High-Temperature UHF RFID Sensor Measurements in a Full-Metal Environment

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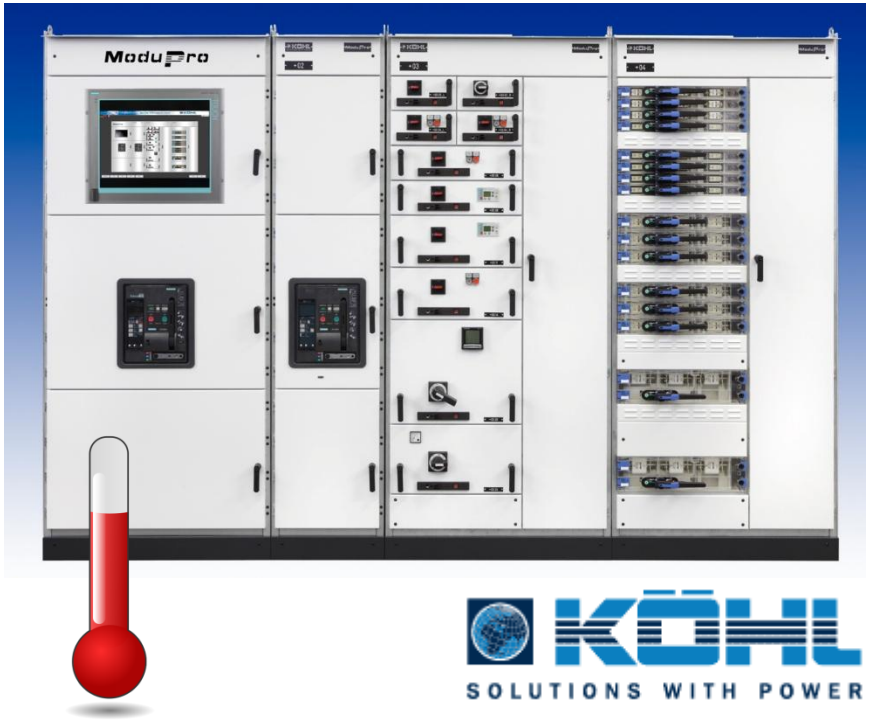
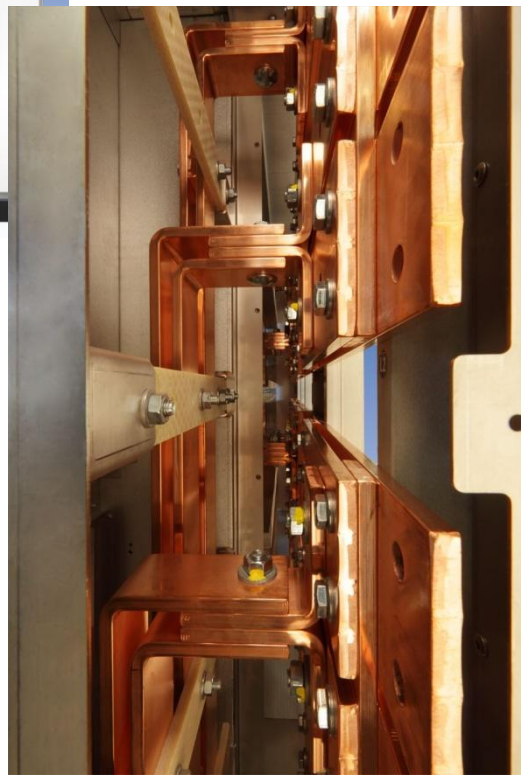


