Scientific Seminar on structure, architecture, and application of sensor circuits

List of available topics

Important points to note:

1. Please contact the respective supervisors directly in case you are interested in their topics.
2. Once the supervisor has given you the confirmation, please send an email to vartika.verma@tum.de stating the topic name that has been assigned to you.
3. In addition, please make sure to register for the course from TUM online as well.
4. The list will be updated frequently to show which topics are still available and which have already been taken by other students.
5. After kick-off, only the students with a confirmed topic will be allowed to continue with the course.
6. Keep in mind that the topics will be assigned on a first-come-first-serve basis and it is your responsibility to secure a topic in time.
7. In case your chosen topic is already taken, feel free to contact the supervisor to ask if they are willing to offer a second similar topic to you.

Wearable Electrochemical Sensors:

Low Power Read-Out Techniques

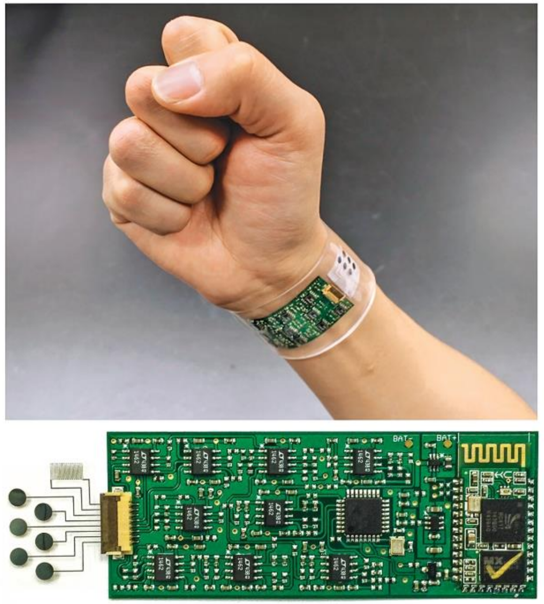

Figure 2. Read-out PCB for a wearble electrochemical sensor

Background:

Wearable sensors are a big trend as they collect physiological information in real time. However, the signal read-out needs to be low-power in order to reduce battery size and increase the time span of continuous monitoring.

Focus:

Low Power Read-Out Techniques for Electrochemical Sensors:

- **Signal amplification (Hardware)**
- Signal Transmission (e.g. NFC)
- Decision-Making Unit (Data)
- Power Unit (e.g. battery, energy harvesting)

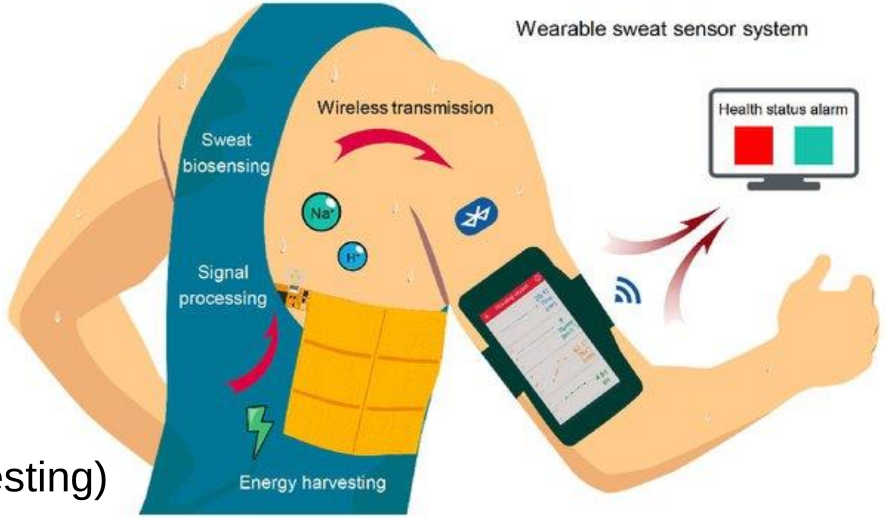

Figure 1. Working principle of a wearble ion-sensor system

Fig. 1: https://www.caltech.edu/about/news/new-device-powers-wearable-sensors-through-human-motion
Fig. 2: Gao, W., *et al.* Fully integrated wearable sensor arrays for multiplexed *in situ* perspiration analysis. *Nature* **529**, 509–514 (2016). https://doi.org/10.1038/nature16521

Planar Hall-Sensors for magnetic field compensation

State-of-the-Art, Design, Limitations

Problem:
Sensitivity of planar sensor systems (capacitive) get limited by disturbing magnetic fields.

