Oticon

NOCs in
highly optimized
commercial chipsets
for hearing aids.

Mogens Cash Balsby

Sr. Director Silicon Engines

oticon
PEOPLE FIRST

the introduction
the challenges
the design choices
the implementation

Agenda

oticon
PEOPLE FIRST

the introduction

your presenter

your Hearing Aid manufacturer

the hearing aid

oticon
PEOPLE FIRST

Introduction

Your presenter

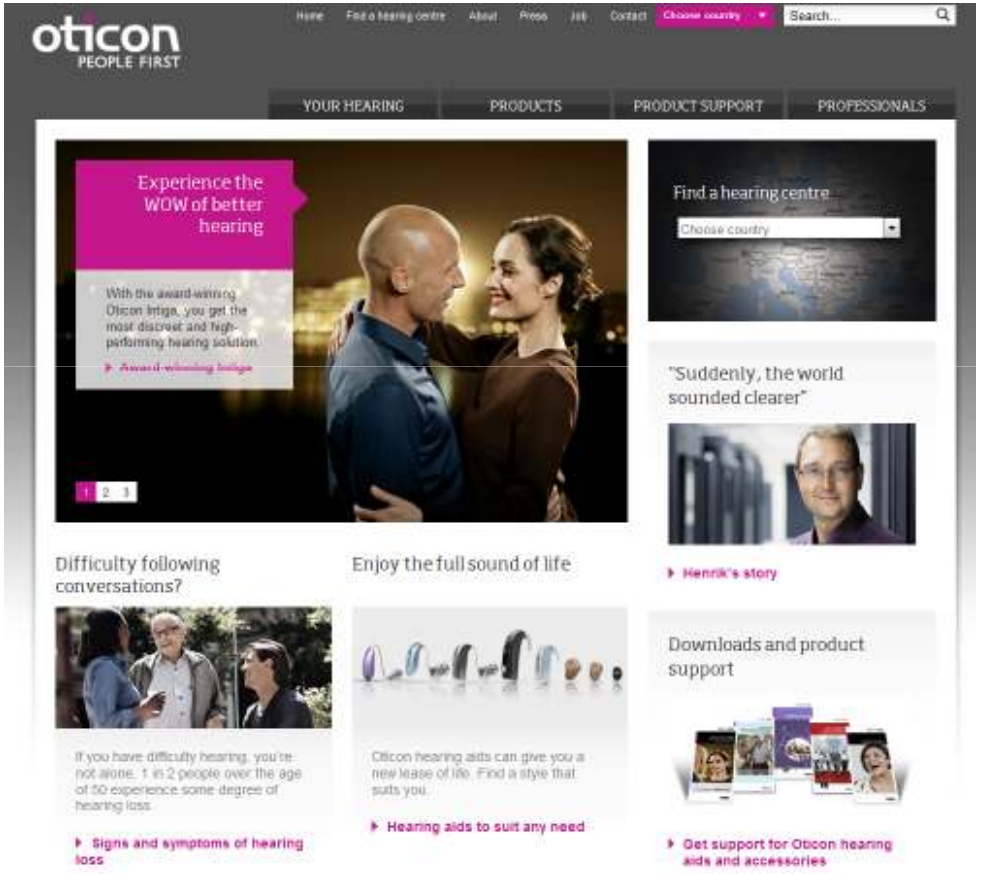
- Sr. Director Silicon Engines in Oticon
- B.Sc.E.E
- PCB → ASIC designer
- Networking
- MIPS processors
- Hearing Instruments

oticon
PEOPLE FIRST

Oticon

Your hearing aid manufacturer

- Oticon part of William Demant
- World leading manufacturer
- 1,5 B$
- 5.000 people
  - 1.400 in Denmark
- 400 in R&D
  - In Demark and Switzerland



oticon
PEOPLE FIRST

The Oticon history

- Founded in 1904 by Hans Demant
- Hans wanted to help his deaf wife
- H.D. died in 1910
- His son, William, took over the business
- The 20's and 30's: Sales in Europe

H. Demant,
Symaskine- & Cyklefabrik,
57, Kongensgade 57,
Odense.

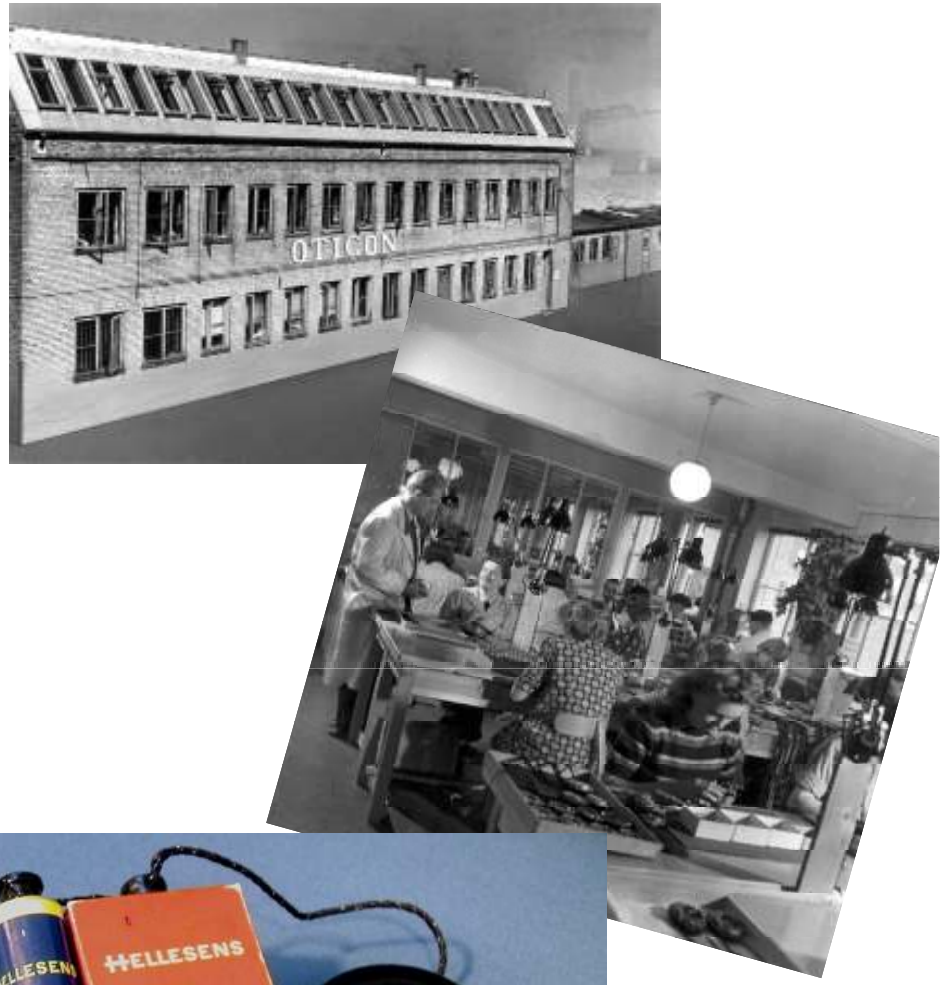
oticon
PEOPLE FIRST

The Oticon story

- **The 40's**
Own production

- **The 60's**
Own distribution network in Europe

- **The 70's**
The world's leading hearing aid producer with a market share of 15%



oticon
PEOPLE FIRST

Oticon Product Breakthroughs

- **MultiFocus,** 1991, world's first fully automatic
- **DigiFocus,** 1996, world's **first fully digital** at ear-level
- **Adapto**, 2001, world's first with voice recognition
- **Oticon Syncro,** 2004, world's first with artificial intelligence
- **Oticon Delta,** 2006, revolutionary design
- **Oticon Epoq,** 2007, world's first truly binaural with spatial sound
- **Oticon Dual**, 2008, outstanding beauty & brains
- **Oticon ConnectLine**, 2009, world's first low-latency high quality audio streaming
- **Oticon Agil**, 2010, world's first cognitive friendly hearing system

1991
MultiFocus

1996
DigiFocus

2001
Adapto

2004
Oticon Syncro

2006
Oticon Delta

2007
Oticon Epoq

2008
Oticon Dual

2009
Oticon
ConnectLine

2010
Oticon Agil

oticon
PEOPLE FIRST

Oticon Product Breakthrough 2011

World smallest fully wireless HI

The hearing aid industry

Characterized by…

- Small market size ~10M units/y
- 6 big players
- No standardization
- High degree of design optimizations

