MOBILE TEST SUMMIT 2024

SELF-POWERED WIRELESS SENSORS FOR THE IOT

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Make ideas real

Self-powered Wireless Sensors for the IoT

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Self-powered Wireless Sensors for the IoT

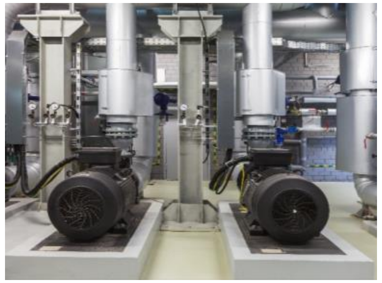
Agenda

- Motivation
- Energy Harvesting
- Examples of self-powered sensors
  - Thermal power supply
  - Mechanical power supply
- Outlook
- Summary

Self-powered Wireless Sensors for the IoT

Motivation

- Presently, there are more than 13 billion wireless **IoT devices** worldwide, expected to reach 25 billion by 2030
- **Industrial IoT** is connecting machines, plants and processes to increase efficiency, productivity, safety and reliability
- **Information and Communication Technology (ICT)** is collecting transmitting and processing data by sensors to control machines, plants and processes:
  - Monitor consumption: **Save resources**
  - Predict maintenance: **Avoid down-time, increase productivity**
  - Stop operation when failures happen: **Minimize or avoid damages**
- **Bottleneck:** Power supply
  - Cables: Huge installation effort and access to the power grid
  - Batteries: Maintenance effort, huge amounts of waste and energy for battery production



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Self-powered Wireless Sensors for the IoT

Energy Harvesting: Principles and Benefits

Energy Harvesting uses ambient energy like light, heat or movement to generate electric power.

Benefits

- Wireless power supply
- Low installation costs (no wires)
- No maintenance for battery replacement or charging
- Reduction of costs (installation costs vs. maintenance effort)
- Unlimited stand-by and operation time
- Operation in inaccessible locations
- Higher temperature range
- Environmental friendly(ier)

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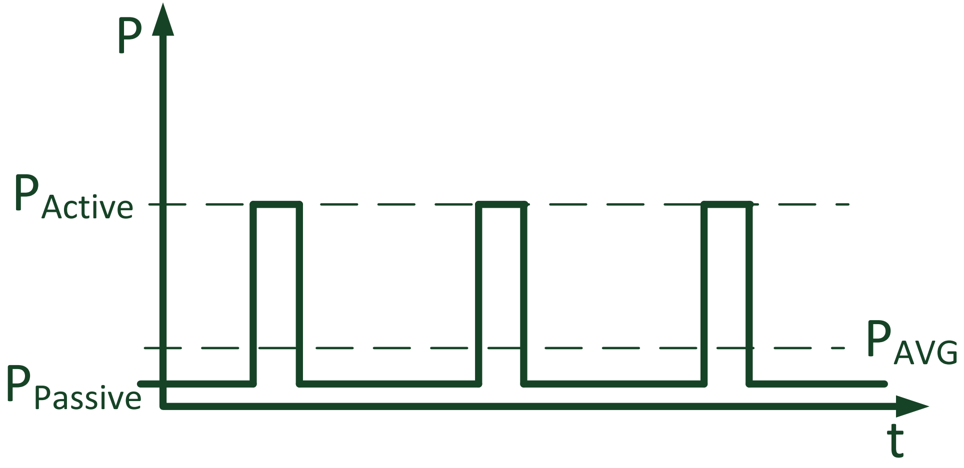
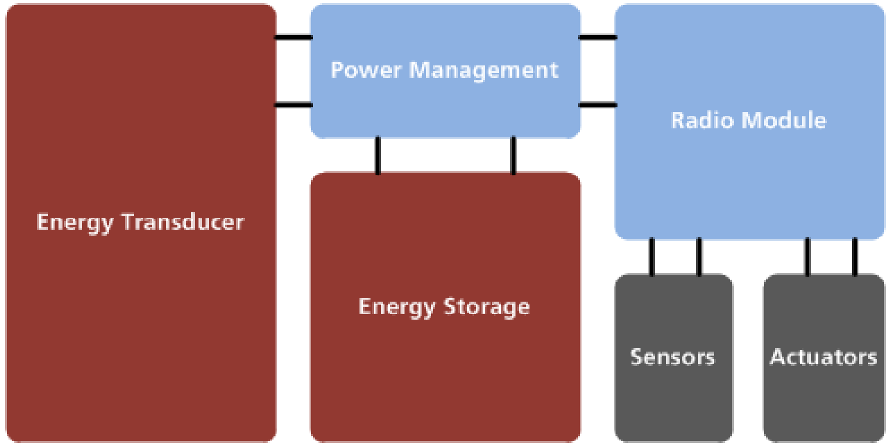
Energy Harvesting: Generic Architecture

