Architectural Challenges for mm-scale Sensor Nodes

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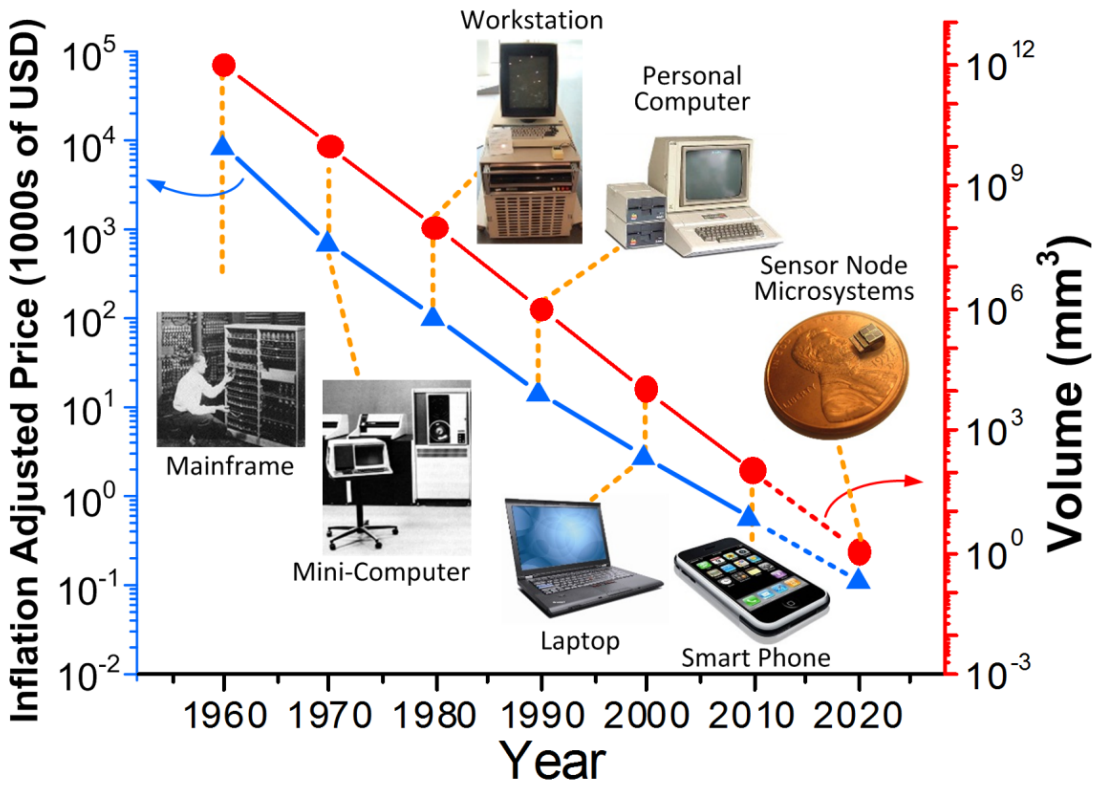
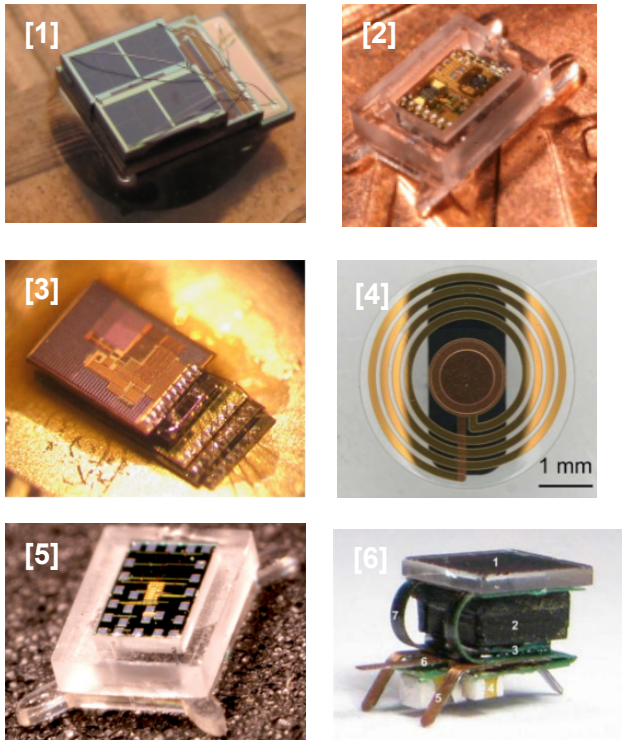
mm-Scale Sensor Nodes