oticon
PEOPLE FIRST

the challenges

- Discreteness
- Power
- Sound

oticon
PEOPLE FIRST

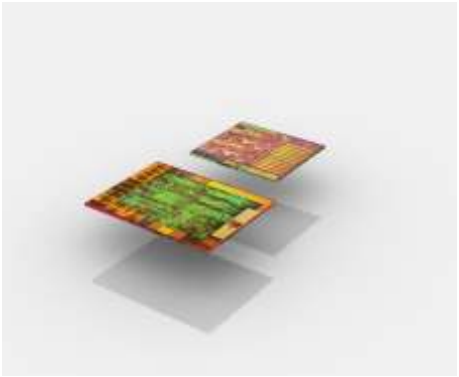
One chipset

multiple brands, products, styles

oticon
PEOPLE FIRST

bernafon
Your hearing · Our passion

SONIC
Everyday Sounds Better



Few Chipsets

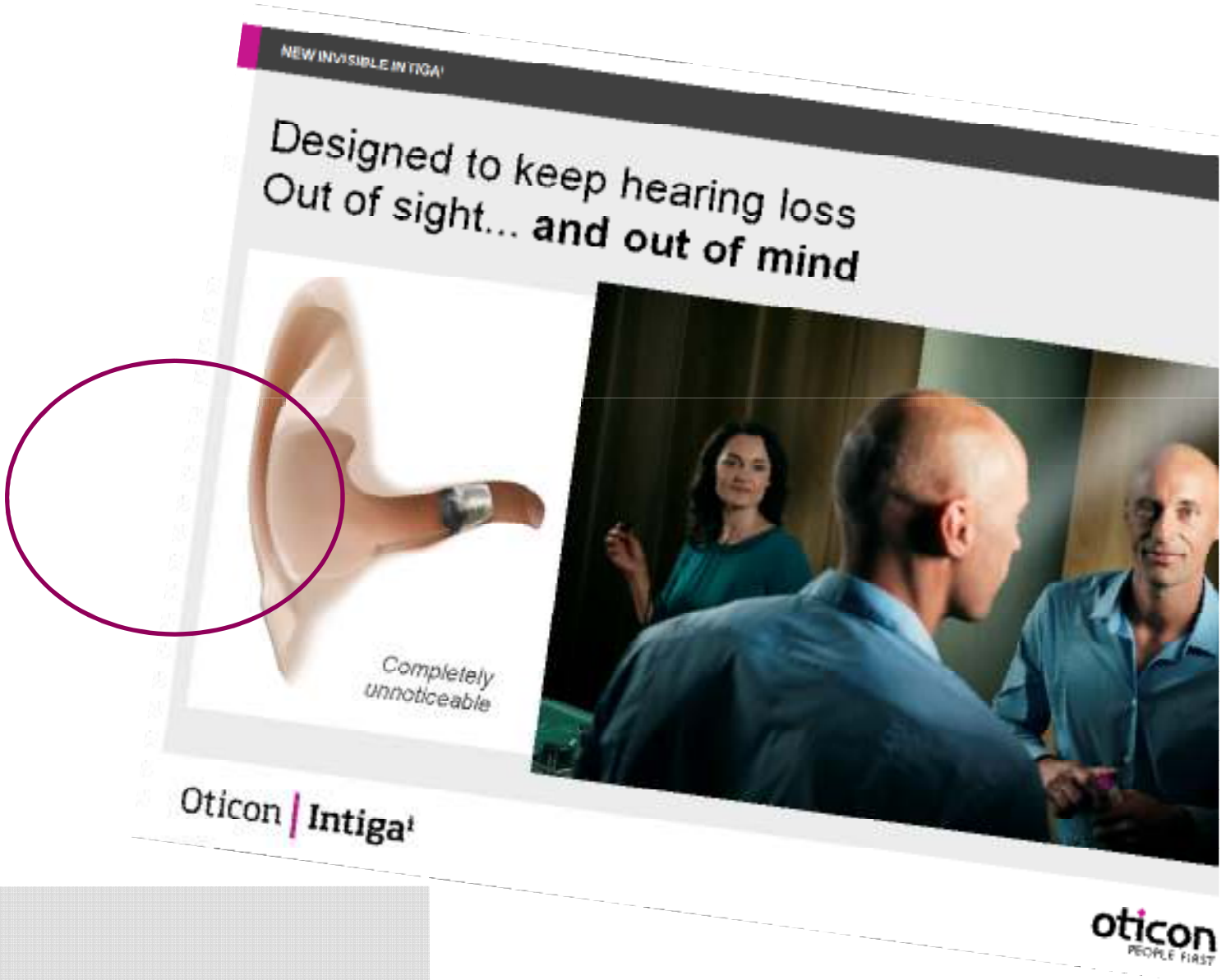
oticon
PEOPLE FIRST

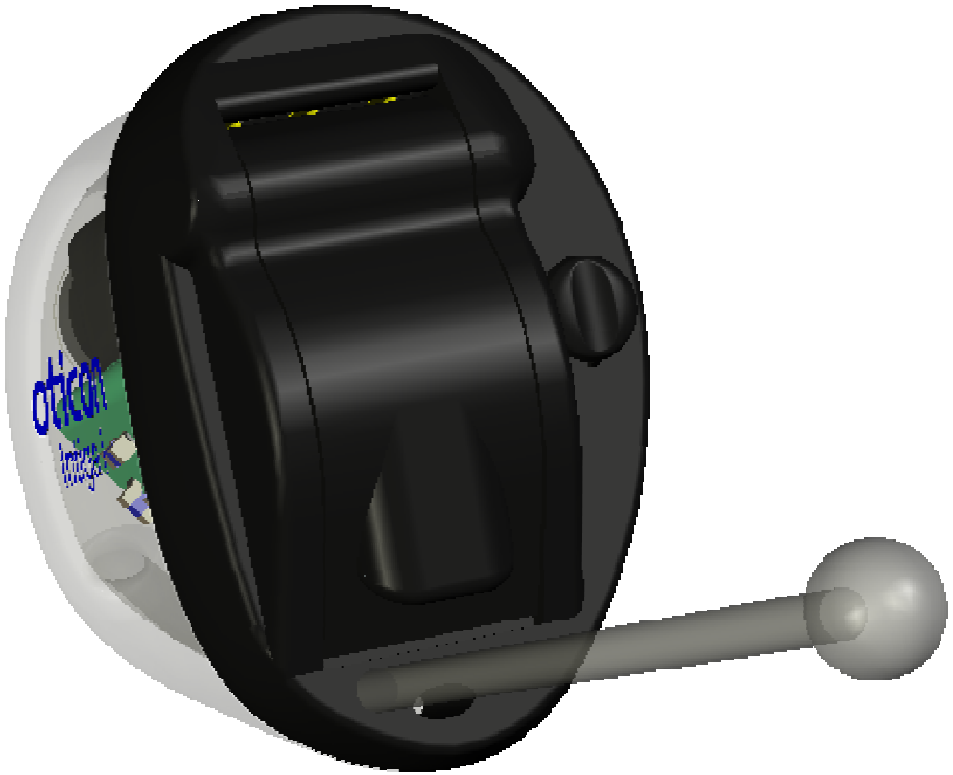
The mechanical challenge

discreetness

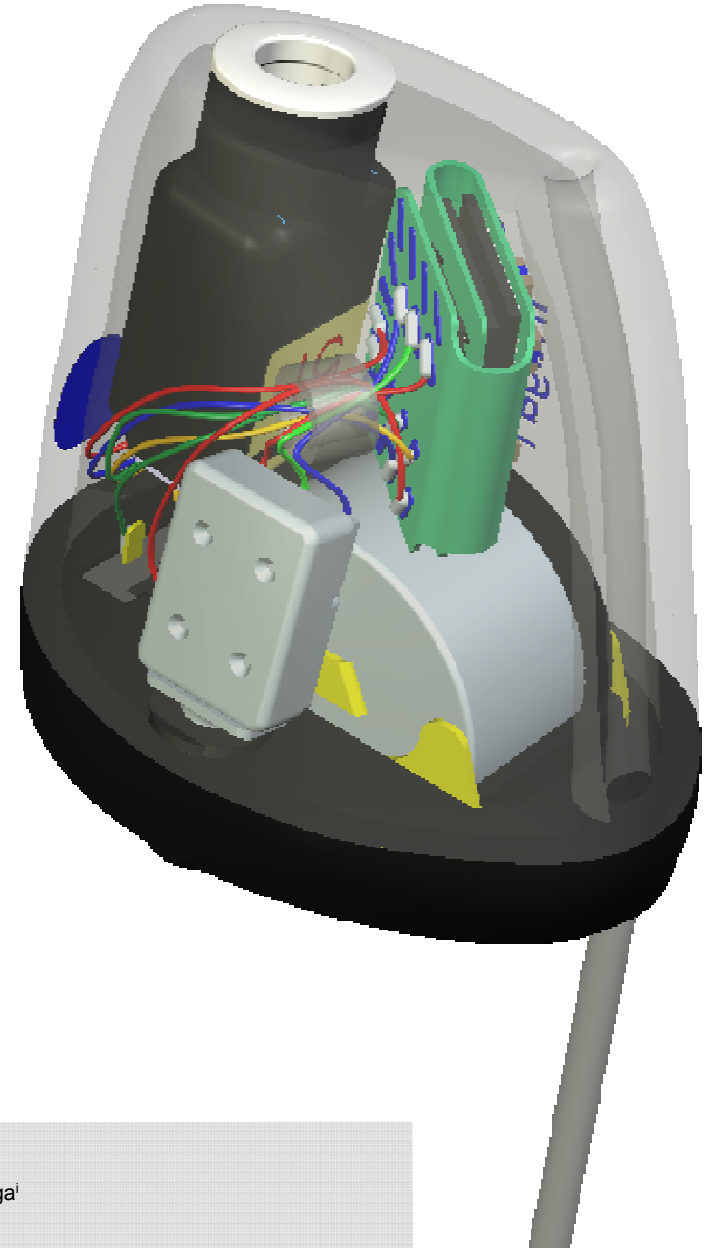
The mechanical challenge

discreetness