The challenge is to collect and make use of even smallest amounts of ambient energy to power shorts actions.

Functional blocks

- Energy transducer
- Power management
- Energy storage





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Self-powered Wireless Sensors for the IoT

Examples of self-powered sensors

BlueTEG
Temperature sensor with Bluetooth LE connectivity and thermoelectric power supply

Use Case:	Machine Monitoring
Duty Cycle:	1 sec
Coverage:	10 m

VIHWA
Vibration sensor with Bluetooth LE connectivity and mechanical power supply

Use Case:	Machine Monitoring
Duty Cycle:	1 sec
Coverage:	10 m

Q-Bo®
Preload force sensor with LPWAN module and solar or thermoelectric power supply

Use Case:	Screw Monitoring
Duty Cycle:	1 h
Coverage:	5 km

ENTRAS
GPS-Tracker with cellular communication and energy harvesting power supply

Use Case:	Metering, Tracking
Duty Cycle:	1 h
Coverage:	10 km

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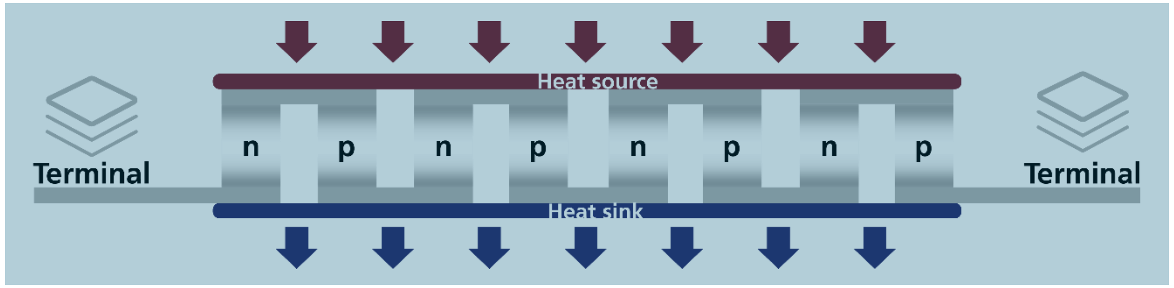
BlueTEG: Thermoelectric Power Supply

The thermoelectric generator uses a heat gradient to generate an electric voltage (Seebeck effect).

- Heat difference on a surface
- Cold side has to be cooled to maintain thermal gradient
- Heat sources: Machines, engines, pipes, HVACs, human body, etc.
- Voltage is proportional to the temperature difference (e.g. 50 mV/K)
- Low thermal gradients can be used with ultra-low start-up voltage converters

