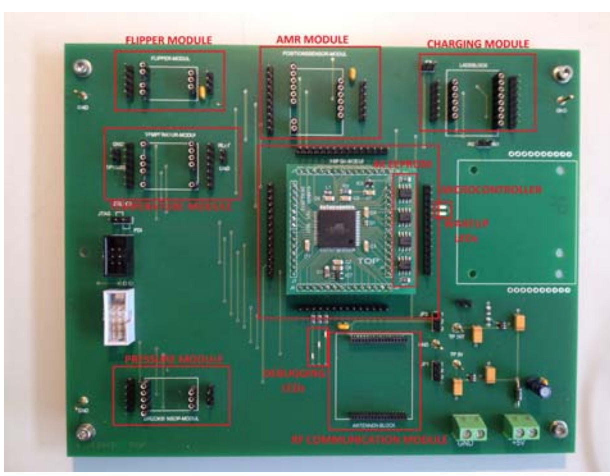


Sensor Node Prototype and Test Issues

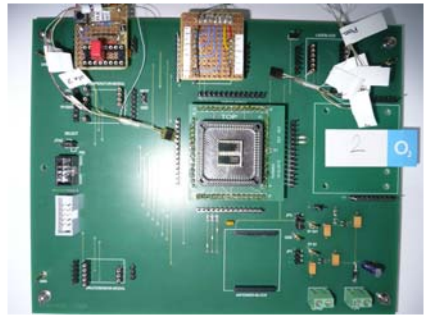
- First prototype wire-wrapped, thus ´´cranky´´ and ´´*buggy*´´
- Modular test of emerging 3D-CSP units difficult
- No back-up in case of defect/problems
- 3D-CSP complete sensor node unavailable, but needed for SW dev.
- Thus SoA modular PCB-system conceived (lot size 5)
- Numerous bugs found in design data base, e.g. pressure sensor, EEPROM etc.
- Shipped to partner (IMST) for better cooperation



Sensor Node Prototype and Test Issues



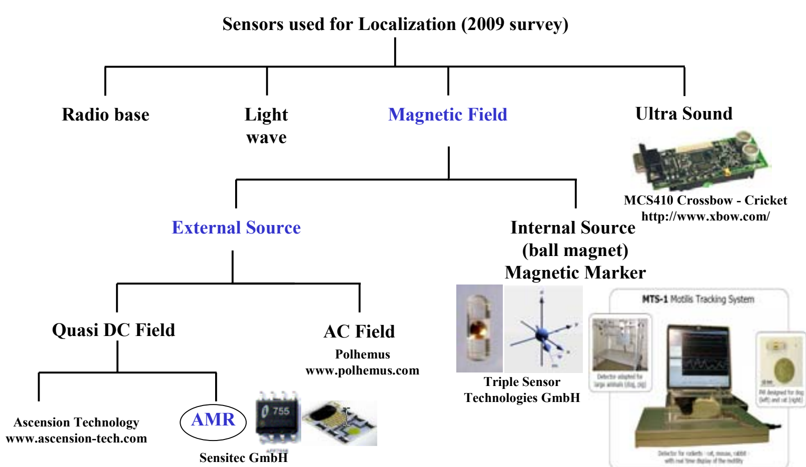
Sensor Node Prototype and Test Issues



- PCB & 3D-CSP modules exchanged and tested
- SW development advanced
- Measurement became feasible
- Designed for small volume test of 3D-CSP

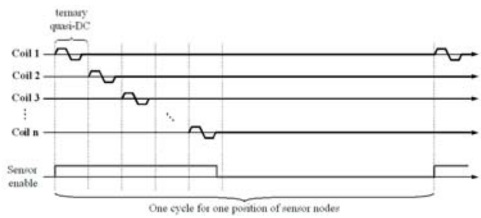
- Remaining problems:
- Connectivity of 3D-CSP to PCB-Adapters ´´cranky´´
- Complete and functional 3D-CSP module set never available
- ´´Lot size one policy´´ created problems

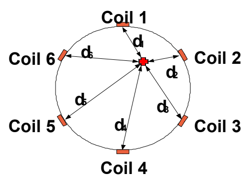
Magnetic Localization

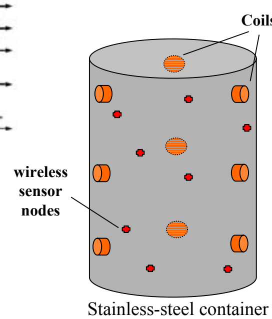


Magnetic Localization

- Triaxial Anisotropic Magnetoresistive (AMR) sensor for 3D localization
- Ternary quasi-DC coil switching alleviate need for flipping of AMR