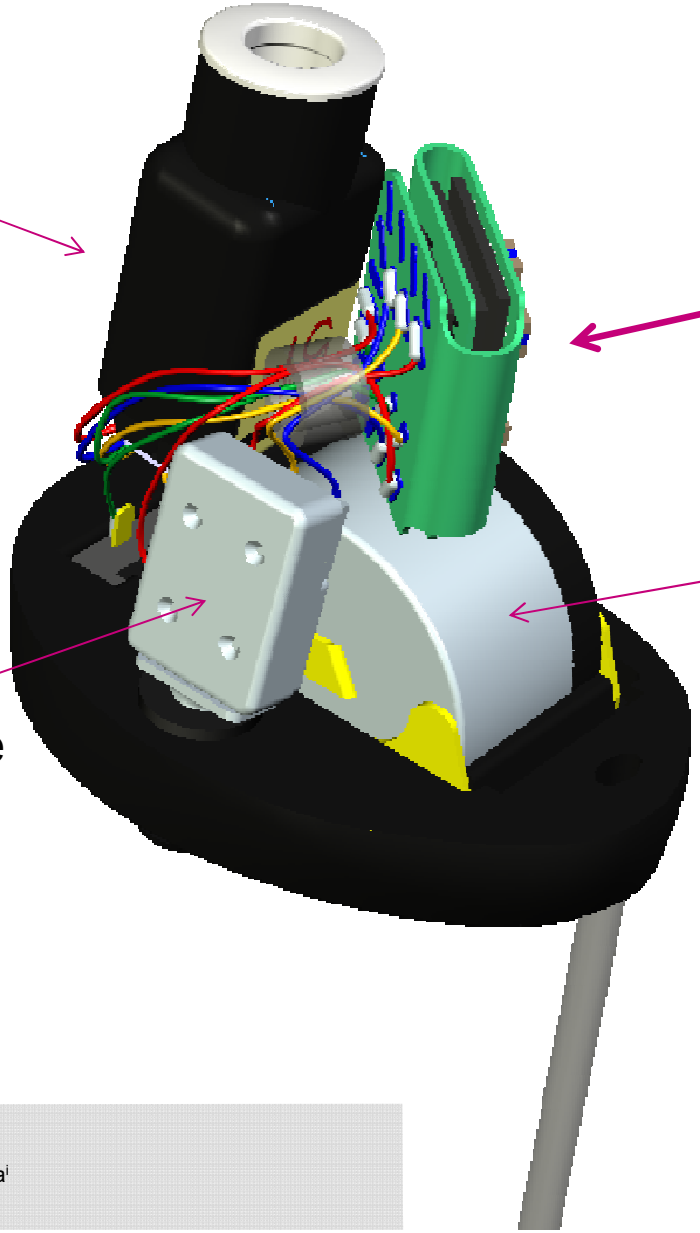
oticon
PEOPLE FIRST



New Invisible Intiga[i]

oticon
PEOPLE FIRST

Miniature speaker



Compact **low power**
RISE 2 amplifier

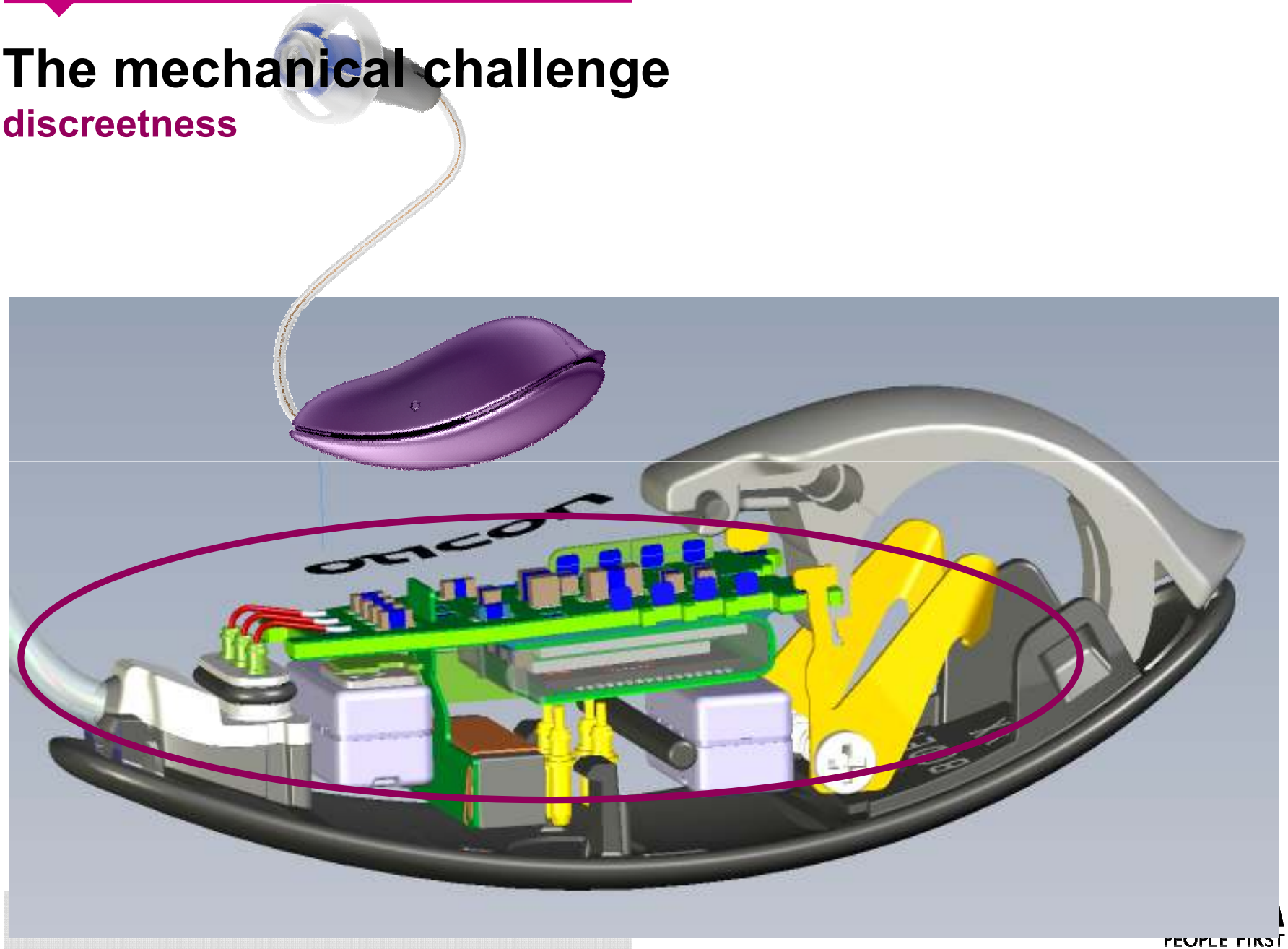
Standard 10A
battery

Miniature microphone

oticon
PEOPLE FIRST

The mechanical challenge

discreetness



The power challenge

we save on everything

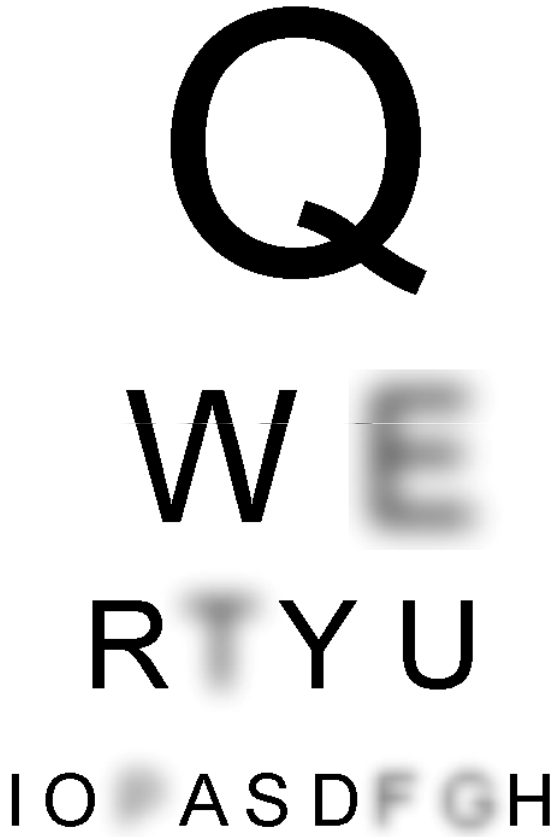
Battery type	Capacity	Consumption in 1 week
13	~260 mAh	2,0 mA
312	~130 mAh	1,0 mA
10A	~70mAh	0,5 mA