Inside of a switchgear

- Voltage: 690V
- Current: 4kA
- Frequency: 50Hz
- Temperature: 125°C



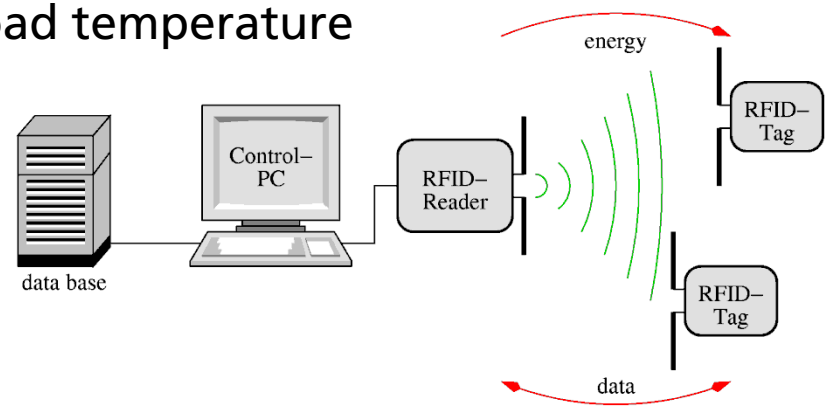
The Problem

- Screw connections may become loose
  - Thermo-mechanical stress
- Electrical contact resistance increases
  - Contact points heat up
- Catastrophic result:
  - Fault arc
  - Power loss in the supplied building

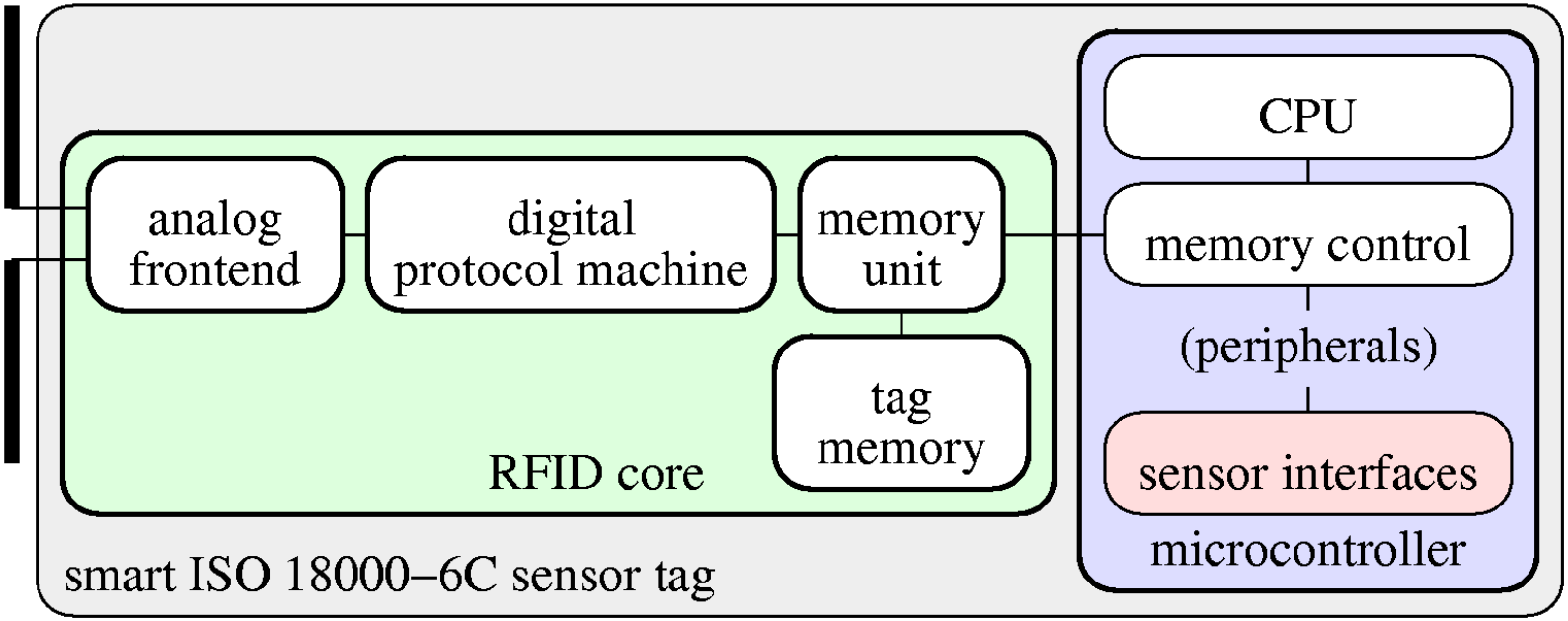
→ Observation of the temperature
  - Long-term trend analysis

