# 6D-1: Biological Information Sensing Technologies for Medical, Health Care, and Wellness Applications

Masaharu Imai, Yoshinori Takeuchi,
Keishi Sakanushi, and Hirofumi Iwato
Graduate School of Information Science and Technology
Osaka University, Japan

# Agenda

- Introduction – Motivation and Background
- Biological Information Sensing
- MeSOC-I: Medical Domain Specific SoC
- MeDIX-I: Medical Domain Specific Processor
- Future Challenges
- Conclusion

# Motivation

- Background
  - Aging Society：Japanese has the longest life expectancy in the world.
  - Issues in Medical System in Japan
    - Increasing Medical Expense
    - Co-medical's Dissatisfaction and Uneven Distribution
- Challenges
  - Long Term Continuous Inspection (23 h 50 m at home) rather than Short Term Inspection (10 min in hospital)
    (esp. for Chronic Disease)
- Goal
  - Better QoL (Quality of Life):
    Decrease Patients' Physical and Mental Stress

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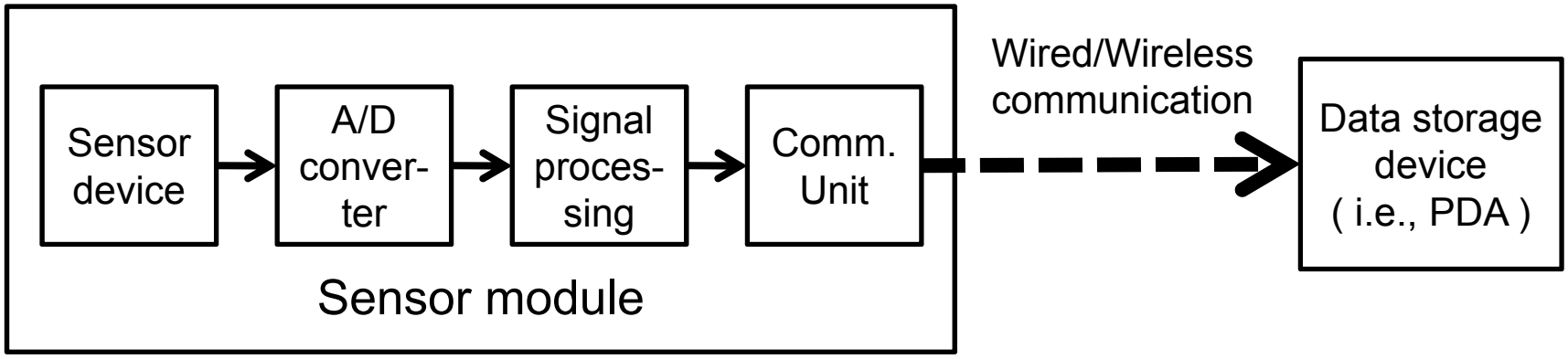
# Typical Biological Information Sensing System



# Major Biological Information

| Biological Information | Range | Sensor Device |
|---|---|---|
| Blood Pressure | 10 ~ 300 [mmHg] | Pressure Sensor |
| Pulse Count | 10 ~ 250 [bpm] | Phototransistor<br>Pressure Sensor |
| $SpO_2$ | 50 ~ 100 [%] | Phototransistor |
| Respiration | 5 ~ 60 [bpm] | Pressure Sensor |
| Electrocardiogram (ECG) | +/- 6.25 [mV] | Electrode |
| Electromyogram (EMG) | 50 ~ 1,000 [μV] | Electrode |
| body temperature | 25 ~ 45 [C] | Temperature Sensor |