- Always on
- Wireless streaming

oticon
PEOPLE FIRST

The sound processing challenge

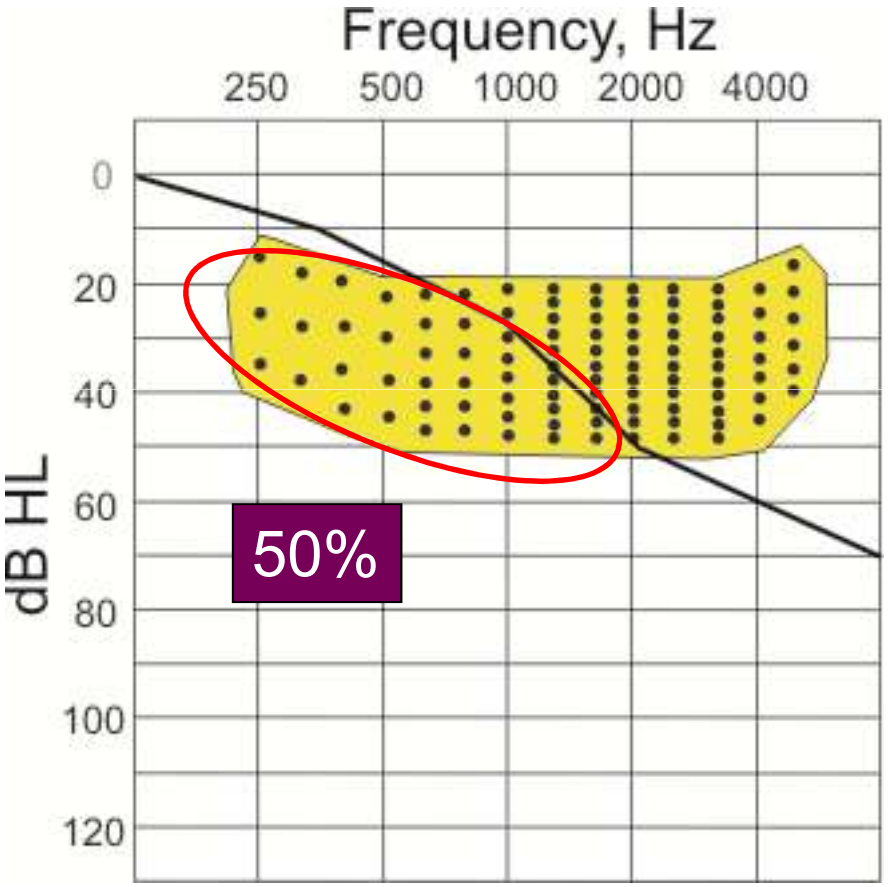
lots of compute power



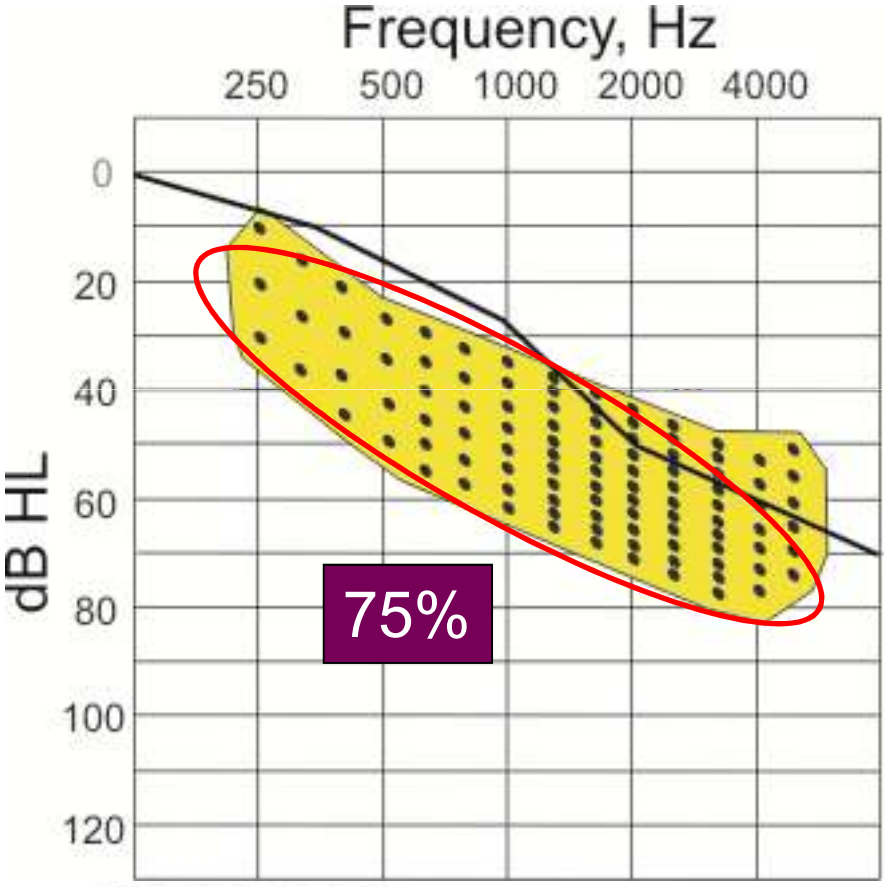
oticon
PEOPLE FIRST

The sound processing challenge

lots of compute power



No surrounding noise, no aid

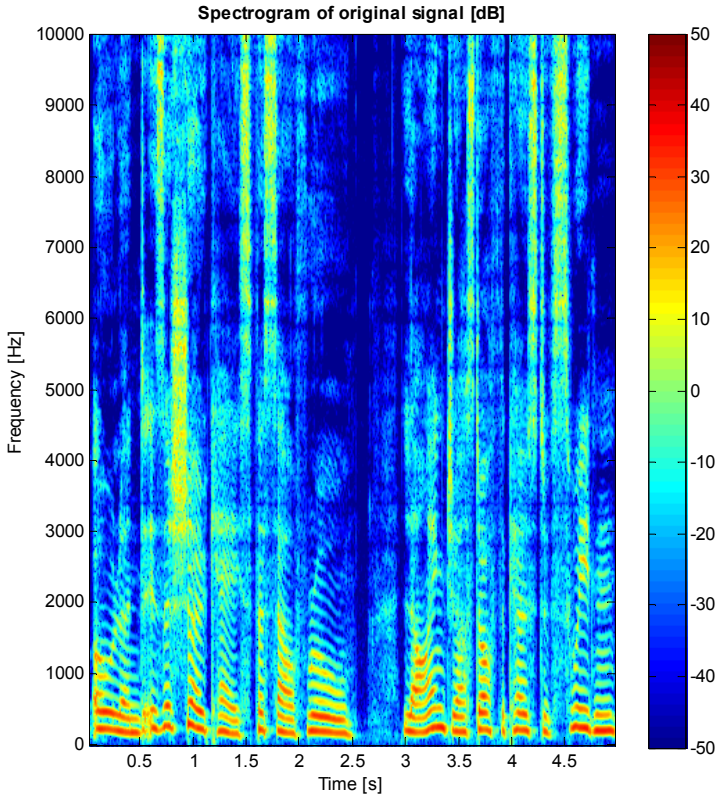


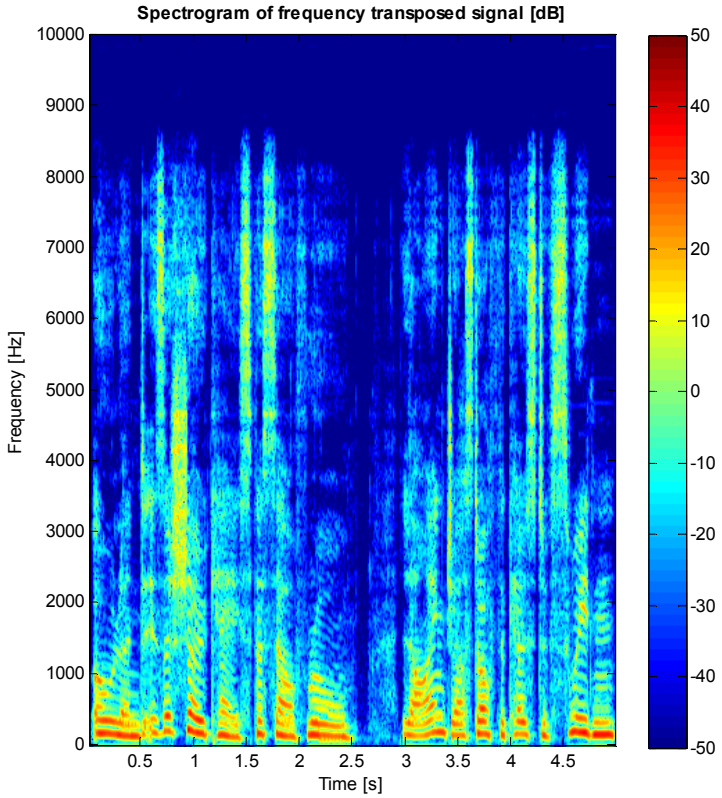
No surrounding noise, aided

oticon
PEOPLE FIRST

The sound processing challenge

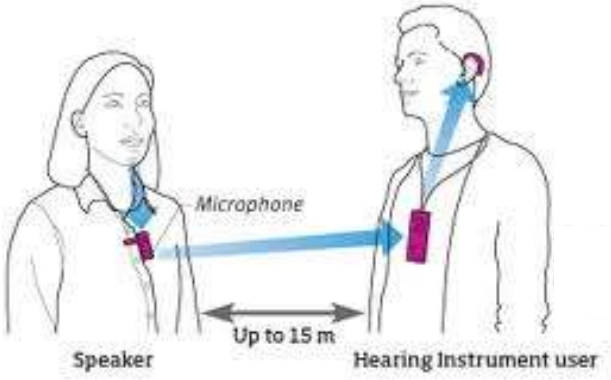
frequency transposition





The connectivity challenge

wireless connection



- Audio streaming
- Ear to ear
- Phone
- TV
- Partner microphone

oticon
PEOPLE FIRST

the design choices

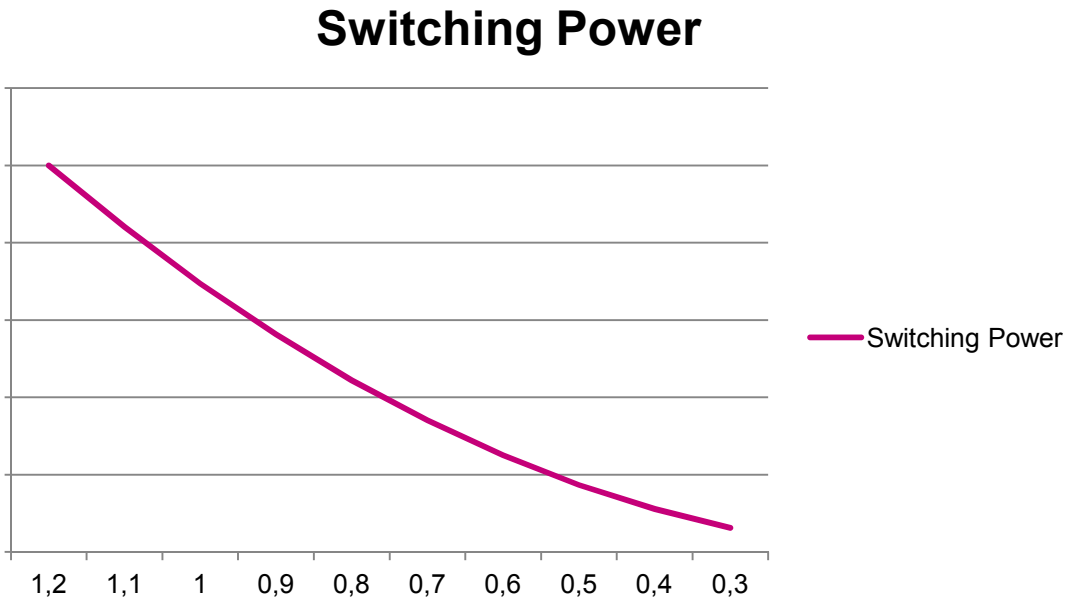
- Voltage^2
- Multiprocessor
- NOC

oticon
PEOPLE FIRST

Voltage^2

