Miniature Implantable Medical Devices

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Miniature Implantable Medical Devices

1. Miniature Implantable Medical Devices
2. Enabling Technologies
3. Design Opportunities
4. Custom IC Design Techniques
5. MIMD Case Study
6. Conclusions

Miniature Implantable Medical Devices

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Miniature Implantable Medical Devices

IMDs

Pacemakers/Defibrillators

Spinal Cord Stimulators

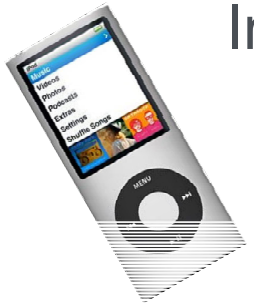
Drug Infusion Pumps

Chest/Abdomen

Long Leads

Invasive Surgery

~ 15 to 50 cc



MIMDs

Cardiac Monitors

Peripheral Nerve Stimulators

Micro Infusion Pumps

Head/Neck/Limbs

Small Leads

Minimally Invasive

< 5 cc

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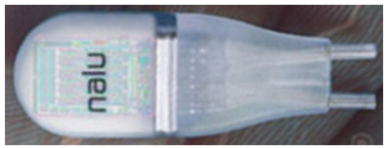
- **MIMD Examples**
  - Insertable Cardiac Monitor

https://www.medtronic.com/

  - Leadless Pacemaker

https://www.cardiovascular.abbott/

  - Peripheral Nerve Stimulator



https://nalumed.com/

  - Vagus Nerve Stimulator

https://setpointmedical.com/

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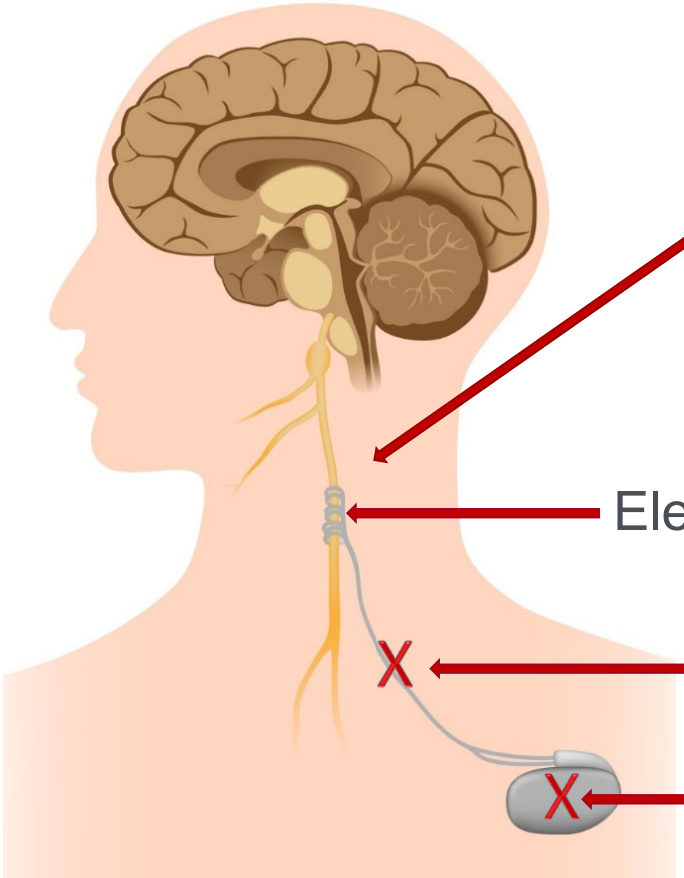
- **Vagus Nerve Stimulator**



Device volume << 5cc

Small enough to implant at point of therapy

Electrodes attached to nerve

Leads routed to neck

IMD implanted in chest

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Enabling Technologies

- **Micro-Electro-Mechanical Systems (MEMS)**
  - Microscopic sensors, actuators & machines
  - Fabricated on silicon wafers
  - Semiconductor processes & equipment

