SENSOR AND TRANSDUCER ELECTRONICS

FIRAT YAZICIOGLU

CATRENE WORKSHOP - 2014

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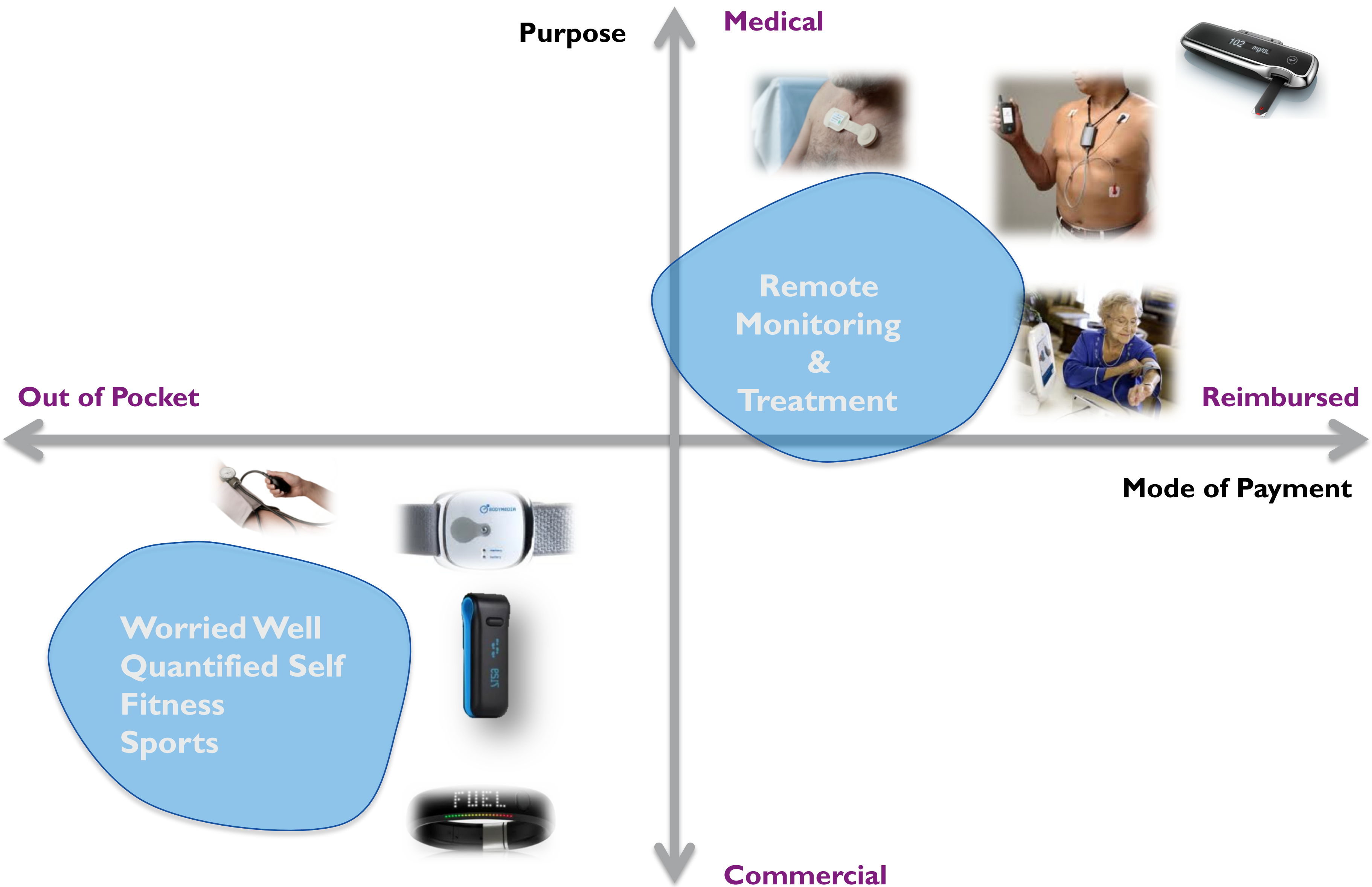
HEALTH & WELLNESS - TODAY



* Rock Health Report – connected health sensors

HEALTH & WELLNESS - TRENDS

Curative

Remote Monitoring & Treatment

Hypertension

Out of Po

Reimbursed

Preventive

USER ACCEPTANCE

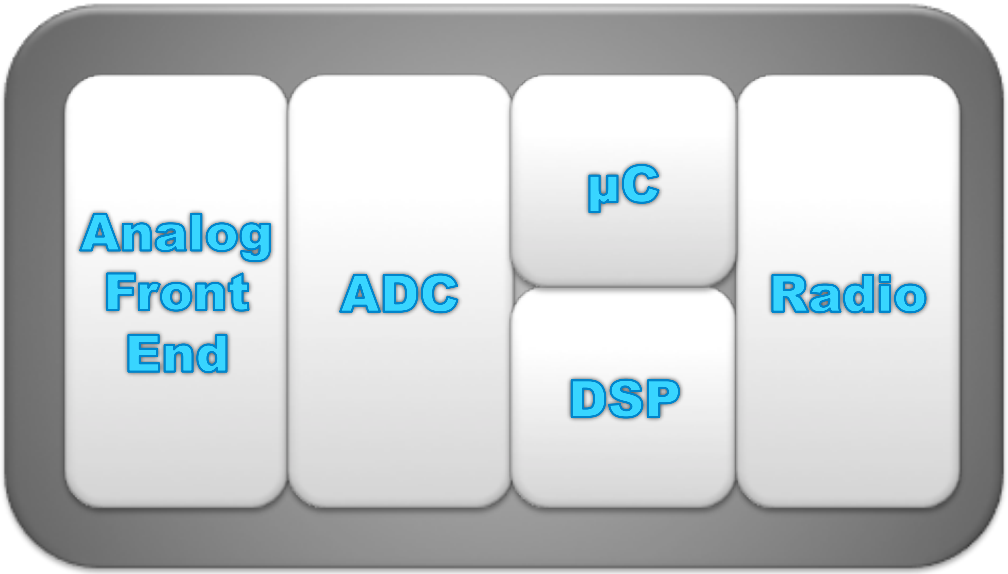
driven by

Comfort

Functionality

Cost

WEARABLE & IMPLANTABLE MEDICAL DEVICES



Low-Power

Miniature

Sensor Electronics

TRENDS – SENSOR INTERFACE DESIGN

Already Happening (10Y): Miniaturizing
Smart
Low-Power Design
Miniaturization

Low-Power Design Techniques

Recently Started (2Y-): Multi-Modal Systems
Multi-Sensor Interfaces
Sensor Fusion

Mixed Signal Designs

Third Wave (Now -): Adaptive Systems
Personalized
Situation Aware

Adaptive Architectures
Holistic Design Approaches
New Sensing Paradigms

Context Aware Wearable Devices

WORLD IS ANALOG (INTER)FACE IT!