The best way to save power

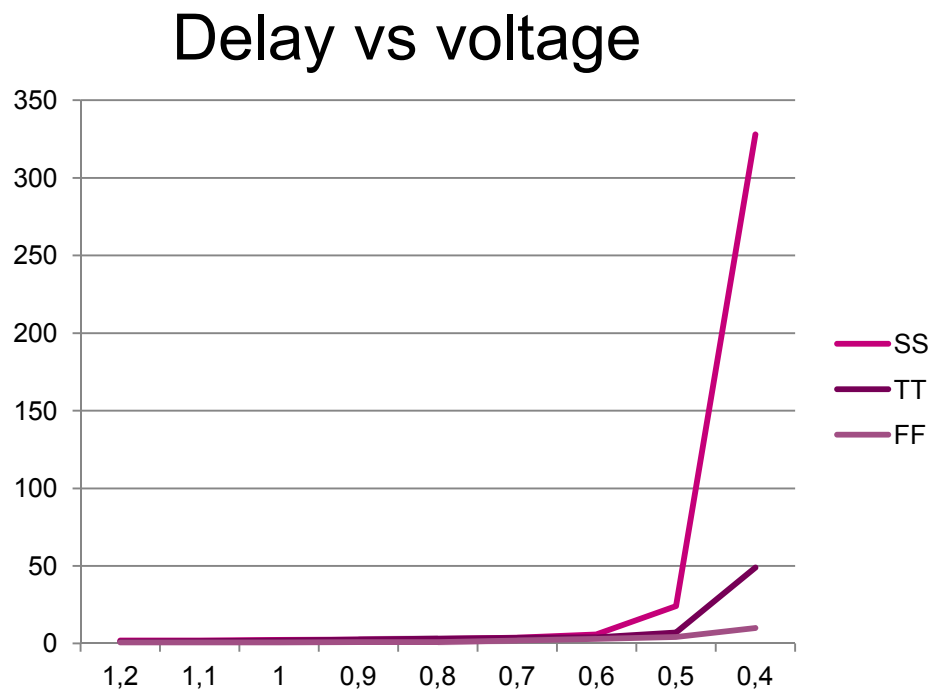
- Switching power follows $P = V^2/R$
- Lower operating voltage -> lower power



oticon PEOPLE FIRST

The 2Vt wall

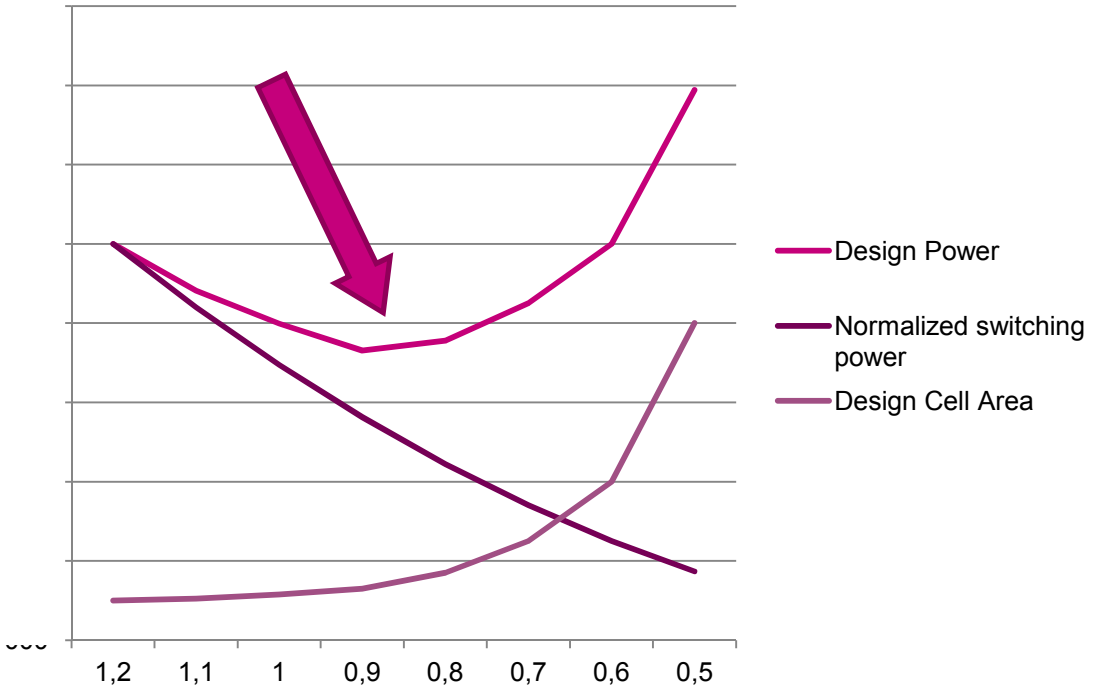
- Approaching 2 Vt (NVt + PVt) the cell delay becomes very non linear



oticon PEOPLE FIRST

Optimal operating voltage

- Sweet spot between speed and power

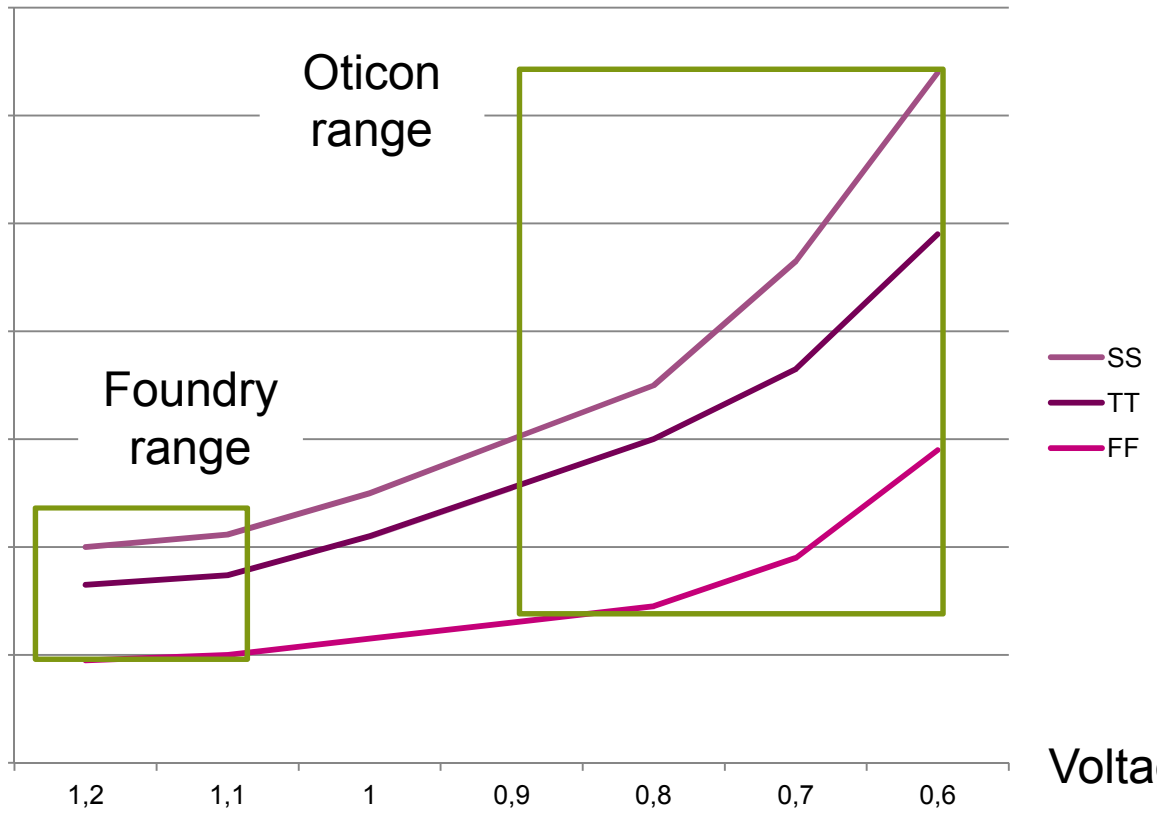


oticon
PEOPLE FIRST

Delay range

over Voltage, Silicon and Temperature

- Foundry range:
  - Factor ~2
- Oticon range:
  - Factor ~10



oticon PEOPLE FIRST

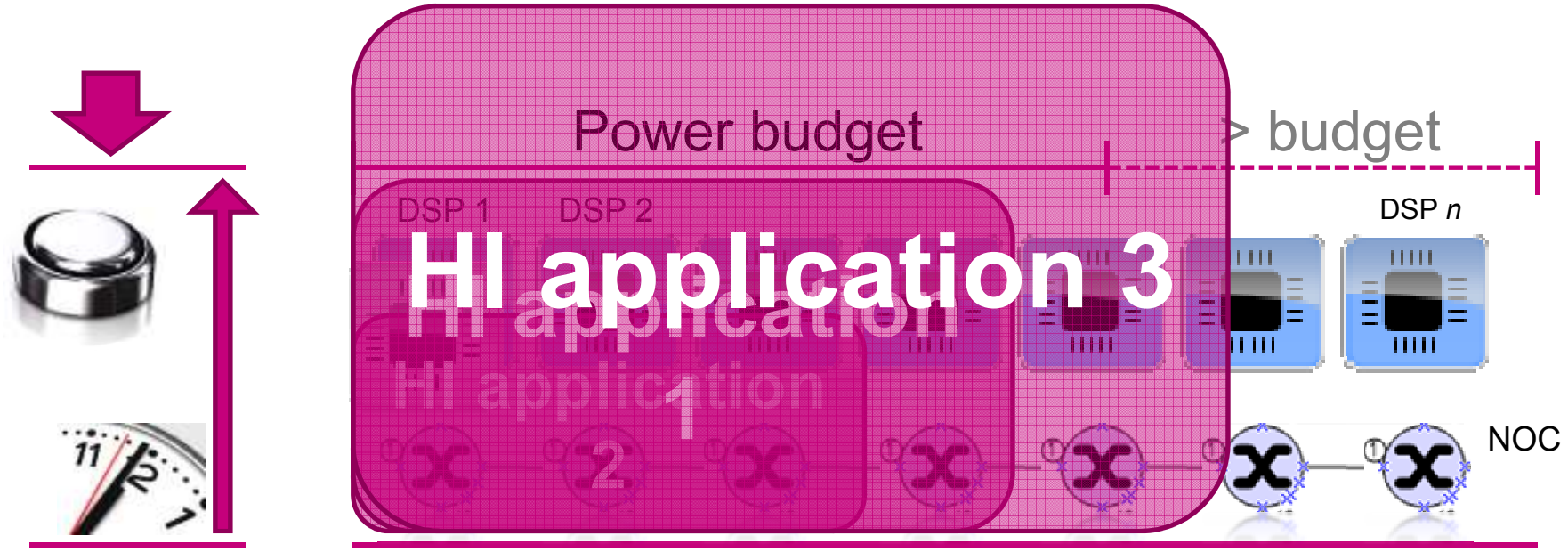
Constraint scenarios

- Functional modes : 3
- Silicon : 3
- Voltage : 5
- Temperature : 3
- Parasitic – R + C : 5
  - Sample Scenario : mode_normal_ss_0v95_n20c_rcmin

