# Electronic Interface Circuitries for Kinetic Energy Harvesters

## Hannovermesse 2011


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# Outline

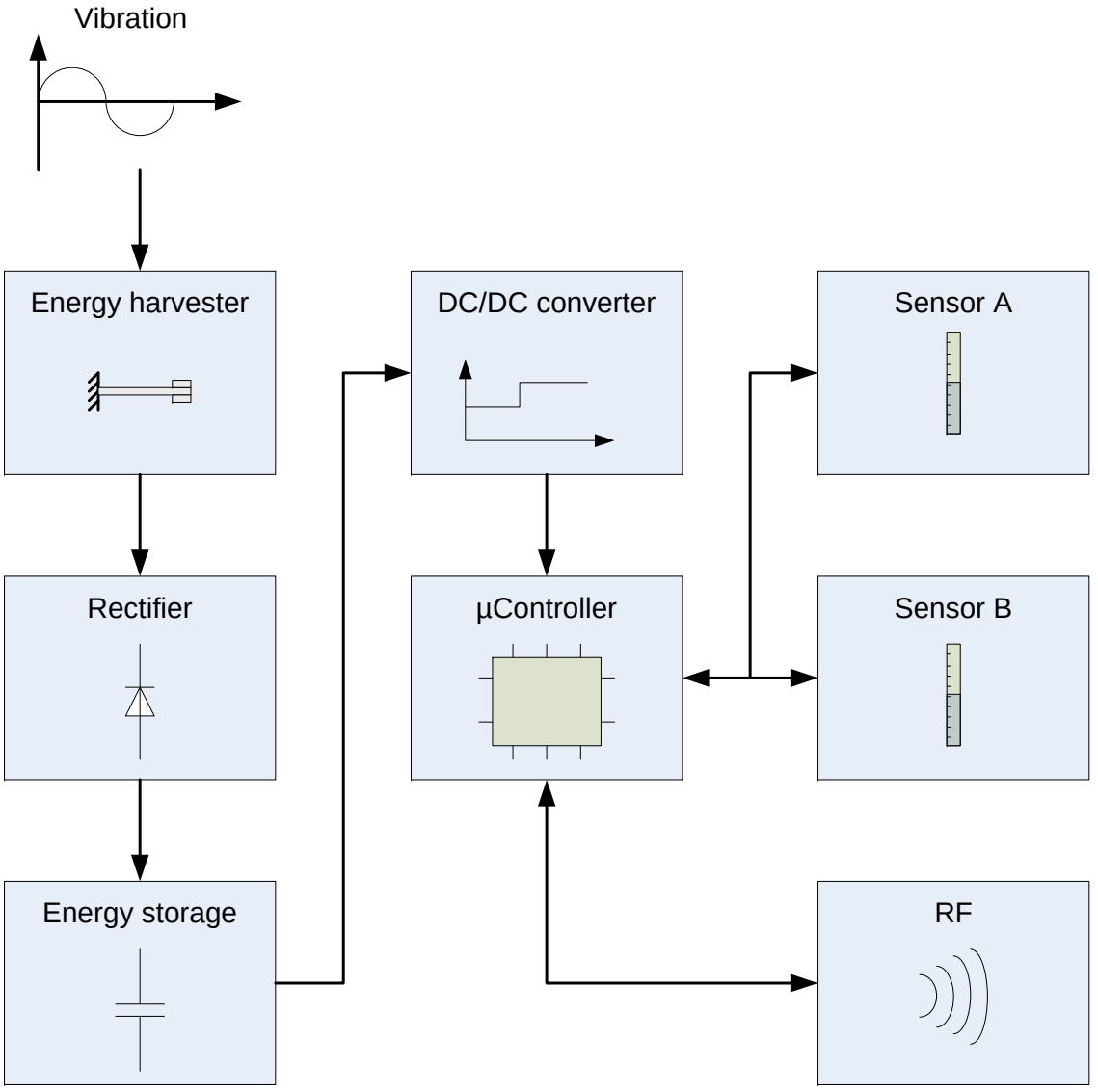
## State of the art

## Interface circuitry

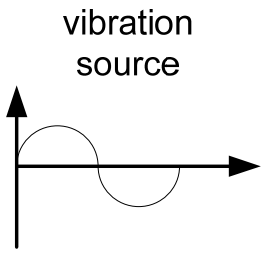
- Interface for electromagnetic energy harvesters
  - Adaptive Switched Capacitors
- Interface for piezoelectric energy harvesters
  - Parallel SSHI
- Direct SSHI:
  - Basic idea of self triggered direct SSHI
  - Generator design
  - SSHI circuitry and control unit
  - Measurement results

## Outlook

# State of the art

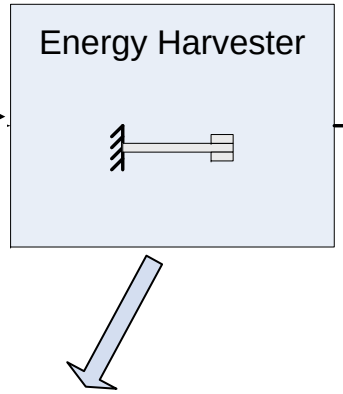


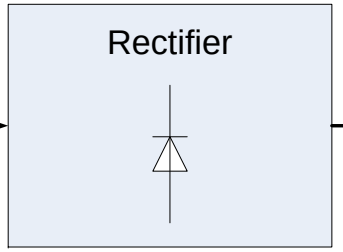
# State of the art

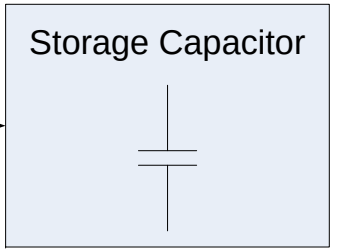


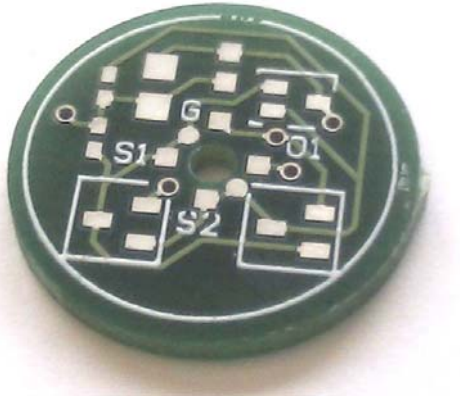

- A lot of the energy provided by the energy harvester remains unused.