Physical Sensors

Temperature
°C

Acceleration
mg

Pressure
Pa

Rotation
°/h

Flow
m^3/h

Medical Sensors

EOG

EMG

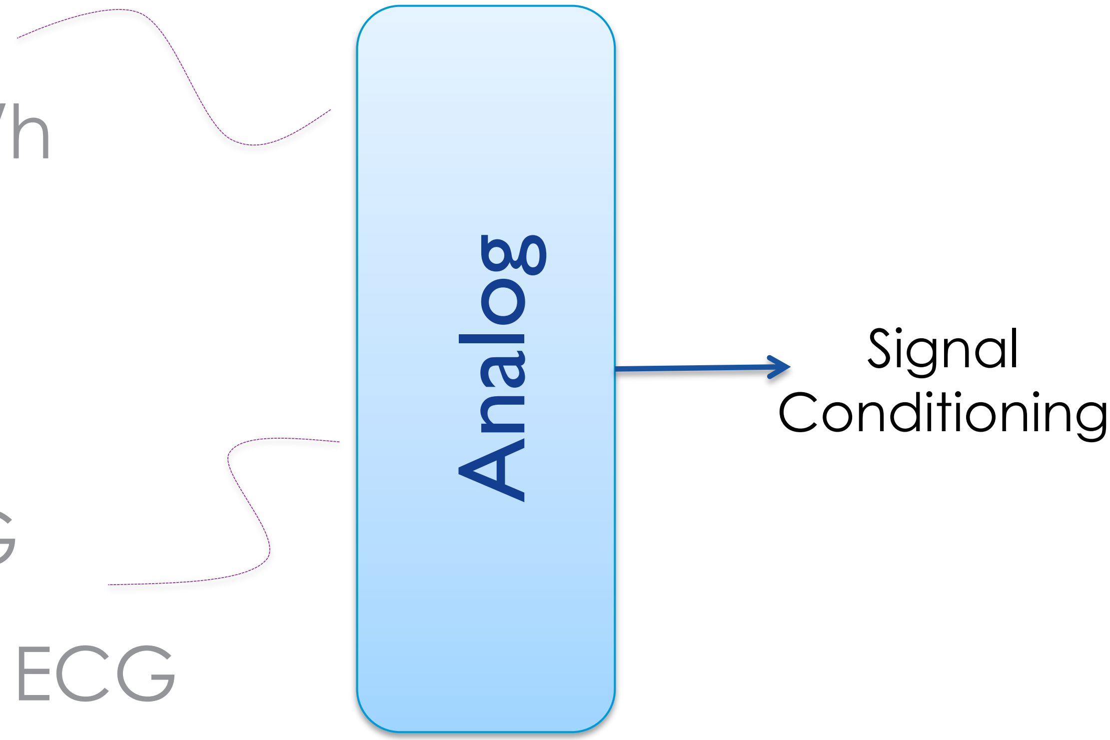
GSR

EEG

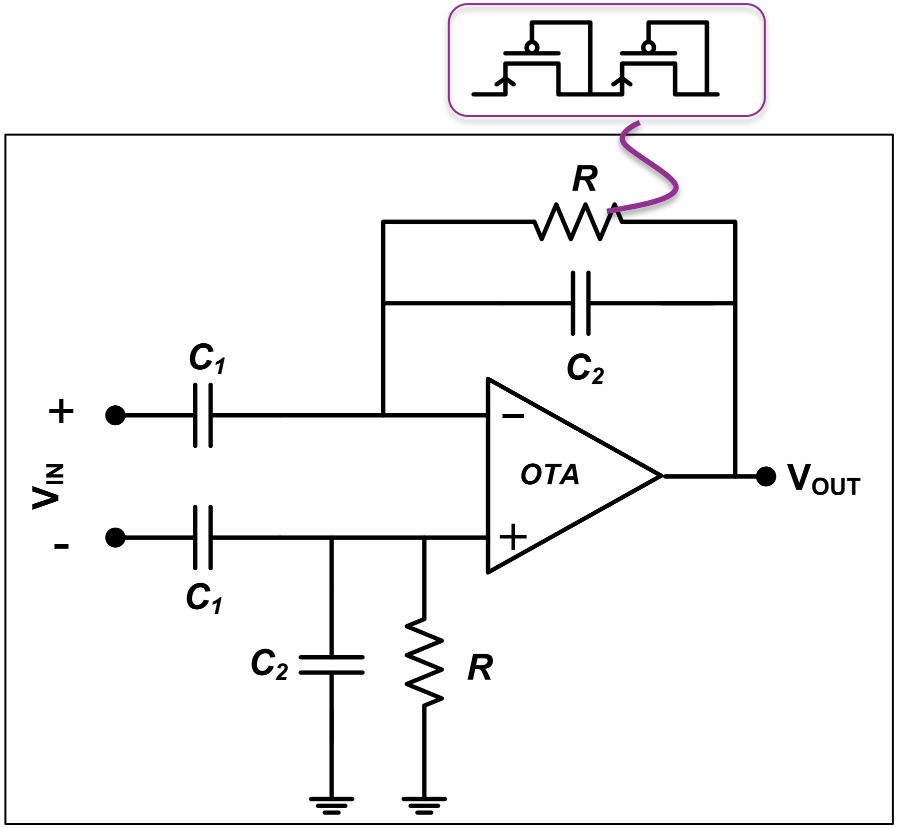
ECG

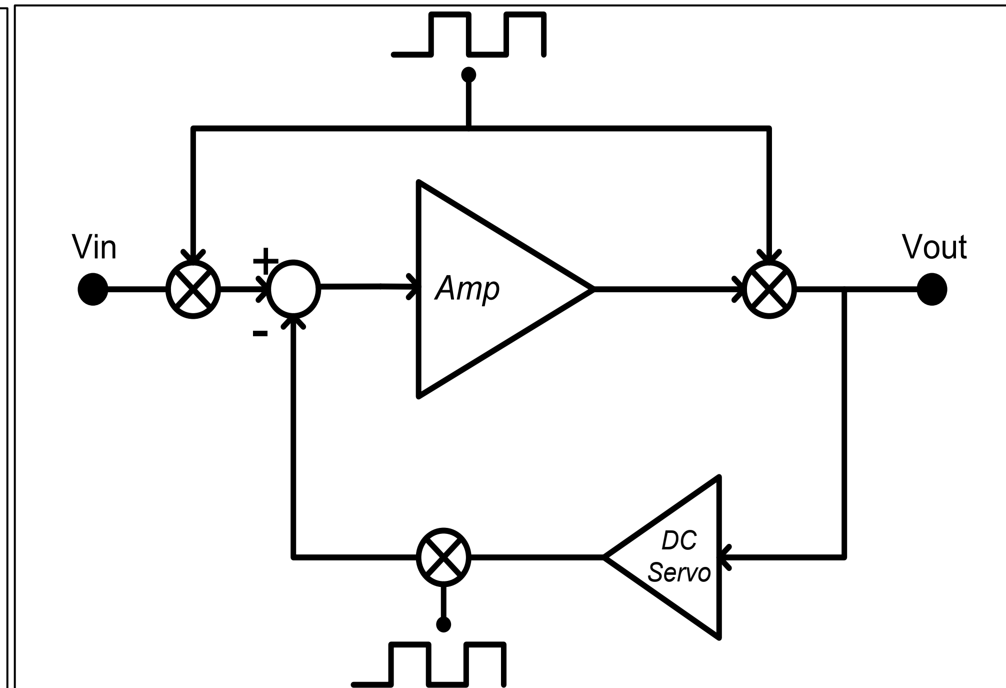
Bio-Impedance

PPG



LOW-POWER DESIGN TECHNIQUES EXAMPLE ARCHITECTURES

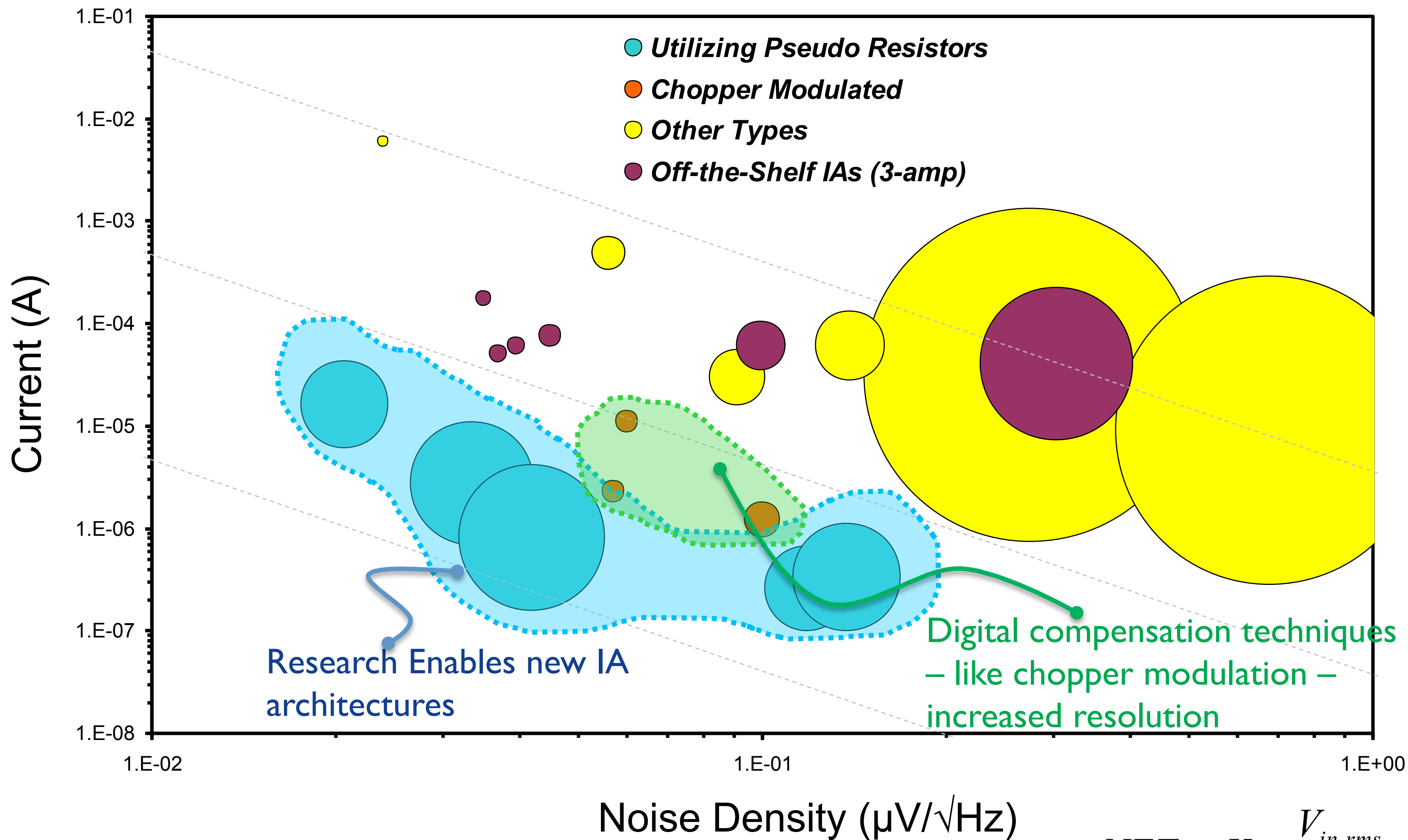




Capacitive instrumentation amplifiers using sub-threshold transistors are resistors

Chopper modulation using DC servo feedback.