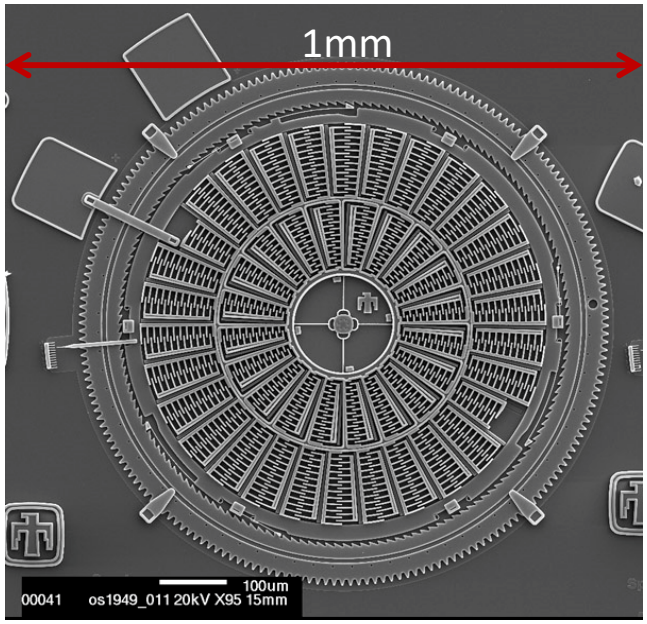
Medical Examples

Pressure Sensors – Blood Pressure

Accelerometers – Position, Activity

Chemical Sensors – Glucose

Fluid Pumps – Drug Delivery



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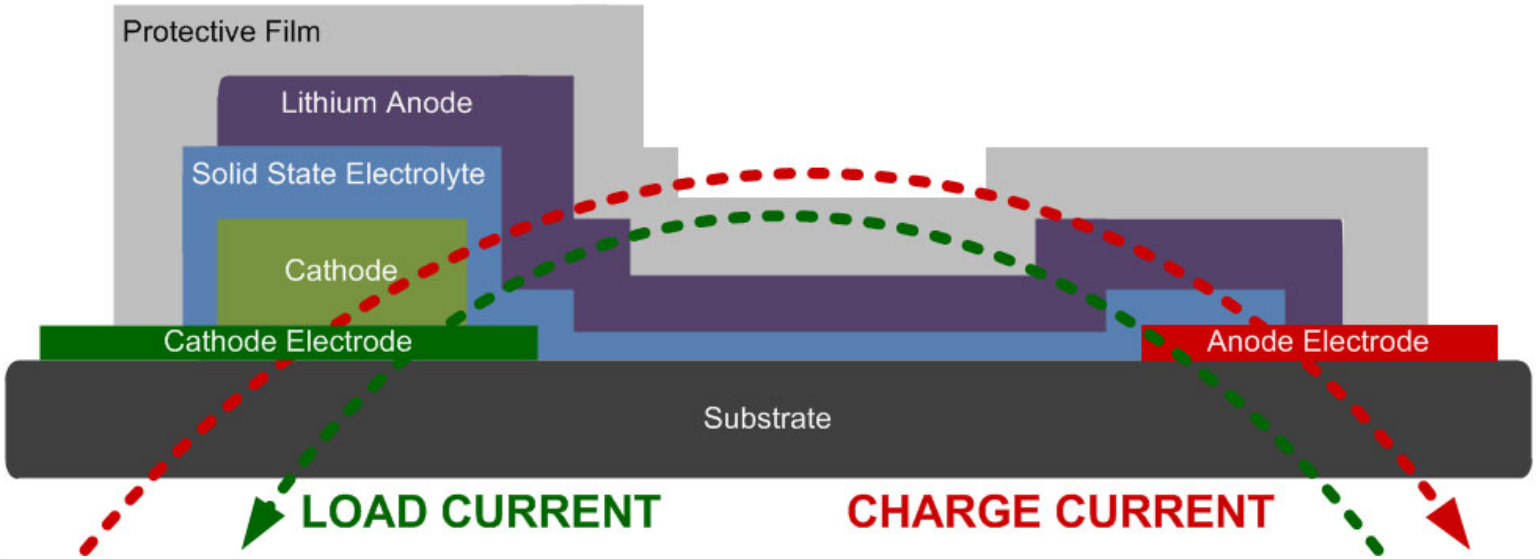
Enabling Technologies

- **Solid State Batteries (SSB)**
  - Functions like standard rechargeable Li-Ion battery
  - Fabricated on silicon wafers
  - Semiconductor processes & equipment



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Enabling Technologies

- **Integrated Passive Devices (IPD)**
  - Resistors, capacitors, inductors
  - Fabricated on silicon wafers
  - Semiconductor processes & equipment