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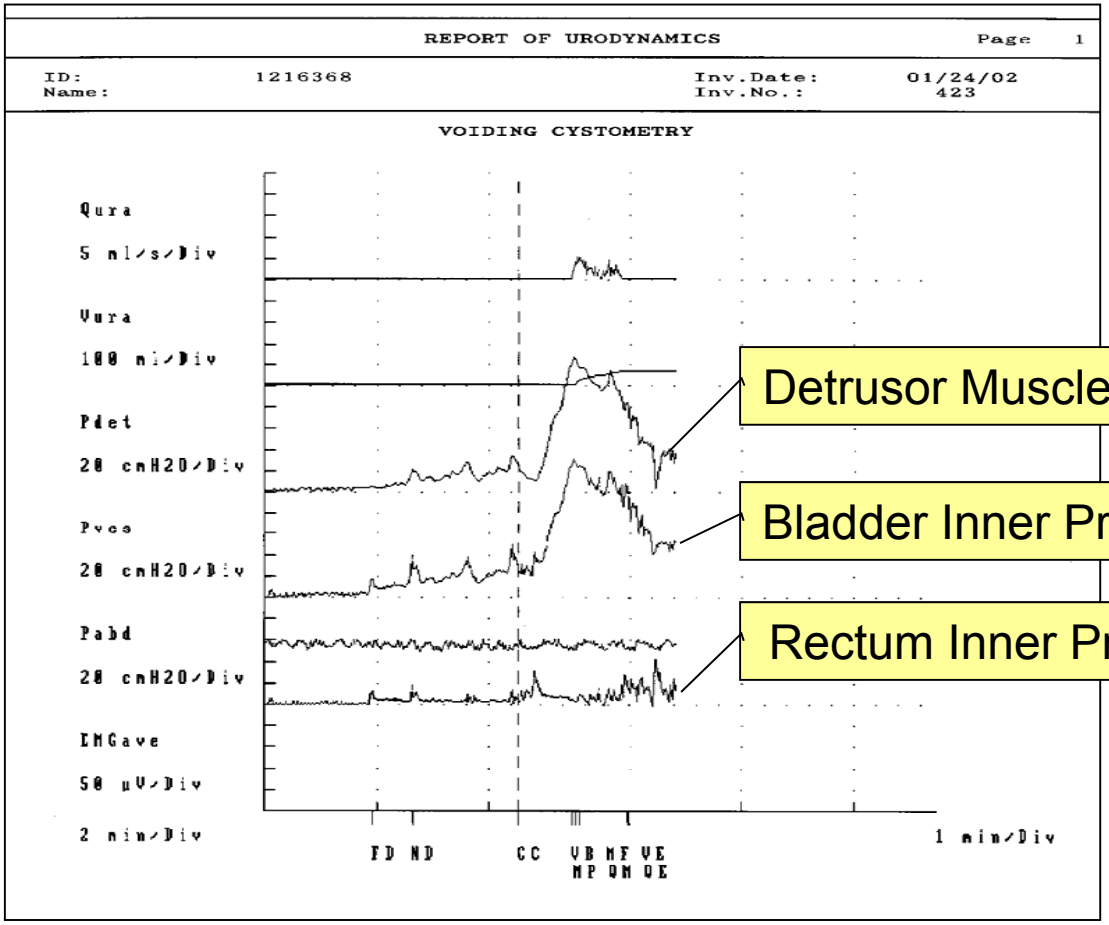
# Requirements to SoC for Ambulatory Urodynamic Monitoring

- Functionality
  - Sensing and Transmission of Inner Body Pressure
  - Applicable to Treat Urinary Disease such as Prostatic Hyperplasia
- Requests from Medical Doctor
  - Less Invasion, Less Restraint, Less Awareness
  - Long Term (72 Hours, 30 samples/sec)
  - Real Time Measurement
- Technical Requirements
  - Smaller Size, Lighter Weight, and Lower Power Consumption