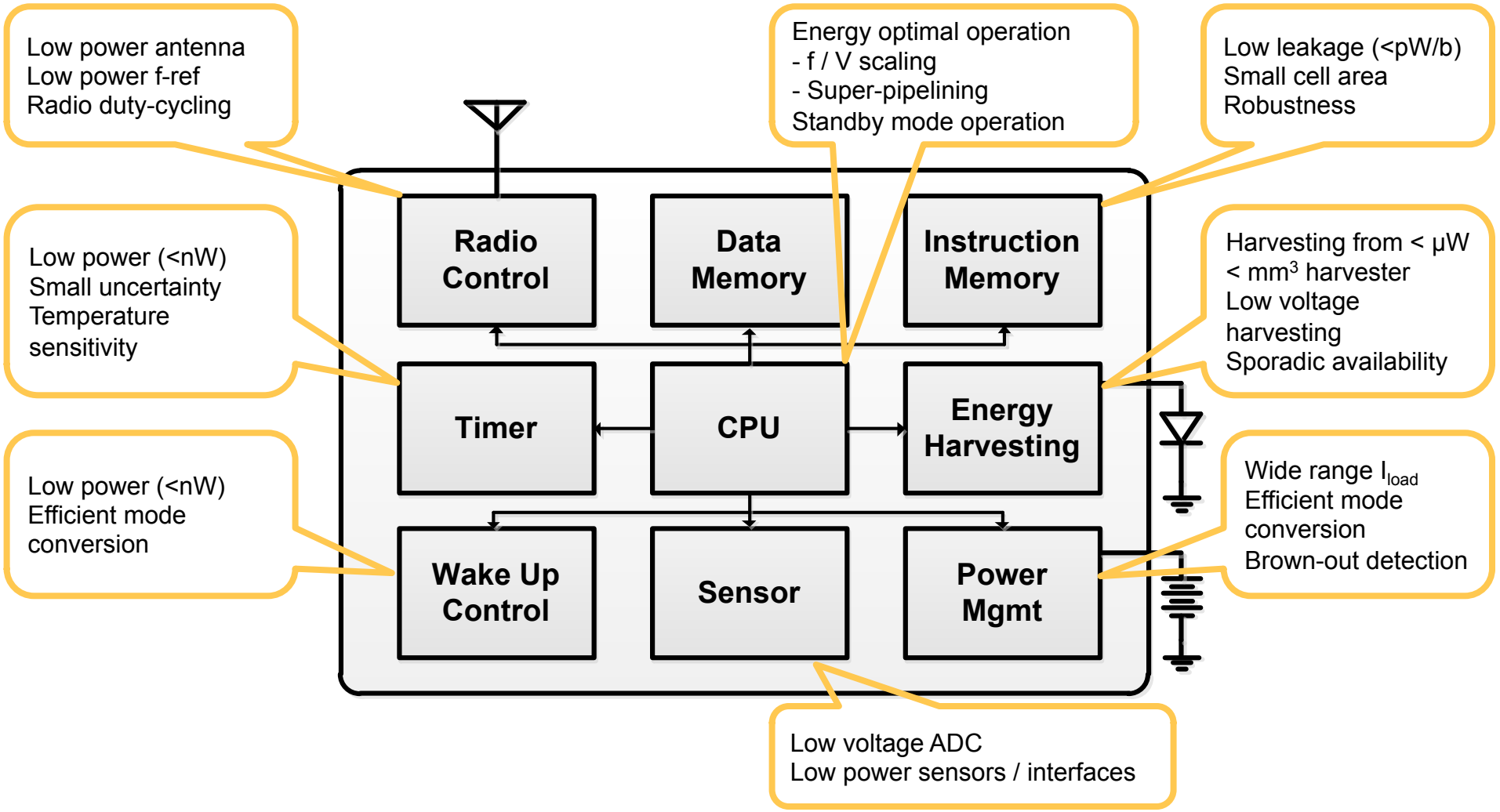


- Emergence of mm-scale systems
  - Smaller form-factor
  - Cheaper price

[1] G. Chen et al. ISSCC 2010
[2] G. Chen et al. ISSCC 2011
[3] Y. Lee etal. ISSCC 2012
[4] P-J. Chen et al. JMEMS 2010
[5] R. Haque et al. MEMS 2011
[6] R. Casanaov ISSCC 2009

