WHITEPAPER

The Future of Smart Sensors in Consumer Electronics

Paper Focus:
Overcoming the challenges of power efficiency and miniaturization demands

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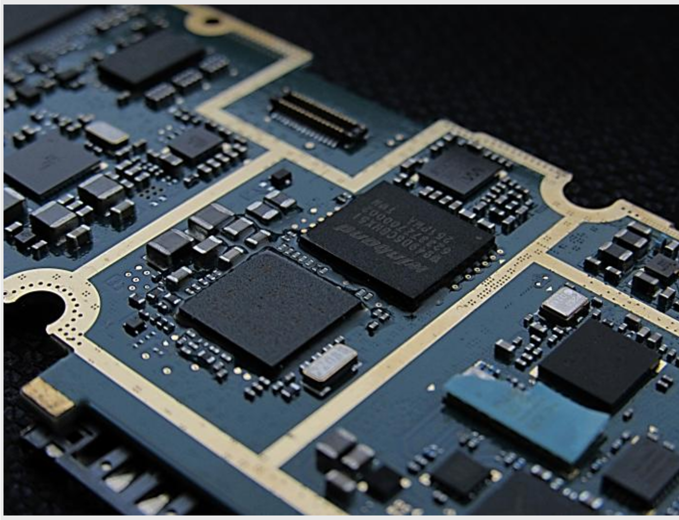
INTRODUCTION

Selected Challenges in IoT

Smart sensors are widely used in consumer electronics such as smartphones, wearables, and smart home devices.

However, several challenges arise when integrating and utilizing these sensors effectively:



Power Consumption

Smart sensors continuously gather and process data, often requiring significant power.

Balancing functionality with battery life is a critical challenge in portable devices.

Low-power designs are essential to ensure that devices like smartphones and wearables maintain a long operational life.

Miniaturization

Consumer devices demand compact designs, requiring sensors to be highly miniaturized without sacrificing performance.

Manufacturing small, yet highly accurate sensors can be expensive and technically challenging.

HOW TO OVERCOME THE CHALLENGES...

- ***Reducing Power Consumption***
- ***Achieving Miniaturization***

Applies to many IoT applications, such as...

Smart City	Smart Home	Smart Energy	Connected Health
Smart Mobility	Public Safety / Environmental Monitoring	Smart Farming	Connected Industry

Reducing the power consumption (I)

1. Use Low-Power Hardware

Energy-Efficient Microcontrollers (MCUs) - select MCUs optimized for low-power operation. Efficient run modes, ultra-low-power sleep modes and fast wake-up times are crucial to reducing power consumption

Low-Power Sensors: Use sensors designed specifically for low-power applications, which often include built-in power-saving modes.
Efficient Analog Front Ends (AFE): Use AFEs tailored to reduce noise and power usage in analog signal processing.

2. Duty Cycling

Periodic Activation: Operate the sensor only, when necessary, by implementing duty cycling, where the sensor sleeps for most of the time and wakes up intermittently to gather data.

Dynamic Scheduling: Adjust the sampling rate dynamically based on real-time needs, reducing unnecessary measurements when activity is low.

3. Optimize Communication

Low-Power Communication Protocols: Use low-energy wireless protocols like BLE (Bluetooth Low Energy), Zigbee, LoRaWAN, or Narrowband IoT (NB-IoT).

Edge Processing: Perform data processing locally (on the edge) to reduce the frequency and volume of data sent to the cloud.

Efficient Data Transmission: Minimize transmission size by using data compression and reducing redundant data before sending.

Example IoT Wearables:

Use MEMS sensors with built-in motion detection to trigger activations instead of continuously sampling.

The Solutions

Reducing the power consumption (II)

4. Implement Energy Harvesting

Ambient Power Sources: Integrate energy harvesting methods like solar, vibration, RF, or thermal energy to supplement battery power.

Supercapacitors and Rechargeable Batteries: Use energy storage components that can be efficiently recharged by harvested energy.

5. Utilize Sleep Modes

Deep Sleep Modes: Configure the sensor and MCU to enter deep sleep modes when not actively sensing or transmitting data.

Peripheral Shutdown: Turn off non-essential peripherals (e.g., LED indicators, idle communication modules) during idle periods.