- Number of Scenarios to signoff : 5 * 3 * 3 * 5 * 3 = 675
- Some can be excluded – reducing the 675 to appr. = 250
- Applying human judgment, no. of scenarios = 24

oticon PEOPLE FIRST

The design choices



oticon
PEOPLE FIRST

the implementation

- the processors
- the NOC
- the chipset

oticon
PEOPLE FIRST

Low-power Multi-processor design

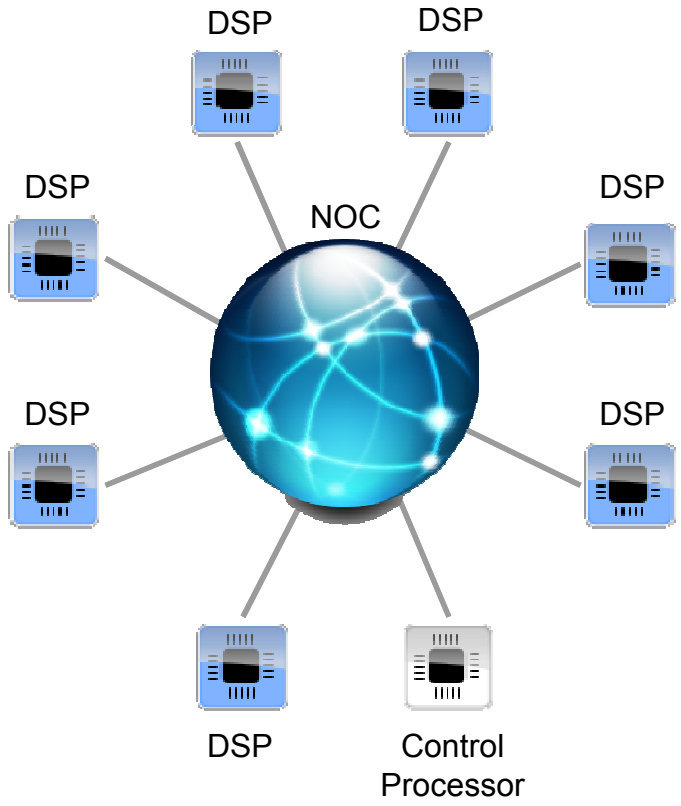
- Scalability
  - Scalable solution to easily change number of DSP processors in future designs

- Algorithm development
  - Current algorithms ”easily” distributed onto parallel DSP processors
    - Algorithms running on each processor can be developed and verified independently
    - Well-defined algorithm interfaces, which separate processing from communication

oticon
PEOPLE FIRST

Multi-processor system

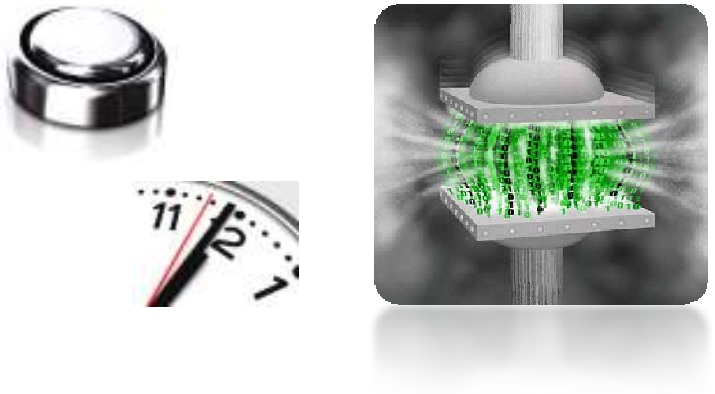
- Multi-processor platform
  - Platform based on set of DSP processors
  - Each DSP processors individually tailored for specific algorithms:
    - Same base processor (ISA) extended with different set of custom hardware accelerators
    - Different amount of dedicated data and program memory
- Control processor
  - Handles system setup and control
    - Select algorithms to be run on DSPs
  - Handles wired/wireless communication

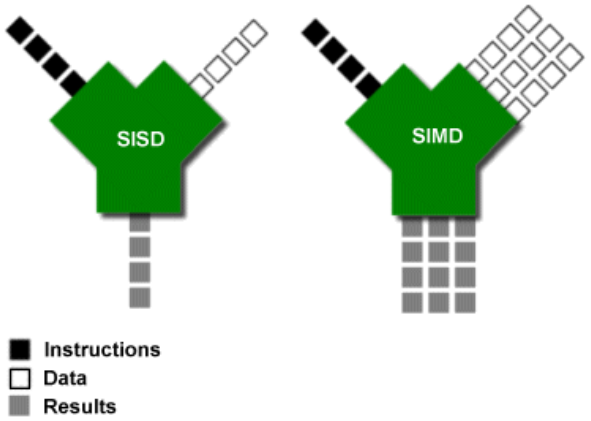


oticon
PEOPLE FIRST

Low-power DSP processors design

- DSP Processor requirements:
  - High efficiency – “Compute power / Watt”
  - Real-time requirements
  - High code density
- Created from algorithm C source code
- DSP Processor features:
  - Vector processing datapath
  - Custom hardware accelerators
  - Parallel instructions
  - Variable instruction length

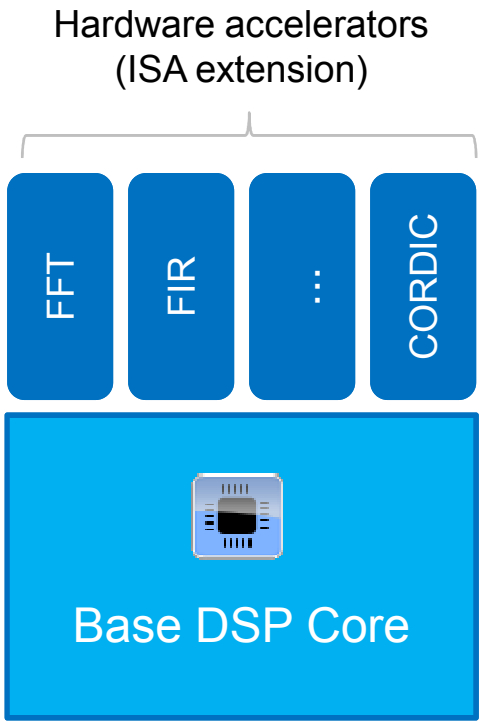




oticon
PEOPLE FIRST

Hardware acceleration for DSP processing

- Reduce power and cycle count
  - Accelerating commonly used functionality using hardware accelerators
    - Identifying *control-intense* code
    - Identifying *compute-intense* code
- Hardware accelerators
  - Implemented as extensions to the instruction set for the base DSP core
  - Single-cycle accelerators (small)
    - Complex valued arithmetic, wide accumulators, data normalization etc
  - Multi-cycle accelerators (large)
    - FFT, FIR, CORDIC, LOG/EXP, Decoders etc



oticon
PEOPLE FIRST

Multi-processor software development

- All algorithms developed in C
  - Great advantage for developing and debugging platform/architecture independent code
- Software optimizations
  - Vector processing
    - Requires consideration about data alignment, data storage, data permutations, and memory access patterns
  - Pragmas to guide the compiler
    - Restricted data areas, software pipelining, annotated loop iteration and branch probability
- Software challenges
  - Algorithm partitioning (manual)