# Diagnostics by Measurement of Detrusor Muscle Pressure

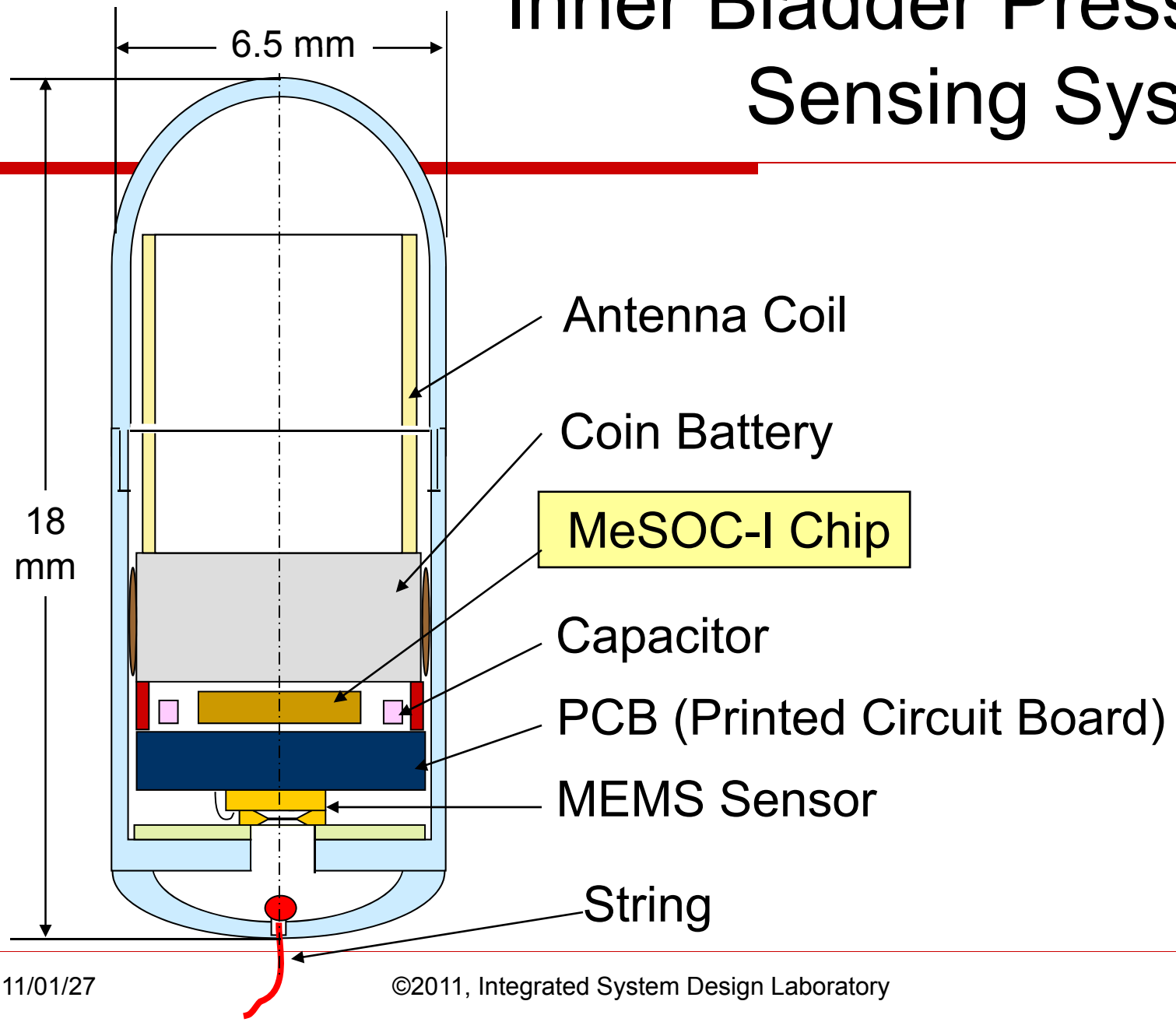



Detrusor Muscle Pressure (=A-B)

Bladder Inner Pressure (A)

Rectum Inner Pressure (B)