→ Interface circuitry



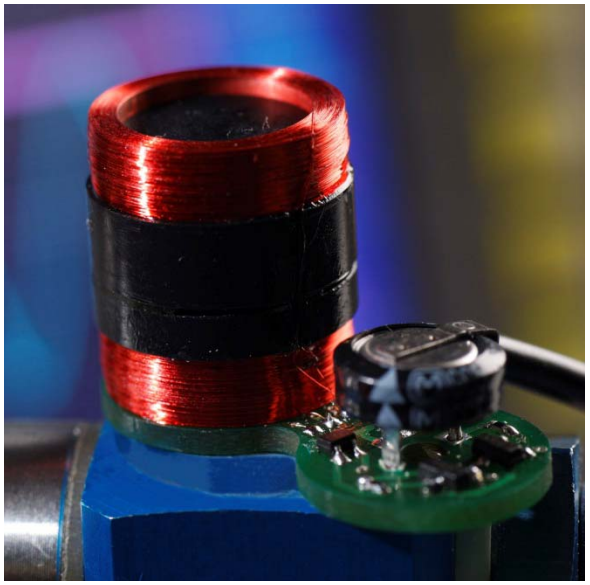




# Energy harvesters

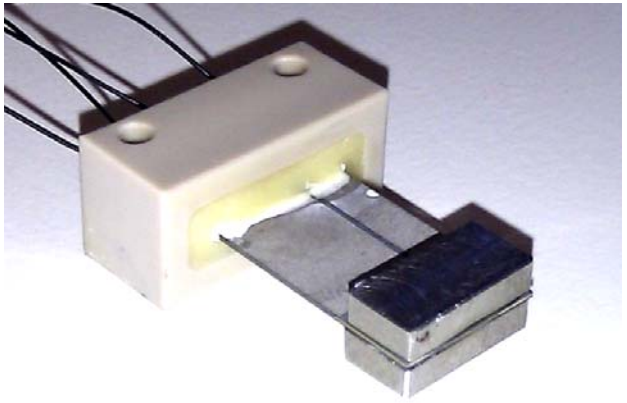
## Electromagnetic energy harvester

- Characteristic values
  - Relatively low output voltage
  - Relatively high output current



## Piezoelectric energy harvester

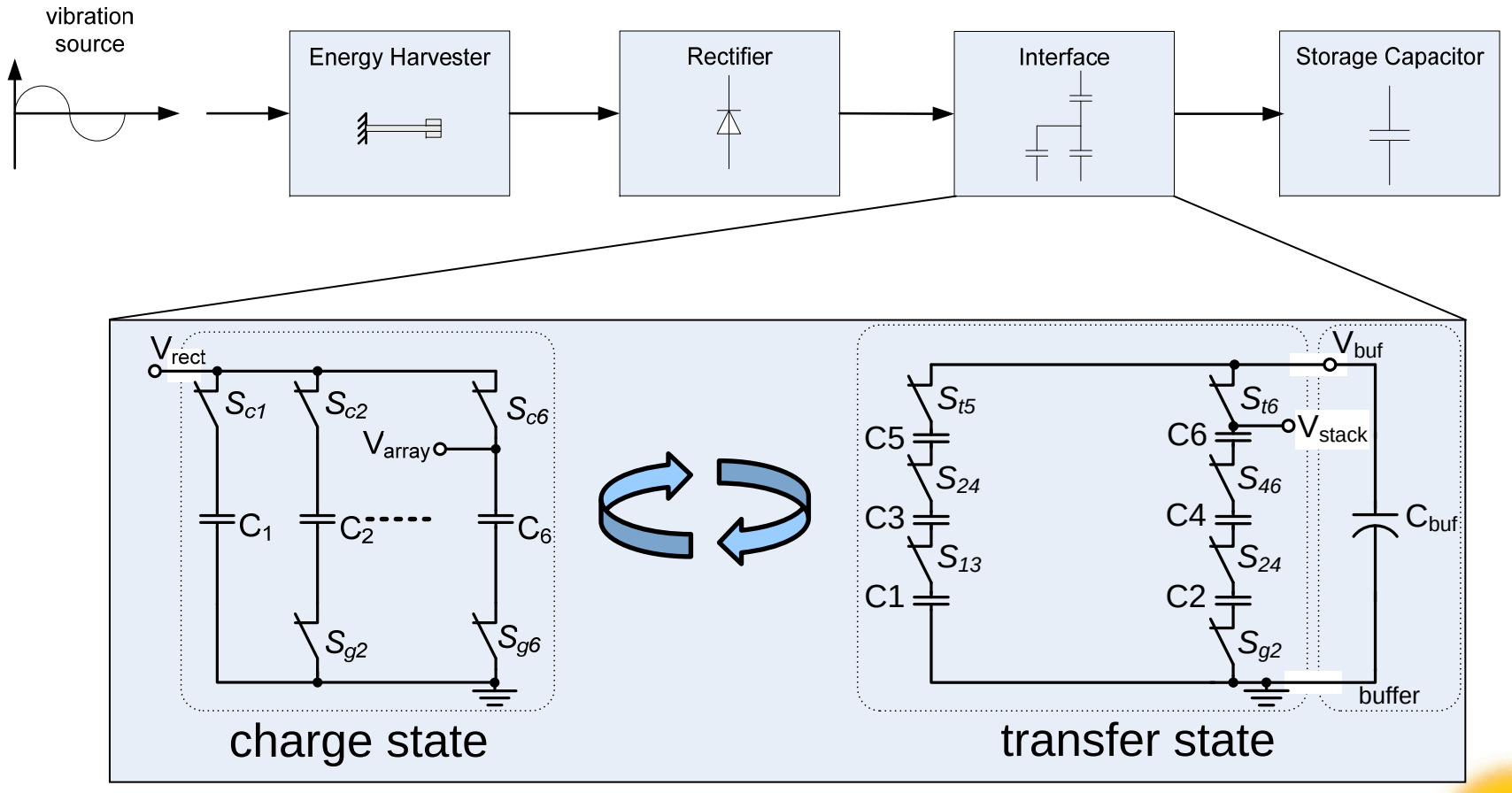
- Characteristic values
  - Relatively high output voltage
  - Relatively low output current



# Interface for electromagnetic EH

## Basic concept of Adaptive Switched Capacitor Interface (Maurath et. al.)

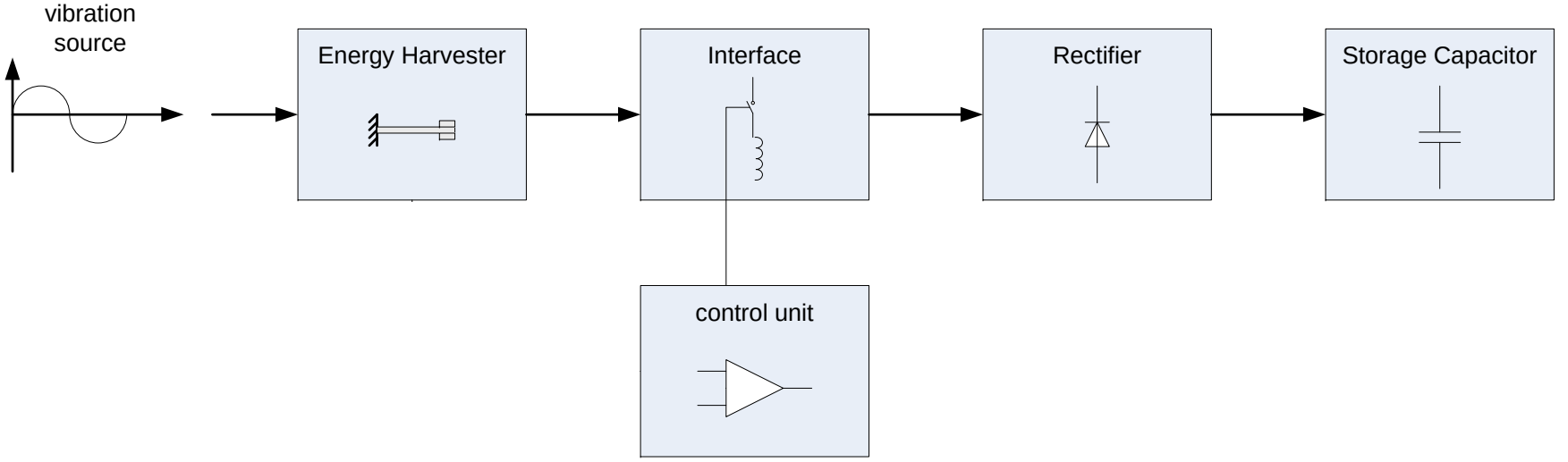
- Voltage conversion by changing the arrangement of a capacitor array