RESEARCH ENABLED POWER EFFICIENT INSTRUMENTATION AMPLIFIERS



$$NEF = K\frac{V_{in,rms}}{\sqrt{\frac{\pi}{2}\times BW}}\sqrt{I_{total}}$$

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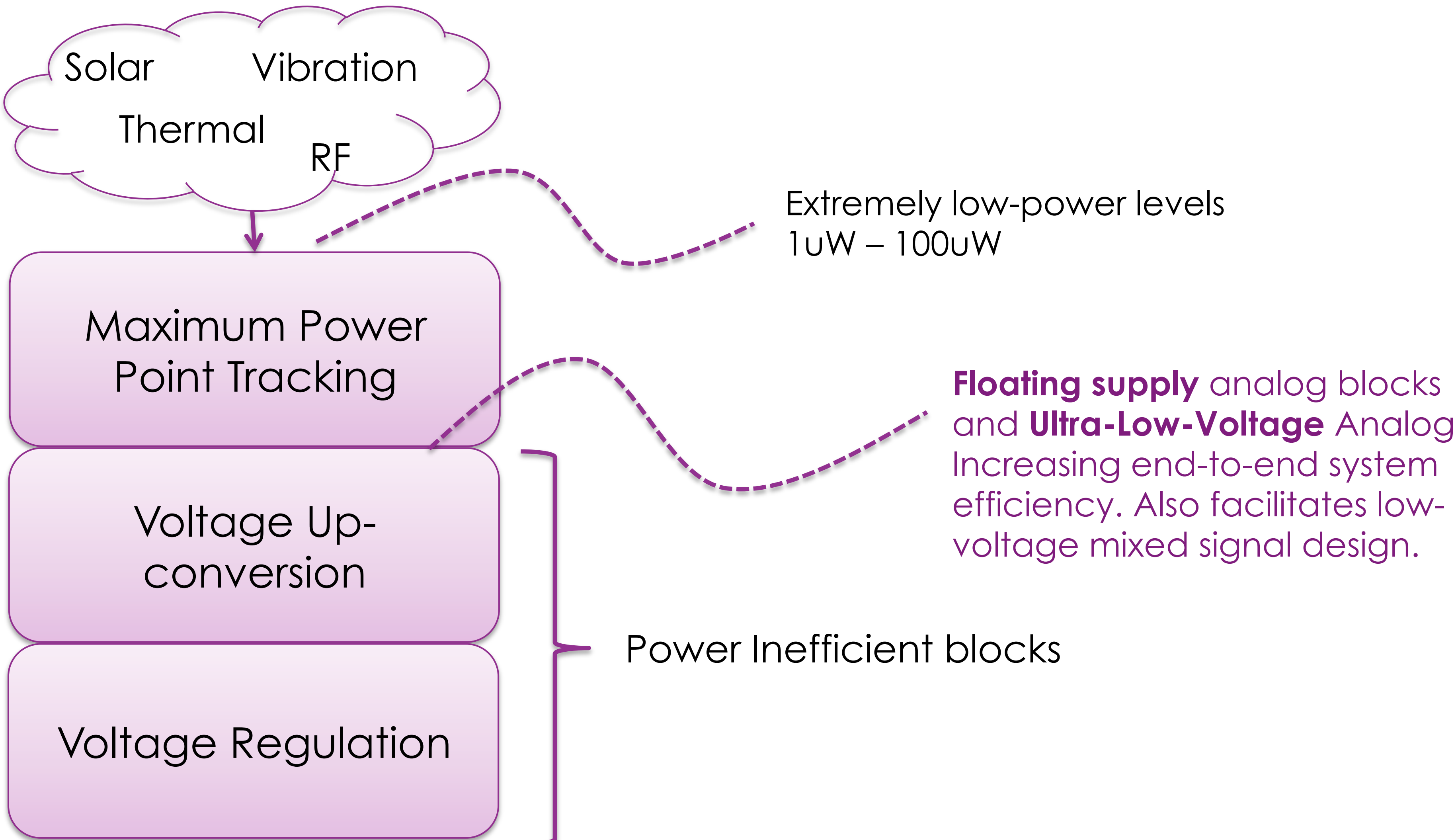
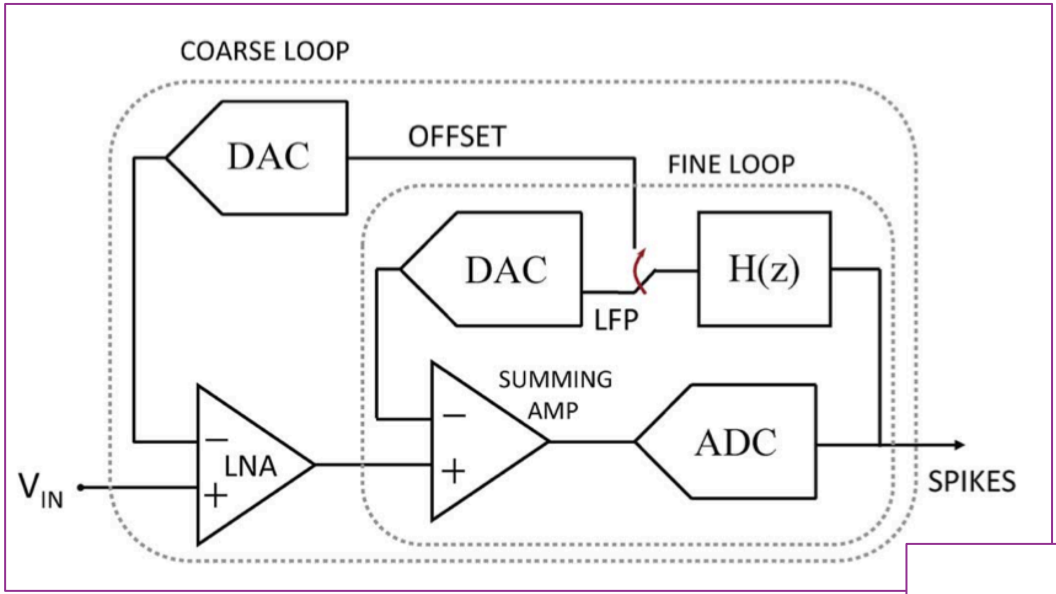
LOW-POWER DESIGN TECHNIQUES
NEW INTERESTS: LOW-VOLTAGE & MIXED SIGNAL DESIGN