Thermoelectric generator



Functional principle thermoelectric generator

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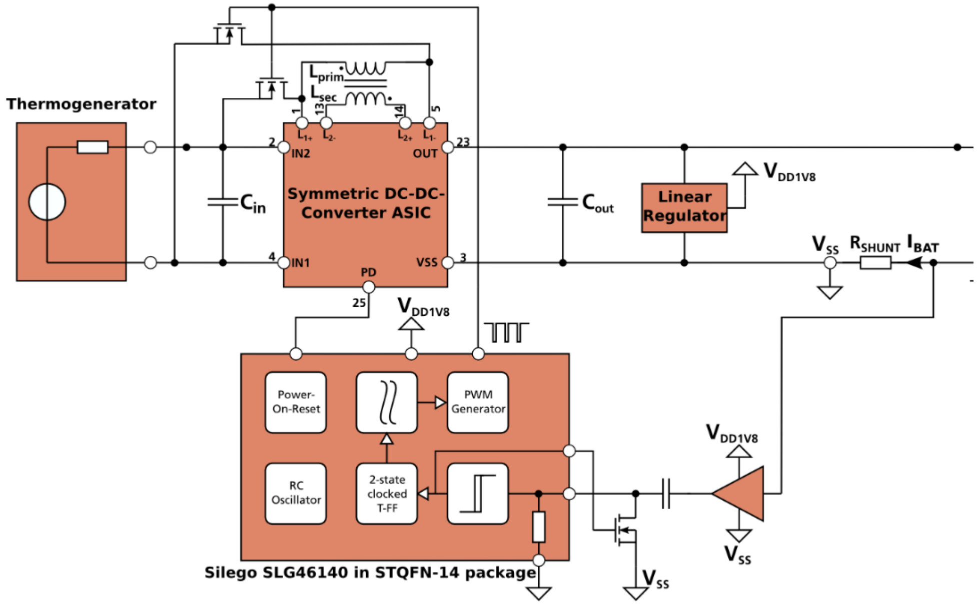
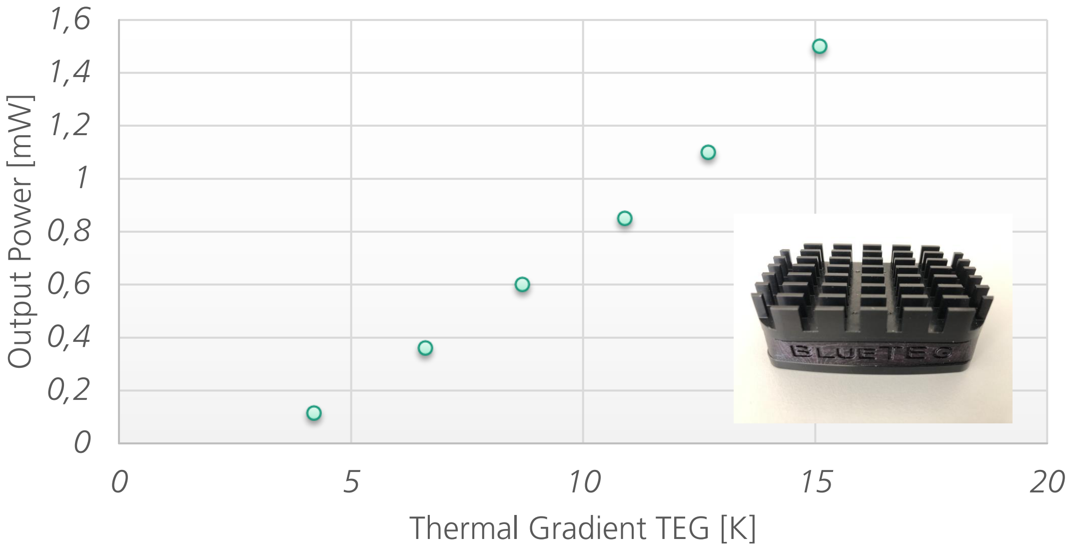
BlueTEG: Power Management

Optimized ultra-low power voltage converters with a low cold-start voltage enable the use of smallest thermal gradients.