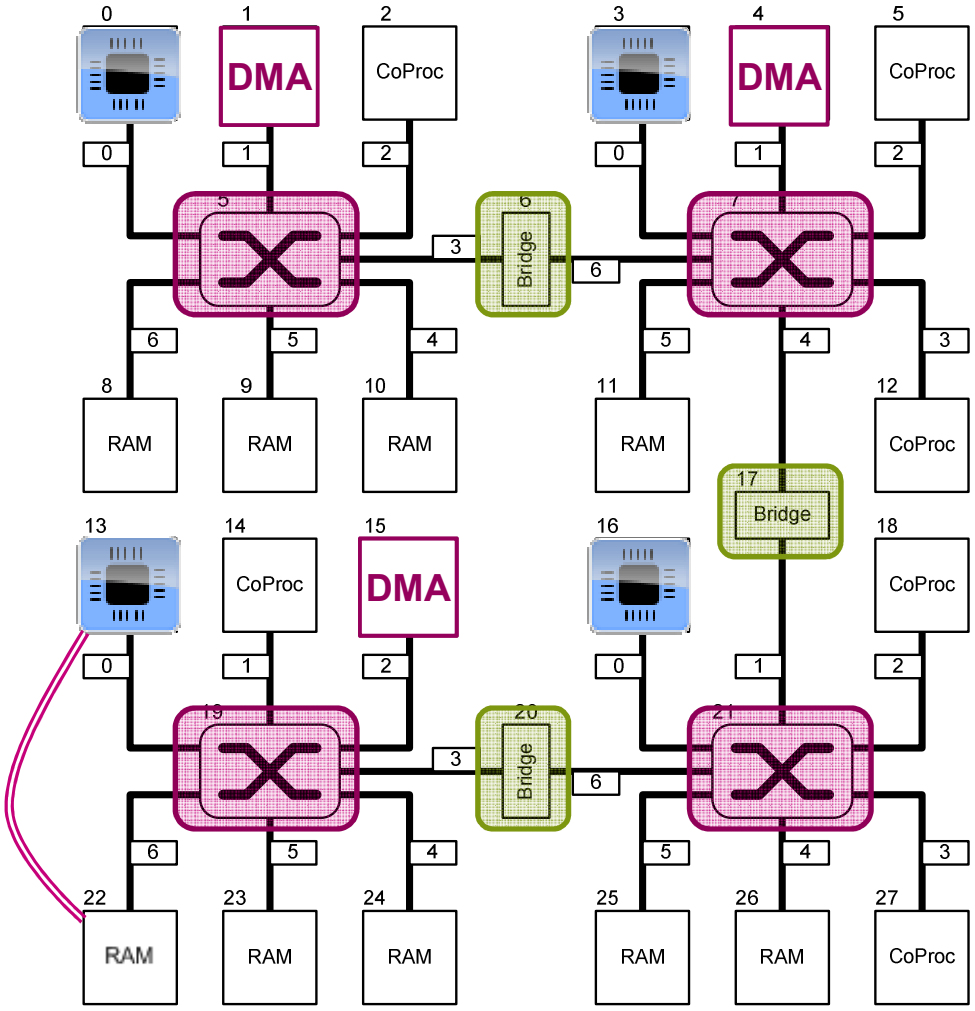
15X

oticon
PEOPLE FIRST

Network on Chip

the NOC

- Switch is asynchronous
- Bridge is synchronous
- Best effort, with prioritization
- No guaranteed service
- Processor has direct connection to RAM



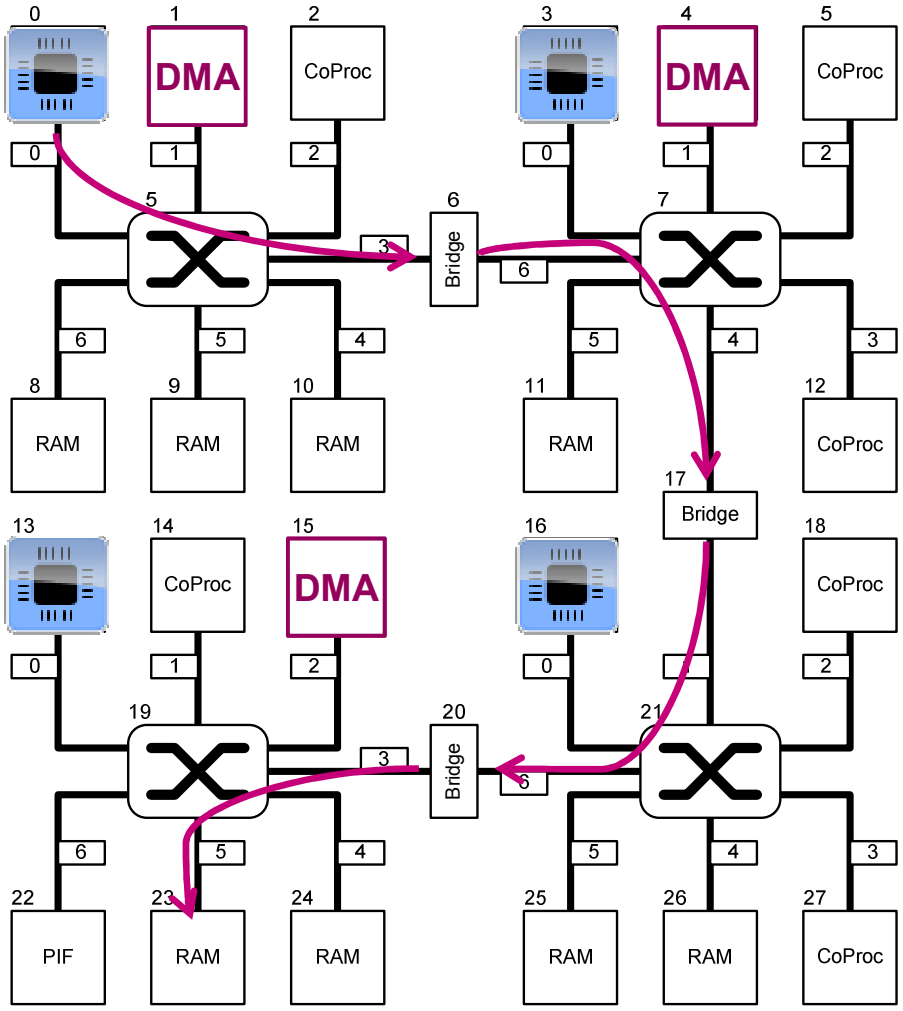
oticon
PEOPLE FIRST

Network on Chip

the connection

- The Control Processor can configure the routes directly

- “Connect cells” can establish route

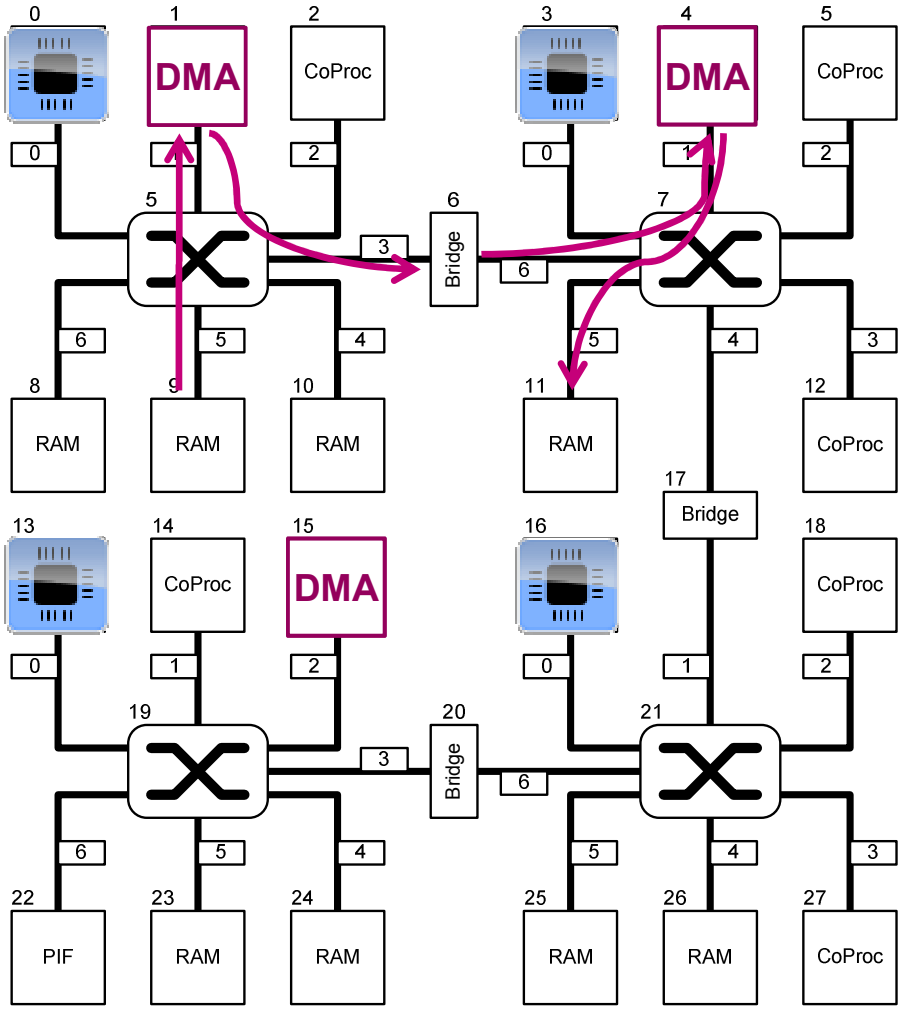


oticon
PEOPLE FIRST

Network on Chip

the DMA

- DMA 2 DMA streams
- Reuse of DMA setup
- Interrupt on completion

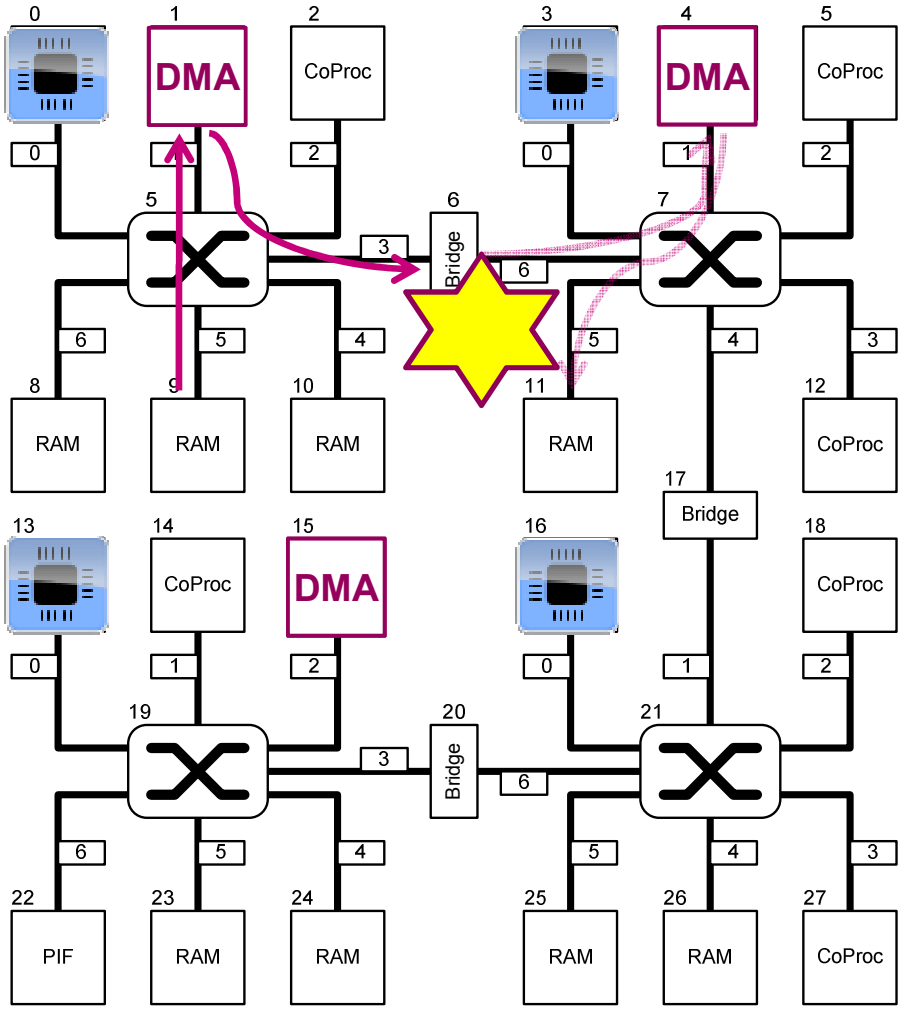


oticon
PEOPLE FIRST

Network on Chip

error handling

- Timeout of stalled transactions
- Debug information stored
- Different recovery options
  - Fail gracefully