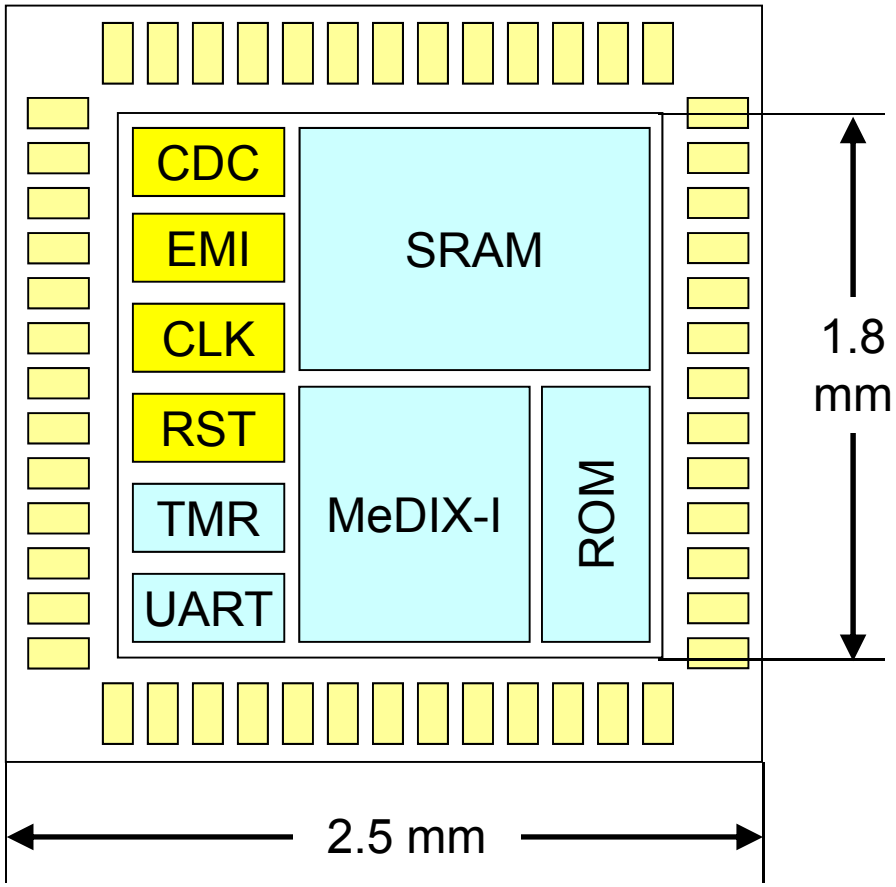
# Inner Bladder Pressure Sensing System



# Power Reduction Strategies

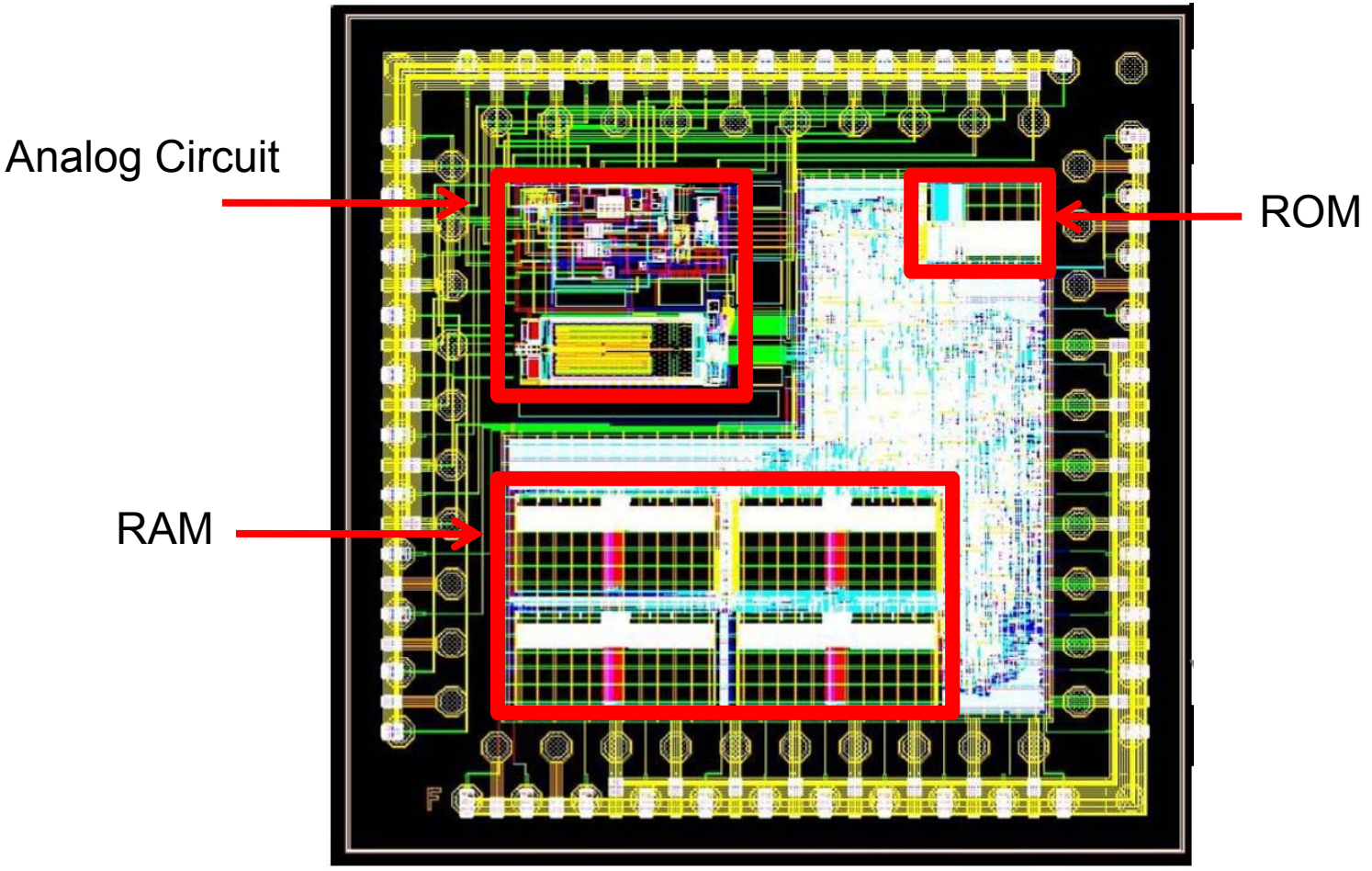
- System Level
  - Power Management
- Architecture Level
  - ASIP (Application domain Specific Instruction set Processor)
  - RISC + Peripheral
- Circuit, Device, and Process Level
  - DVFS (Dynamic Voltage and Frequency Scaling)
  - Sub Threshold Design