mm-Scale Sensor Nodes

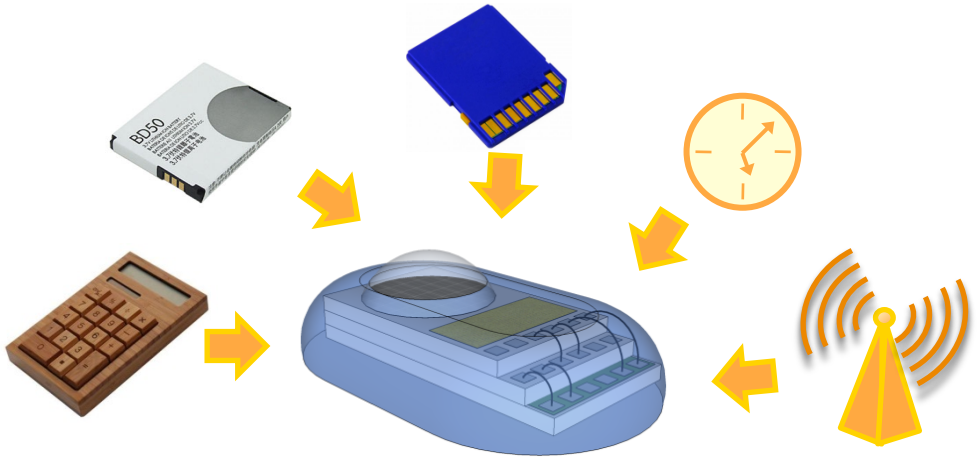
- Key enabler: Low power circuit technologies



Challenges in mm-Scale Sensors

- Building a “SYSTEM” out of low power building blocks

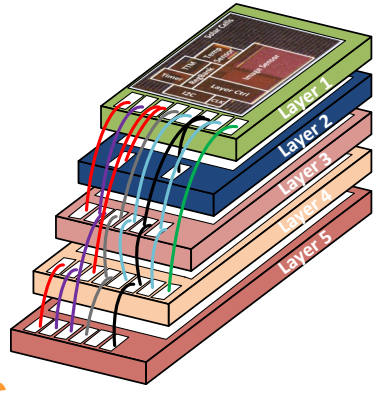
- Integration requirements
  - Volume limit
  - Energy limit
  - Controllability



- Extremely wide application space
  - Medical / Environmental
    Structural Integrity / Surveillance
    Building Management / and so on …

Layer Based Modular Architecture

- Layer approach
  - Maximizing Si area in limited volume
  - Modularization
  - Technology optimization



Generic Layers

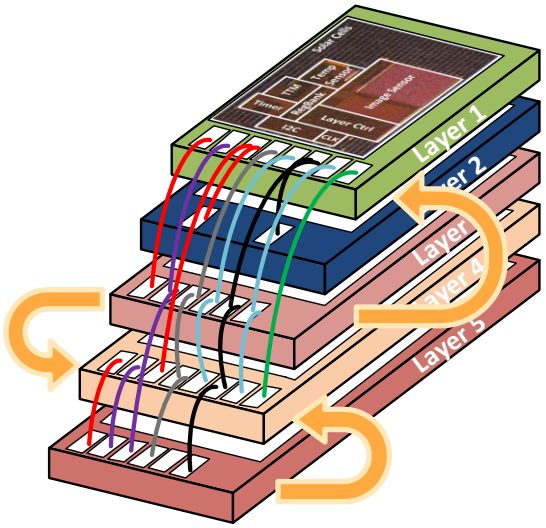
Processor
Flash Memory
Decap
Battery
Power Mng. E-Harvesting