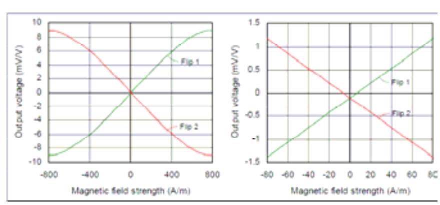




Magnetic Localization

Conversion from Sensor Output to Distance Value

- AMR sensor: Sensitec AFF755B



$$V_i = \frac{V_i^p - V_i^n}{2}, \quad i = \{x, y, z\}$$

$$V_M = \left(V_x^2 + V_y^2 + V_z^2\right)^{0.5}$$

$$B_M = \left(B_x^2 + B_y^2 + B_z^2\right)^{0.5} = \frac{V_M}{S \cdot V_s \cdot G}$$

$$B_M = \frac{\mu_0}{2} \cdot \frac{n \cdot I \cdot R^2}{(R^2 + d^2)^{3/2}} \Rightarrow d = \left(\left(\frac{\frac{1}{2} \cdot \mu_0 \cdot n \cdot R^2 \cdot I}{B_M} \right)^{\frac{2}{3}} - R^2 \right)^{\frac{1}{2}}$$

where

S : sensitivity
V_s : bridge supply voltage
G : gain of amplifier

Measure the magnetic field strength of coils

⇩

Transform the measurement into distance value

⇩

Localization algorithms (Improvement in ongoing research !)

Magnetic Localization
Validation Scenario

- Warstein campaign (Carrella & Groben, Sept. 2011), front & backview of container in brewery ´´Technikum´´ with TUKL/ISE coil system

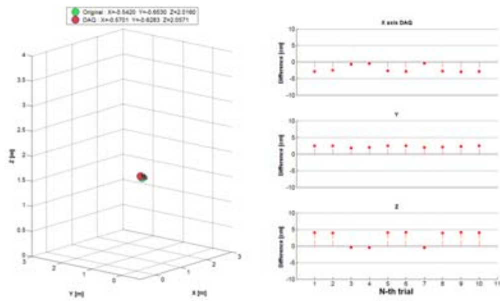
Magnetic Localization
Validation Scenario

- Grid of investigated container volume (left), 3D-AMR sensor & board

- Reported measurements have not been made with the target hardware (atmel Xmega 256A3) but with analog 3D-AMR sensor & DT DAQ
- Field generation with both DAQ & Xmega 256A3 board

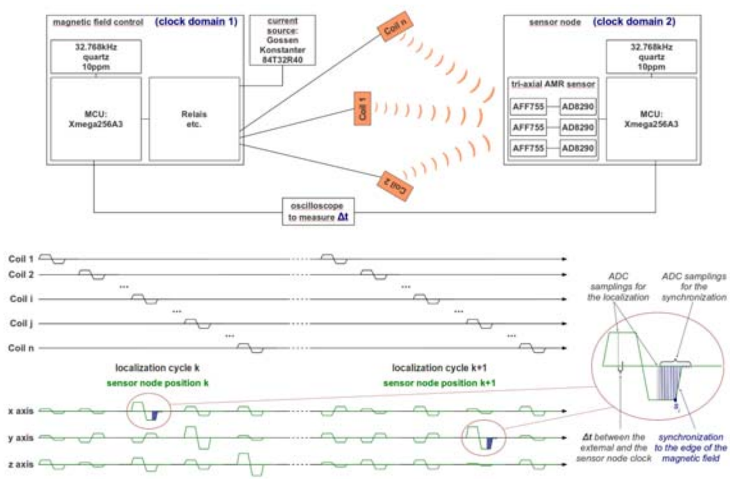
Magnetic Localization
Validation Scenario

- First-Cut (Carrella & Groben, Sept. 2011) data acqusition & analysis
- 30 sensor positions with about 10 repetitions measured in center cube of tank
- Overall result: Mean err. 40.73 cm with standard dev. 16.79 cm !