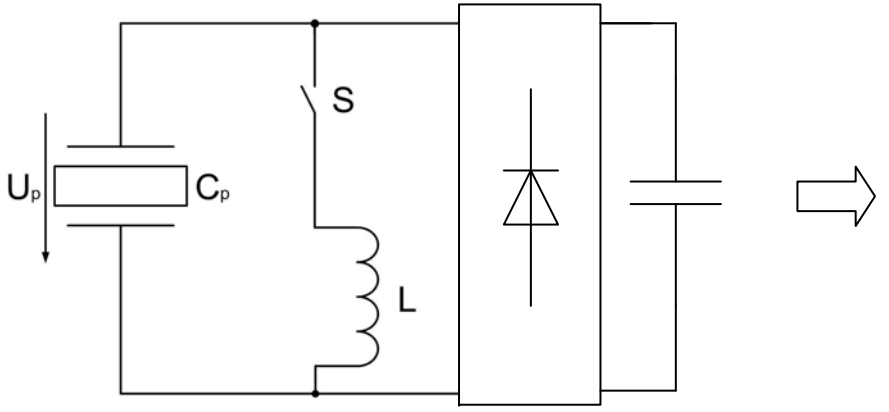


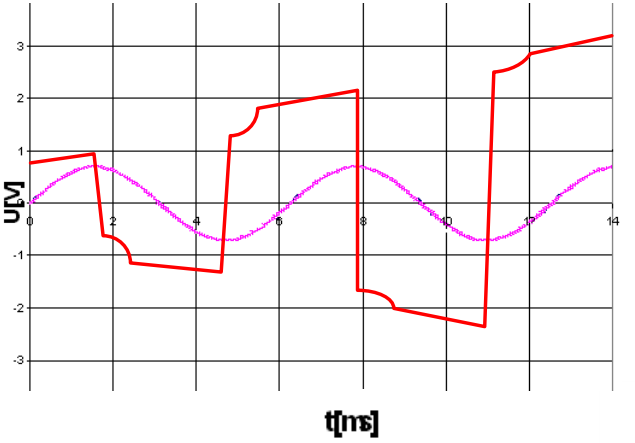
# Interface for piezoelectric EH

## Basic concept of parallel SSHI interface (Guyomar et. al.)

- Switch-on momentary a coil in parallel to the piezoelectric generator



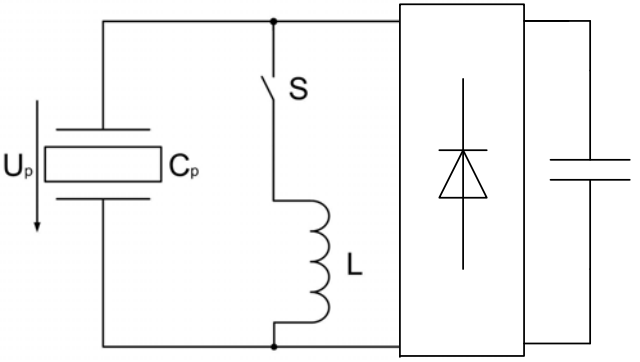



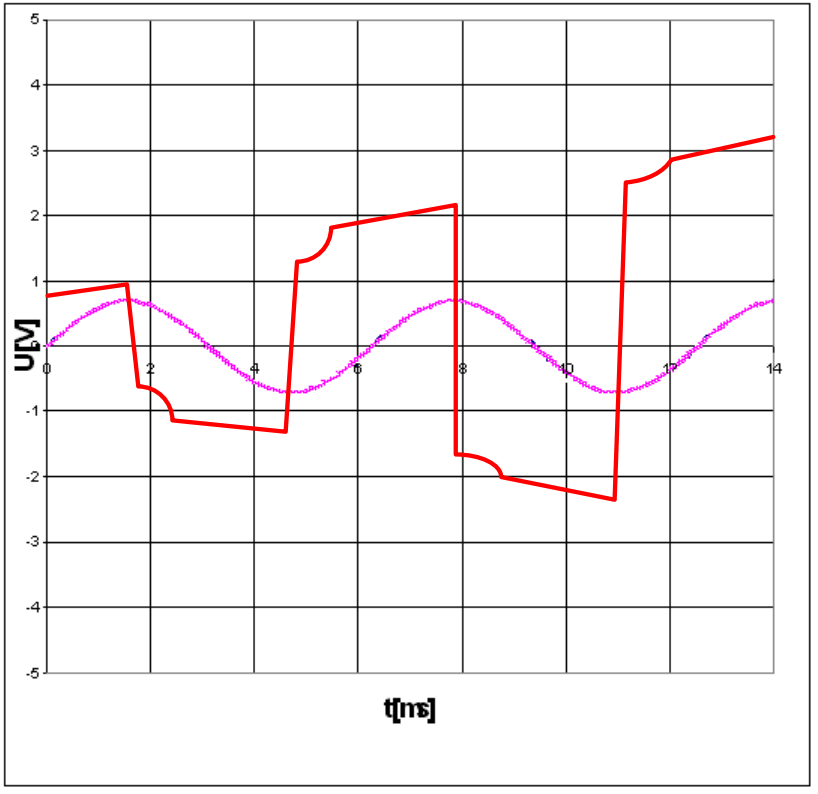



# Parallel SSHI

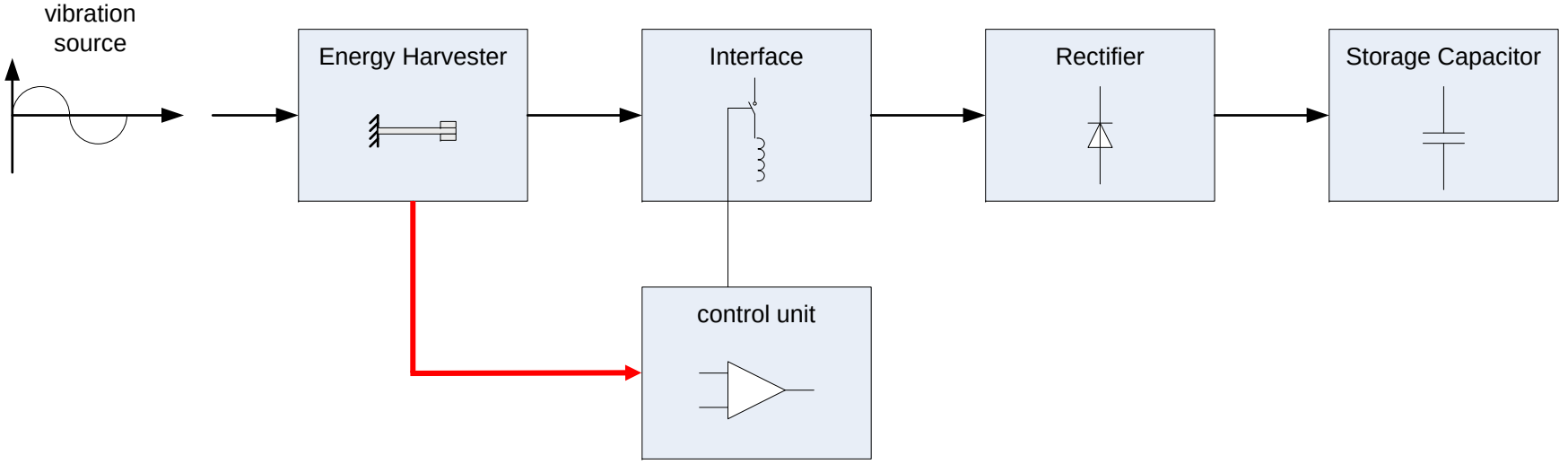
## Exact trigger points

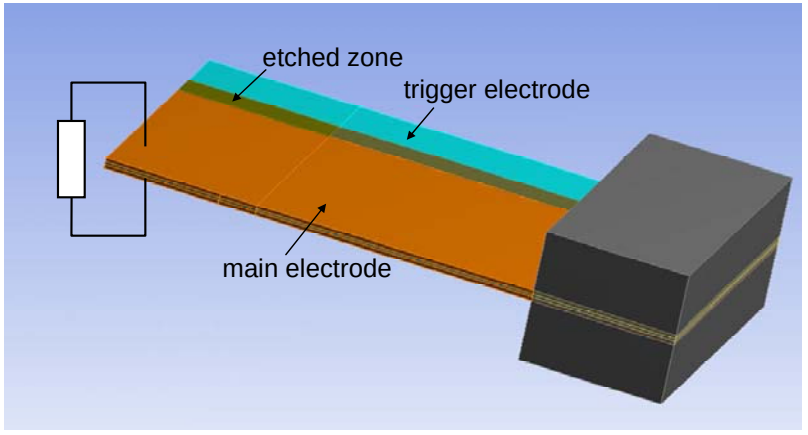
- Highly sensitive influencing parameter
- Switch-on at voltage maximum