Application requirements

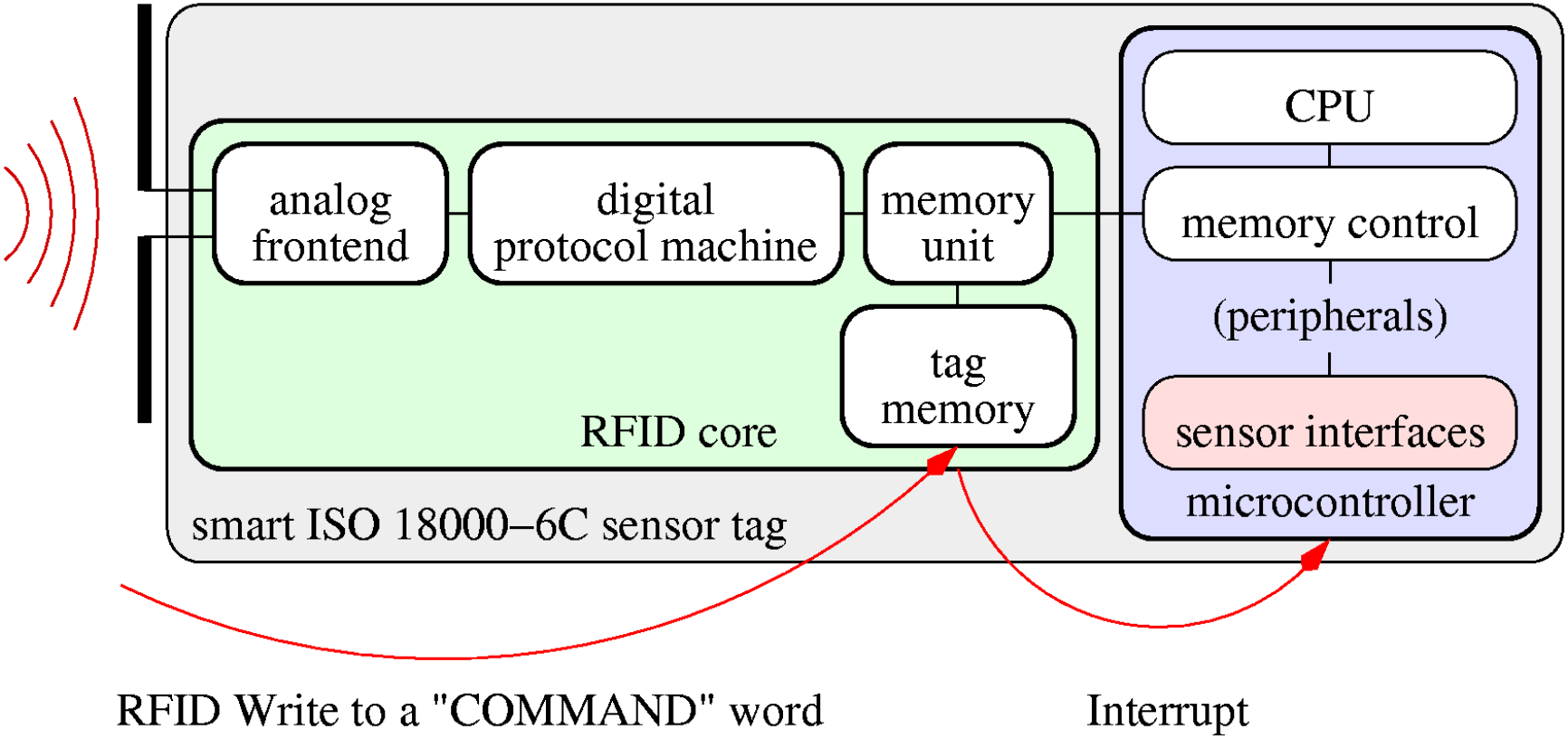
- Wireless temperature sensing
- Monitoring of several contact points inside a safety enclosure
- Maintenance-free / battery-less (10 - 20 years)
- Full metal environment
- High temperatures:
  - 105°C critical operation temperature
  - 125°C maximum acceptable workload temperature