- Starts with 20 mV due to JFET and transformer
- Works with minimum thermal gradient (2-3 K)
- Accepts bipolar inputs voltages: Hot or cold surfaces





Output power of thermogenerator with DC-DC converter (gradient on TEG, module size incl. heat sink: 7*2.5*4 cm)

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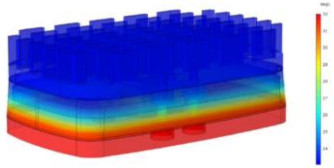
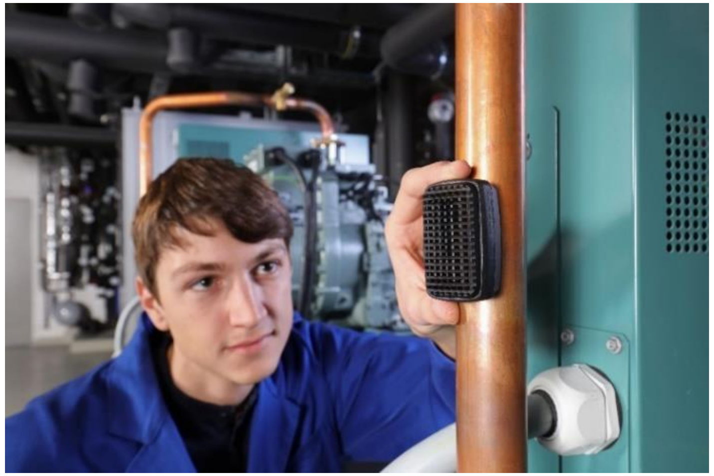
BlueTEG - Self-powered Temperature Sensor

Small thermal gradients are often available on industrial equipment and can be used to power wireless sensors.

- Power supply by thermo-electric generator
- Ultra-low-start-up voltage DC-DC converter
- 3 K thermal gradients provides ca. 100 µW (70 cm^3)
- Bluetooth LE: 1 Telegram per second
- Sensors: Temperature and acceleration
- Applications: Pipes, supply circuits, housings





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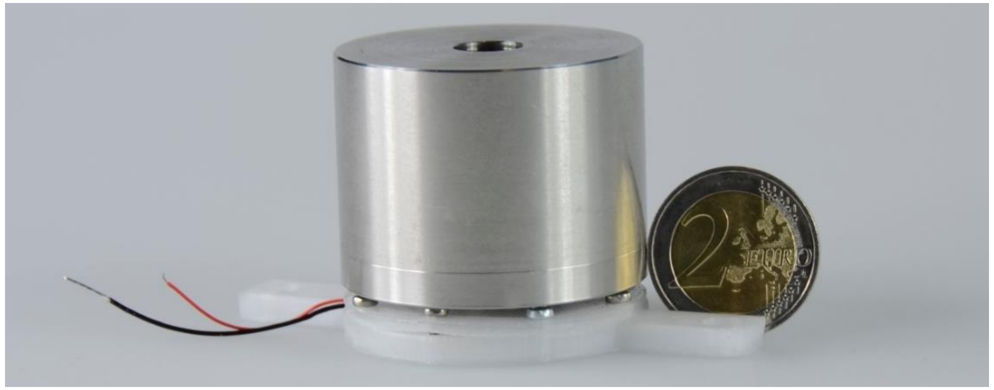
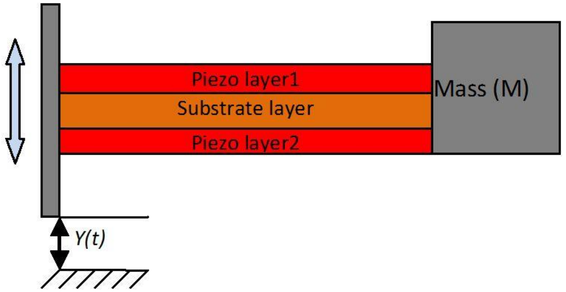
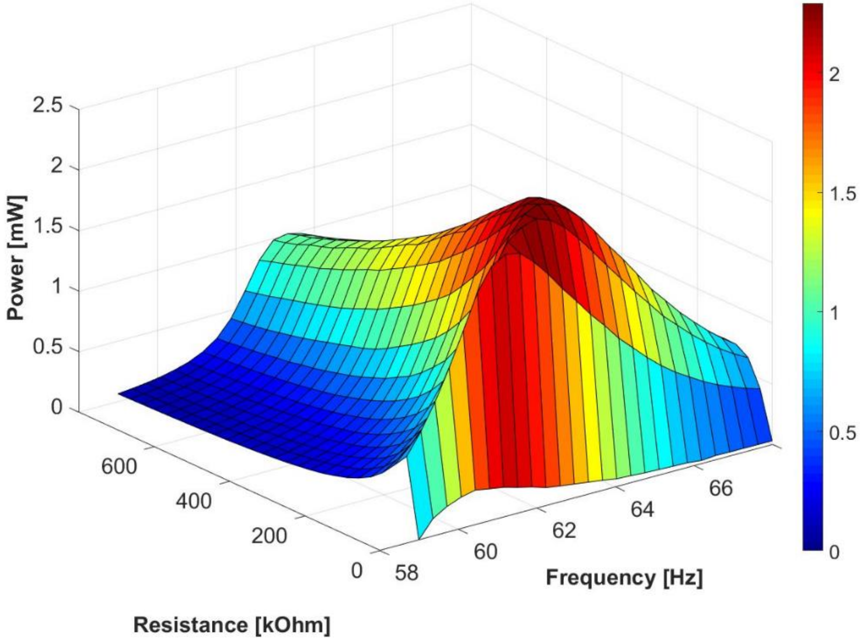
VIHWA: Mechanical Power Supply