- No exact trigger information due to rectifier and storage capacitor
- Default settings
  - ➢ Not possible under varying excitation conditions
- Sensor to observe the piezo movement
  - ➢ Increases the energy consumption of the entire system

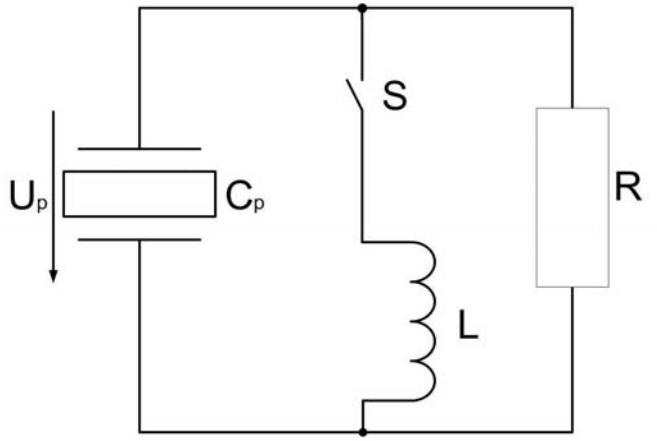


# Direct SSHI



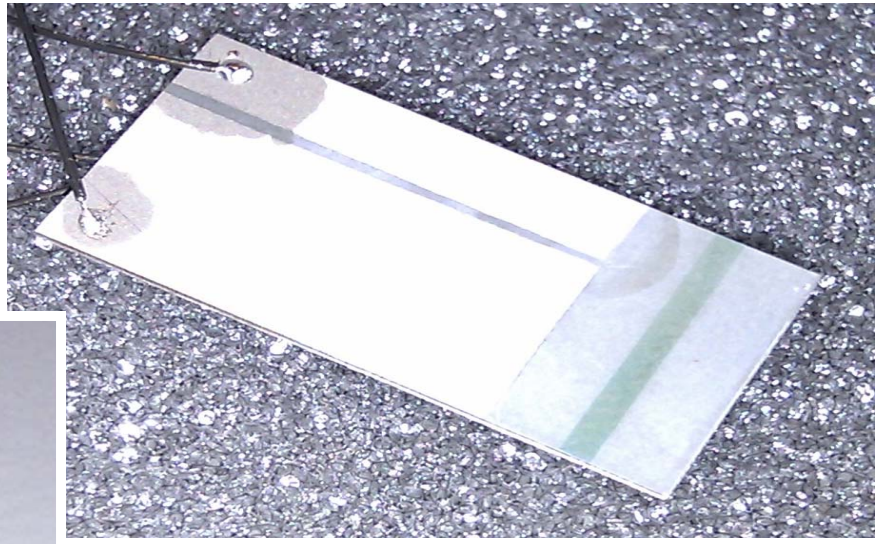



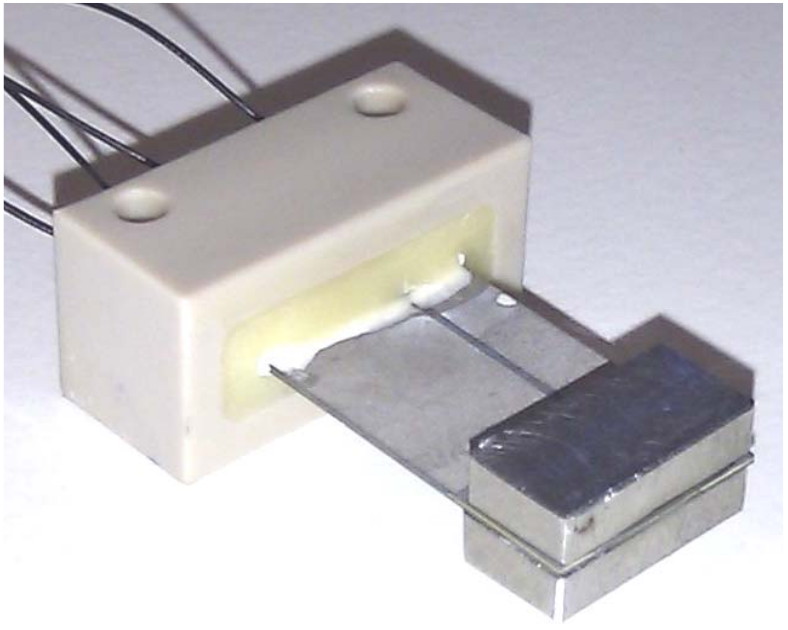

- Energy Harvester / trigger generator
  - 2 electrode structures on the same substrate
- Interface
  - SSHI (Guyomar et. al.)