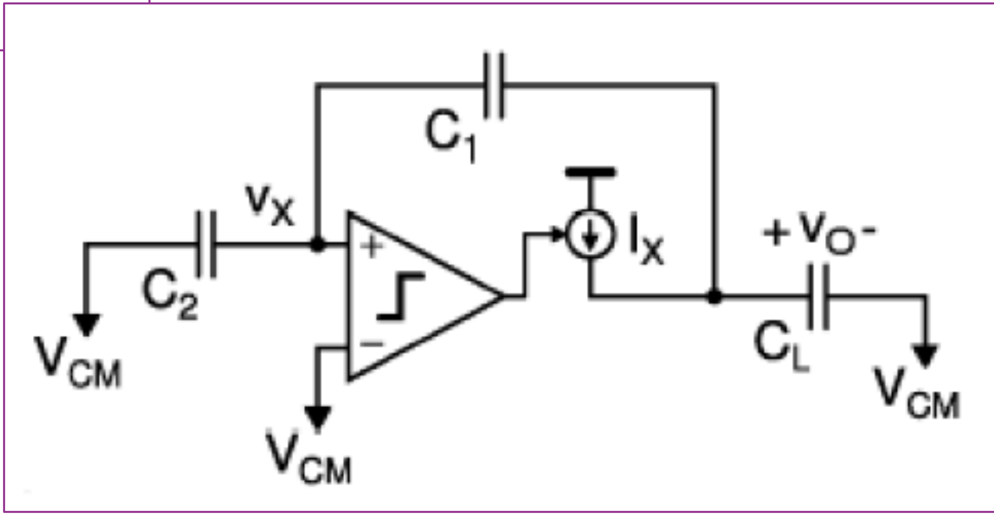


LOW-POWER DESIGN TECHNIQUES
NEW INTERESTS: LOW-VOLTAGE & MIXED SIGNAL DESIGN

Mixed Signal Instrumentation Amplifier Design Operating from 0.5V Supply Voltage



Comparator Based Analog Architectures can operating from 0.35V



MIXED-SIGNAL DESIGNS
MULTI-SENSOR INTERFACING

Physical Sensors

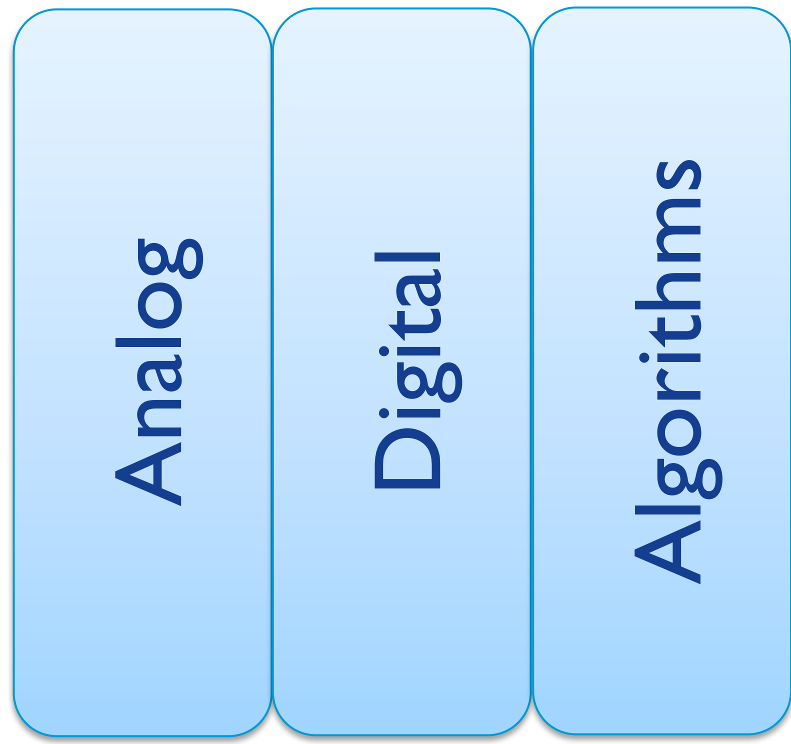
Temperature
°C

Acceleration
mg

Pressure
Pa

Rotation
°/h

Flow
m^3/h



Medical Sensors

EOG

EMG

GSR

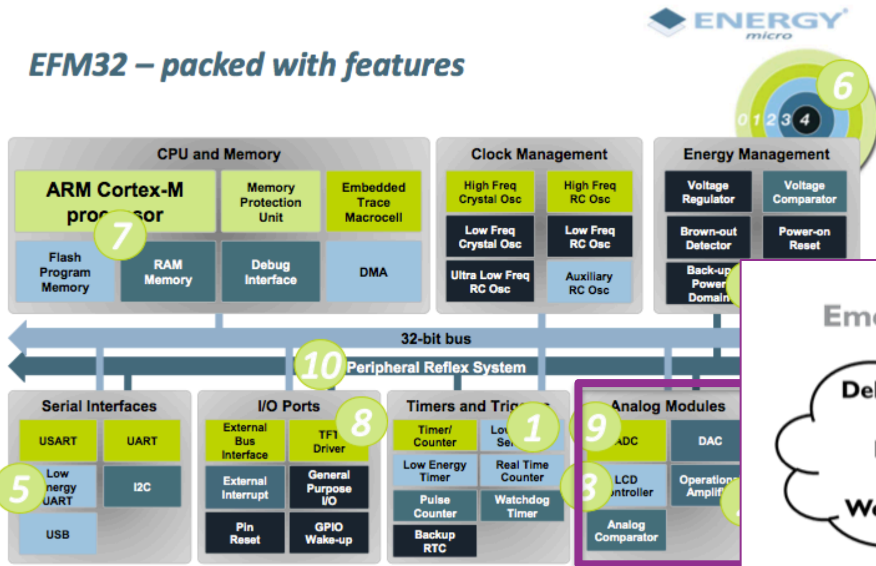
EEG

ECG

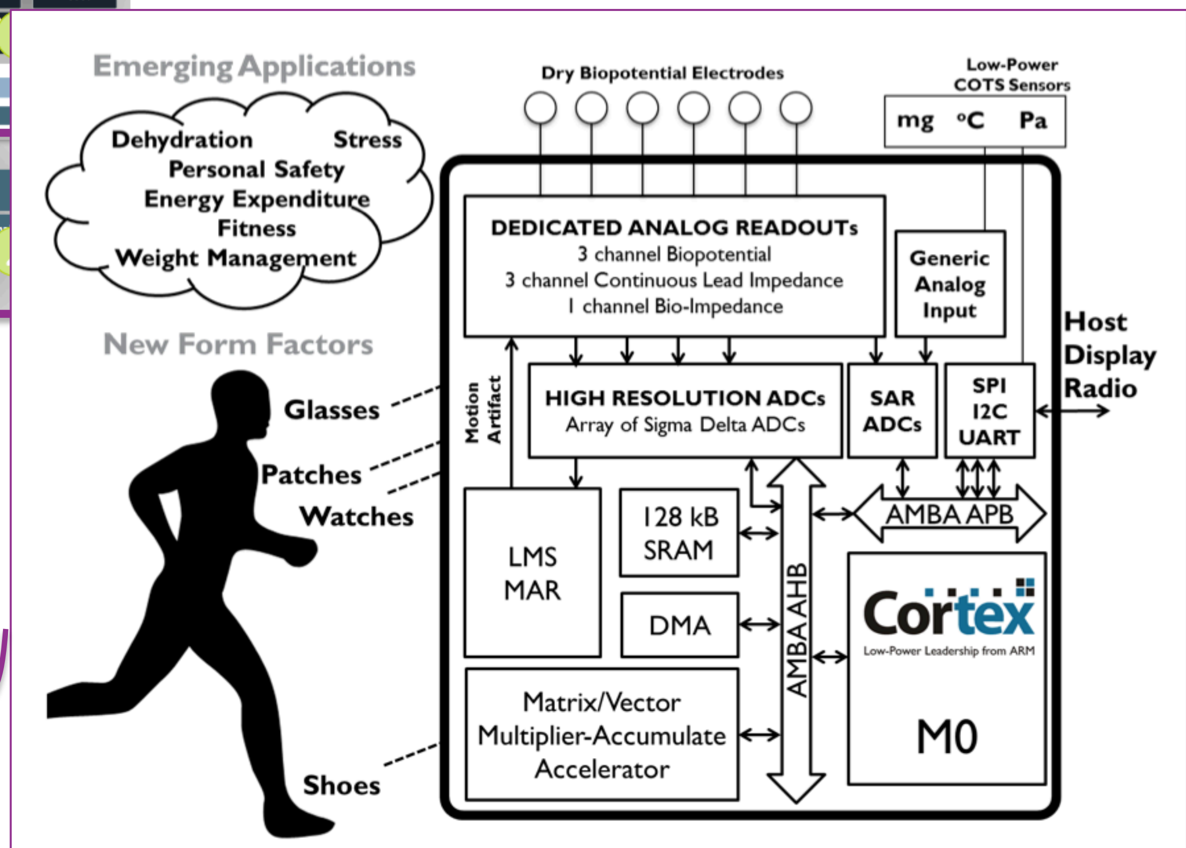
Bio-Impedance

PPG

MIXED SIGNAL DESIGNS
INDUSTRY APPROACH & RESEARCH APPROACH

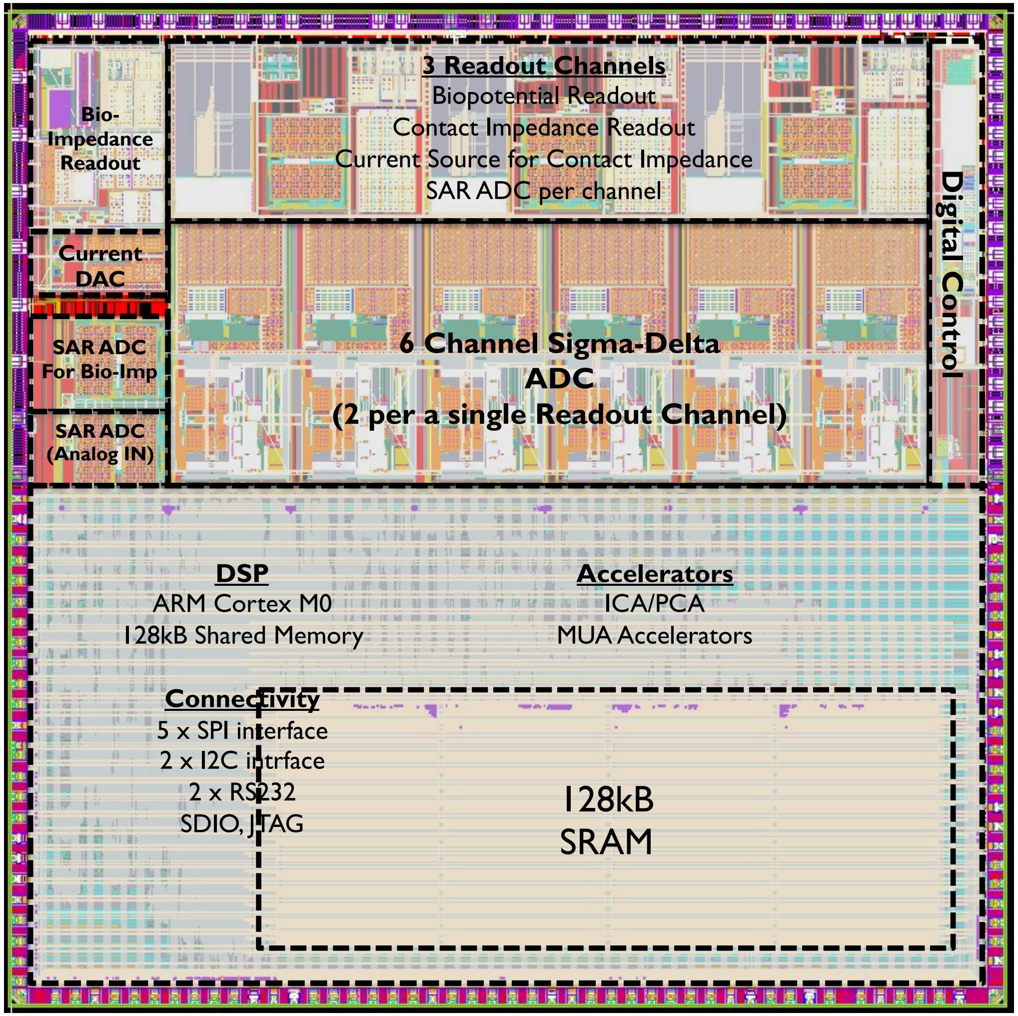


More analog blocks are appearing in digital MCU's



Medical Applications requires even more analog

MIXED SIGNAL DESIGNS
AREA OF ANALOG IS A CONCERN

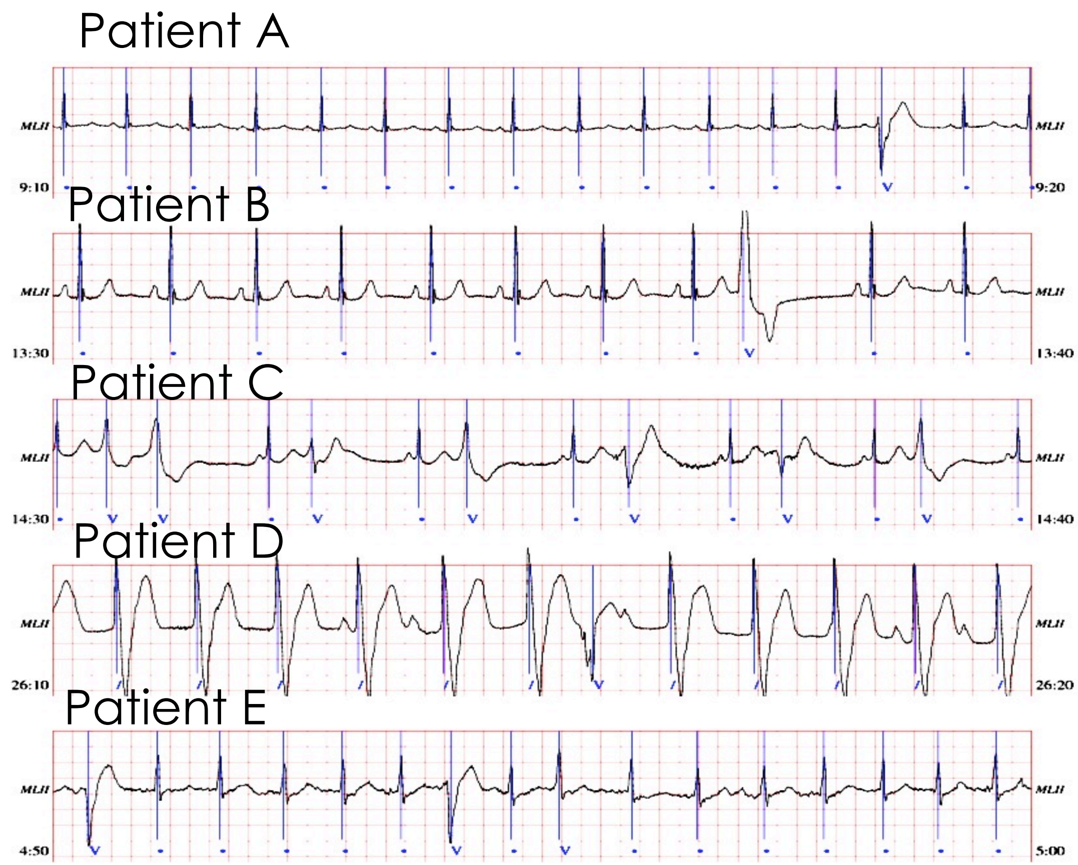


Total Area:
7mm x 7mm

Analog Area:
Dominated by SD ADCs

Digital Area:
Dominated by SRAM
Fill factor of digital area is very low

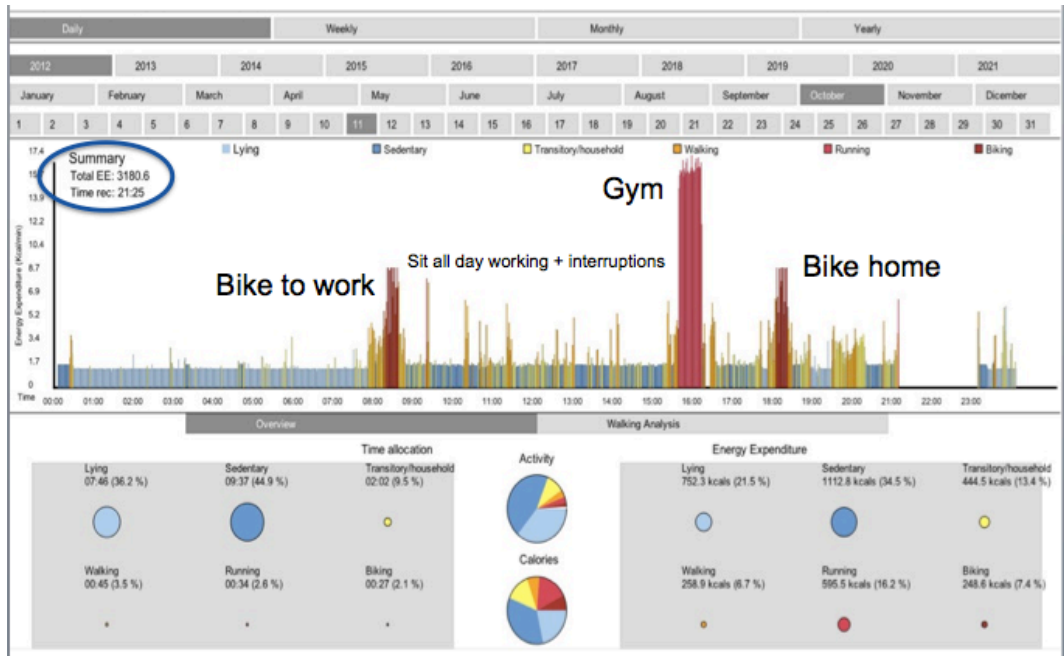
ADAPTIVE SYSTEMS
WE ARE DIFFERENT!



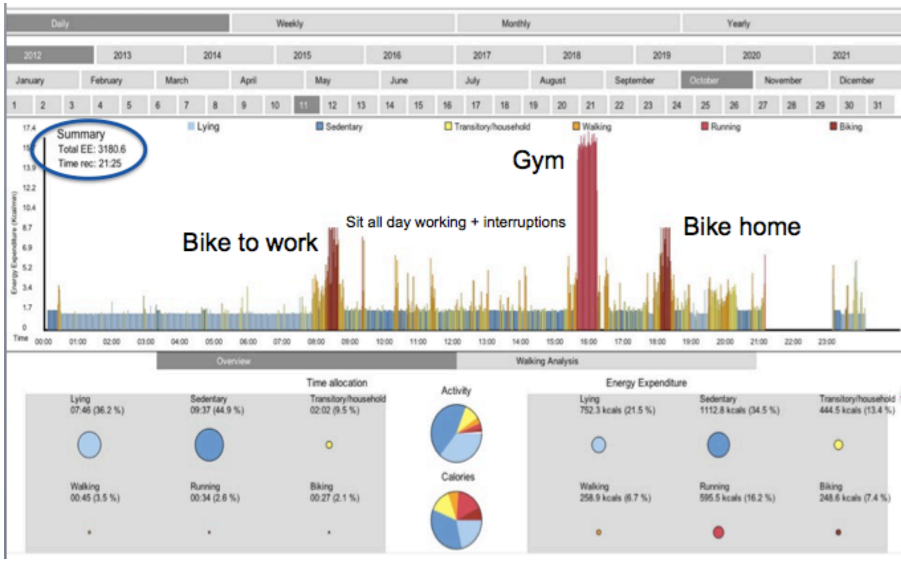
GENETICS

LIFESTYLE

ADAPTIVE SYSTEMS
EACH DAY IS DIFFERENT



CONTEXT AWARE SYSTEMS



Mood
Activity Level

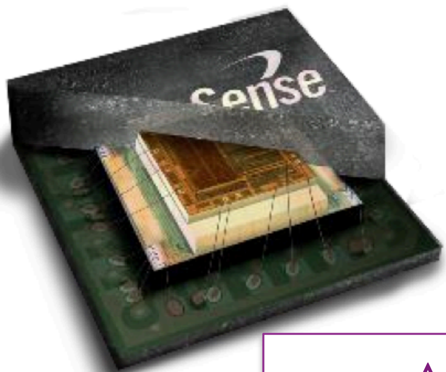
Adaptive Systems

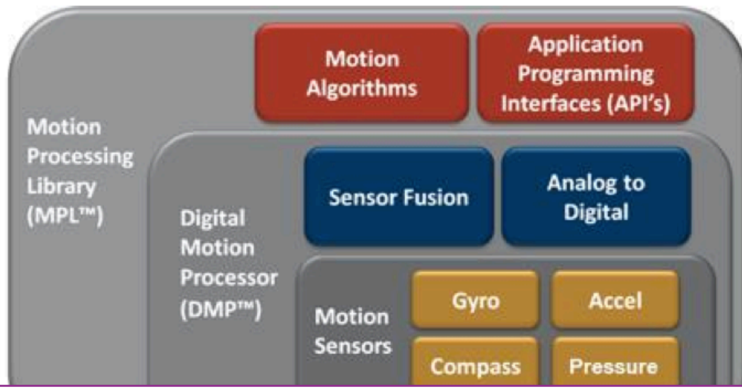
Accuracy/Resolution
Resource Allocation
Feature Definition
Classification

Subject Specific Signal Features
Health Conditions

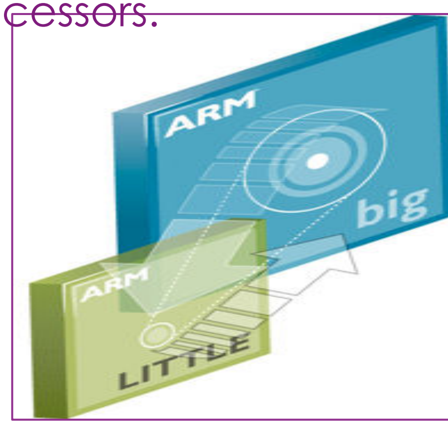
ADAPTIVE SYSTEMS
ADAPTIVE RESOURCE UTILIZATION

Combining a Small processor with a large one more efficient task partitioning can be done.

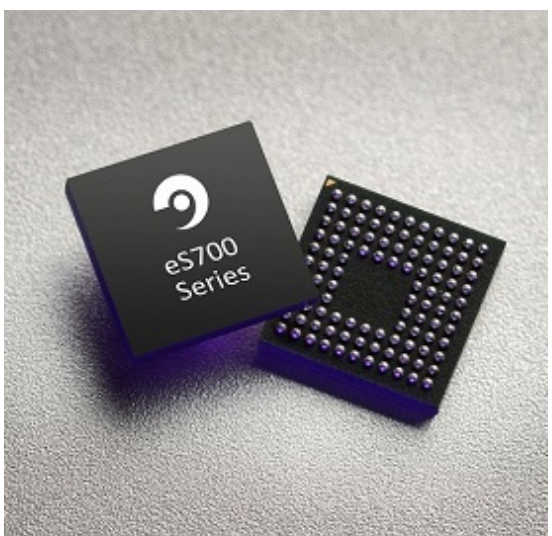




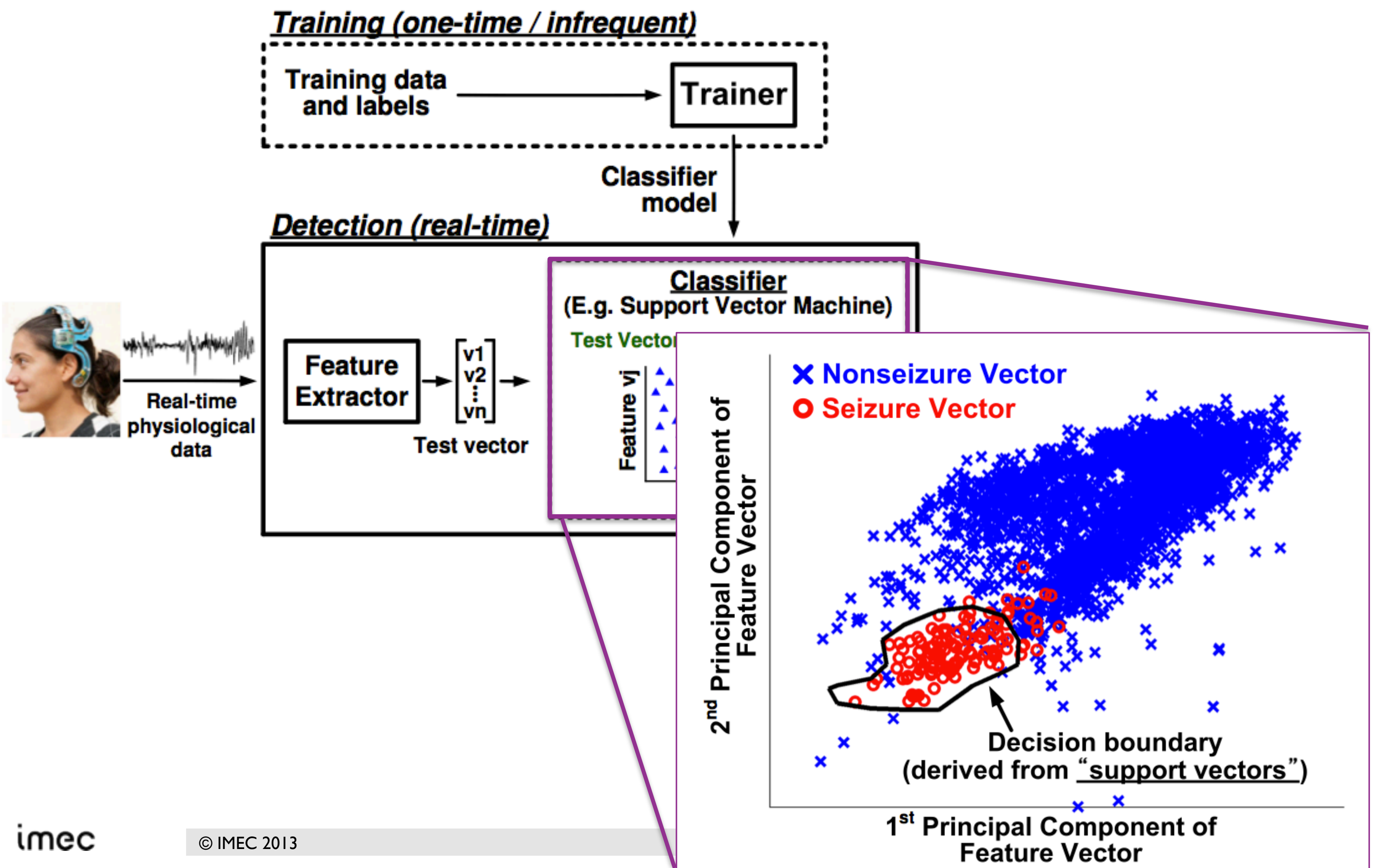
Software automatically moves workload between processors.