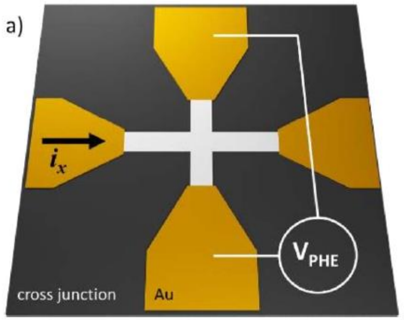

Figure 1. Typical cross-shaped Permalloy based PHE sensor

Focus

- Possibilities for planar detection of magnetic fields
  - Techniques, Effects (Hall)
  - Advantages/Disadvantages
  - Limitations, Sensitivity (Range)
- Planar Sensor Design
  - Materials (prior silicon, CMOS compatible)
  - Structure (arrangement)
  - Read-out
- Compensation possibilities (analog/digital)

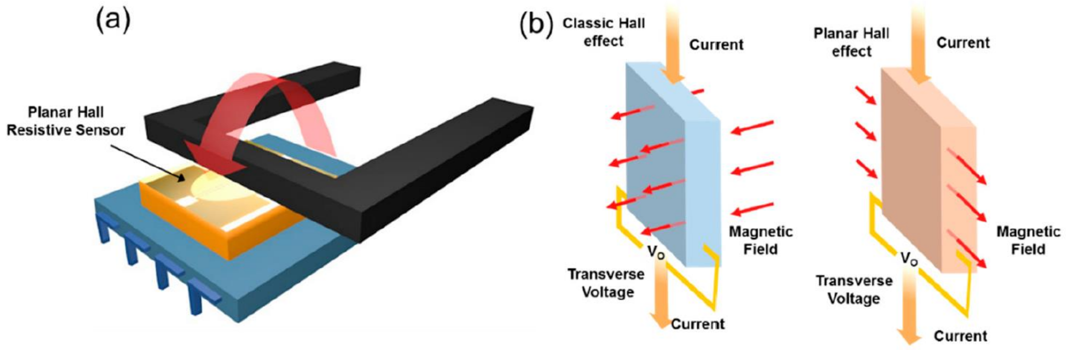

Figure 2. Structure of an open-type current sensor (a), mechanism of PHR sensor (b)

Source Figure 1: A. Elzwawy, et al., "Current trends in planar Hall effect sensors: evolution, optimization, and applications", *Journal of Physics D: Applied Physics*
Source Figure 2: Lee, S.; Hong, S.; Park, W.; Kim, W.; Lee, J.; Shin, K.; Kim, C.-G.; Lee, D. High Accuracy Open-Type Current Sensor with a Differential Planar Hall Resistive Sensor. *Sensors* **28** ,

Dual-Slope A/D-Converter: Techniques, Efficiency, Flexibility

State-of-the-Art, Design, Features, Comparison

Problem:
Need for efficient, flexible converter considering topology, effort and effeciency (targeting: area, noise, current, resolution)

Focus

- State-of-the-Art: Dual-Slope Converter
  - Efficiency (FoM), Resolution, …
  - Features: Higher slope techniques, noise cancelling, etc.
  - Limitations of topology
- Comparison to other topologies
  - SAR-Converters, Sigma-Delta ADCs, …
  - Advantages/Disadvantages
- Flexible converter: Resolution, sample frequency, accuracy
  - Adjustable designs?