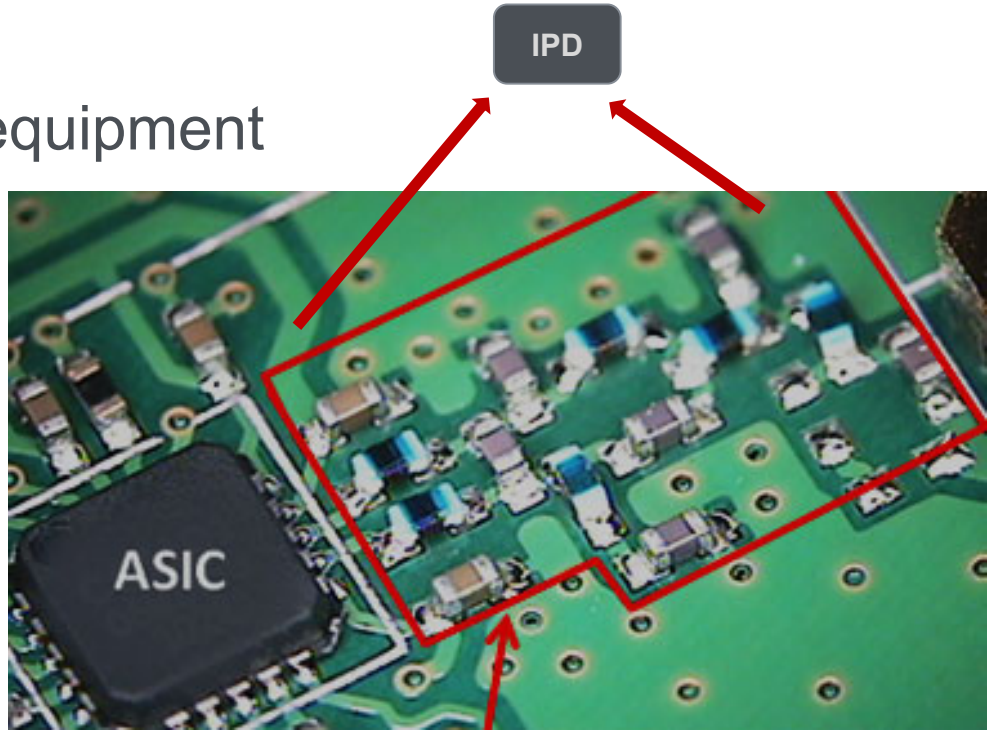
Device Types

High Density Capacitors

High Q Inductors

Polysilicon Resistors

Metal Interconnects



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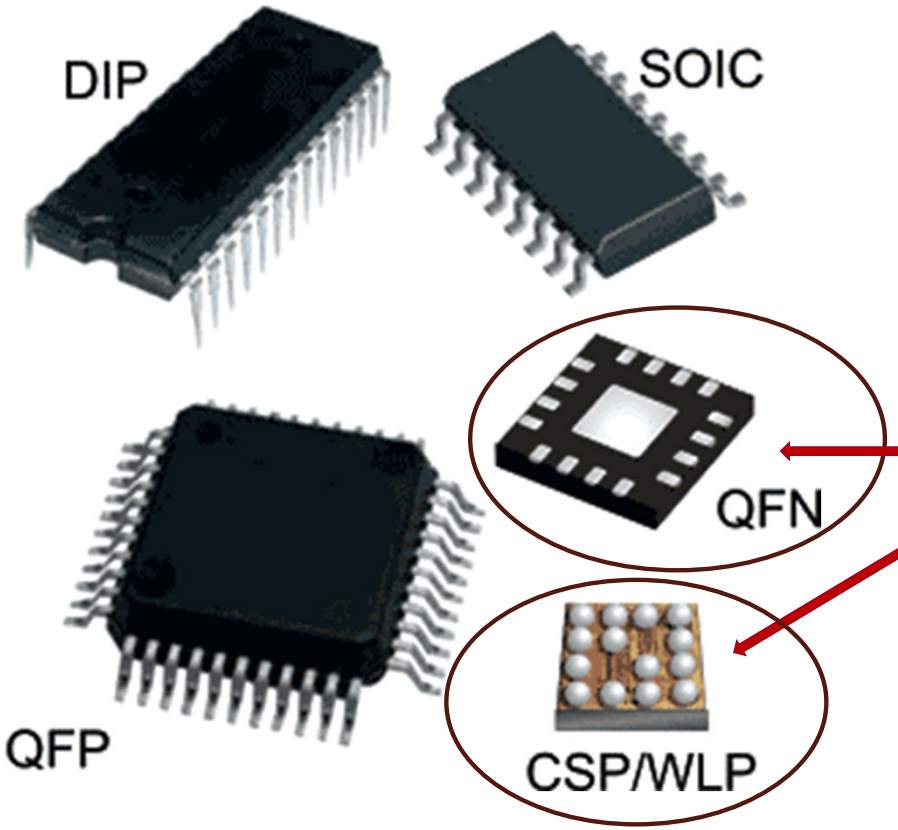
Enabling Technologies

- **Chip-Scale Packaging (CSP)**



28-pin CSP:
250x smaller than DIP

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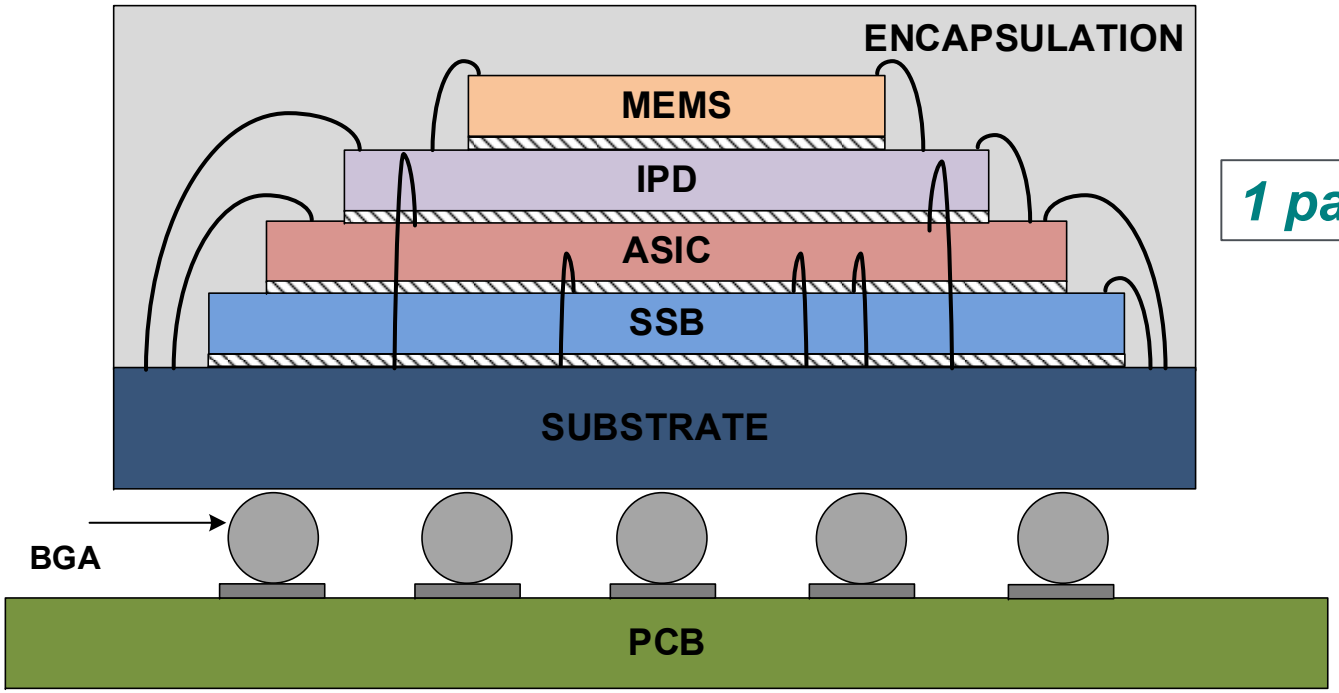
Enabling Technologies