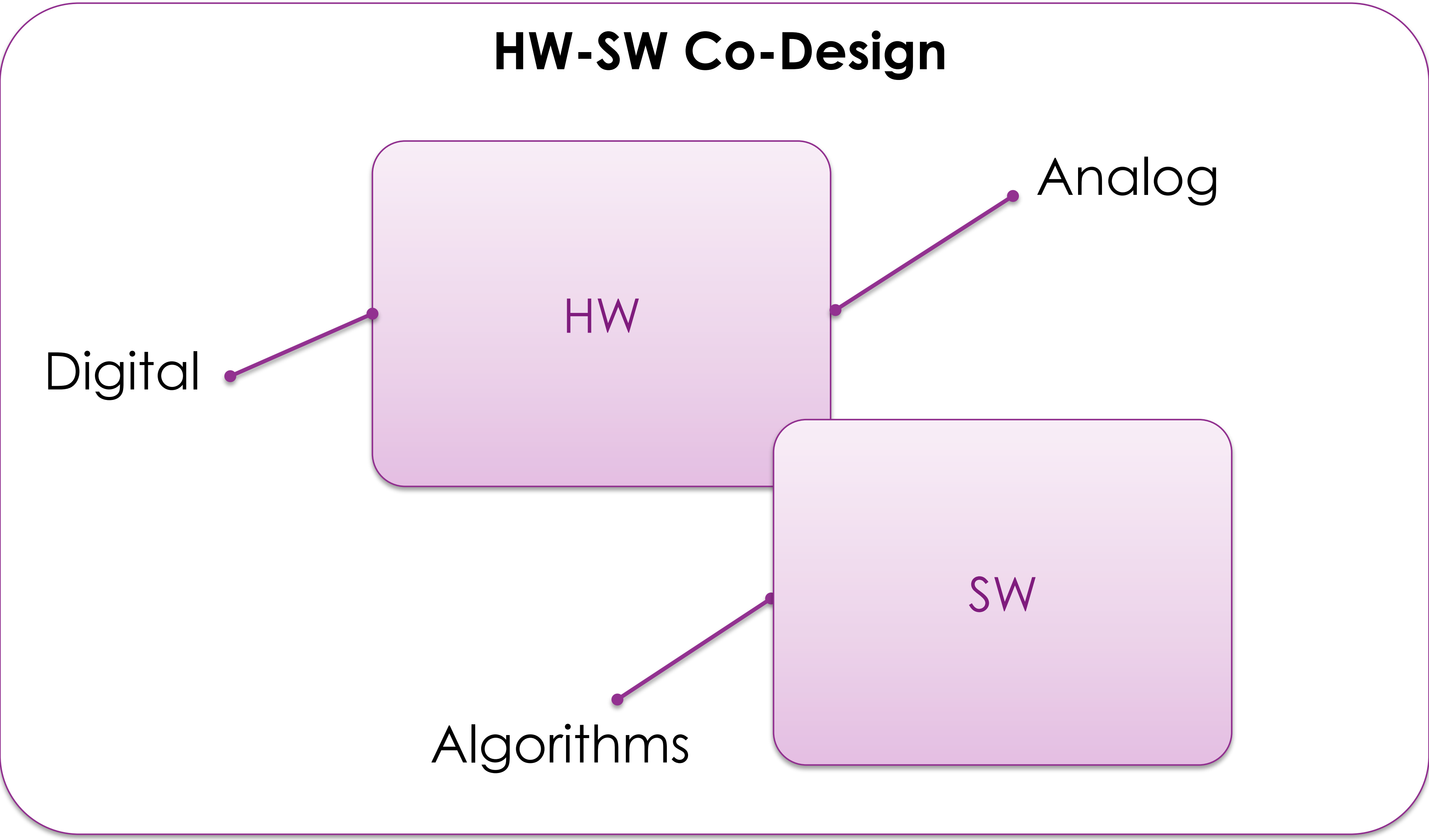
Always On Voice Recognition – adaptive resource utilization