Wake-on-Event Mechanisms: Use event-based triggers, such as interrupts, to wake the system only when certain thresholds are met.

6. Optimize Sensor Design

Intelligent Thresholds: Configure sensors to operate only when a specific threshold is crossed (e.g., temperature exceeding a limit), reducing active time.

Multi-Function Sensors: Use multi-functional sensors to reduce the number of components, which can simplify circuitry and lower power draw.

Analog Signal Processing: Perform basic analog pre-processing (e.g., filtering, amplification) before data is digitized, reducing computational load.

Example Smart Agriculture Sensors:

Utilize LoRaWAN for low-frequency data reporting and solar power for recharging.

Reducing the power consumption (III)

7. Software Optimization

Code Efficiency: Write efficient firmware code to minimize unnecessary loops, computations, and power-draining operations.
Adaptive Sampling Rates: Use machine learning or adaptive algorithms to adjust sampling rates based on conditions or trends.
OTA Updates: Support over-the-air updates to improve sensor algorithms and optimize power use over time.

8. Use Advanced Power Management ICs (PMICs)

Energy-Efficient Regulators: Use low-dropout (LDO) regulators or switching regulators optimized for low-power operation.

Dynamic Voltage Scaling (DVS): Adjust the operating voltage of the sensor system based on workload requirements.

9. Collaboration Between Hardware and Software

Ensure tight integration between hardware capabilities (e.g., low-power modes) and software optimization to maximize efficiency.

Leverage application-specific integrated circuits (ASICs) for tasks like machine learning inference to save energy.

10. Monitoring and Testing

Power Profiling: Use power profiling tools to measure and analyze the power consumption of each component, identifying inefficiencies.
Iterative Optimization: Continuously test and refine the design to address specific power bottlenecks.

Example Smart Home Devices:

Use Wi-Fi modules with sleep modes and trigger them via wake-on-LAN signals.

Achieving Miniaturization (I)

1. Choose Compact Sensor Technologies

MEMS (Microelectromechanical Systems):
Utilize MEMS technology, which integrates mechanical and electrical components at the microscale, for compact and efficient sensors. Common in accelerometers, gyroscopes, and pressure sensors.

NEMS (Nanoelectromechanical Systems): Use NEMS for even smaller-scale sensors, leveraging nanoscale materials and processes for extreme miniaturization.

2. Integrate Multi-Functionality

Multi-Sensing Capabilities: Use sensors capable of measuring multiple parameters (e.g., temperature, humidity, pressure) to reduce the number of components.

System-on-Chip (SoC): Incorporate all components necessary to run a system (power supply, MCU, sensors, etc.) into a single chip.

System-in-Package (SiP): Package multiple integrated circuits (ICs) with sensor elements into a single module.

3. Use Advanced Materials

Nanomaterials: Incorporate nanomaterials such as graphene, carbon nanotubes, or quantum dots, which can enable high sensitivity and performance in smaller footprints.

Flexible Substrates: Use flexible and stretchable substrates (e.g., polyimide, PDMS) for wearable or conformal sensor applications.

Example Wearables:

Smartwatches integrate MEMS sensors for heart rate, GPS, and motion tracking into a small, wrist-worn device.

Achieving Miniaturization (II)

4. Optimize Circuit Design

ASIC (Application-Specific Integrated Circuit): Design custom ASICs to handle sensor signal processing, which are smaller and more power-efficient than general-purpose ICs.

Low-Power Circuitry: Use low-power analog and digital circuits to reduce energy demands, minimizing the need for large power supplies.

PCB Miniaturization: Optimize PCB layout using high-density interconnect (HDI) technology and multi-layer designs to reduce size.

5. Use Advanced Manufacturing Techniques

3D Printing: Use additive manufacturing techniques to create complex, miniaturized sensor structures with high precision.

Photolithography: Employ photolithography for creating microscale features in MEMS and NEMS devices.

Wafer-Level Packaging (WLP): Integrate sensor elements at the wafer level to eliminate bulky packaging.

6. Improve Sensor Packaging

Chip-Scale Packaging (CSP): Use CSP to minimize the size of sensor packages while maintaining functionality.

Monolithic Integration: Develop sensors and electronics on the same silicon die to eliminate interconnects and packaging layers.

Encapsulation Techniques: Use thin, durable encapsulation methods like atomic layer deposition (ALD) to protect sensors without adding bulk.