- **Stacked Chip-Scale Packaging (SCSP)**
  - Multiple chips in one package



1 package vs 4

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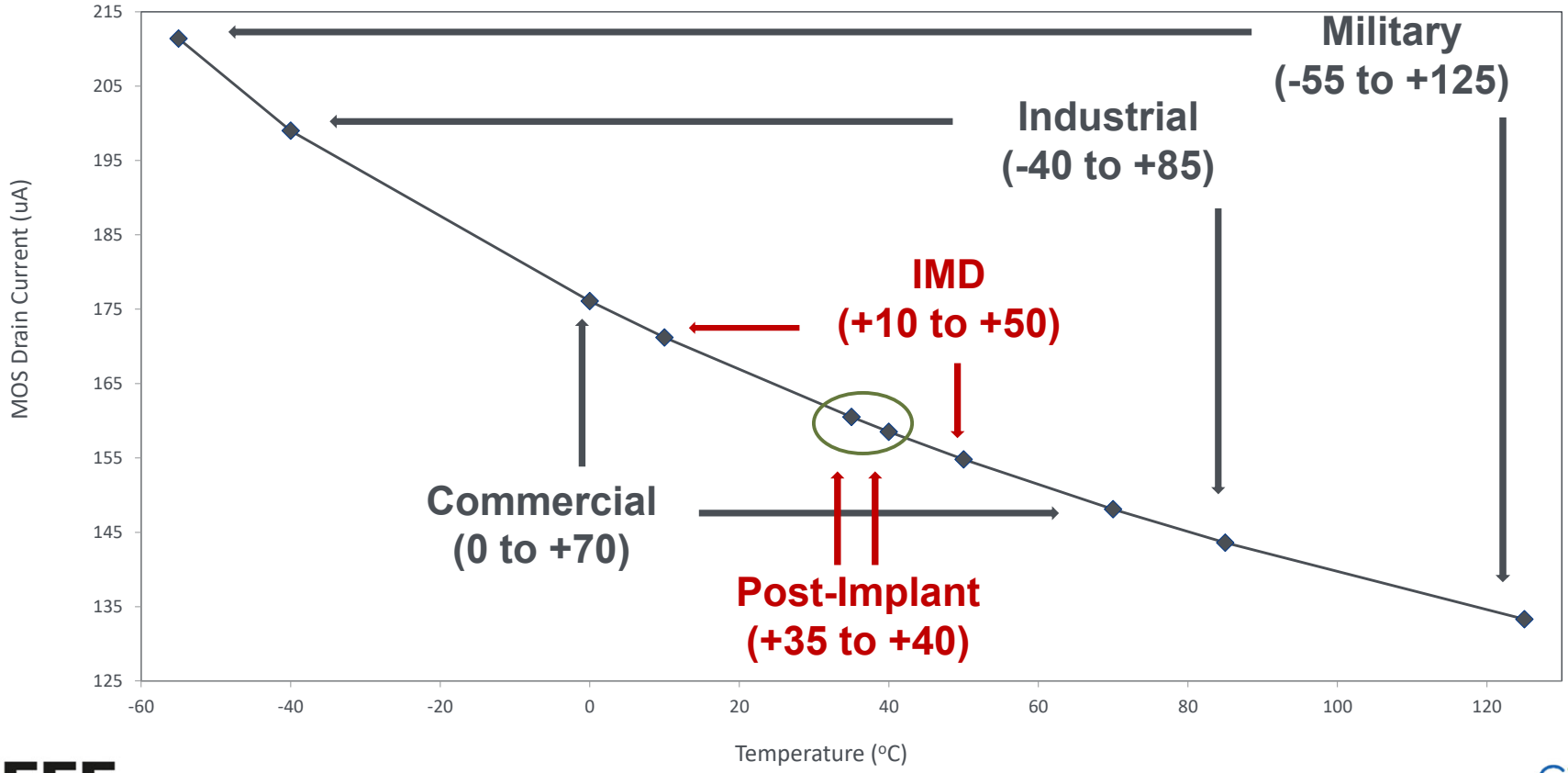
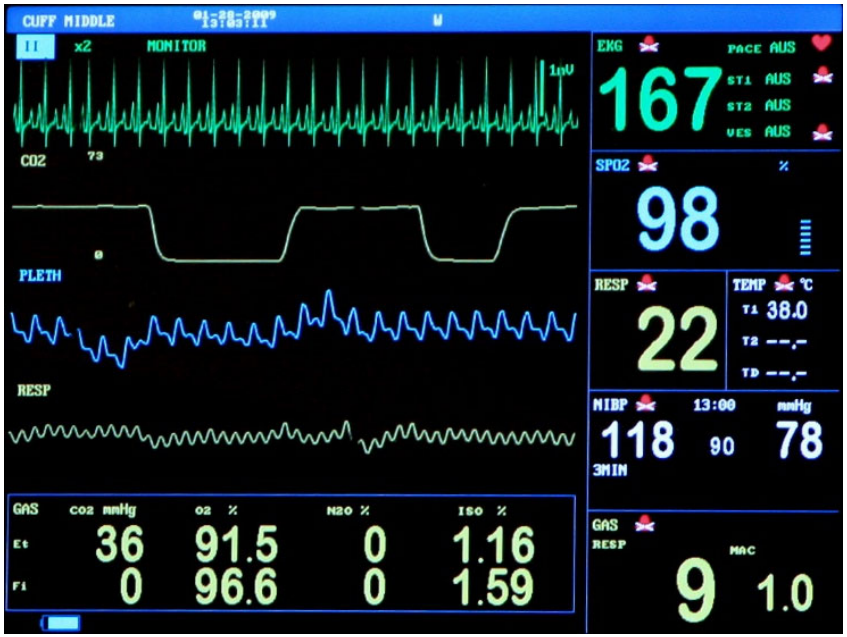
Design Opportunities