Mechanical energy in form of vibrations and deformation can be used to generate electrical energy.

- Low-cost, simple design with piezoelectric material
- Power output up to 3 mW with 0.1 g excitation
- Wide harvesting bandwidth up to 12 %
- Center frequency mechanically tunable (e.g. 65 and 100 Hz)







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VIHWA – Self-powered Vibration Sensor

Machines, plants or vehicles provide serious amounts of vibration in a given spectrum to be used for powering wireless sensors.

- Self-powered wireless sensor VIHWA
- Ultra-low-power energy management
- 1 mW from 0.1 g at 60 Hz
- Bluetooth LE: 1 Telegram per second
- Sensors: Temperature, acceleration
- Applications: Engines, plants, vehicles etc.

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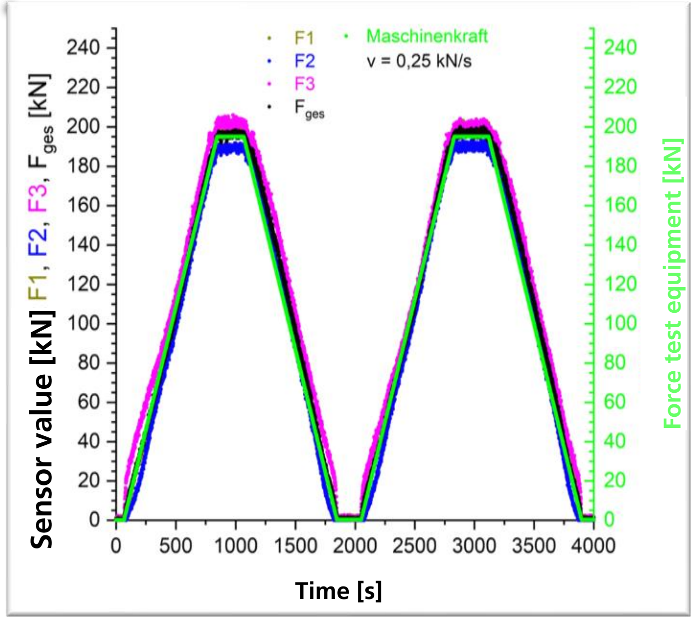
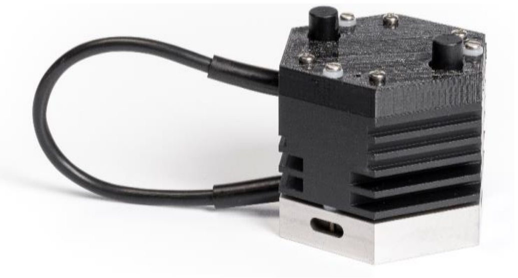
Self-powered Wireless Sensors for the IoT

Q-Bo®: Preload Force Sensor

Regular inspection of screws and fasteners is mandatory in numerous applications. It can avoid failure and downtime.