# Energy Harvester

## First prototype of the piezoelectric generator

- Piezoelectric bimorph beam with 2 separated electrode structures
- Relatively big trigger electrode for the test structure
- Size may be reduced for the end device

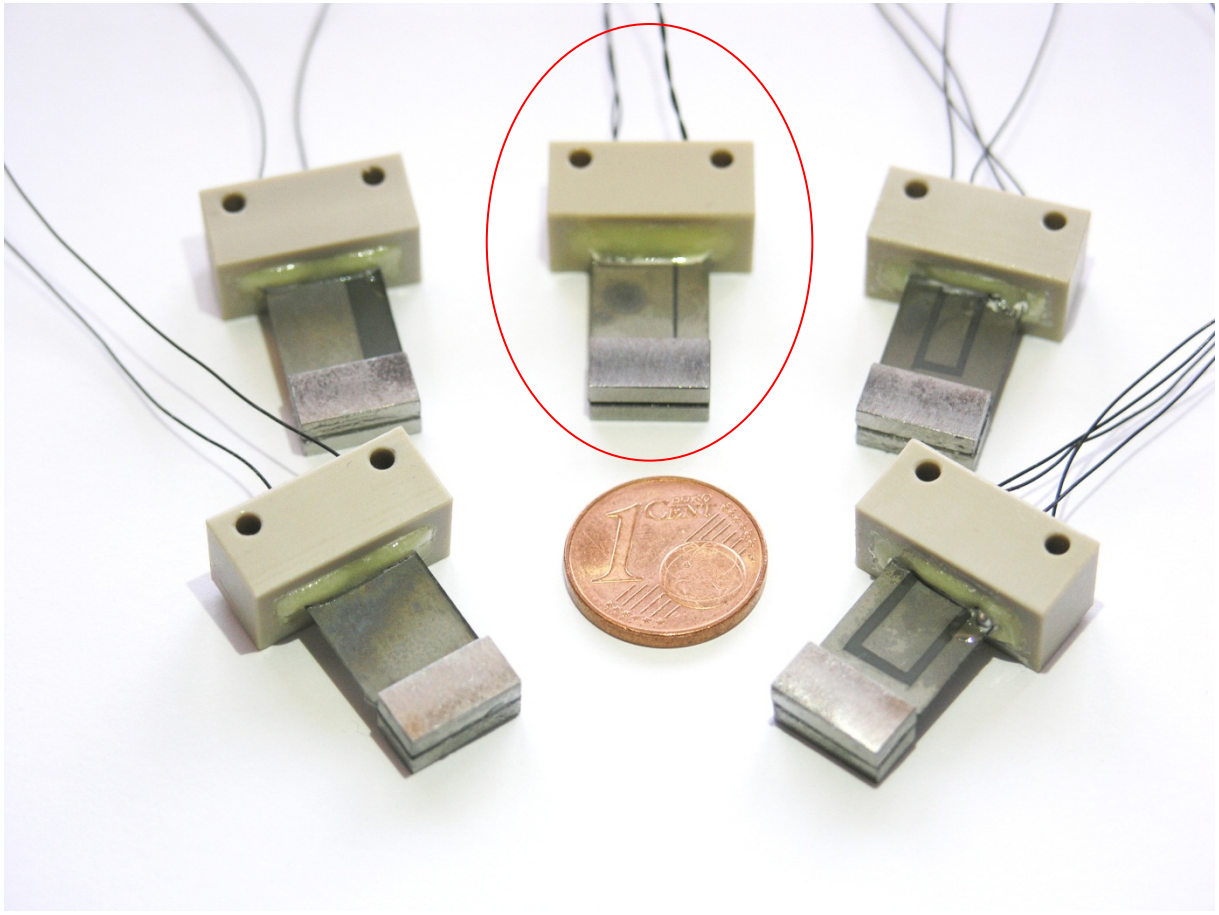




# Energy Harvester

## Generator design

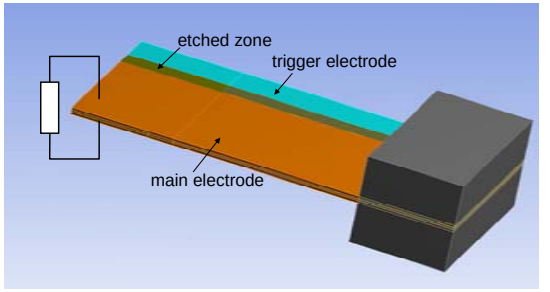
- Different electrode structures



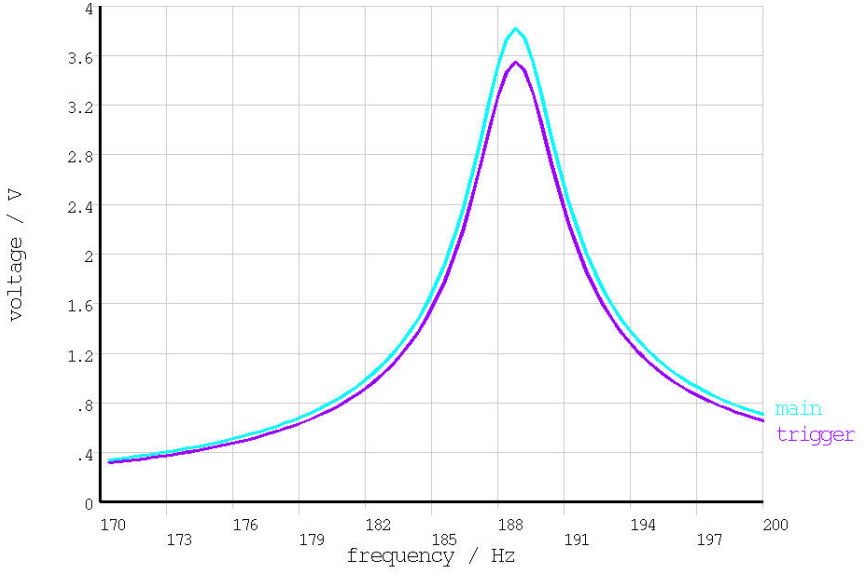
# Energy Harvester

## Piezoelectric bimorph beam with 2 separated electrode structures

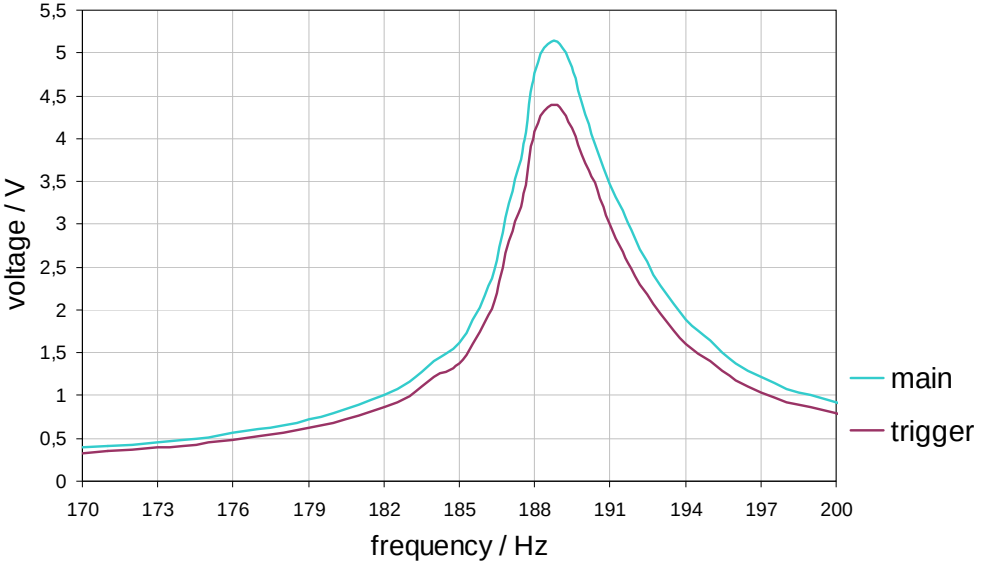
- FEM simulation for calculation of the resonance frequency
- Main generator & trigger generator
- Measurement results