Application-specific Layers

Imager	Motion Detection
Pressure Sensing (C to D)	Temperature Sensing
ECG monitor	Strain Sensing (R to D)
Light Sensing	Analog Voltage (ADC)
Near Field Radio	Far Field Radio

Inter-Layer Interconnect

- How are the layers connected?
  - Delivery of Power
  - Control
  - Data exchange

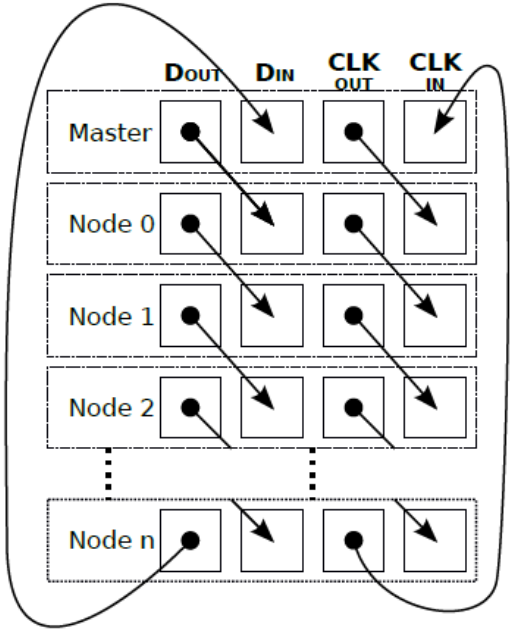


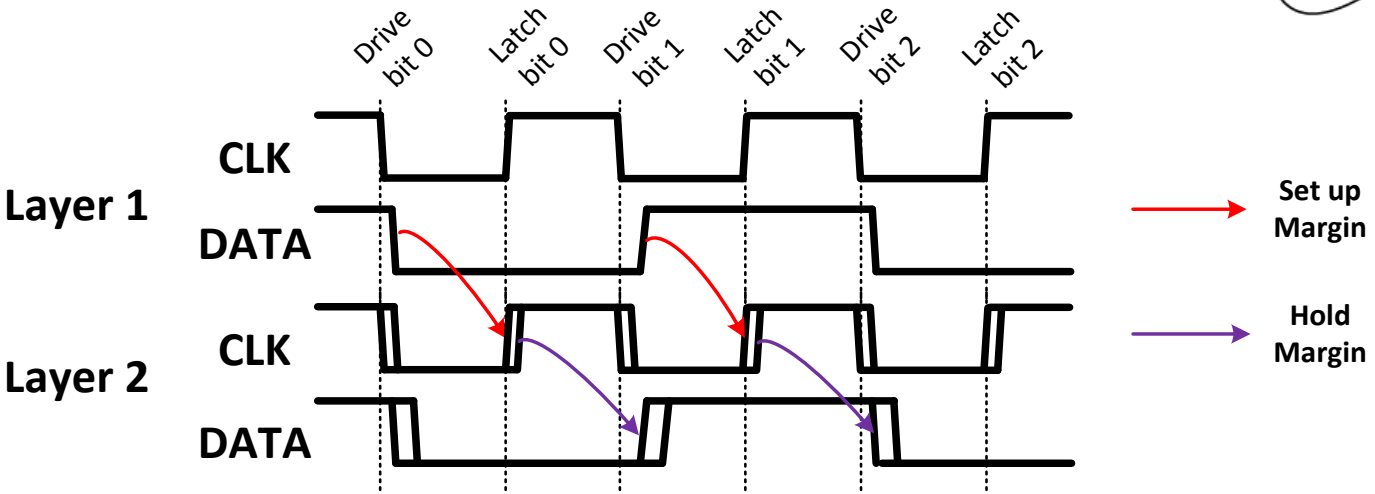
- Traditional solutions
  - I^2C
    - Bidirectional – pull up resistor power
    - Distributed clock control – clock generation on each device
  - SPI
    - >3 wires - limited expansion
    - No slave TX initiation / slave ACK
    - No slave to slave