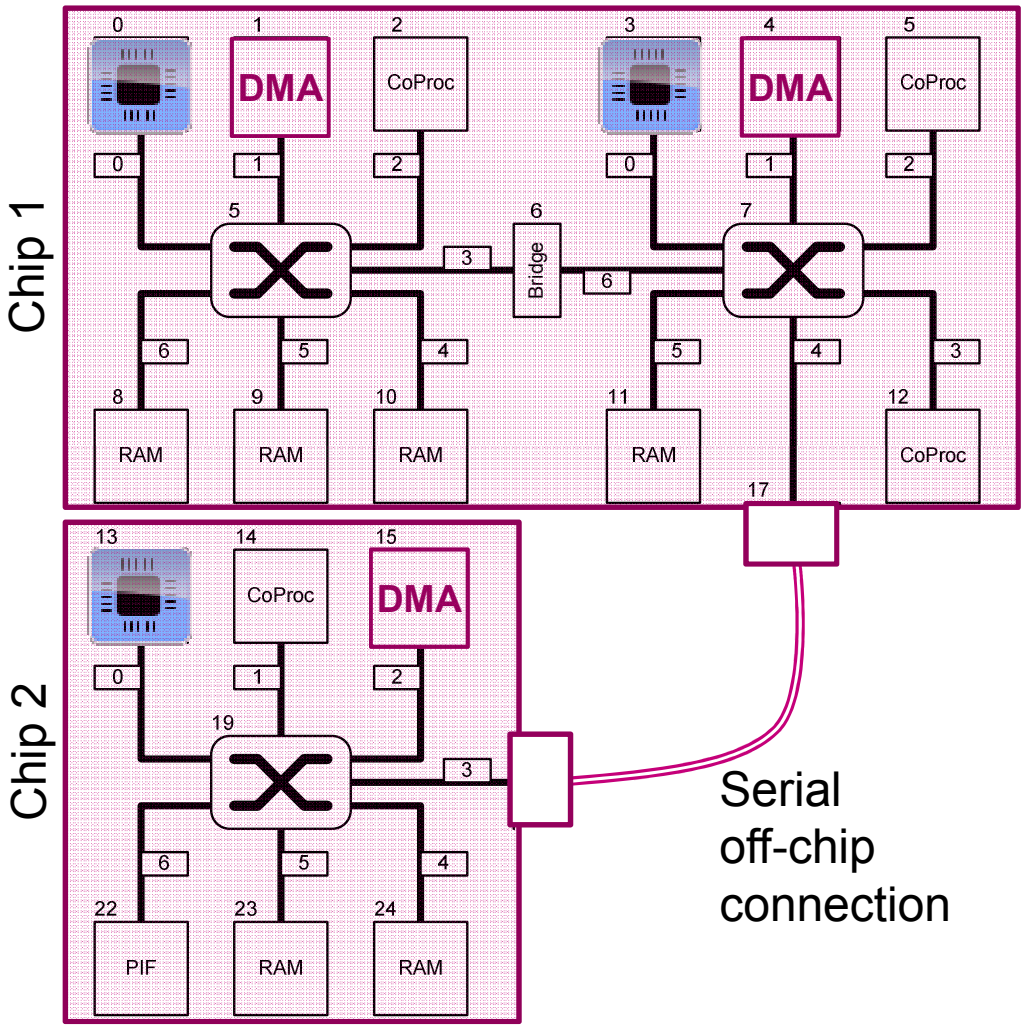


oticon
PEOPLE FIRST

Network on Chip

long connections

- NOC between chips



oticon
PEOPLE FIRST

The chipset

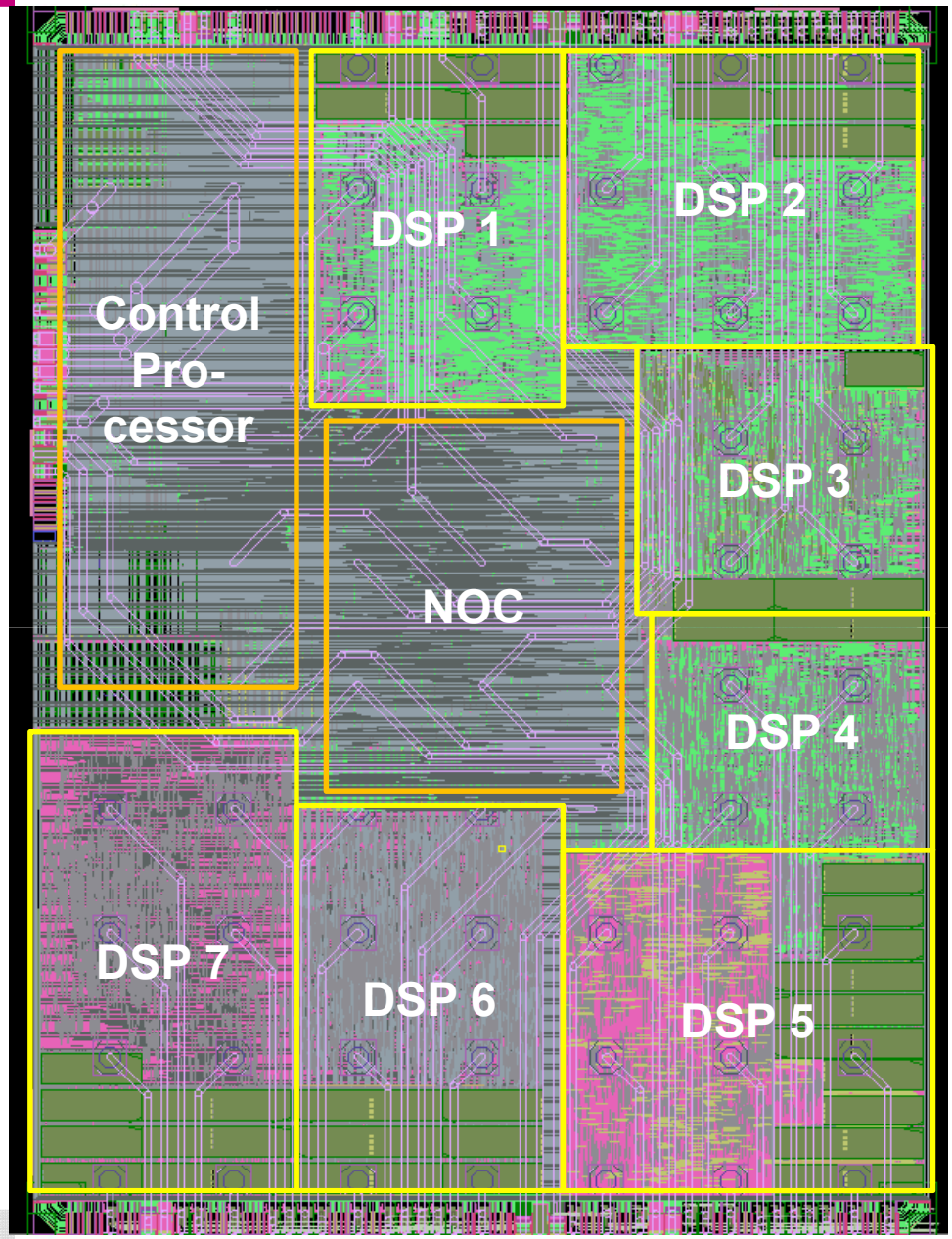
2,75 x 3,74 = 10,2mm^2

35M transistors

8½M gates

1,3M wires

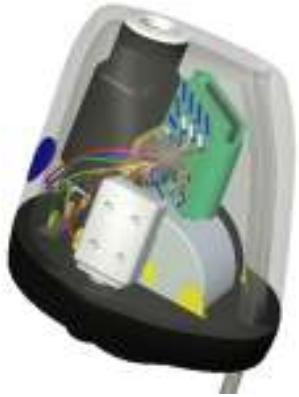
52m total wire length

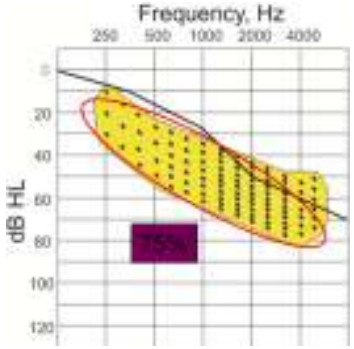


summary

oticon
PEOPLE FIRST

Summary





- So much room for improvement
- So much more to learn
- Keep researching
- We need talent

oticon
PEOPLE FIRST

the end

thanks for listening

oticon
PEOPLE FIRST