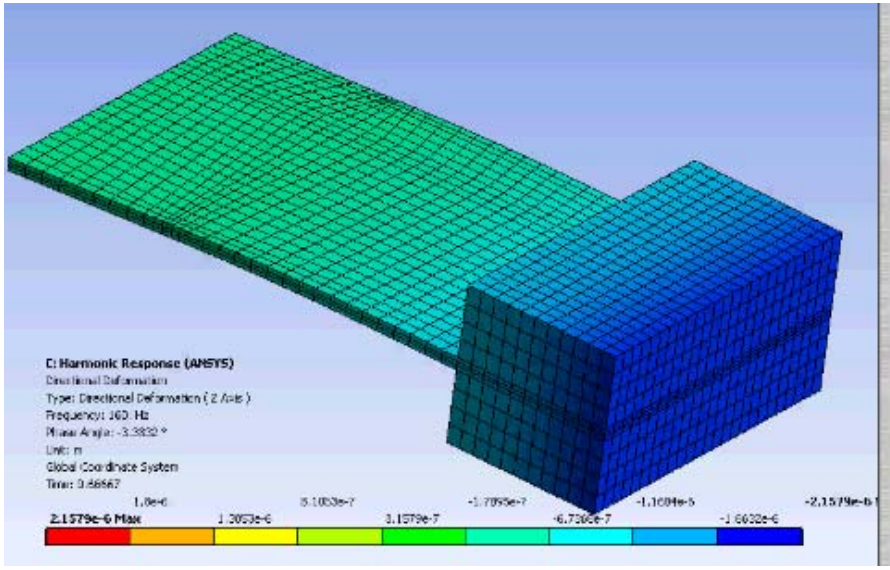

FEM simulation results

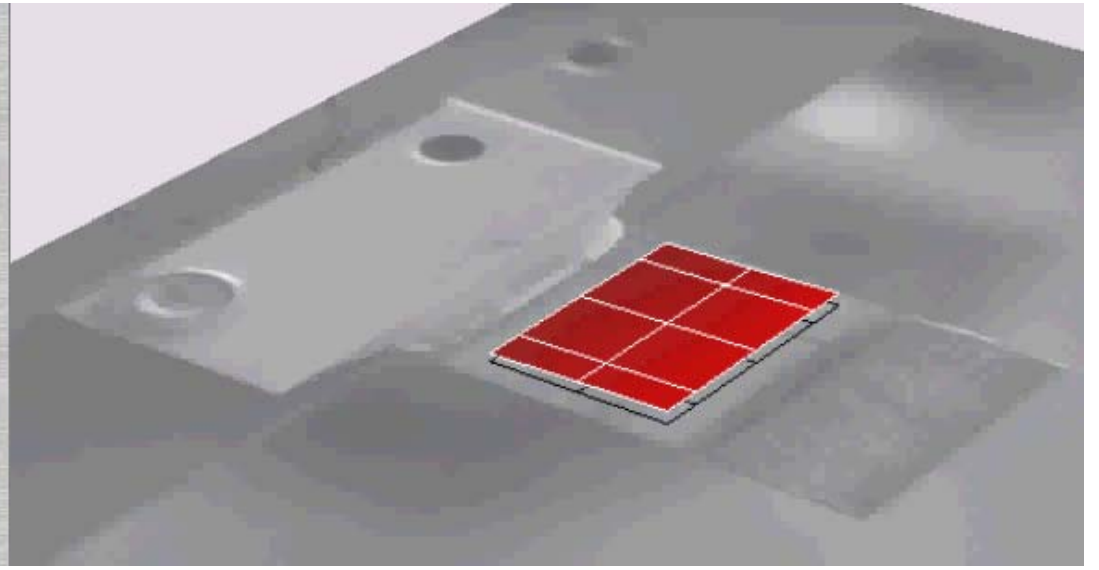



Measurement results



# Generator deformation

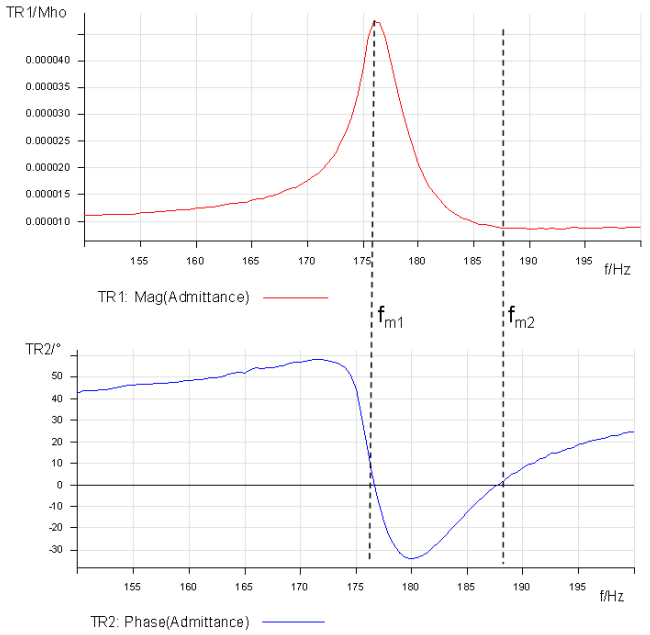


- FEM simulation
- Laser vibrometer measurements

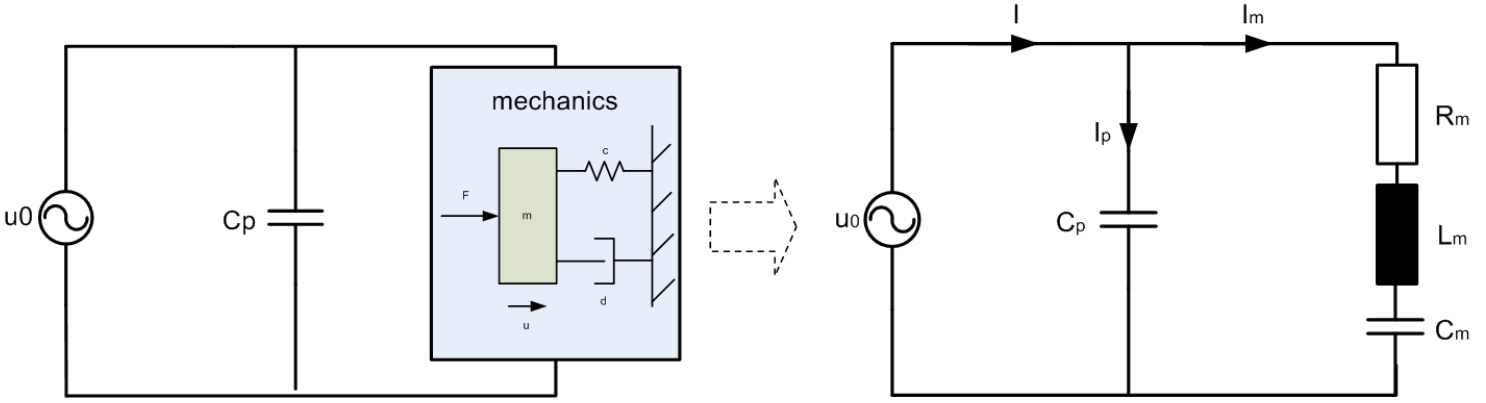
# Generator Design

## Electrical Simulation




## Electro-mechanical analogues

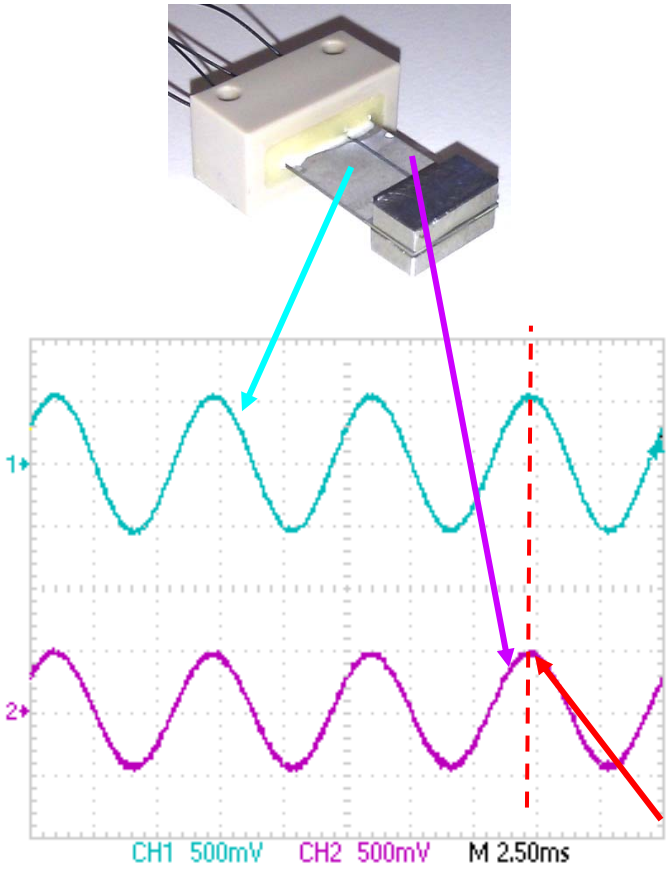
- equivalent circuit
- input for spice based simulations