- Q-Bo®: Integration of a DiaForce®-force sensor in the washer of a screw
- LPWAN mioty®-module for communication
- Self-powered energy supply (solar, thermo-electric, battery)
- Q-Bo transmits periodically preload force and temperature:
  - Solar: 500 lux – 30 min, 18.000 lux – 30 sec
  - Thermal: 8 K – 30 min, 25 K – 30 sec
- Applications: Wind turbines, buildings, bridges, large vehicles, pipelines





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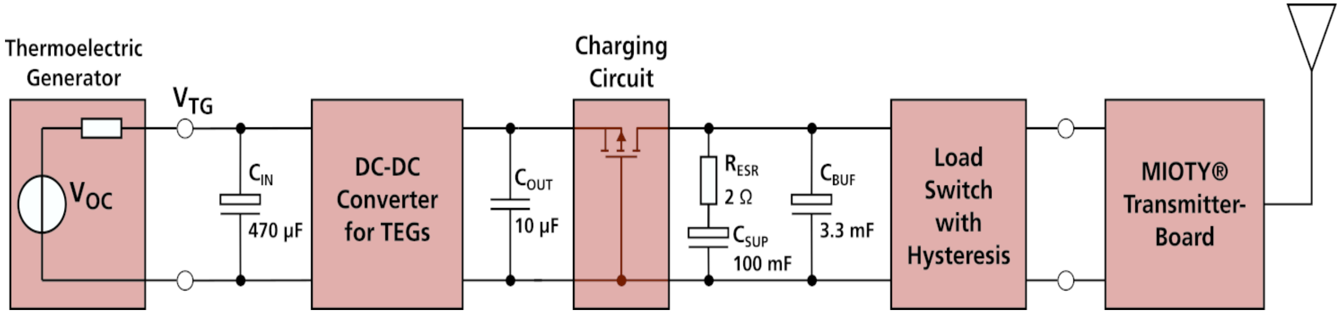
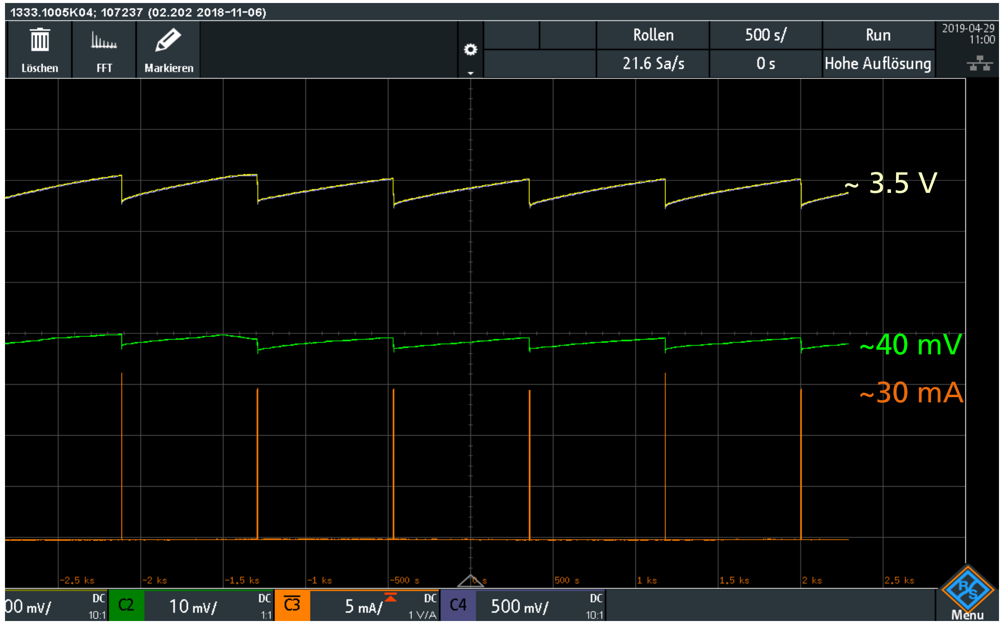
Self-powered Wireless Sensors for the IoT

Q-Bo®: Overall Architecture

Innovative micro energy management enables self-powered LPWAN mioty® in various environments.