The RFID Sensor Platform

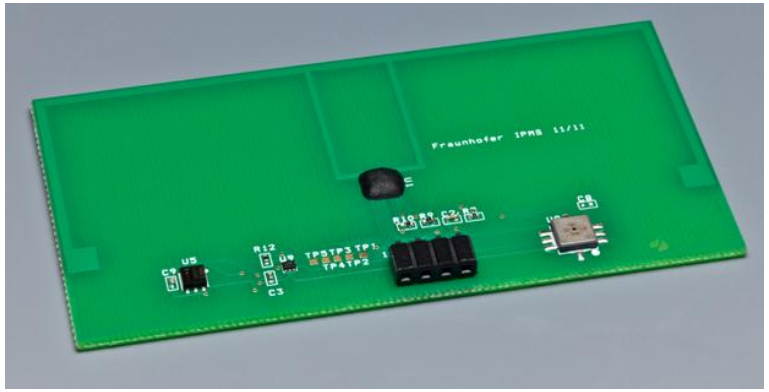


Processing a Command

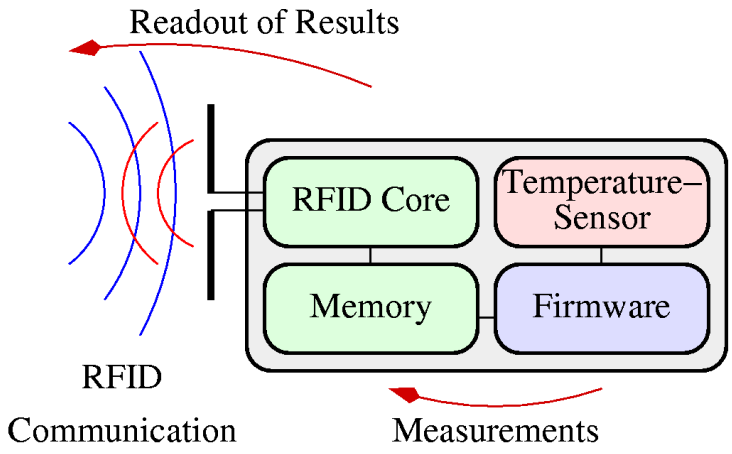


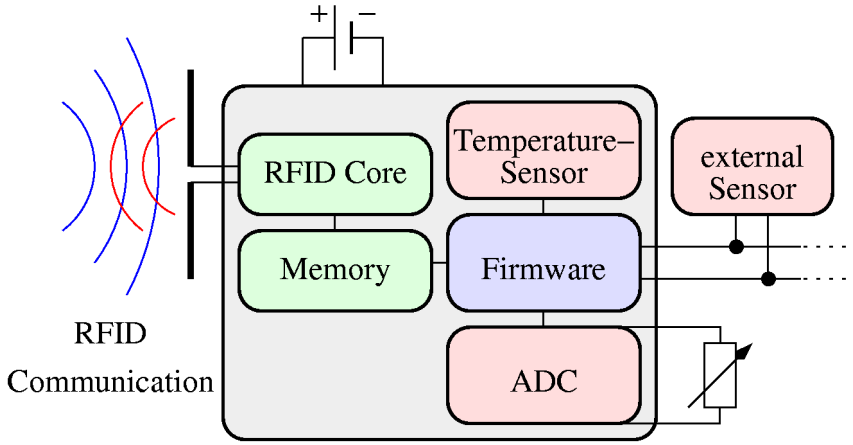
Features of the RFID Sensor Platform

- UHF-RFID: EPC Class1Gen2 / ISO 18000-6C (868MHz in Europe)
- On-chip Microcontroller (8 bit): (re)programmable
  - Firmware Application: Wireless Sensor or Data Logger
- Internal Sensors: Temperature, A/D-Converter
- External Sensors: Temperature, Humidity, Pressure (all I²C)
- Extendable in software and hardware
  - E.g. cryptographic core