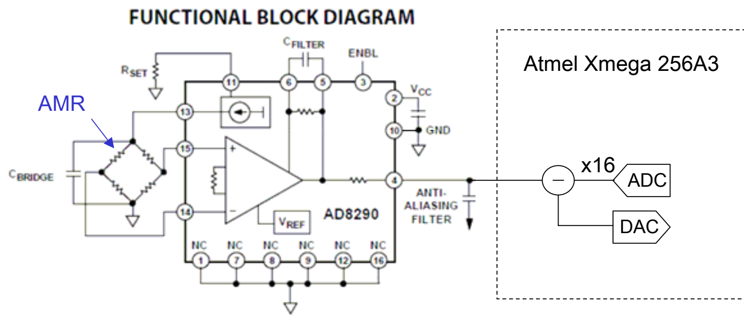
- **Reasons:** imperfect ADC-use, inferior algorithms, missing calibration ....

Magnetic Synchronization
(a) Synchronous Starting (b) Periodic Resynchronization



Low Power and Self-x Issues
Self-x Extension of AD8290 in 3D-AMR

- InAmp AD8290, enable pin is available (for shut down), and gain is 50 V/V

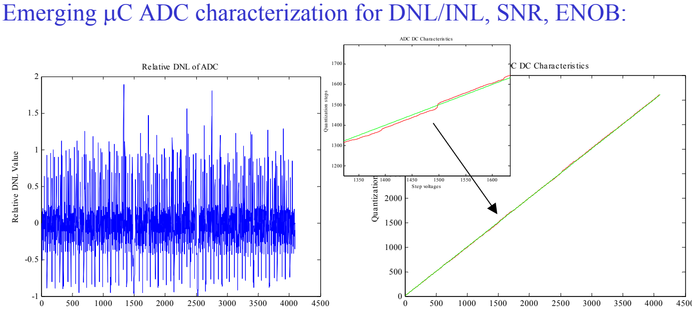


- Offset & gain programmable in differential ADC mode
- Offset read for each channel and compensated
- Gain set for full-scale: Zooming & self-x achieved !

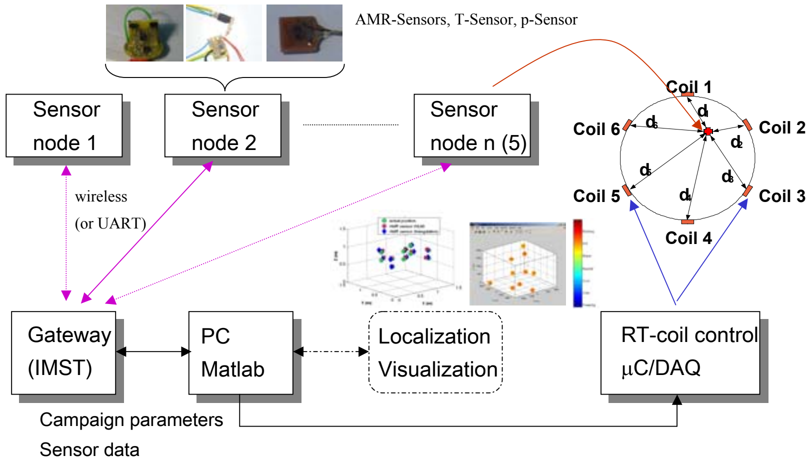
Low Power and Self-x Issues
Additional Self-x Extension

- Alternative AMR sensor (reconfigurable) architectures studied
- MEMS switches application for reconfiguration/self-trimming
- Implicit temperature measurement and self-monitoring

- Emerging µC ADC characterization for DNL/INL, SNR, ENOB:

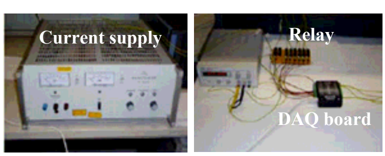


ROSIG Demonstrator



ROSIG Demonstrator

- Relay board for switching purpose
- DAQ board: Data Translation 9816
- Current supply is 5A



- The volume used is 1.5m x 1.5m x 1.5m (coils rearranged to cylinder !)
- Applying 6 (previous) coils with diameter of 13cm and 100 windings
- WSN node has been tested (12 bit ADC, reduced sampling rate, triangulation)
- The *error is in the order of 10cm* (depends on-center/off-center loc.!)
- ADC/cal. problems and coil to sensor node angle require improvement !

Conclusions and Future Research & Exploitation

- Concept & PCB-implementation of sensor node with magnetic localization and magnetic synchronization
- First self-x features added
- Large scale scenario data acquisition (benchmark data)
- Efficient localization algorithms developed (synch. alg. in prep.)

- First-cut demonstrator of the measurement system achieved (2013)

  Baseline for follow-up research & exploitation/commercialization

- Miniaturized sensor node (swarm) implementation pursued by various accessible MEMS/3D printing technologies (prerequisite for cal. !)
- Mobile demonstrator in preparation

Vielen Dank

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