- **Low/Small Temperature Range**



Design Opportunities

- **Low Frequency Requirements**
  - EEG/ECG bandwidth ~ 200Hz
  - Blood pressure bandwidth < 100Hz
  - Accelerometer bandwidth < 1KHz
  - Stimulation therapy < 10KHz
  - [5G Wireless > 50GHz]



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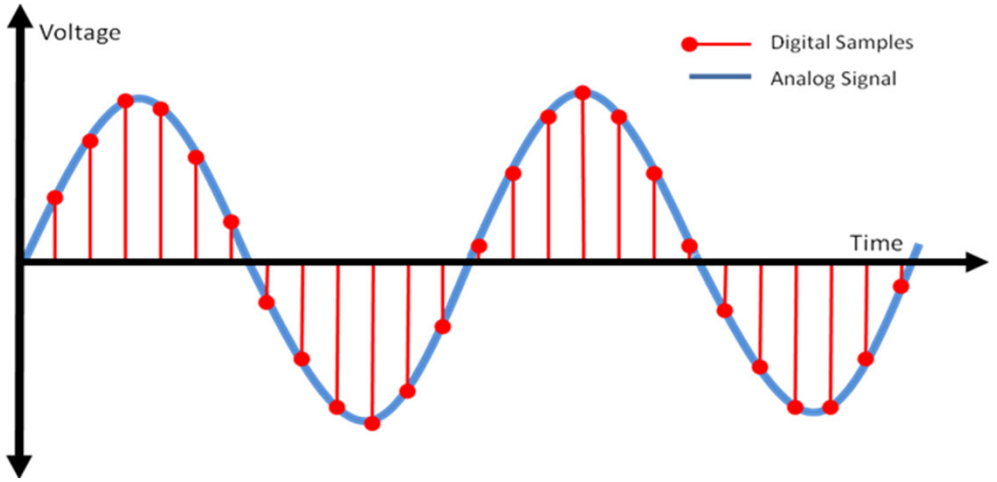
Design Opportunities

- **Moderate Precision Requirements**
  - Stimulator DAC amplitude ~ 8-bits
  - ECG/EEG ADC resolution ~ 12-16 bits
  - Pressure sensor ADC resolution ~ 10-bits
  - Accelerometer ADC resolution ~ 10-bits
  - [Audio DAC ~ 24-32 bits]

8-bits = 256 steps

32-bits > 4 billion steps



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Design Opportunities

- **Non-Volatile Memory (NVM)**
  - Included in most MCUs – or OTP in ASIC
  - Holds memory when power is removed
  - MCU/RAM can be disabled – most of the time
  - Calibration for analog circuits
    - Reduces analog performance requirements

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Design Opportunities

- **Battery Recharge**
  - Required for most MIMDs
  - Recharge session used for communication
  - Communication used to calibrate circuits
    - Reduces absolute accuracy requirements
    - Reduces accumulation of timing errors