Application Examples





Wireless Sensor
- Internal Temp. Sensor, ADC
- External Sensors

Data Logger
- Up to 3 sensors at a time
- Programmable measurement interval
- External interrupts
- 2 Logging modes
  - All measurements
  - Only measurements outside selectable limits

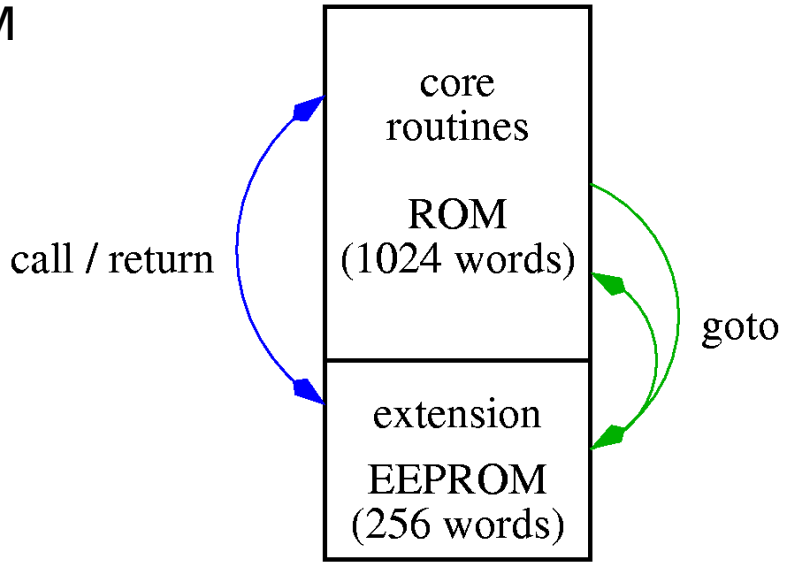
Adaption of the System to the Usecase

- ASIC fabrication process: XFab xa035 (170°C)
- Internal temperature sensor
  - Adjustment for desired temperature range
- Internal A/D converter
  - Support of K-type thermocouples added (Chromium / Nickel contacts: thermoelectric effect)
- No EEPROM
  - Serial number in OTP zap-diodes (32)
  - Firmware fixed in ROM

Regaining Flexibility for a ROM-based Microcontroller

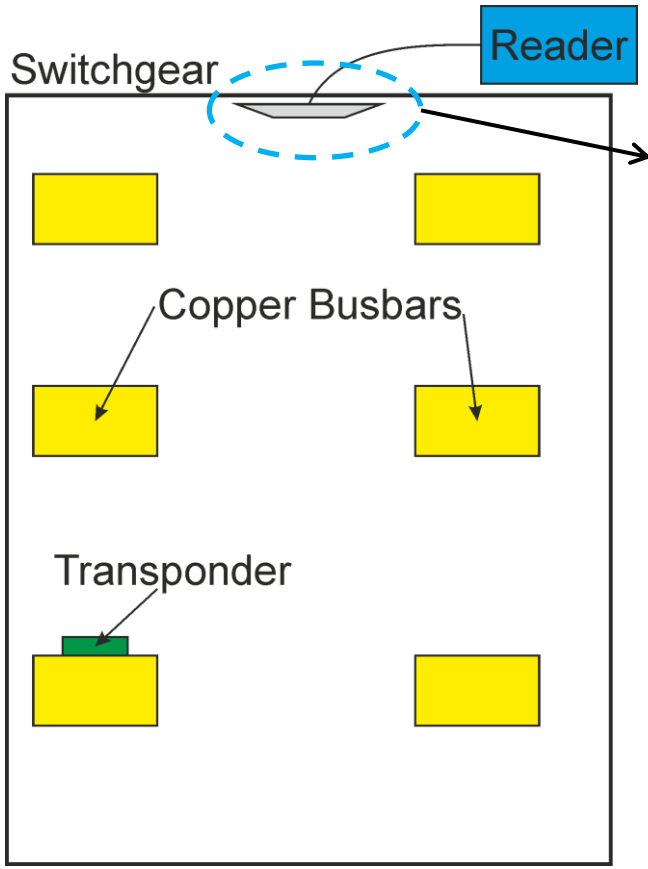
- In ROM: Flexible functions, configurable at runtime
  - Usage of parameters in the COMMAND word

