Special Topics in Advanced Digital System Design

by

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Slide Set: 4

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Slide Set Overview

- Embedded Systems
  - Definition
  - Design Methodology
- Specifying the Application's Platform
  - SoC? Custom/ASIC/FPGA?
  - Processor Choices
  - Other hardware and software choices

Slide Set Overview

- An implementation study example
  - To demonstrate why we have to make choices in our implementation platform to meet application specification requirements
  - Example Application:
    - A digital camera

Slide Set Overview

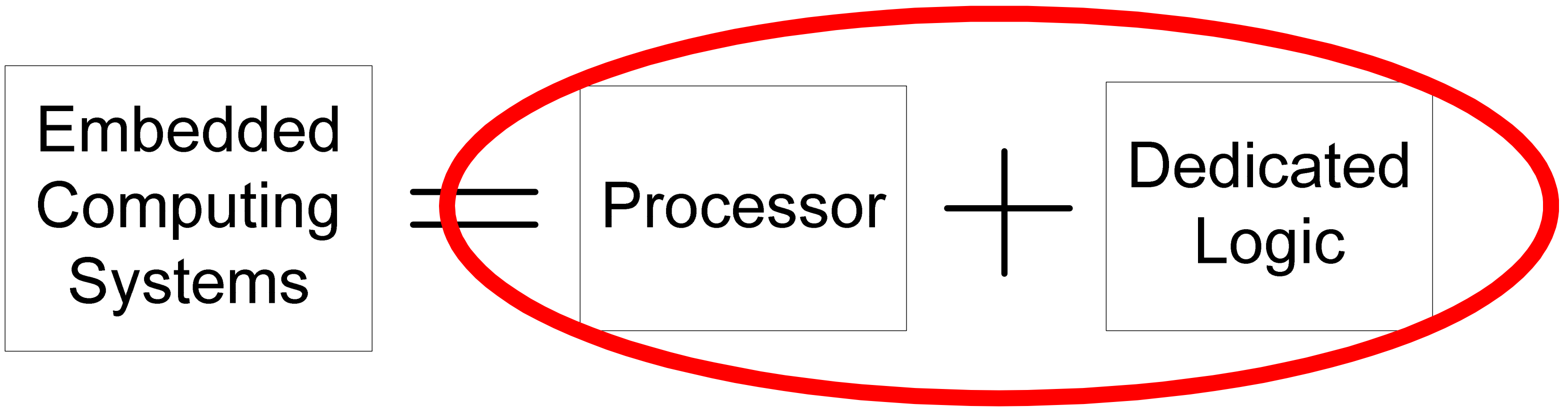
- We've been talking about the EDK tools, FPGAs, and FPGA CAD Flow and Compilers
- Now we're going back to how you make design implementation decisions throughout the design process
  - Once you have a specification, you have to choose a platform that will allow you to meet this specification.

Embedded Computing Systems

Embedded Computing Systems = Processor + Dedicated Logic

- Design Constraints:
  - Area
  - Power
  - Performance
  - Cost

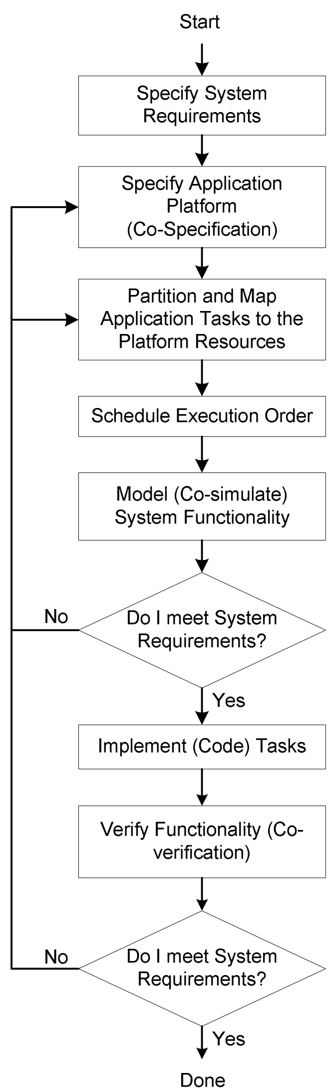
Embedded Computing Systems



- Design Constraints:
  - Area
  - Power
  - Performance
  - Cost

Embedded System Design Methodology: see Handout

Embedded System Design Methodology



System-on-Chip

- What are the other options?
  - Multiple dedicated integrated circuits on a PCB
  - A personal computing station
    - completely software implementation
  - What are other options?
- Why implement a System-on-Chip?
  - Performance constraints
  - Area constraints
  - Why else?