- Need low power solution for control & data exchange

MBus: Low Power Inter-Layer Interconnect

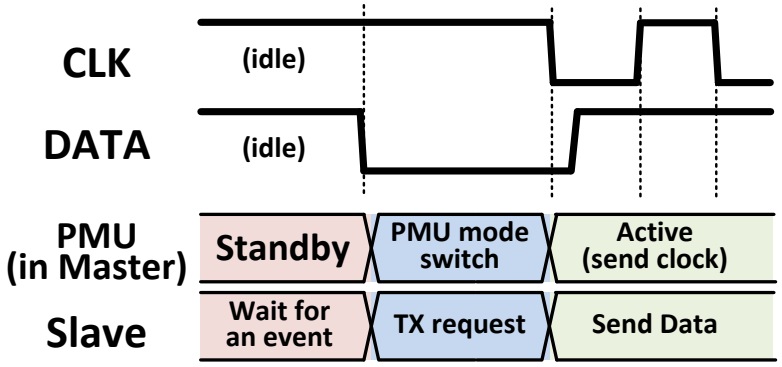
- MBus
  - 1 Master, multiple Slave layers
  - 2 wires: CLK, DATA
  - Unidirectional: Daisy-chained
  - 2 phase clocking: Improve setup/hold tolerance
    - for arbitrary layer combination
    - for irregular loading



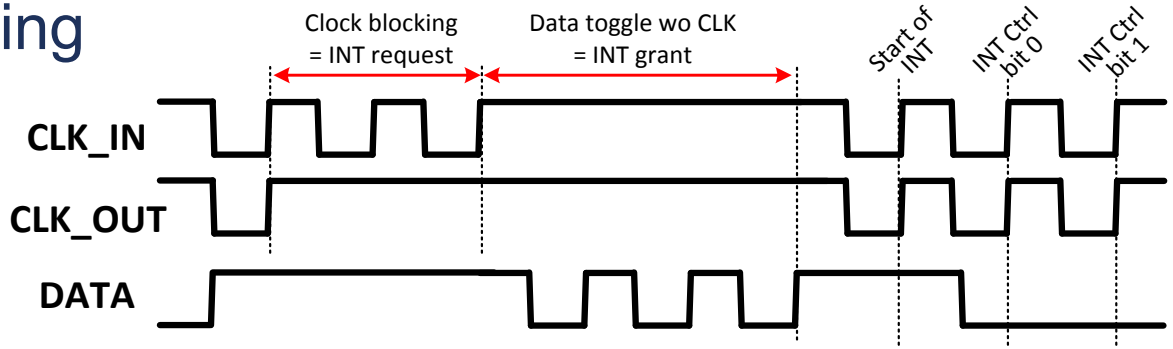


MBus: Low Power Inter-Layer Interconnect

- CLK driven by Master layer
  - ➔ No clock generation on other layers
  - ➔ Slave request TX by DATA pull down
  - ➔ Request wake up by DATA pull down



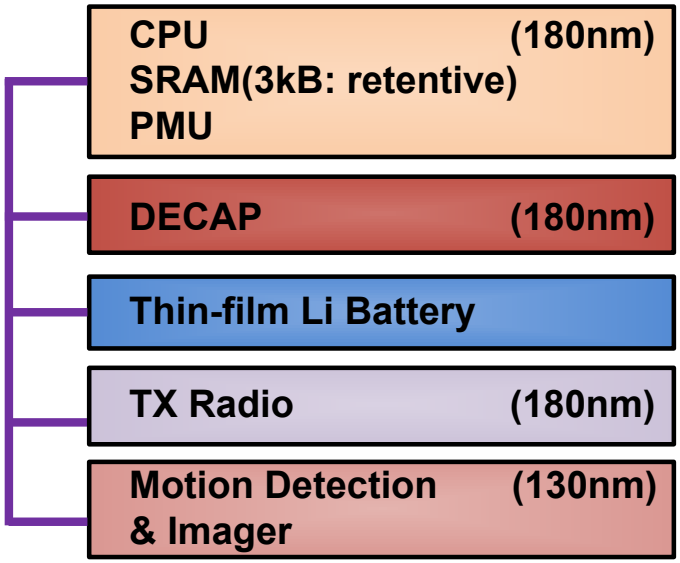
- Interrupt by clock blocking
  - ➔ Prioritize messages
  - ➔ Reset bus