- For low temperature operation:
  Firmware extandable using an EEPROM
  - During normal operation:
    No jump into EEPROM
  - If requested by a COMMAND:
    Jump to a predefined address
    in the EEPROM



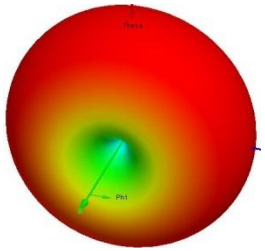
System Design

- Outside of the enclosure is build up by a metallic box
- Inside has irregular and switchgear-individual metal shapes
- Reader antenna is placed inside the box (lower temperature)
- Transponders are placed on the busbars (high temperature)

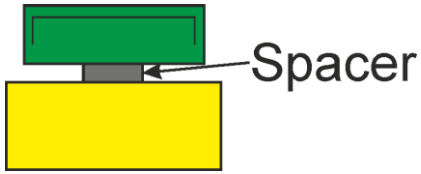


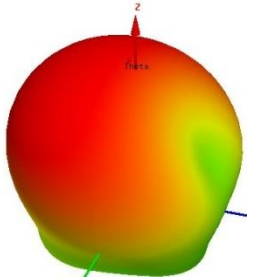
System Design

- First tests with our previous Sensor Platform ASIC
  - Is designed to operate in free space
- Placing on the busbar with a small spacer leads to
  - Enhanced gain
  - Reduced impedance match
- Reflections in the enclosure
  - Amplification and cancellation points
  - High field strengths
- → Operation range is enlarged
- Next step: Optimization of the transponder antenna



Radiation pattern in free space





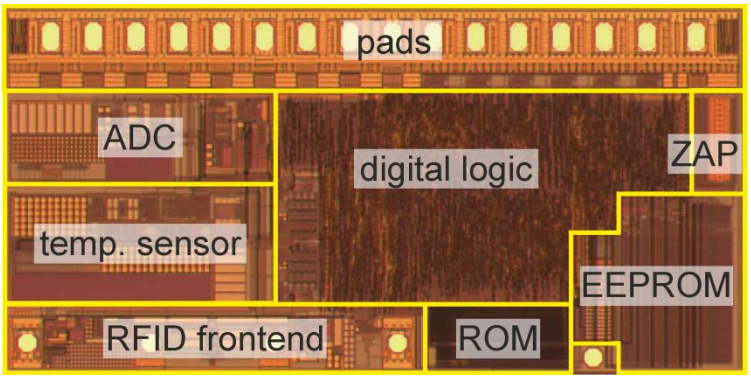
Radiation pattern on bus bar

Results

- Sensor measurements in a full-metal enclosure using our previous Sensor Platform ASIC and commercial I²C sensors
  - Free space communication: 1m
  - In switchgear: 1,5m
- Development of a new ASIC for high-temperature operation
  - Successful wafer test
  - Internal sensors under test and in qualification
  - Improved free space communication range: 2m

Benefits

- Human operator protection
  - Prevention of fault arcs
  - Fully automated observation at runtime including all safety mechanisms
- Reduction of power dissipation
- Scheduled maintenance
  - Shutdown and maintenance can be planned weeks before the system runs critical



Hannover Messe

Thermo Oberservation via RFID

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