- ULP DC-DC converter to use voltages from smallest thermal gradients
- Charging circuit for super capacitor
- Load switch to avoid start before enough energy is available





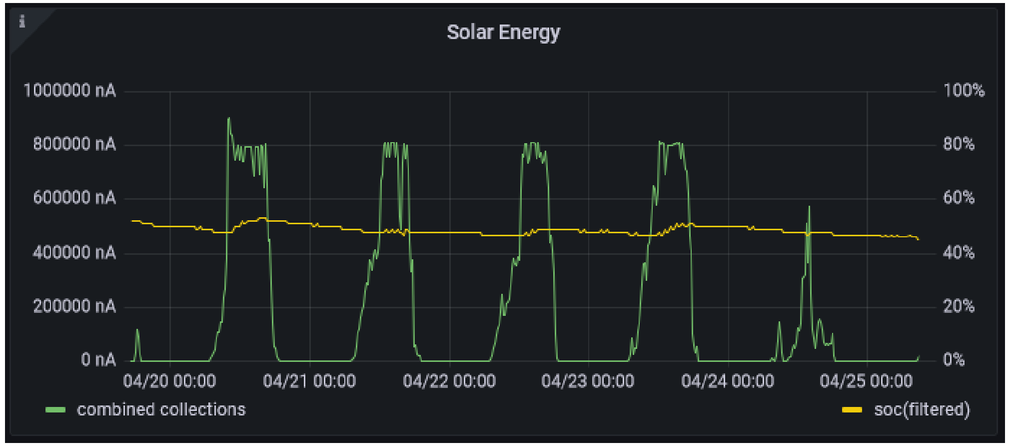
Output voltage TEG (green, 10 mV/div); Output voltage energy management (yellow, 500 mV/div); Input current MIOTY board (orange, 10 mA/div)

Self-powered Wireless Sensors for the IoT

ENTRAS: GPS-Tracker

Self-powered cellular communication can be used to read out various kinds of industrial sensors.

- Narrow-Band IoT (NB-IoT), alternatively LTE-M for public communication
- Thermal power supply
  - Thermal gradient of 13 K, TEG harvester 37 *37 * 20 mm
  - Measurement every 15 min, transmission every 1 h
- Solar power supply
  - Solar module 72 * 48 * 3 mm
  - Measurement every 15 min, transmission every 1 h
- Use Cases: Tracking (container, vehicles, waggons, assets), building monitoring, energy metering



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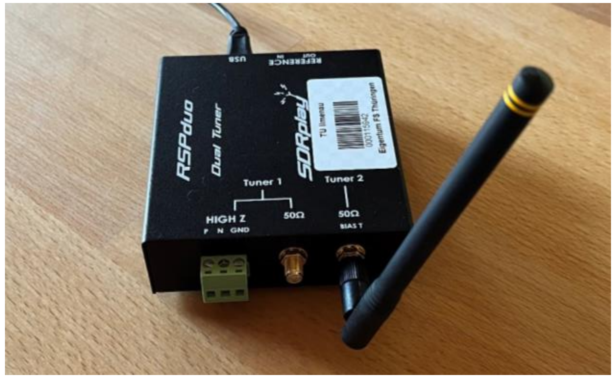
Self-powered Wireless Sensors for the IoT