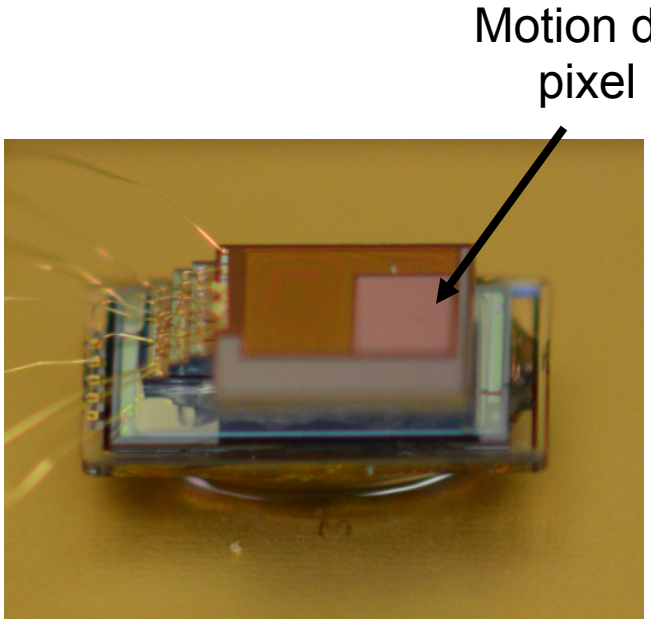


- Termination sequence
  - ➔ Utilize interrupt as termination sequence
  - ➔ Enable slave ACK (control bit) & arbitrary length message

1st System

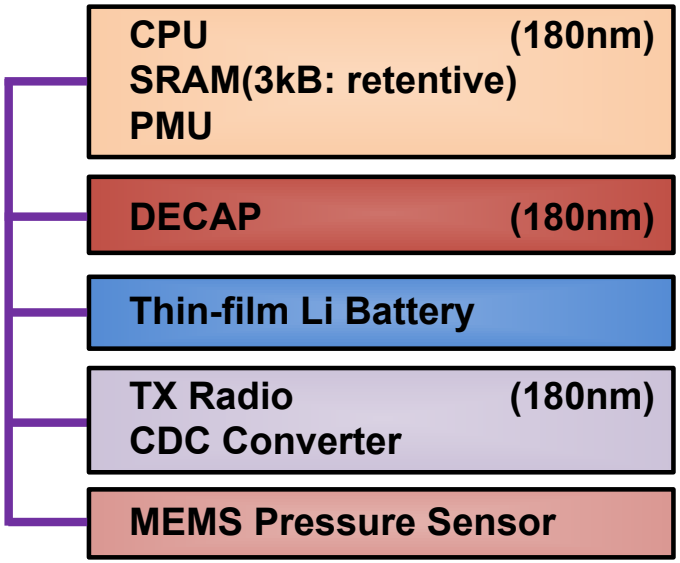
- Motion detection surveillance sensor
  - Application specific: Motion detector layer
  - Motion detection in standby mode (200nW)
  - Data transmission in active mode (40µW)