ADAPTIVE SYSTEMS
PERSONALIZING SIGNAL ANALYSIS

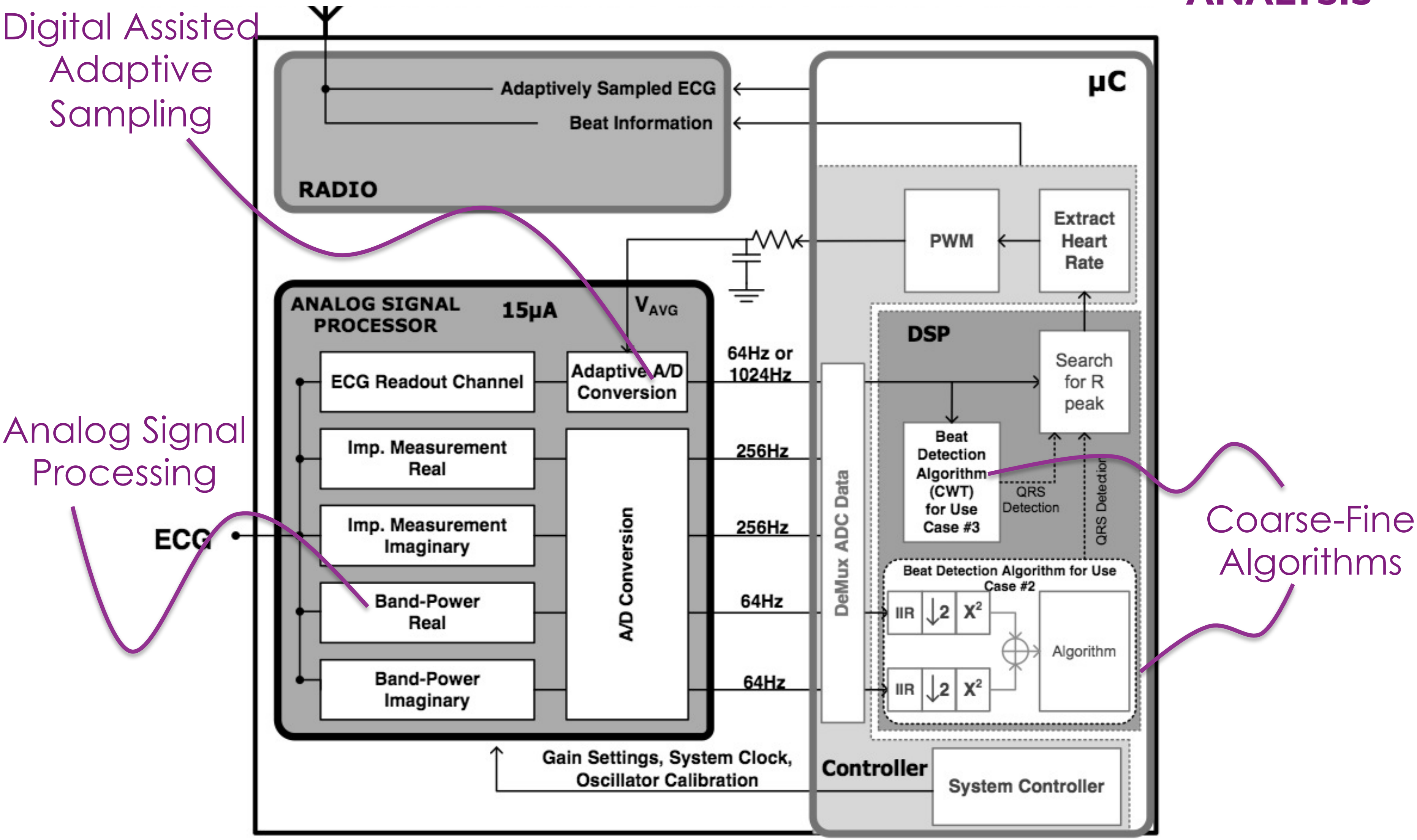


HOLISTIC DESIGN

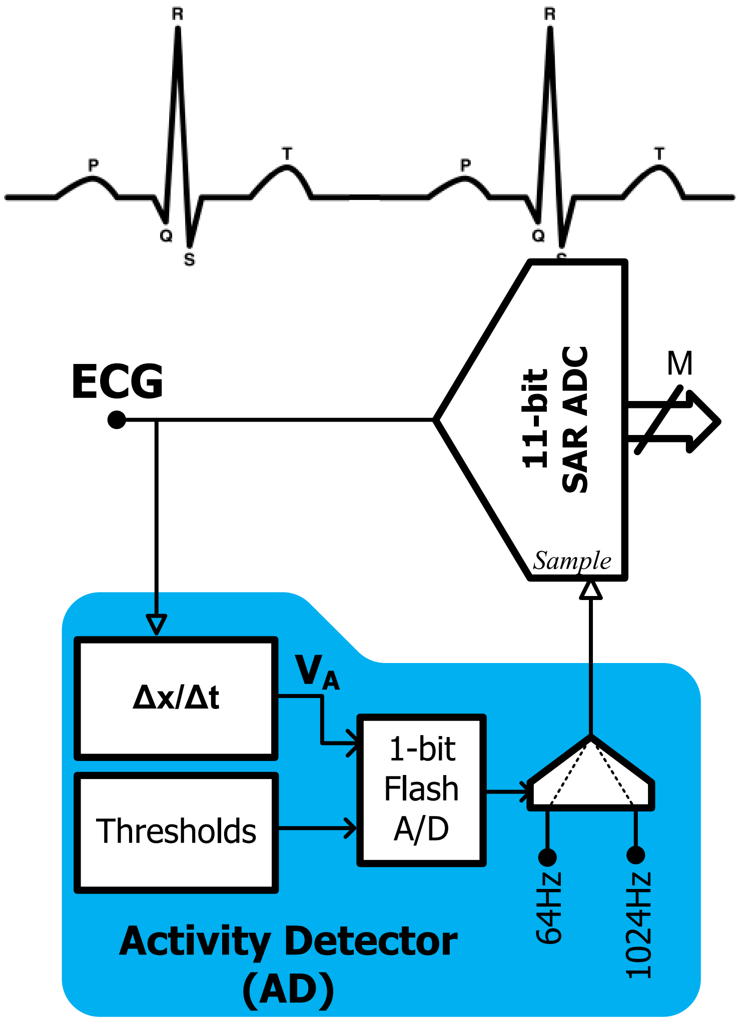


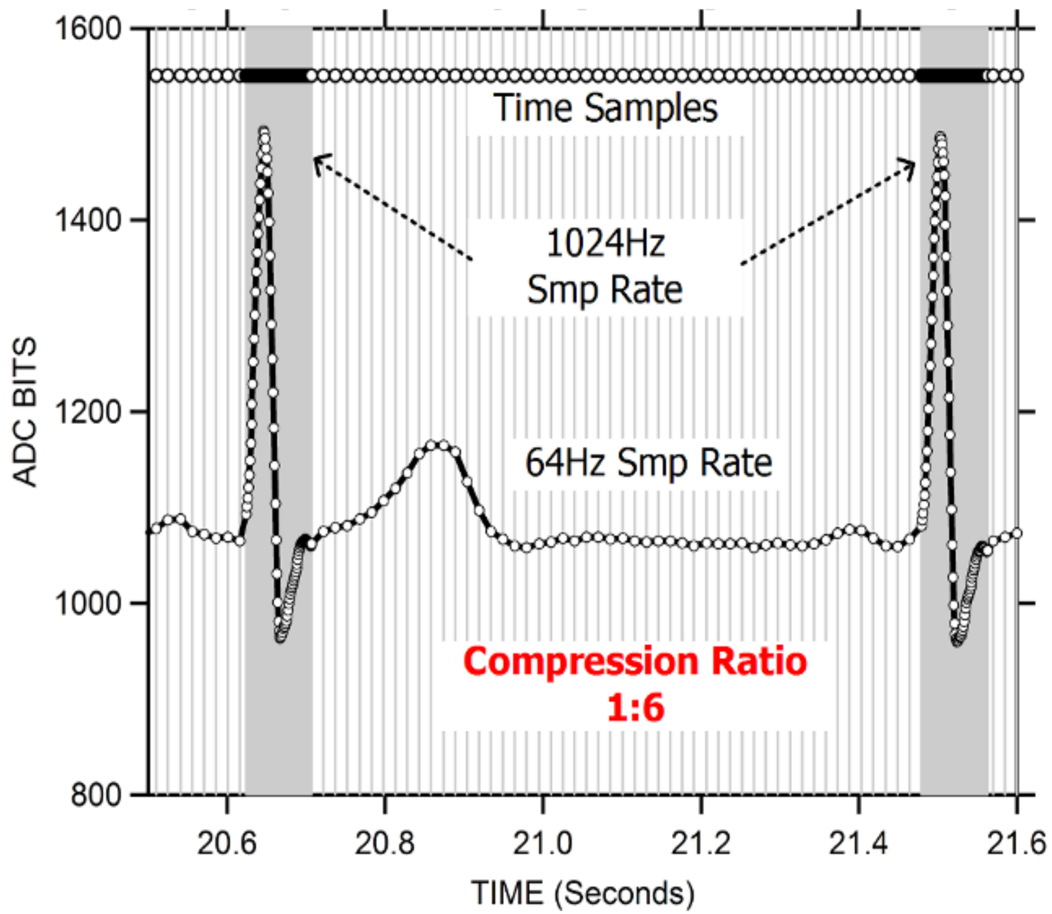
HOLISTIC DESIGN

CO-DESIGN ANALOG READOUT, ADC, AND ALGORITHMS FOR HRV ANALYSIS



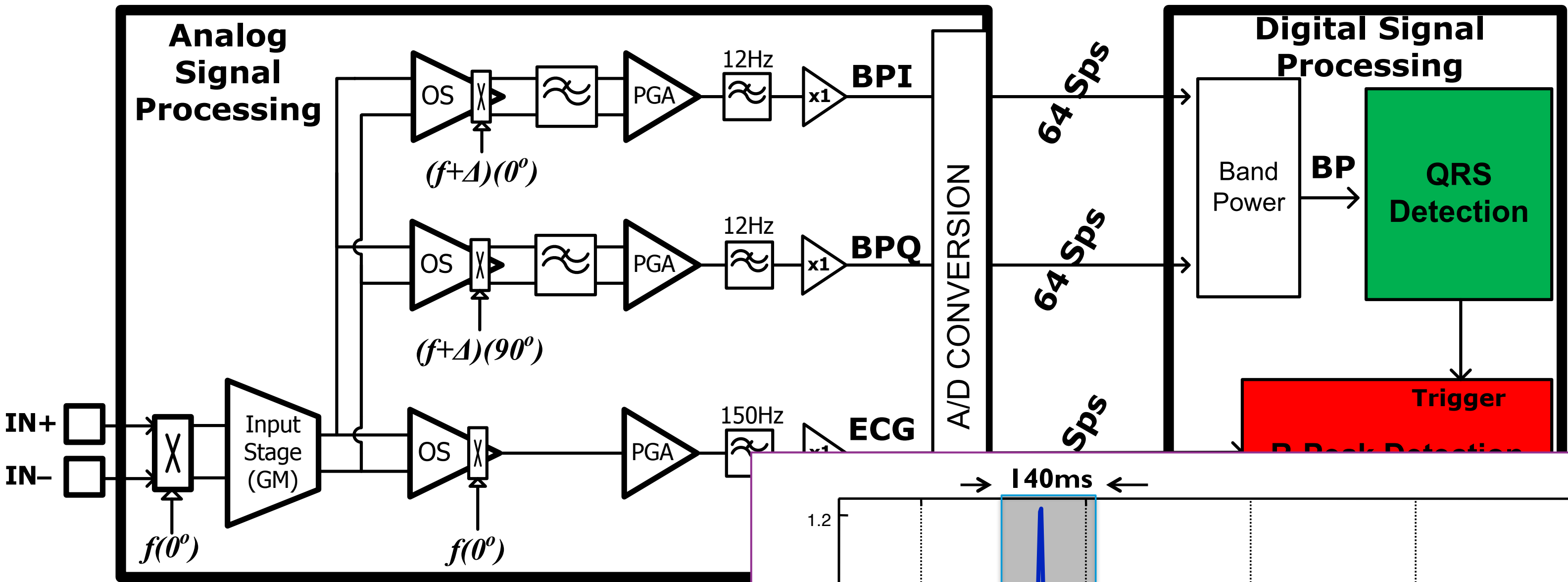
ADAPTIVE SAMPLING ADC & DATA COMPRESSION