Example Medical Devices:

Smart pills use ingestible sensors with ultra-compact electronics to monitor health metrics inside the body.

Achieving Miniaturization (III)

7. Leverage Wireless Connectivity

Compact Antennas: Use small, efficient antenna designs (e.g., fractal or patch antennas) for wireless communication.

Integrated Communication Modules: Incorporate communication technologies (e.g., BLE, Zigbee, LoRa) directly into the sensor package.

8. Reduce Power Supply Size

Energy Harvesting: Use energy-harvesting components (e.g., solar cells, thermoelectric materials) to eliminate bulky batteries.

Thin-Film Batteries: Opt for thin-film or micro-batteries to provide power without compromising size.

9. Computational Optimization

Edge Processing: Minimize the need for external processing by integrating edge computing capabilities into the sensor system.

Firmware Efficiency: Use lightweight and efficient firmware to reduce computational hardware requirements.

10. Collaboration Between Disciplines

Cross-Functional Teams: Collaborate across materials science, electronics, and mechanical engineering to create synergistic designs.

Co-Design of Hardware and Software: Design hardware and software simultaneously to ensure seamless integration and minimal overhead.

Example Environmental Monitoring:

Micro-sensors embedded in compact drones provide environmental data from hard-to-reach locations.

Past Projects (excerpt)

LiteQ

- Pocket light spectrometer
- Realtime visualization of light spectrum
- Evaluation of visible light quality
- Easy to use two-button UI
- USB accessible flash storage
- Excellent battery life despite small 300 mAh battery

- Milestones:
  - High density PCB design
  - Utilizing standby mode

SmartLock

- Electronic lock with configurable unlock sources e.g. remote app
- Up to 10 years of battery life (non rechargeable)
- Small footprint (50 mm x 25 mm)
- Secure BLE communication with comprehensive user management
- Persistent event log e.g. unauthorized unlock attempts

- Milestones:
  - Optimized run and sleep modes with effective scheduling
  - Efficient BLE-Communication
  - Buffer to sustain high current pulses

About Androlite

Product development is our passion. We develop smart software and electronics solutions for the world of tomorrow. Our products solve the problems of everyday life - with electronics, big data and artificial intelligence. We also help our partners to develop and improve their own products.

Our products are used in a wide variety of areas such as the environment, security, sport and everyday life: using state-of-the-art technologies, we create innovative solutions for the Internet of Things that are technically impressive and unparalleled.

In a dynamically changing world, it is crucial not only to think innovatively, but also to act proactively. Our corporate culture fosters an environment in which ideas are not only born, but also quickly implemented.

By thinking outside the box and allowing unconventional approaches, we enable our employees to fully utilize their talents and achieve great things together.

Every step we take is driven by a shared vision: to drive the digital transformation and fully exploit the potential of our technologies. We are constantly expanding our knowledge and perspectives through targeted interactions with our partners and customers.

We help our partners to create smart IoT solutions.

Smart City	**Smart Home**	**Smart Energy**	**Connected Health**
Smart Mobility	**Public Safety / Environmental Monitoring**	**Smart Farming**	**Connected Industry**

Partnering with Androlite

IoT product development

At Androlite, we also specialize in providing comprehensive end-to-end IoT product design and consultancy services.

Our expertise spans the entire spectrum of IoT development, starting from initial market research and selection of pivotal MVP features, all the way through to the final stages of deployment and testing.

We excel in crafting detailed prototype designs, strategizing effective roadmaps and milestone plans, and offering full-scale consultancy to guide every step of your project. We cover all aspects of IoT Product design.

Electronics Production Partner *(Automotive grade)*

We are associated with the German full service provider, Automotive Synergies GmbH & Co. KG (https://automotive-synergies.com/) with which we cover the manufacturing of electronic devices, components and systems. The services portfolio includes R&D, PCB assembly, testing and worldwide delivery.

The Automotive Synergies with production sites in Germany and Slovenia, is a trusted supplier within the automotive industry and has been in the electronics market for more than 20 years.

Let's partner to bring your Internet of Things vision to life!

HQ in Schwabach, Germany

Plant in Vrbno, Slovenia

Plant in Pristava, Slovenia

Certifications:

ISO 9001:2015
ISO 14001:2015
IATF

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