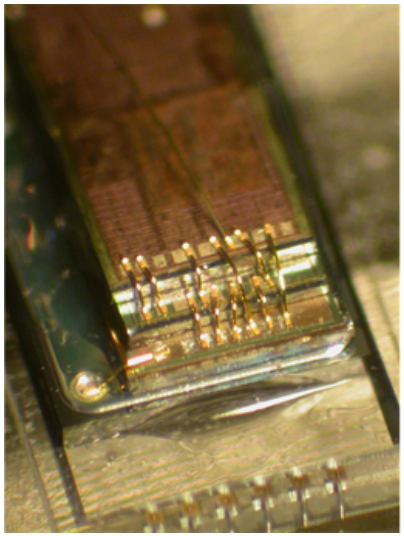


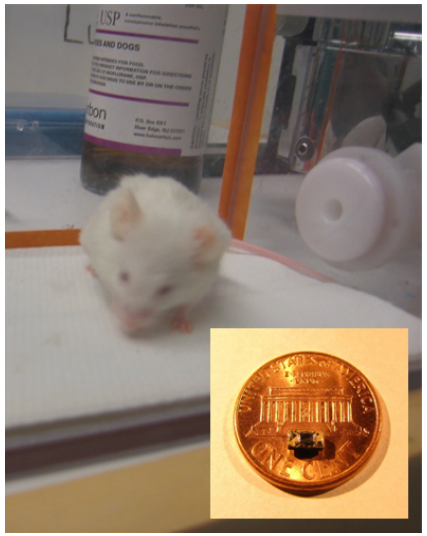


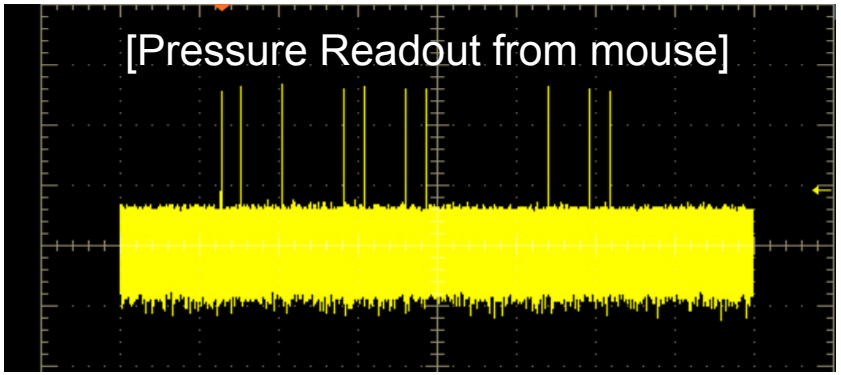
2nd System

- Implantable medical sensor (tumor pressure monitoring)
  - Application specific: MEMS pressure sensor
    CDC conversion



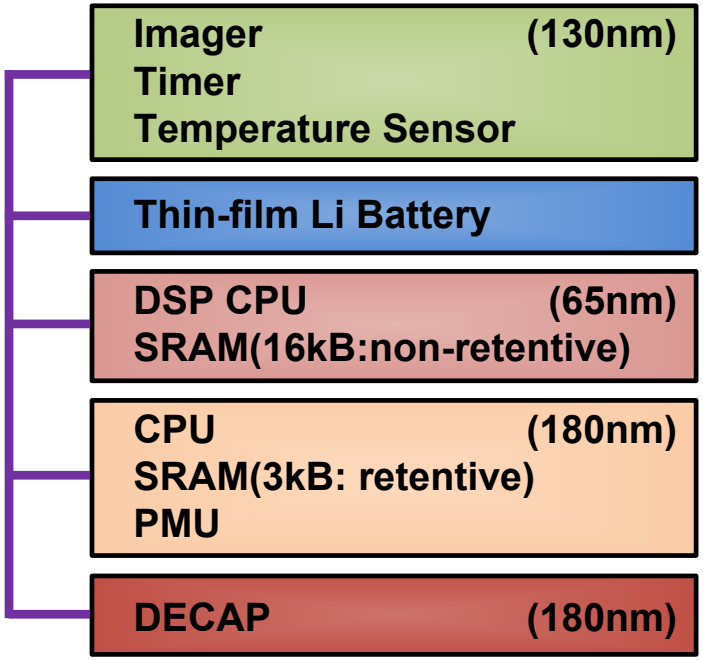


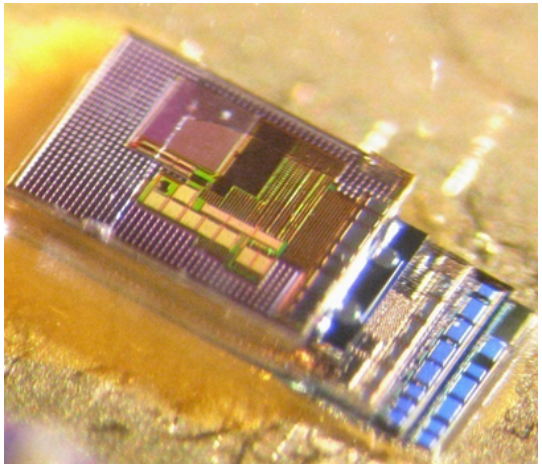




3rd System

- Imager and Temperature monitoring
  - Application specific: Imager
    Temperature sensor





Thank You