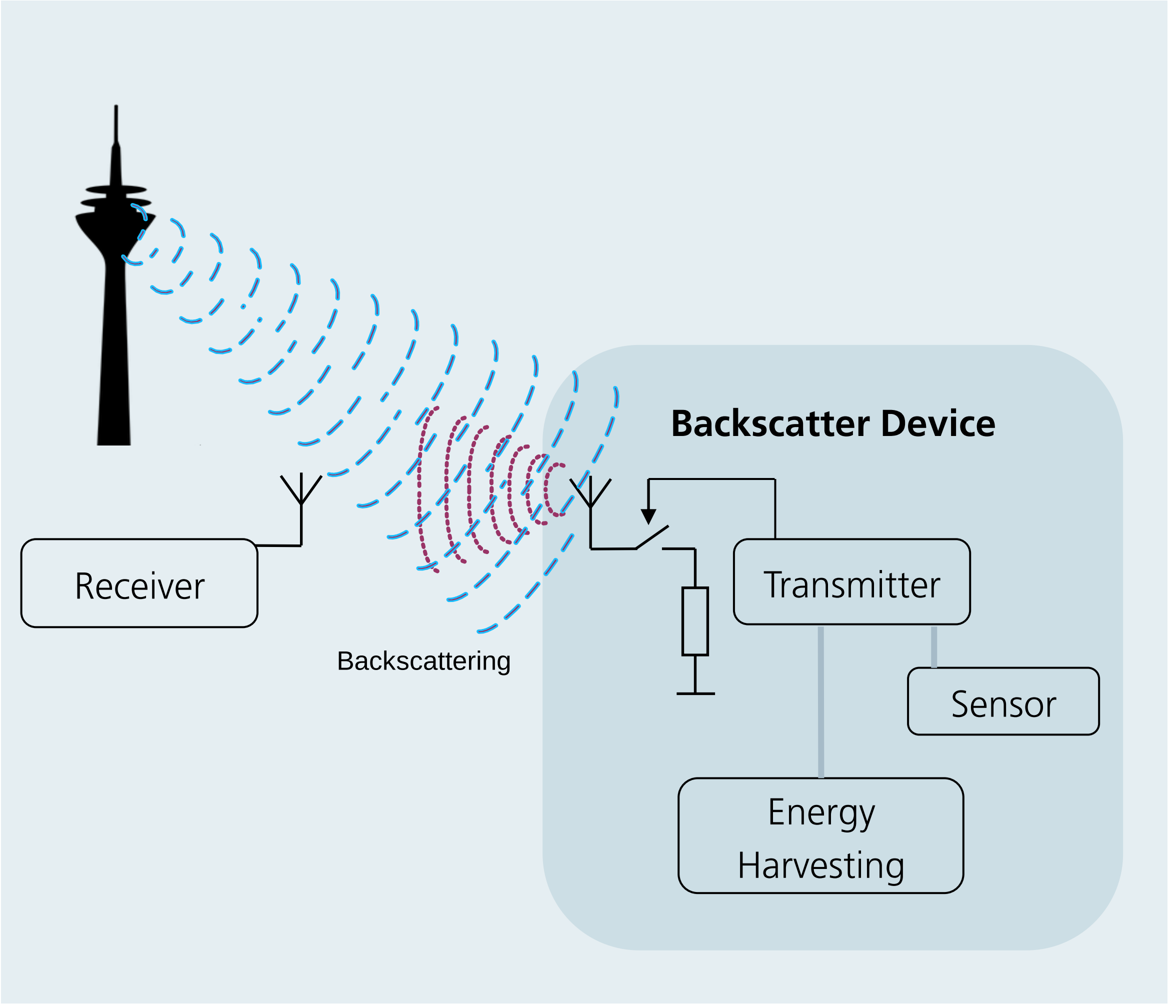
Outlook: Ambient Backscatter

- Reflect and modulate public signals like GSM, DAB, DVB-T, etc.
- Simple, cheap sensor devices possible
- Employ energy harvesting when no RF signal is present or as additional source
- Coverage 10s up to 100s of meters
- Application areas: Smart home, environmental monitoring, health, agriculture

Transmitter: Backscatter Device

Receiver Device





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Self-powered Wireless Sensors for the IoT
Summary

- A bottleneck in wireless IoT sensors is the power supply
- Low maintenance and installation effort are key for feasibility, economic success and low ecologic impact
- Coverage and duty cycle of the wireless sensors determine their power requirements
- Ambient energy sources differ strongly between applications and use cases

Use case specific customization is key to achieve self-powered operation with maximum performance

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