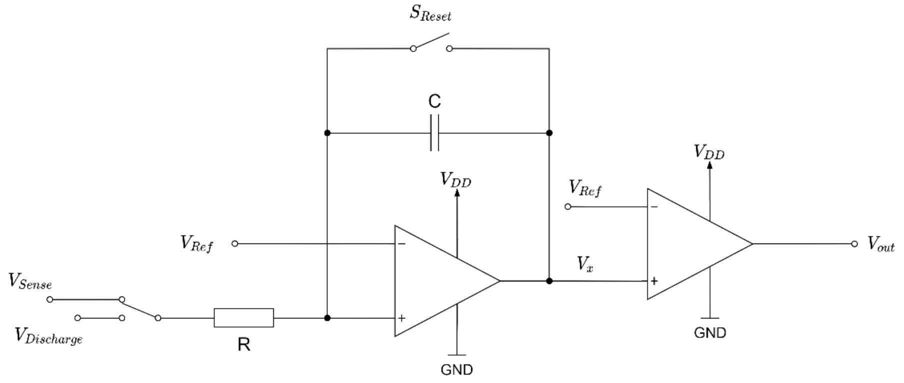

Figure 1. Dual-Slope Converter

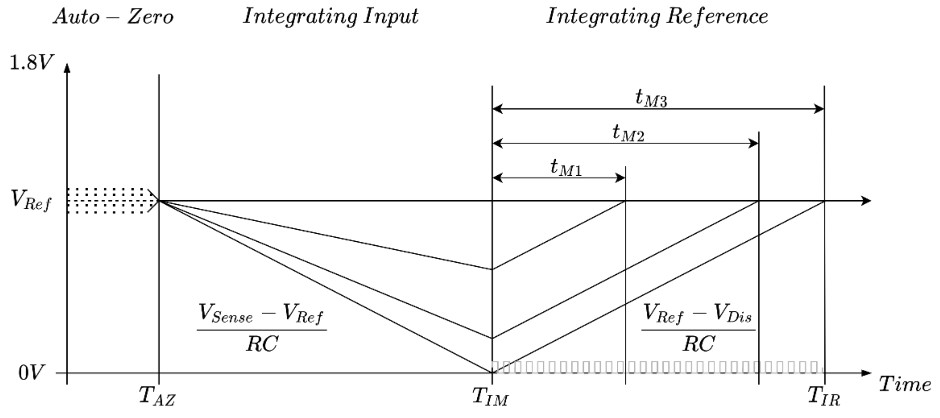

Figure 2. Typical dual-slope conversion cycle

Source Figure 1, 2: Analog-to-digital converter for the genration of keys with mechanical stress compensation, Tobias Chlan

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Silicon based flexible tactile sensors

Key considerations for flexible electronics

Background:
Flexible sensors can be seamlessly applied to irregularly shaped surfaces. This benefits conformability dependant applications including artificial skins and soft robotics.

Focus:

- Investigating possible materials that can be used for flexible sensors.
- Focusing on silicon based touch sensors and the challenges associated with it.
- Analyzing the dependence of material properties on sensor output.
- Discussing different types of sensor array patterns and arrangements in order to create most optimal performance.

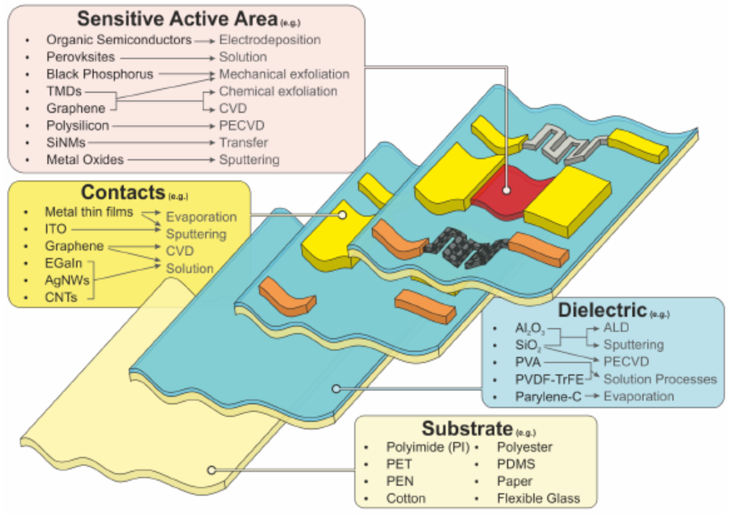

Fig. 1: Common materials and respective fabrication methods used for the fabrication of flexible sensors[1].

Fig. 2: An example of e-skin using flexible printed circuit boards[2].