System-on-Chip

- If you choose to implement an SoC, it could be a:
  - Custom Designed ASIC
  - Standard Cell ASIC
  - Structured ASIC
  - FPGA

Custom Designed ASIC

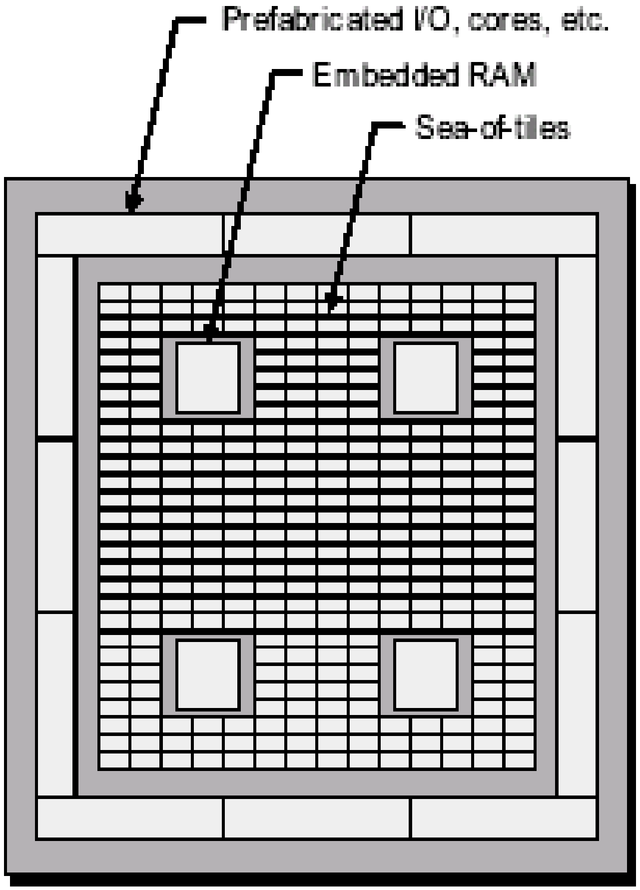
- Hand Tailored at the Transistor Level to perform Application Functionality
  - Could be digital or analog circuitry or mixed signal
  - Can you think of some examples that might use this technology?
    - Hint: think of standard cell libraries

Standard Cell ASIC

- Foundries (e.g. TSMC) have libraries of standard cells
  - Can be very low-level (inverter)
  - Can represent basic modules (e.g. full adder)
  - Can you think of some examples that might use this?

Structured ASIC Architecture

- Two Main Levels
  - Structured Elements
    - Combinational and sequential function blocks
    - Can be a logical or storage element
  - Array of Structured Elements
    - Uniform or non-uniform array styles
    - A fixed arrangement of structured elements

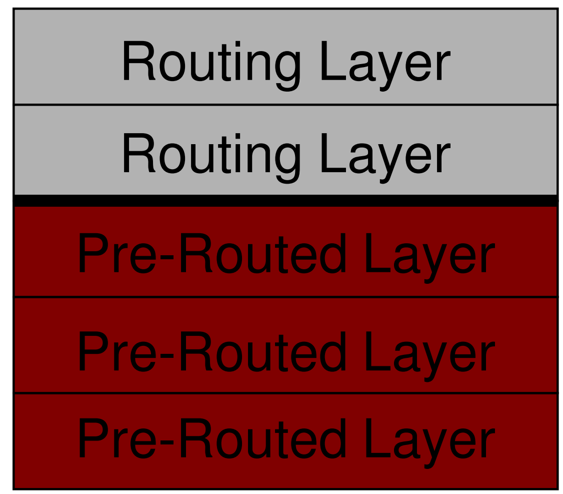


Structured ASIC Concept

- A Structured ASIC falls between an FPGA and a Standard Cell-based ASIC
- Structured ASIC's are used mainly for mid-volume level designs
- The design task for structured ASIC's is to map the circuit onto a fixed arrangement of known cells