# Block Diagram of MeSOC-I

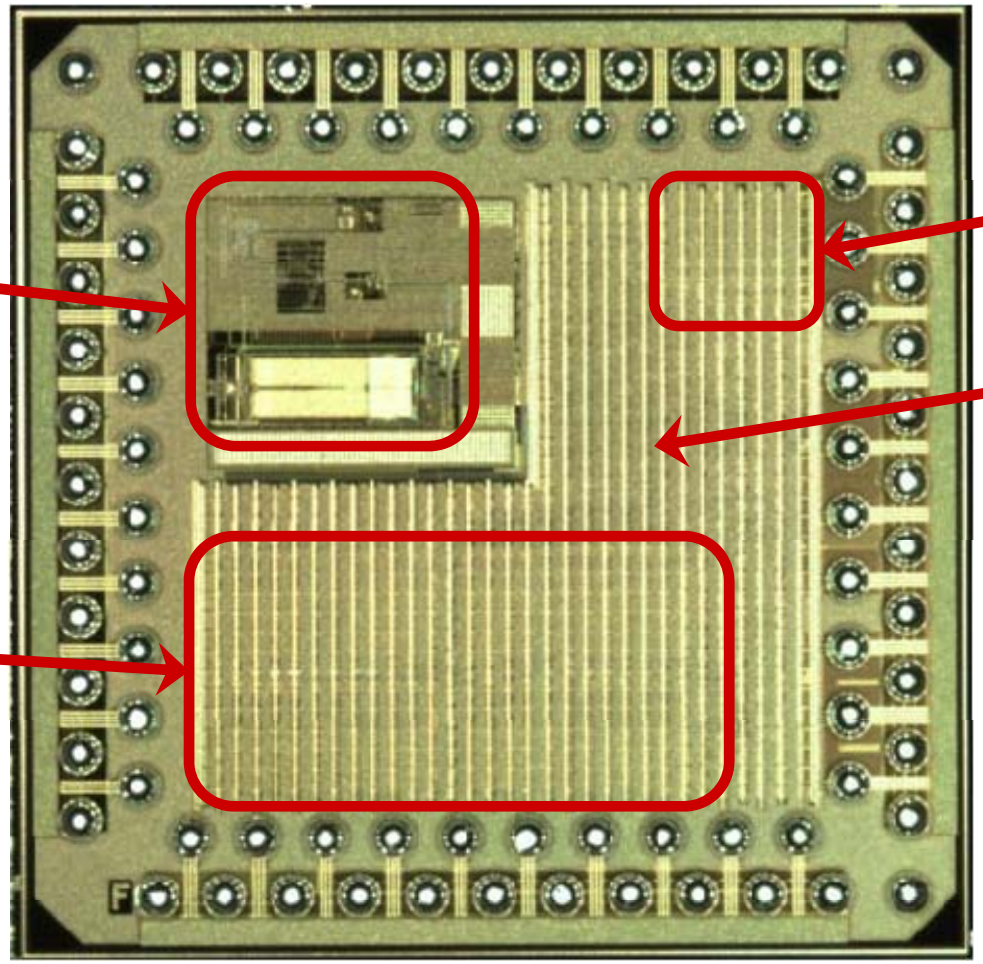



- Digital Circuit
  - MeDIX-I: Controller
  - SRAM: 8KB
  - ROM: 6KB
  - TMR: Timer
  - UART: Serial I/O
- Analog Circuit
  - CDC: Capacitance to Digital Converter
  - EMI: Electro-Magnetic Induction CODEC Circuit
  - CLK: Clock Generator
  - RST: Power-on Reset Circuit

# Chip Layout of MeSOC-I



# Photomicrograph of MeSOC-I (CSP: Chip Size Package)



# Specification of MeSOC-I

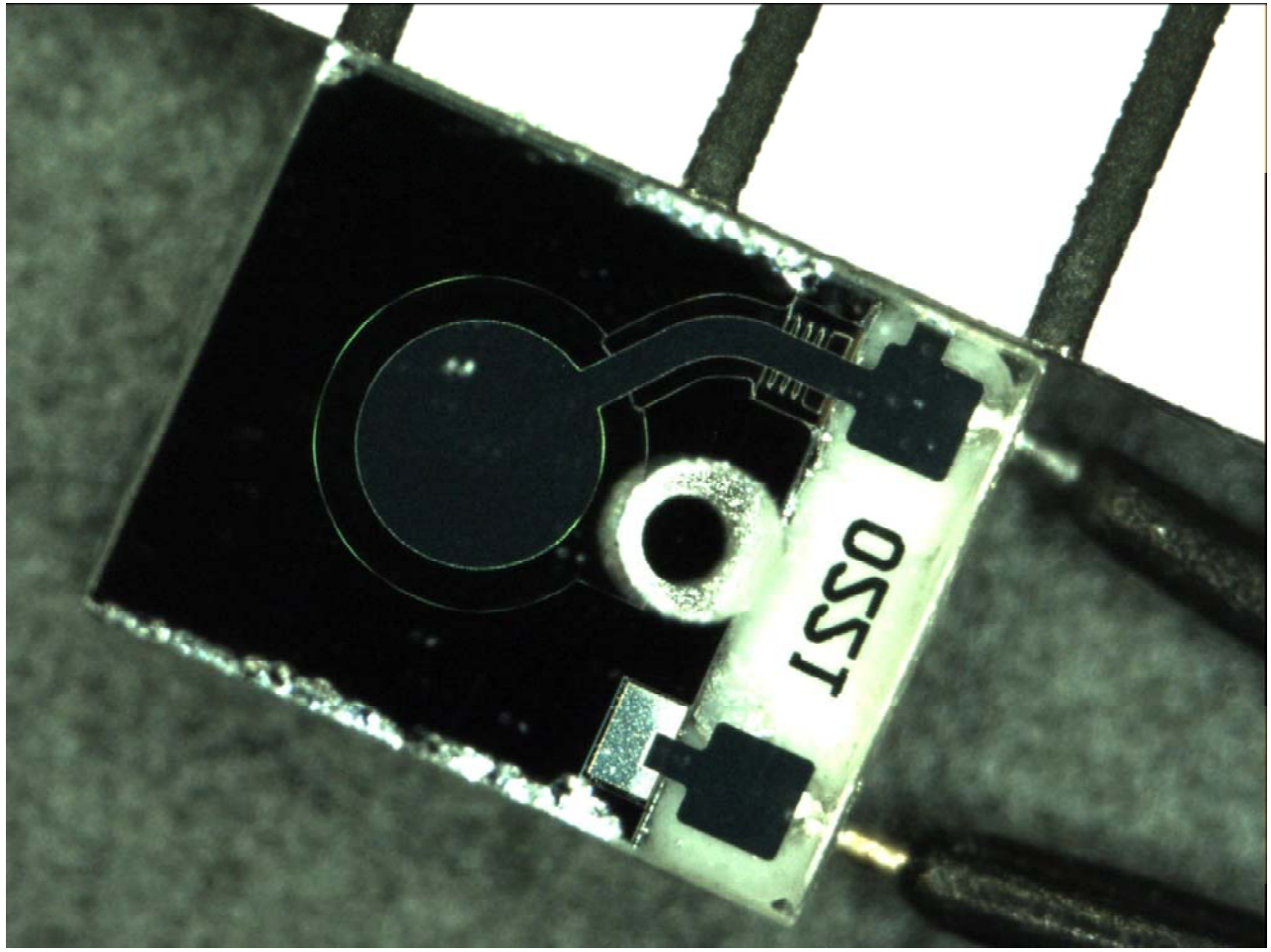
| Item | Specification |
|---|---|
| Technology | 0.18 μm CMOS (TSMC, 1.8V) |
| Chip Area | 2.5 mm x 2.5 mm |
| Logic Gate Count | 32.5 Kgate |
| Processor | MeDIX-I (16 bit RISC + 10 Special Instructions) |
| Memory | ROM: 6 KB, RAM 8 KB |
| ADC(CDC) | 10 bit |
| Peripheral | UART, MODEM for Electro-Magnetic Induction |
| Source Voltage | 1.55 V (Coin-Cell Battery) |
| Clock Frequency | 968KHz (Processor: 161.4 KHz) |
| Power Consumption | 123μW (127μW/MHz) |