1 - Costa, Julio C., et al. "Flexible sensors - from materials to applications." Technologies 7.2 (2019): 35.
2 - ROBOSKIN - www.roboskin.eu.

Charge Amplifier OpAmp topologies

Who built the best one?

Background:
A piezoelectric sensor uses the piezoelectric effect. With this effect the change in pressure, temperature, strain, etc. can be measured. For this measurement a charge amplifier will be used.

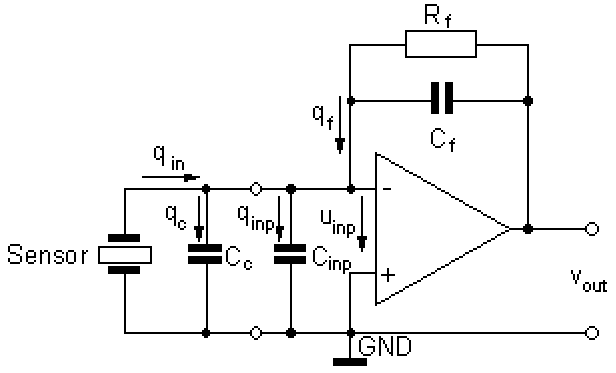

Figure 1. Charge Amplifier

Focus:

A charge amplifier are used in many different application. The task is to compare the integrated amplifier topologies of different kind of applications and figure out the disadvantages and advantages of the opamp design.

Figure 2. Non-Sense cute Cockatiel

Source Figure 1: https://www.mmf.de/messtechnik.htm
Source Figure 2: https://de.wikipedia.org/wiki/Nymphensittich

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The golden reference – voltage references

A comparison of state-of-the-art architectures and their performance

Problem:
Voltage References suffer from inaccuracies (e.g. offset, temperature drift, noise,…). Therefore, different architectures, circuit design techniques and error correction mechanisms have been developed.

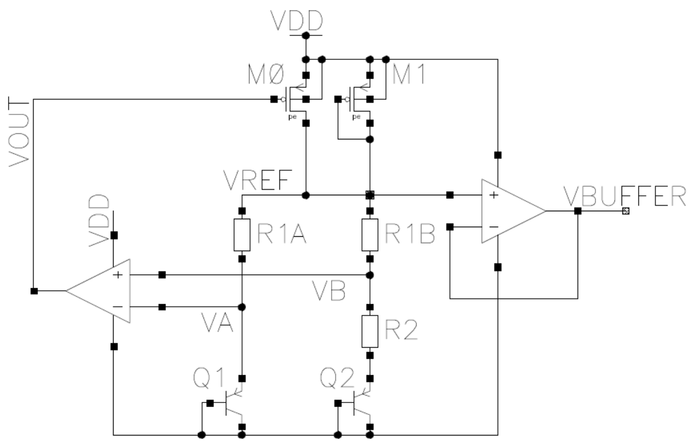

Figure 1. top-level schematic of a voltage reference circuit

Focus/Tasks

- Circuit topologies
  - What kind of circuit architectures are existing?
  - Can they be categorized?
  - What kind of advantages/disadvantages do they have?
- Possible Countermeasures to enhance the accuracy
- Performances
  - Typical performances for certain topologies
  - State of the art accuracy and circuit design techniques