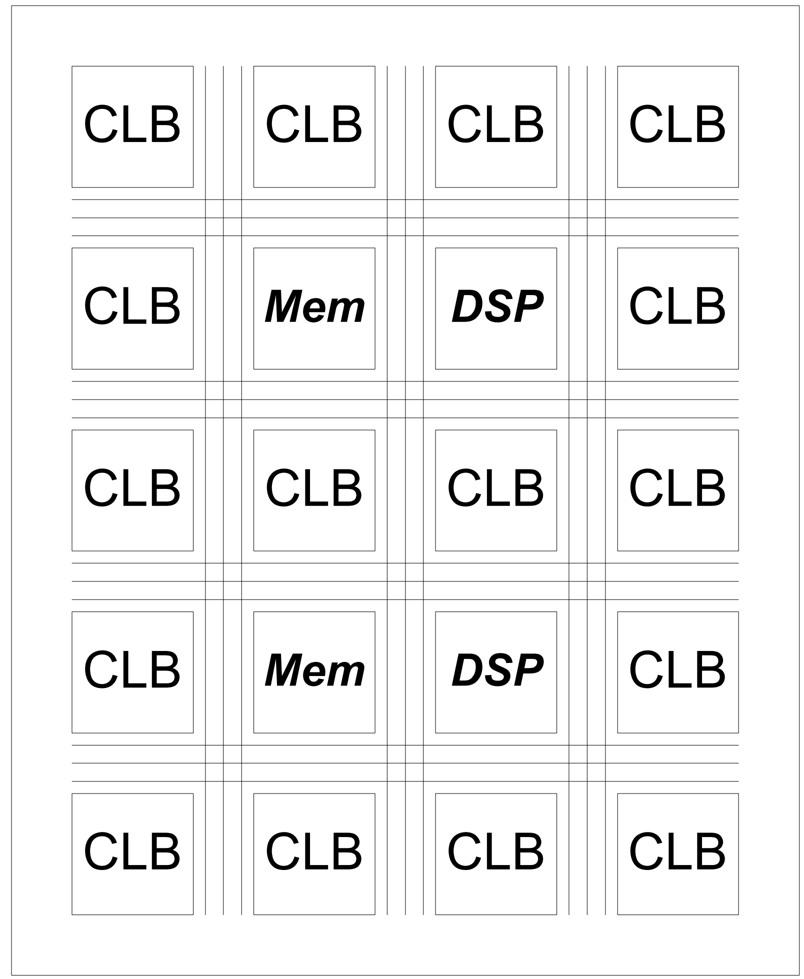
Structured ASIC Concept

- Largely Prefabricated
  - Components are “almost” connected in a variety of predefined configurations
  - Only a few metal layers are needed for fabrication
  - Drastically reduces turnaround time
- Commercially available:
  - Altera’s HardCopy



Field Programmable Gate Arrays

- Prefabricated programmable circuitry
- Configurable Logic Blocks (CLBs)
- Heterogeneous Blocks (Memory & DSP)
- Configurable Routing
- Can implement >30 uprocs!



Pros and Cons of Custom ICs/Standard Cell ASICs/Structured ASICs/FPGAs

FPGA vs Standard Cell ASIC

- Easy to Design
- Short Development Time
- Low NRE Costs
- Design Size Limited
- Design Complexity Limited
- Performance Limited
- High Power Consumption
- High Per-Unit Cost

- Difficult to Design
- Long Development Time
- High NRE Costs
- Support Large Designs
- Support Complex Designs
- High Performance
- Low Power Consumption
- Low Per-Unit Cost (at high volume)

Structured ASIC's Combine the Best of Both Worlds (the HardCopy sales pitch) 

Structured ASIC Advantages

- Low NRE cost
  - Implementation engineering effort
  - Mask tooling charges
- High performance
- Low power consumption
- Less Complex
  - Fewer layers to fabricate
- Small marketing time
  - Pre-made cell blocks available for placing

Custom ASICs

- Homework: From the above, figure out the pros and cons of custom ASICs.

Processor Choices

Processor Choices

- You could pick:
  - An off the shelf processor, or
  - “Roll out your own” processor
- You could also create a more complex platform by combining a processor with hardware units

Processor Choices

- If you just use a single processor
  - Then write software to run on that processor
- But what type of processor do you use?
  - Pentium and friends are good for desktop use
    - Often not a good choice for embedded systems
      - Too complex (means it is more expensive)
      - Not necessarily suitable for real-time
      - High-end processors might use a lot of power
- Other Processors are available…