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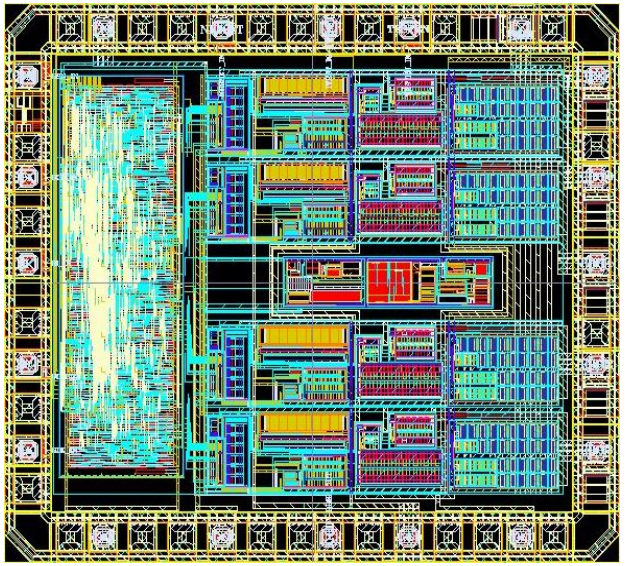
Custom IC Design Techniques

- **Application-Specific ICs (ASICs)**
  - Eliminate unnecessary features & functions
  - Optimize performance for single application
  - Optimize size & power for MEMS interfaces
  - Optimize interconnect for SCSP
  - Optimize overall integration
  - Optimize total power consumption
    - Enables battery size reduction

Customize design to minimize size & power



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Custom IC Design Techniques

- **Complex Power Management**
  - Multiple supply domains
  - Switched-mode power supplies
  - Detailed enable/disable control
  - Digital clock gating
  - Energy harvesting