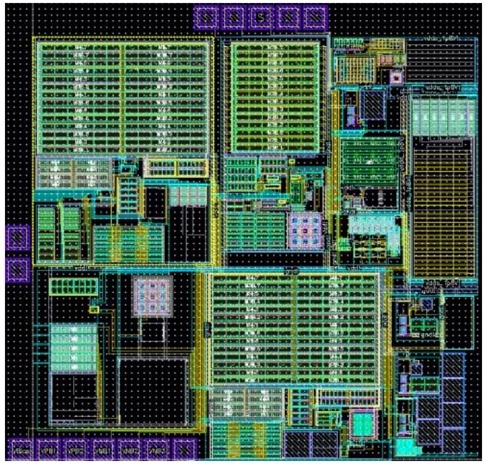

Figure 2. layout of voltage reference circuit

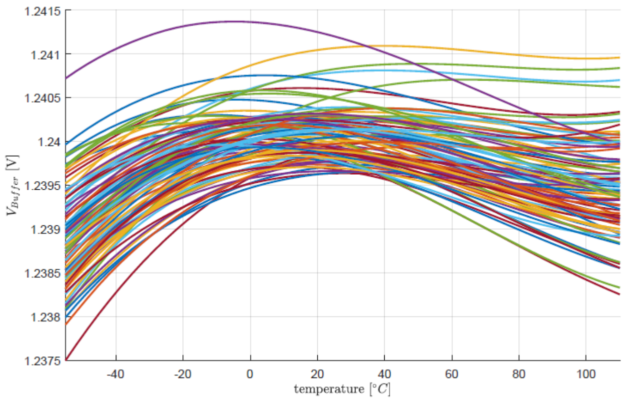

Figure 3. simulated accuracy after calibration for 100 statistical samples

Oversampling PLL or a faster update than the reference frequency

- Literature Research
- Find different approaches

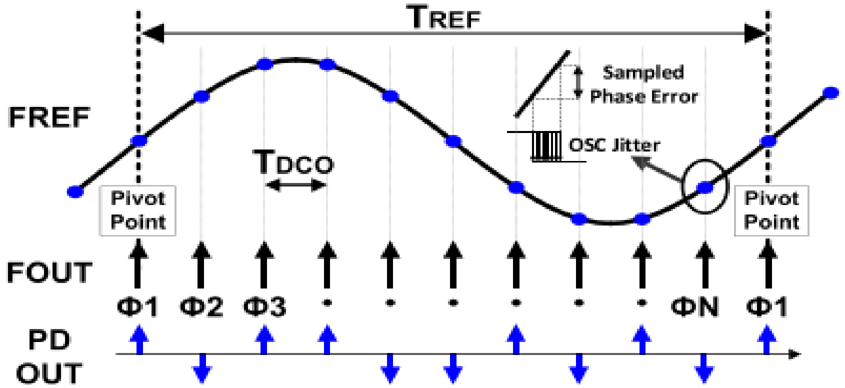

Fig. 2. Operating principle of the reference OSPLL.

[1]

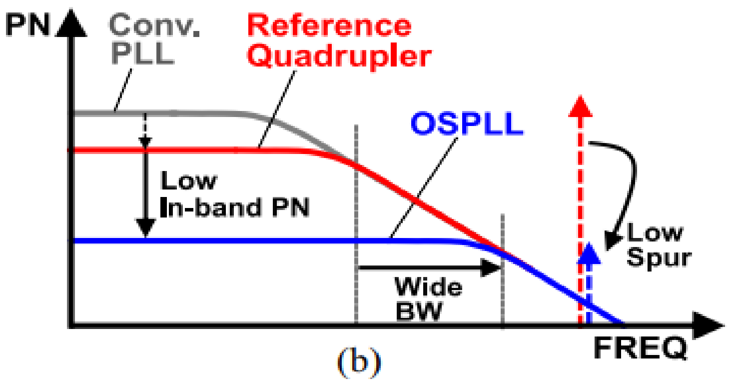

Fig. 1. Comparison of OSPLL versus reference quadrupler. (a) Block diagram. (b) Phase noise and spur improvement.

[1]

In many PLL applications a higher Bandwidth would be desirable. But Bandwidth is very often limited by the reference frequency. There are new approaches, that try to overcome this.

[1] SEOL, Ji-Hwan, et al. A 67-fs rms Jitter,− 130 dBc/Hz In-Band Phase Noise,− 256-dB FoM Reference Oversampling Digital PLL With Proportional Path Timing Control. IEEE Solid-State Circuits Letters, 2020, 3. Jg., S. 430-433.