# Other Componets

- Battery (Maxell SR421SW)
  - Voltage： 1.55V
  - Dimension: 4.8mmΦ×2.15mm
  - Weight: 160mg
  - Capacity: 12mAh
- MEMS Pressure Sensor
  - Dimension: 1.7mm x 2.21mm x 0.85mm

# MEMS Pressure Sensor

## (MEMS＝Micro Electronic Mechanical System)




Size:
1.7mm x
2.21mm x
0.85mmt

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# MeDIX-I: Small Low Power Processor

- MeDIX = Medical Domain specific Instruction set processor eXtension
- 16 Bit Configurable RISC Processor (Brownie Micro 16 from ASIP Solutions, Inc.) used as a Base Processor
- Architecture Customized using ASIP Meister® (EDA Tool for Processor Design)
  - ECC (Error Check and Correction) Instructions
  - ADC (CDC) Control Instructions
  - Task Switching Instruction
  - Sleep Instruction

# ECC: Error Check and Correction

- MDPC: Multi Dimensional Parity Code
  - 1 Bit Error Correction
  - 2 Bits Error Detection
  - 2*n* Redundant Bits for up to $2^n$ Bits Data
- Heavy Use of Bitwise Exclusive-OR Operations
  - Software implementation (RISC operations) takes 272 cycles for 22 bits data.
  - Implementation using peripheral is less flexible in terms of data bit length.
  - Special Instructions for ECC have been added.

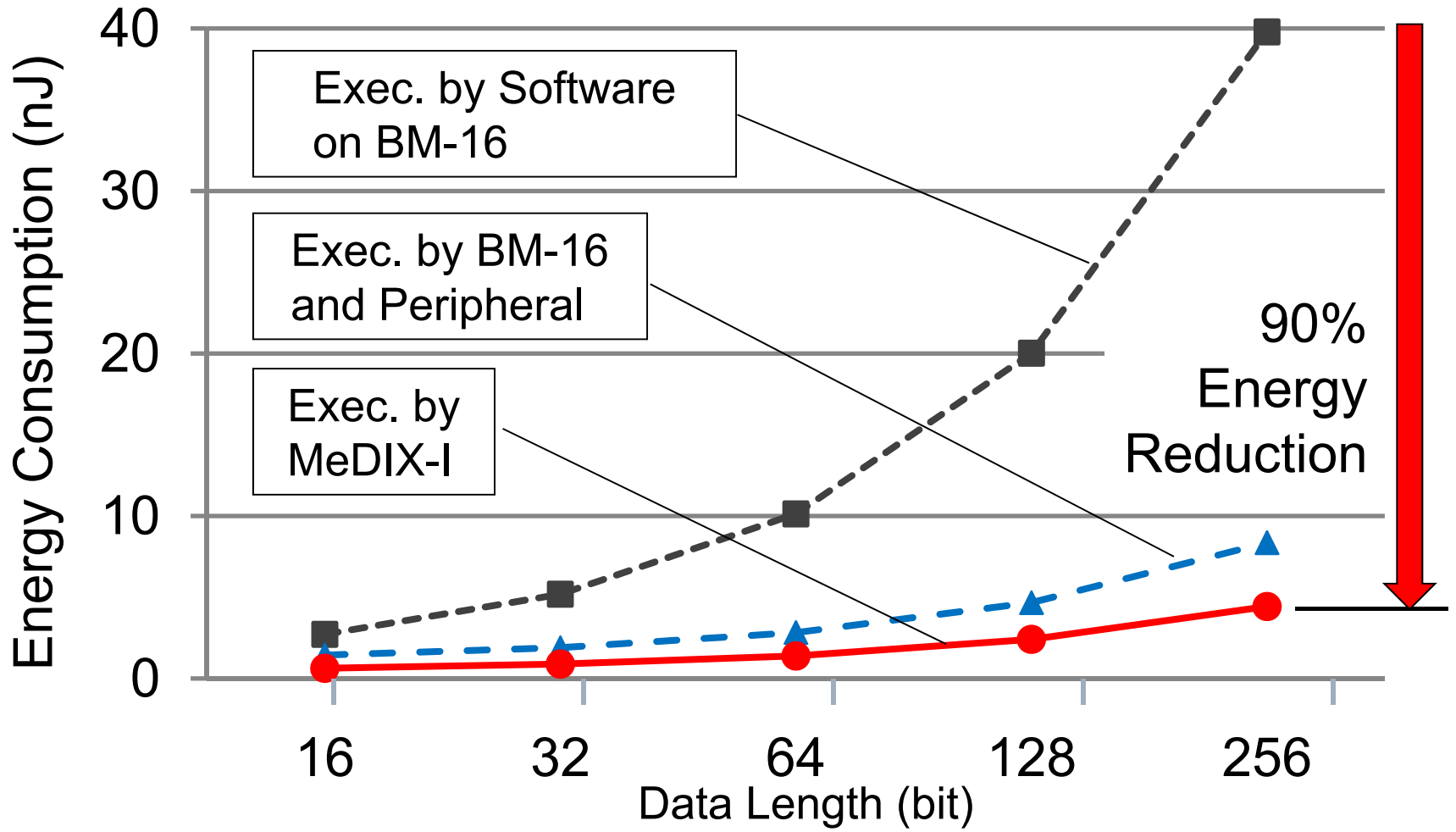
# Effectiveness of Special Instructions for ECC