Effective power management minimizes power consumption

Example MIMD

4V Battery

10V Wireless antenna

Inductive buck for battery charging

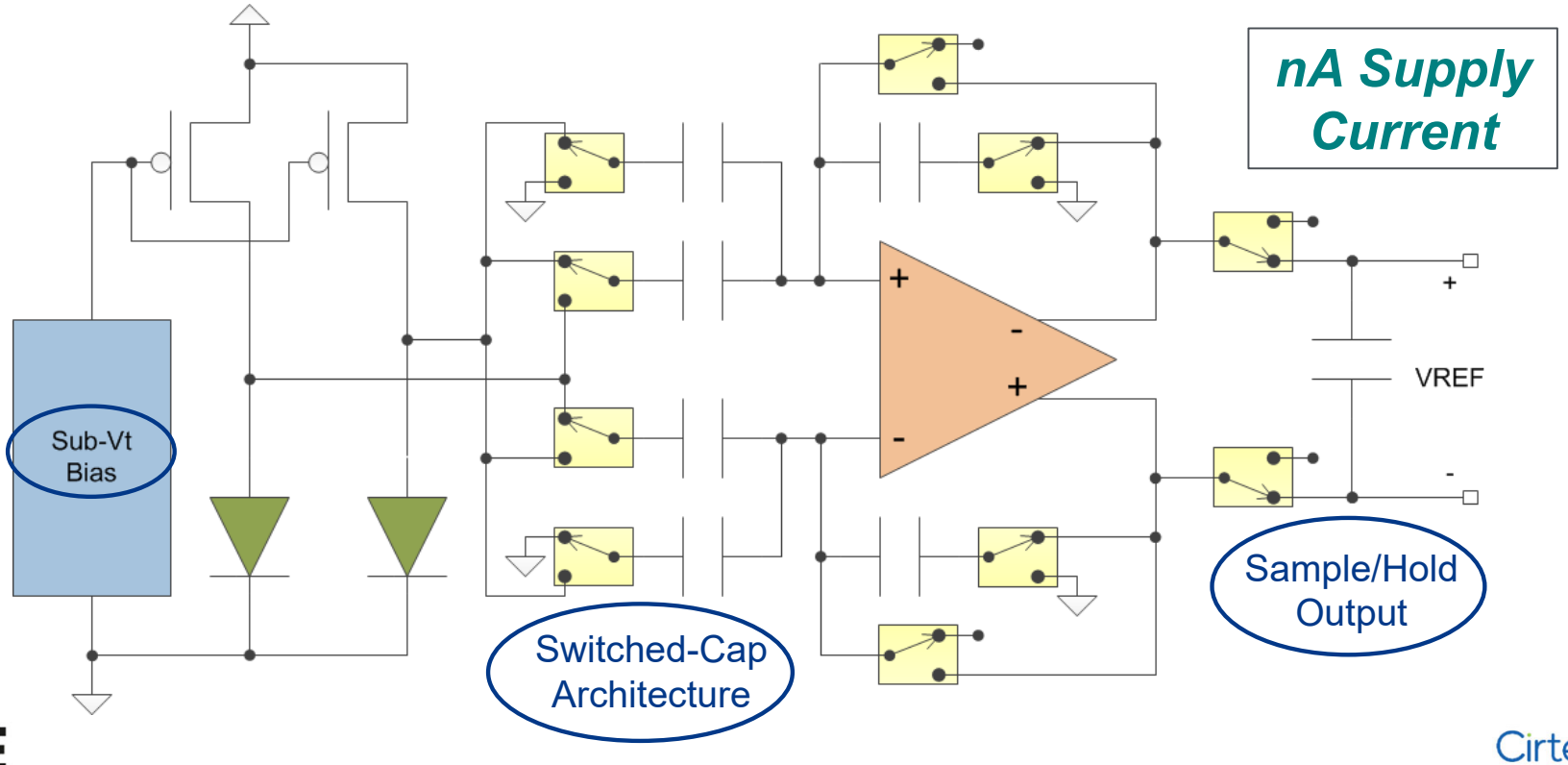
Capacitive buck for 1.8V analog/digital

Linear regulator for 0.9V timekeeping

Inductive boost for 18V Stimulation

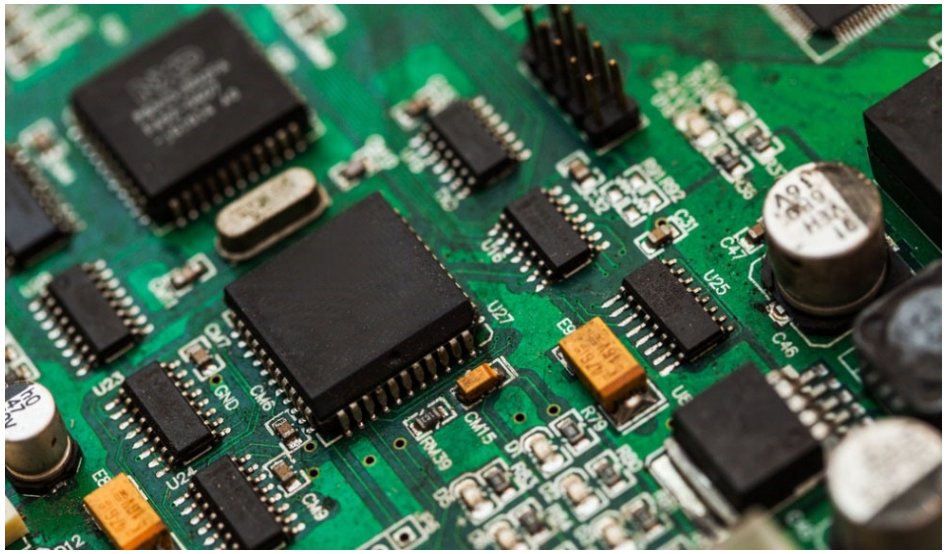
Custom IC Design Techniques

- **Ultra-Low Power Circuit Design**
  - Example: Ultra low power voltage reference



Custom IC Design Techniques

- **Smart Integration**
  - Assess all available components
  - Consider size, power, cost, schedule, risk
  - Partition design: only customize as needed
  - [Not maximum integration]



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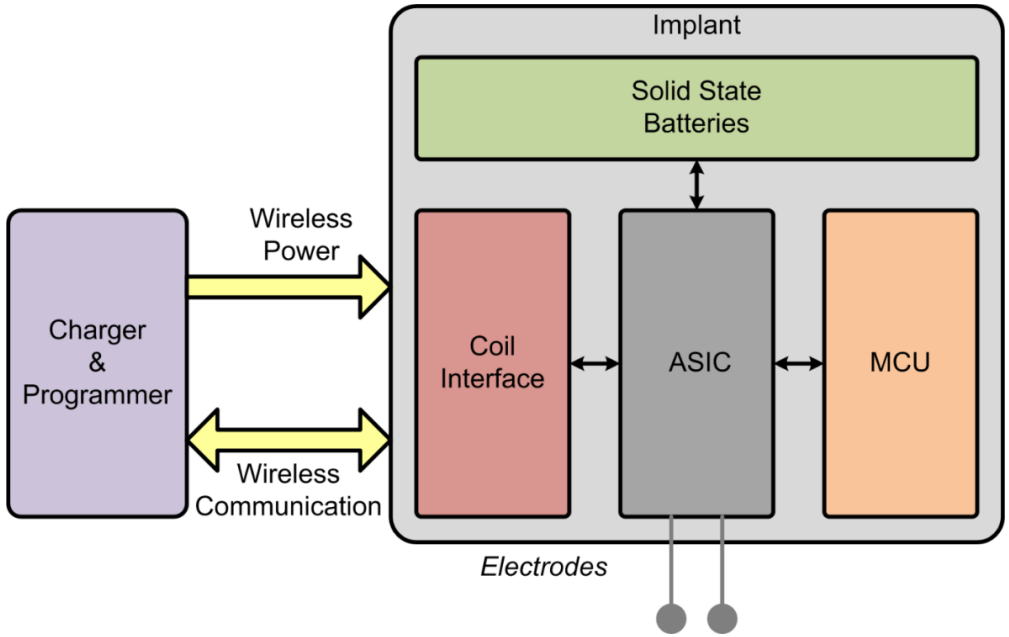
MIMD Case Study

- **Vagus Nerve Stimulator**
  - Programmable stimulation current
  - Wireless communication & recharge
  - Integrated power management & timekeeping