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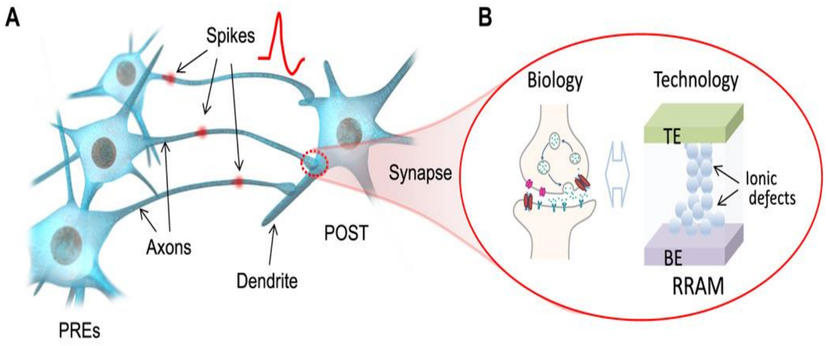
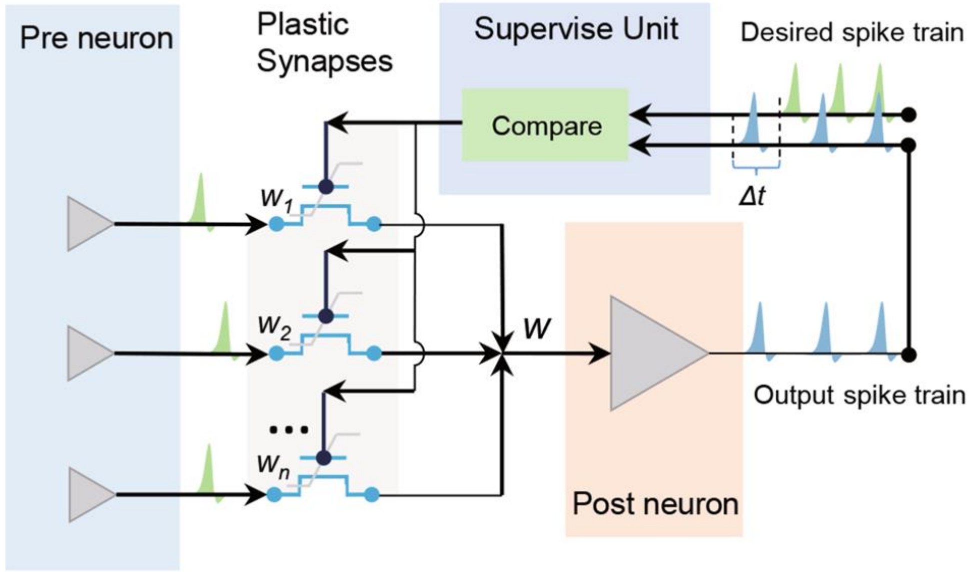
Training Algorithms for Spiking Neural Networks and their Implementation in Hardware

- Spiking Neural Networks (SNN) are often referred to the 3rd Generation of Neural Networks. They mimic the biology of the human brain in a more realistic way. The information are processed in spikes.
- The training algorithms are responsible for updating the strength of the connections (synapses) between the different neurons. In an analog implementation this should be done in hardware for efficiency reasons.
- This work should regard the following topics:
  - Get an overview of the main types of learning algorithms (supervised, unsupervised and reinforcement learning)
  - Focus on supervised algorithms (Backprop-Through-Time (BPTT, e-prop, etc.)
  - Presenting the state of the art for the analog implementation for SNNs. This also includes a differentation for learning algorithm or different memory elements
  - Find recently published examples and compare their performance





Chen, Yangyang, et al. "Graphene–ferroelectric transistors as complementary synapses for supervised learning in spiking neural network." *npj 2D Materials and Applications* 3.1 (2019): 1-9.

Topic availabilty:

No.	Topic	Supervisor	Availability
1	Wearable Electrochemical Sensors	Eva Korek	Not Available
2	(Near) Zero-Power Electrochemical Sensors	Eva Korek	Not Available
3	Planar Hall-Sensors for magnetic field compensation	Tobias Chlan	Not Available
4	Dual-Slope A/D-Converter: Techniques, Efficiency, Flexibility	Tobias Chlan	Not Available
5	Silicon based flexible tactile sensors	Vartika Verma	Not Available
6	Charge Amplifier Op Amp topologies	Marco Schewa	Not Available
7	The golden reference – voltage references	Carl Riehm	Not Available
8	Sampling PLL performance versus Charge-pump PLL	Markus Dietl	Not Available
9	Oversampling PLL or a faster Update than the Reference Frequency	Markus Dietl	Not Available
10	High bandwidth fractional PLL	Markus Dietl	Not Available
11	Training Algorithms for Spiking Neural Networks and their Implementation in Hardware	Matthias Ochs	Available