- Measurement Results of Area, Power Consumption, Performance (Clock Cycles), and Energy Consumption

| | Area [$\mu m^2$] | Power [$\mu W/MHz$] | Exec. Cycles | Energy [nJ] |
|---|---|---|---|---|
| BM16 | 101,265 (100%) | 34.5 (100%) | 291 (100%) | 10.0 (100%) |
| BM16+ Peripheral | 169,193 (+67%) | 57.1 (+66%) | 49 (-83%) | 2.8 (-72%) |
| MeDIX-I (BM16+ECC) | 107,233 (+5.9%) | 41.9 (+21%) | 33 (-89%) | 1.4 (-86%) |

Cell Library TSMC 0.18μm CMOS, Clock Freq = 1MHz, Bit length = 64 bit, VDD=1.8V

# Energy Comparison for ECC



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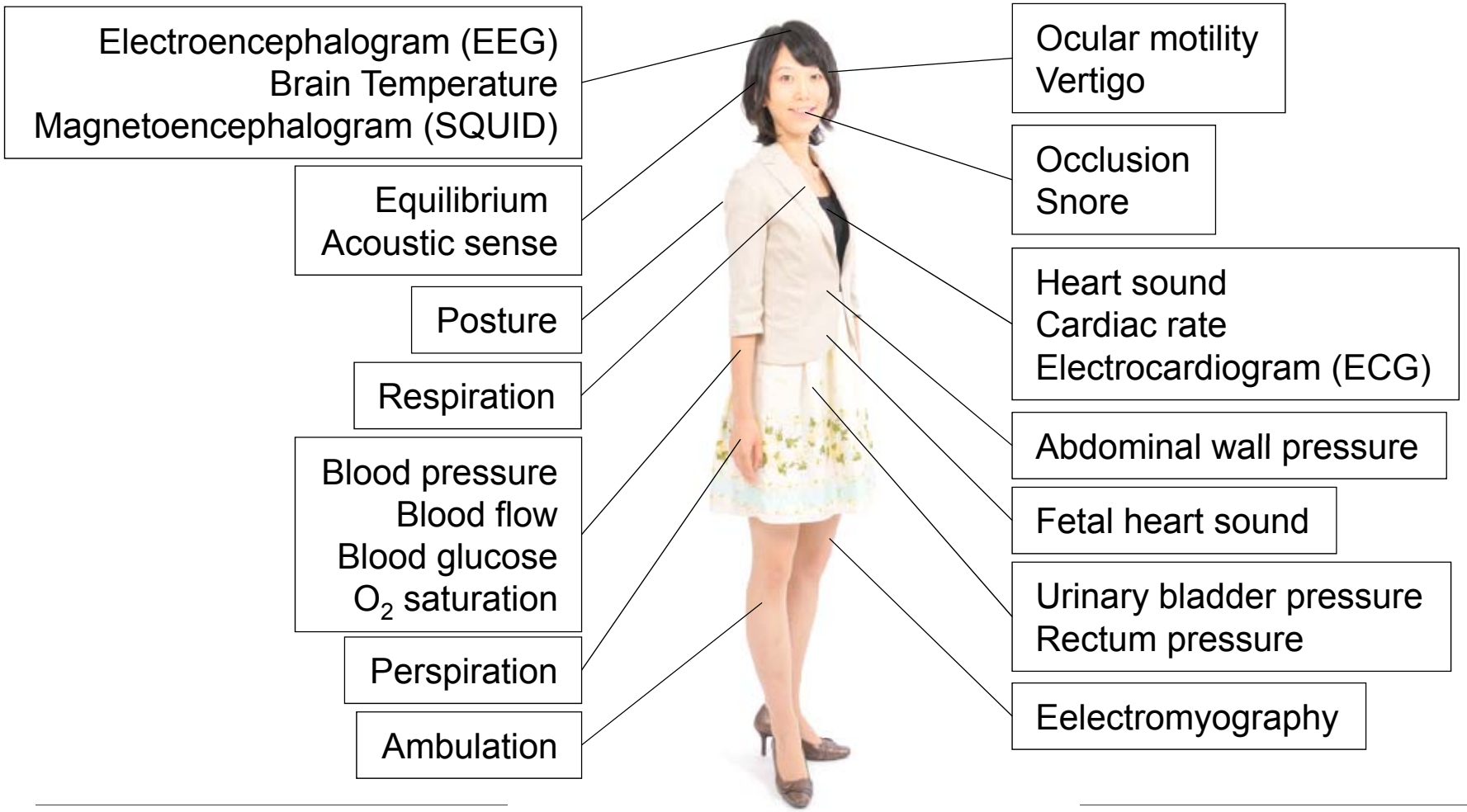
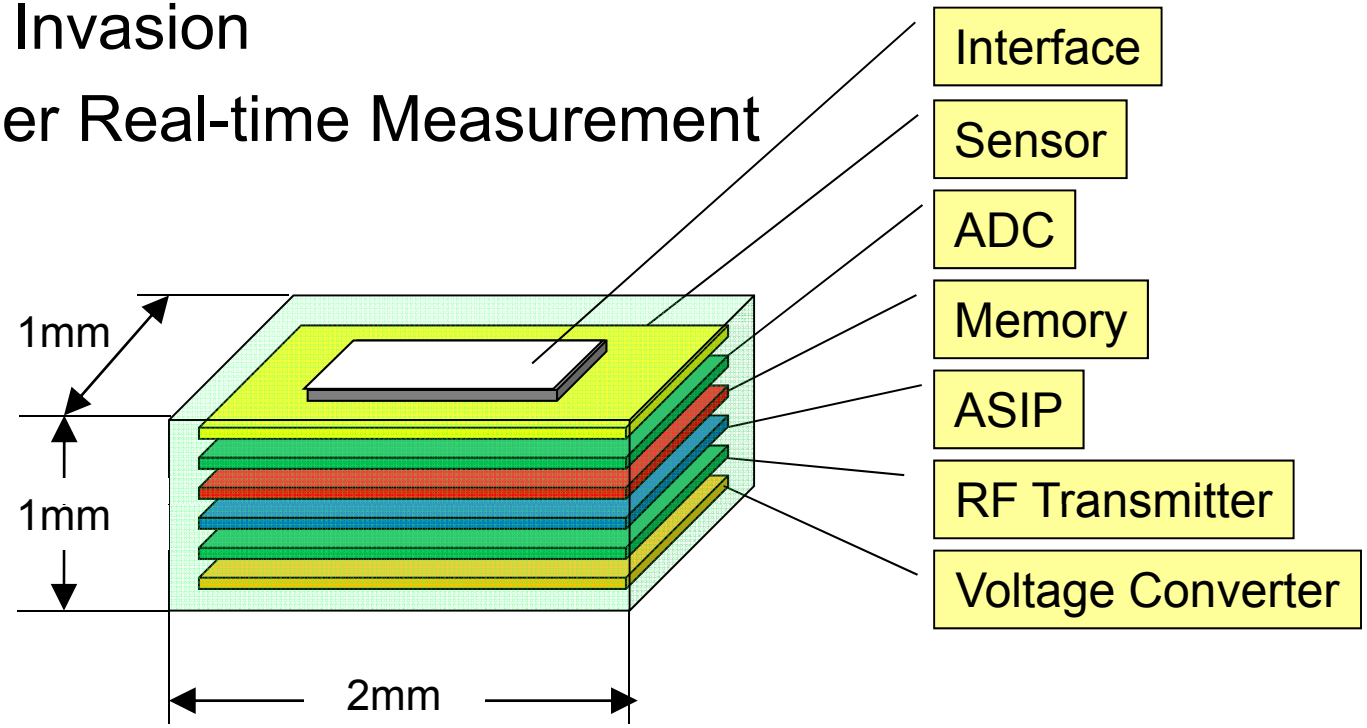
# Biological Information for Aging Care and Healthcare



# Future SoC (SiP) for Bio-Medical Information Sensing Node

- Smaller, Lighter and Cooler
- Less Energy Consumption
- Less Invasion
- Longer Real-time Measurement



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# Conclusion

- SoC/SiP technology is the key to realize biological information sensing systems for intelligent medical, healthcare, and wellness applications in the aging society.
- ASIP will play very important role in the SoC/SiP to reduce size, weight, and power consumption, while keeping high programmability.

# Acknowledgement


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