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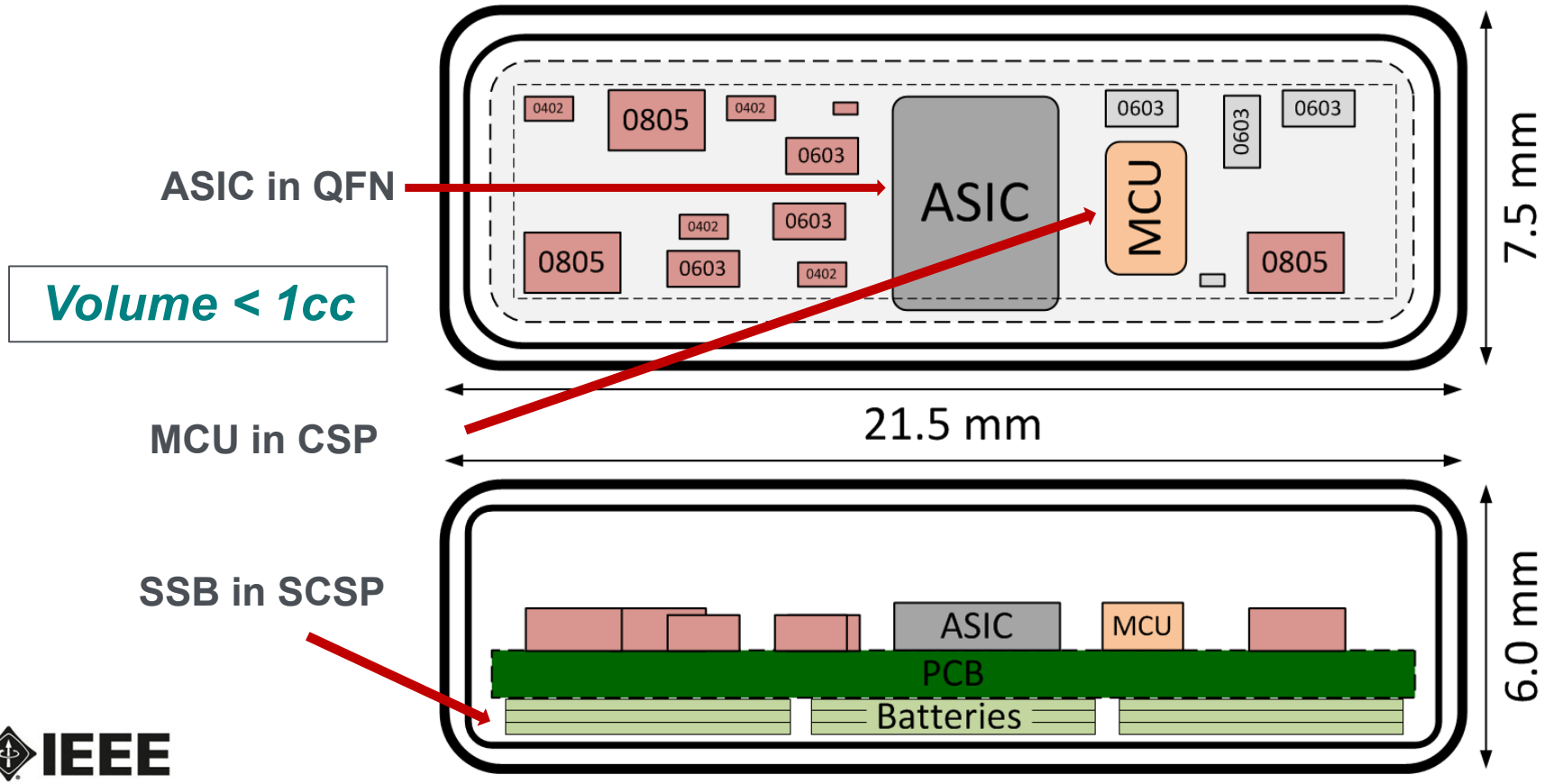
MIMD Case Study

- **Vagus Nerve Stimulator**



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Conclusions

- MIMDs are achievable by capitalizing on Enabling Technologies and exploiting Design Opportunities
- Custom IC Design using unique Design Techniques allows us to optimize the solution
- Smart Integration approach helps to reduce time, cost, & risk

Learn More

- **IEEE – Engineering in Medicine and Biology Society**
  - EMBS is the world's largest international society of biomedical engineers.
  - Join the Phoenix chapter - https://www.embs.org/membership/
- **International Microelectronics and Packaging Society**
  - IMAPS is the largest society dedicated to the advancement and growth of microelectronics and electronics packaging.
  - Attend the Medical Electronics Workshop - https://imaps.org/page/medical
- **The Center for Neurotechnology**
  - CNT is an Engineering Research Center funded by the National Science Foundation to create devices to restore the body's capabilities for sensation and movement.
  - Learn about the latest research - https://centerforneurotech.uw.edu/
- **Cirtec Medical**
  - Cirtec Medical's Semiconductor group is a full-service provider of low-power mixed-signal ASICs specializing in miniaturized portable and implantable medical devices.
  - Join our team - https://cirtecmed.com/careers/

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Thank You!

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