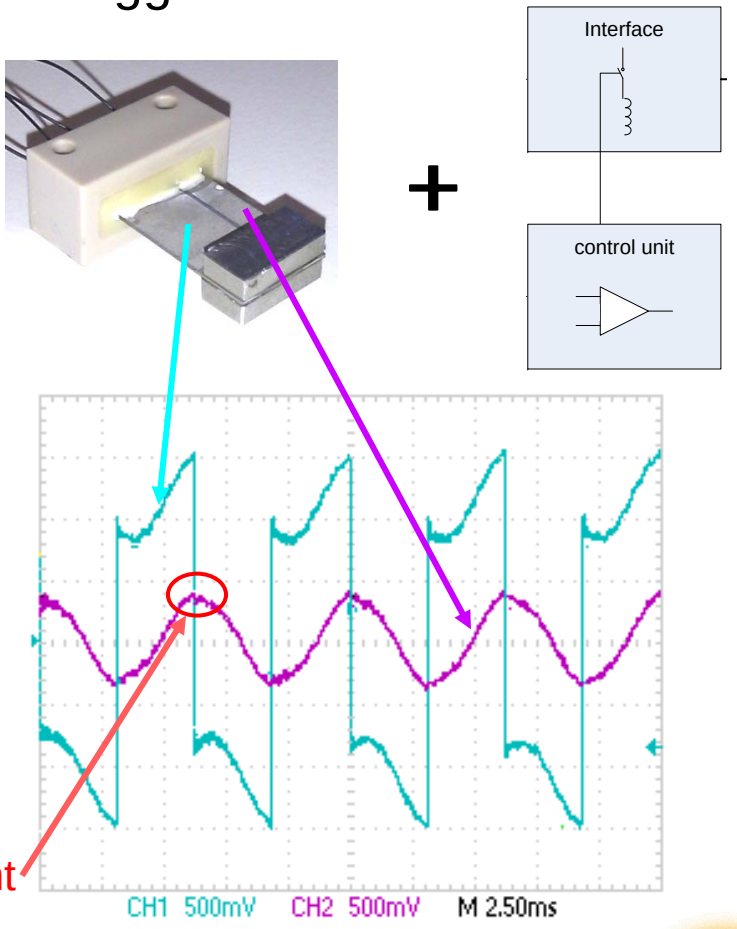
# Measurement results

## Voltage signals of:

- Main electrode
- Trigger electrode




- Main electrode + SSHI Interface
- Trigger electrode

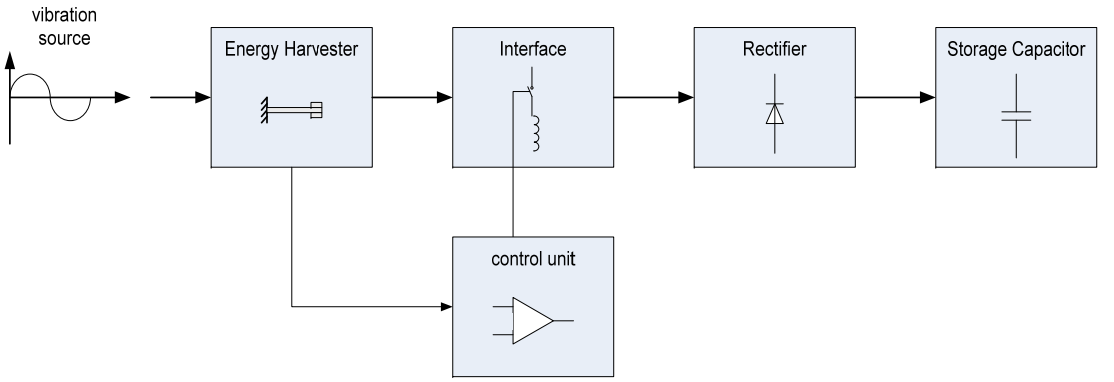



trigger point

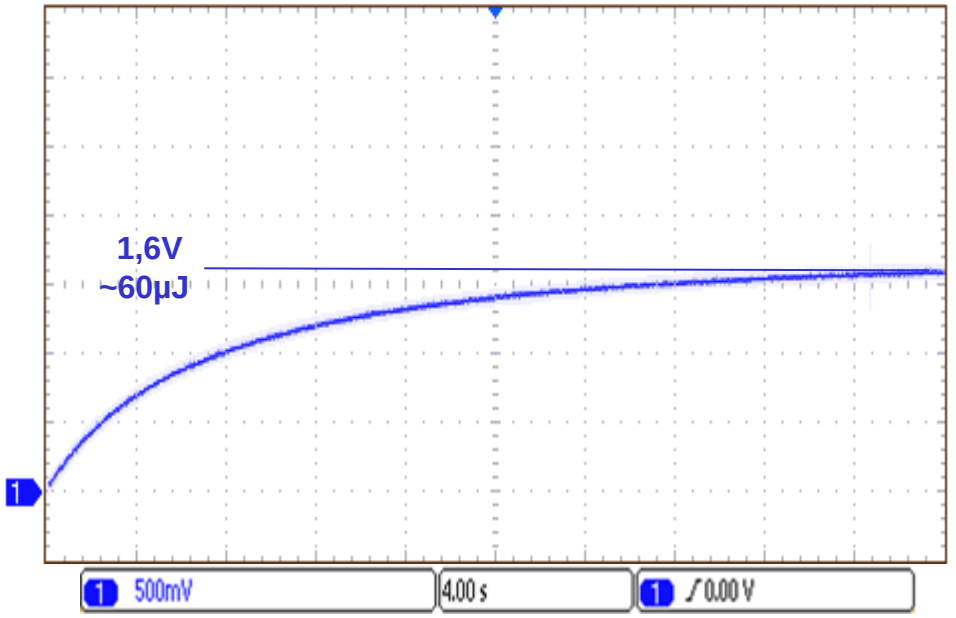
# Charging a capacitor

## Measurement results:

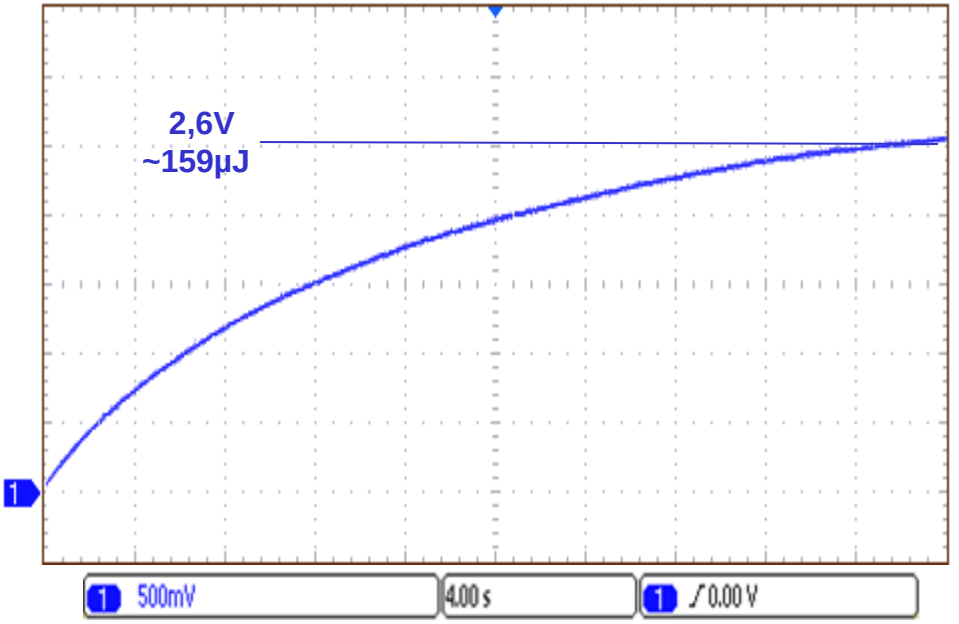
- Charging an energy storage (Capacitor: 47µF)
- W = ½ CU²