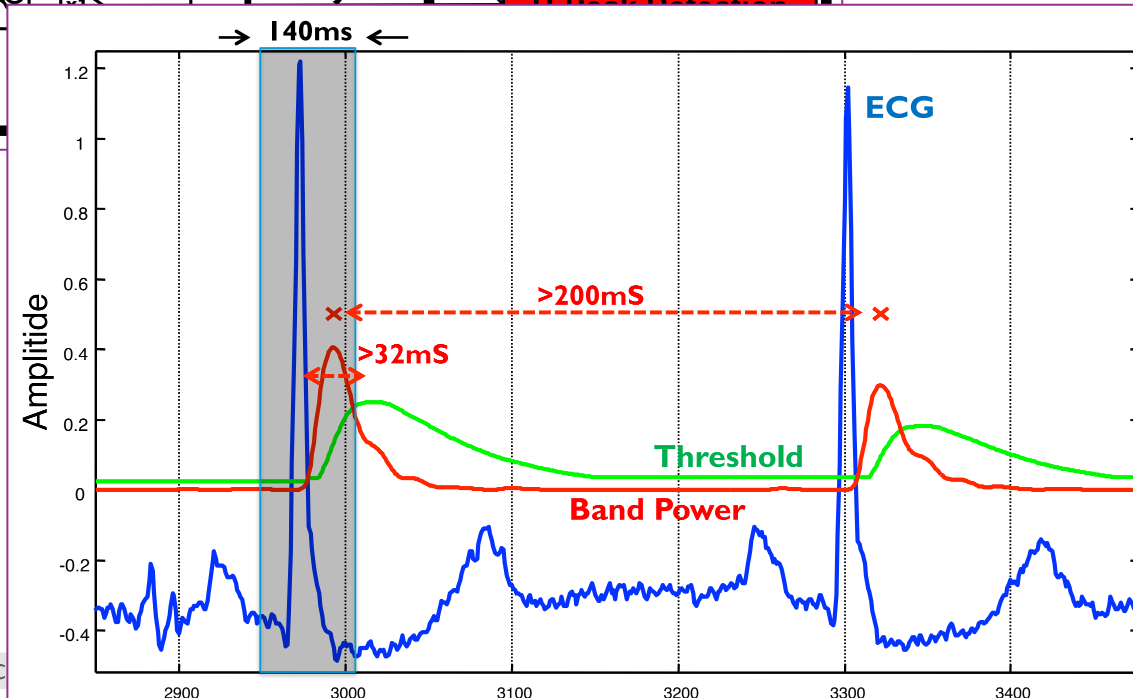


ANALOG SIGNAL PROCESSING AND FEATURE EXTRACTION

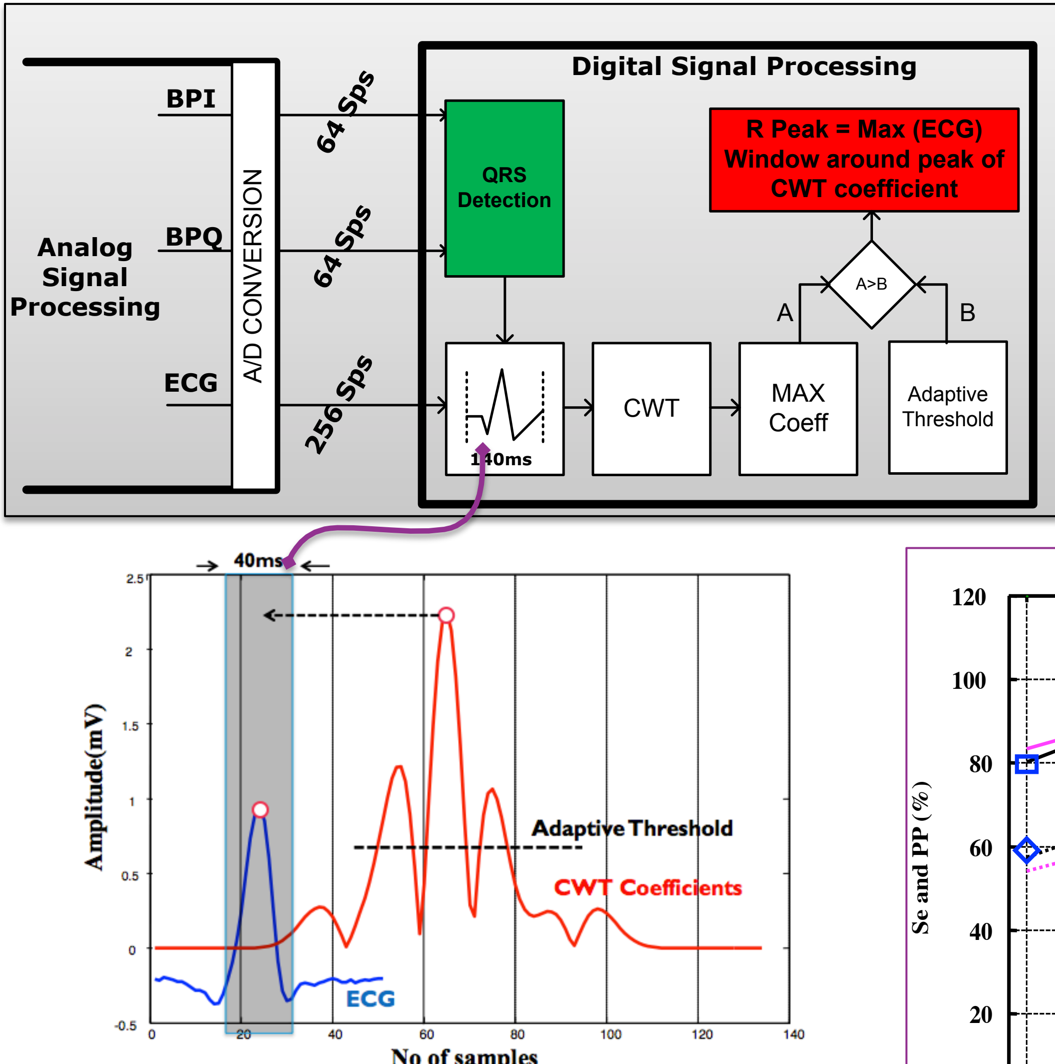
Band-Power Based Feature Extraction



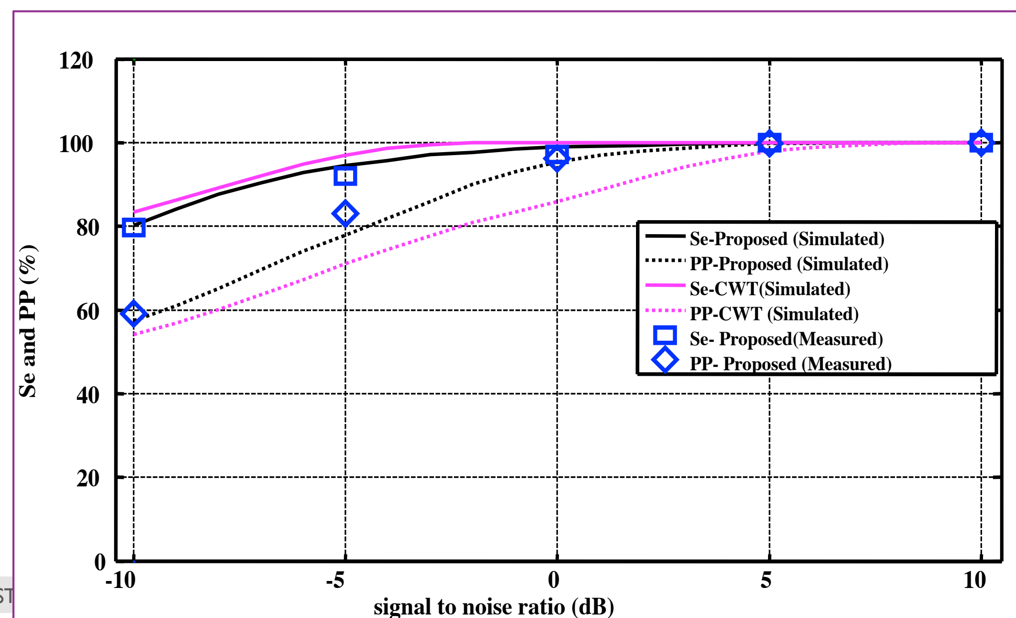
Band-Power Based Beat Detection



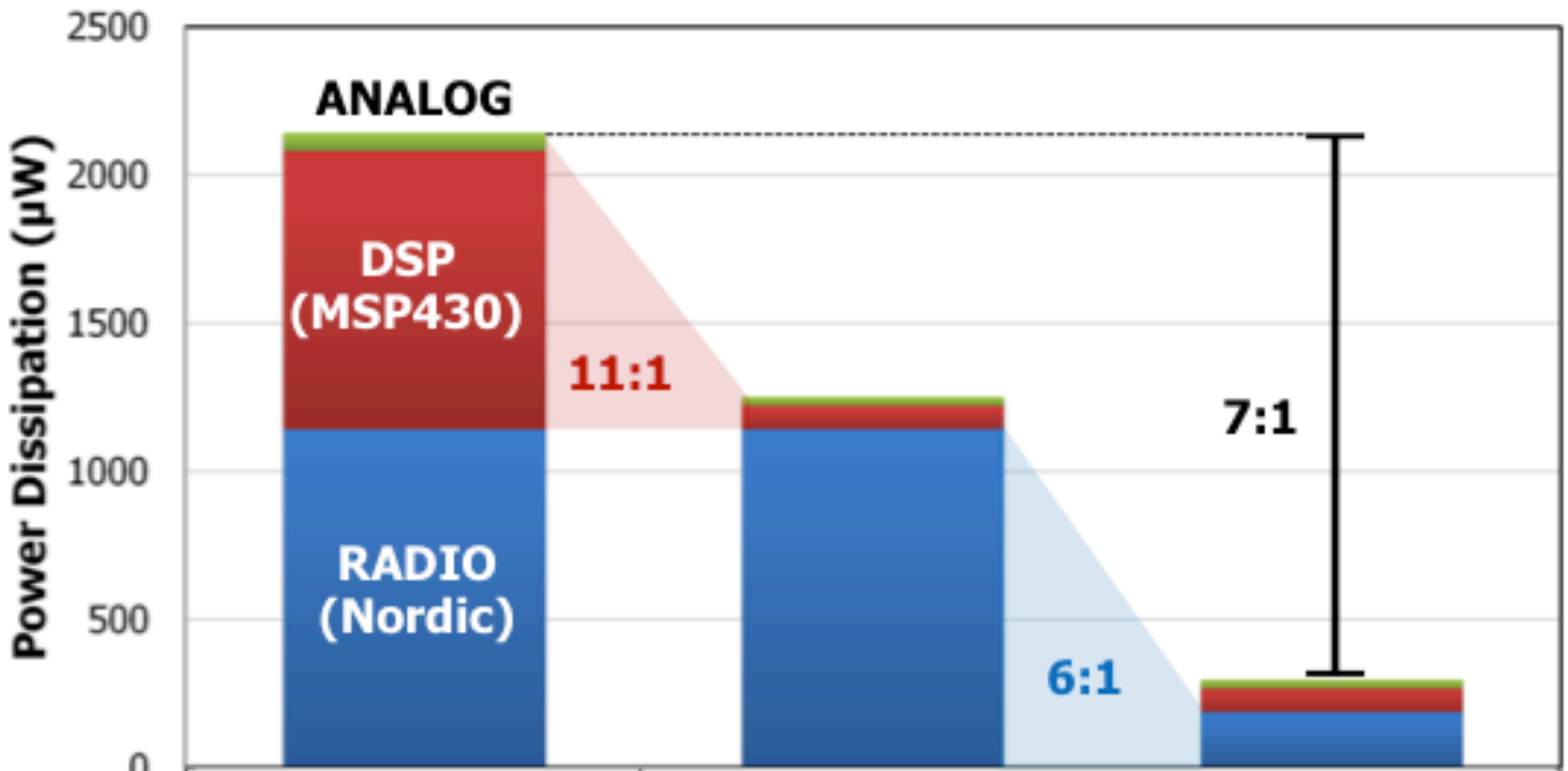
HARDWARE ORIENTED ALGORITHM DEVELOPMENT



Knowing that there is a power efficiency "coarse" algorithm, then the fine (and power hungry) algorithm can make use of fine algorithm to reduce power dissipation



BENEFITS OF HOLISTIC DESIGN



	Conventional DSP	Analog Assisted DSP	
	Continuous ECG Signal		Activity Based Sampled ECG Signal
ANALOG	60	30	30
DSP (µP)	940	80	80
RADIO	1142	1142	186

CONCLUSIONS

- There has been a important trend on low-power sensor interface design for healthcare application (last 10Y)
- The importance of multi-sensor interfaces is increasing tremendously for wearable wellness devices – analog area is becoming a concern
- Emerging design trends: HW-SW, Analog-Digital Co-design
- Emerging application trends: situation adaptive and personalized systems can improve signal analysis accuracy and reduce power dissipation significantly