Standard




Direct SSHI



# Outlook

## Conclusion

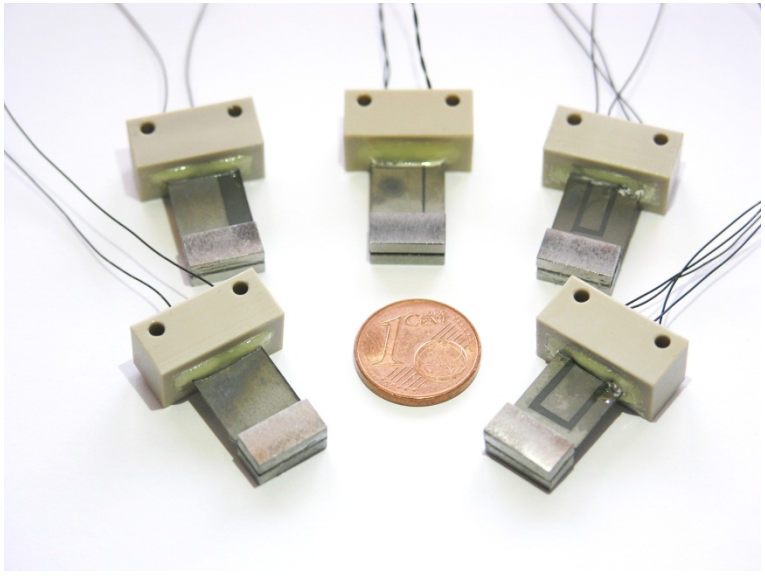
- Different types of energy harvesters need different types of interfaces
- Interface circuits can enhance the usable energy

## Future work:

- Integrated CMOS circuitry
- Optimization of the electrode structures
  - Smaller trigger electrode

# Contact information

## Thank You for Your Attention!

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