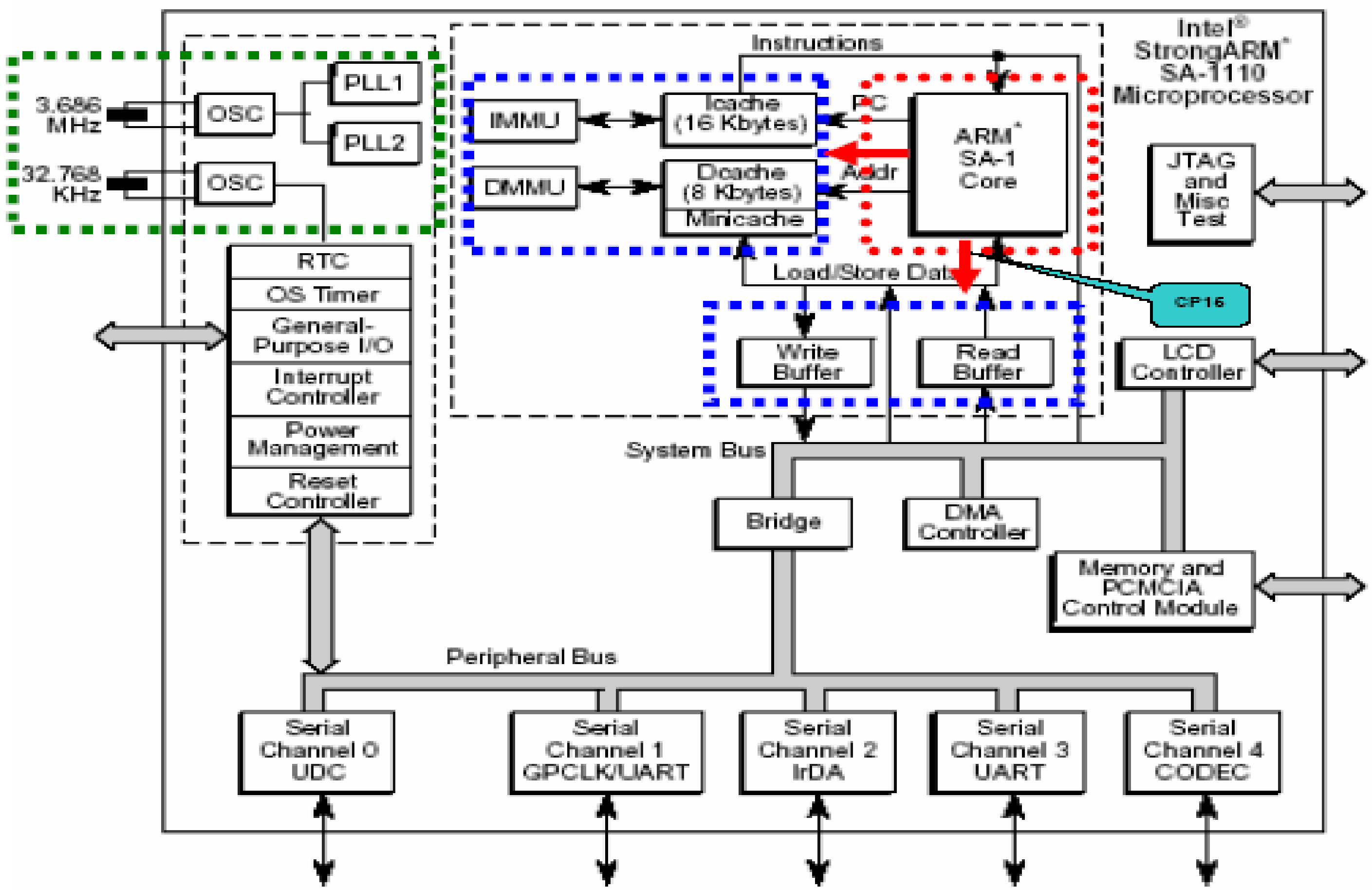
Things to think about

- Overall, things you should think about when choosing a processor:
  - Cost
  - 8-bit, 16-bit, 32-bit?
  - Do you need floating point, or is fixed point arithmetic OK?
  - Power dissipation?
  - Availability?
  - Programming model?
  - Interfaces to the real world? Timers?

- In general, a ***soft*** real-time system may be implementable on a normal workstation, but an embedded system rarely would be.

Simpler Processors

- MIPS, ARM, etc:



Recall our ipod

- The Apple iPod is powered by two ARM7TDMI microprocessors.

The Samsung Miniket Camcorder

- 5 ounces (with battery)
- capture D1-resolution video (720 x 480, the same resolution as DVDs) at 30 frames/sec, with audio
- 10-power optical zoom, along with 100-power digital zooming
- Contains a Samsung SoC containing an ARM processor

Microcontrollers

- Such as the Motorola 68HC11
  - Combine a simple processor with interface blocks
  - Usually one or more timers (important for real-time!)

Digital Signal Processors

- Processors optimized specifically for DSP applications
  - Lots of parallel multiply-accumulates
  - Several different programming models
    - (C, Matlab, etc)
  - Could be either fixed point of floating point
    - Motorola 5600 = Fixed Point
    - Motorola 9600 = Floating Point
- Good if you want to process signals in real time, but not really suitable for control-type applications

“Rolling out your own” processor

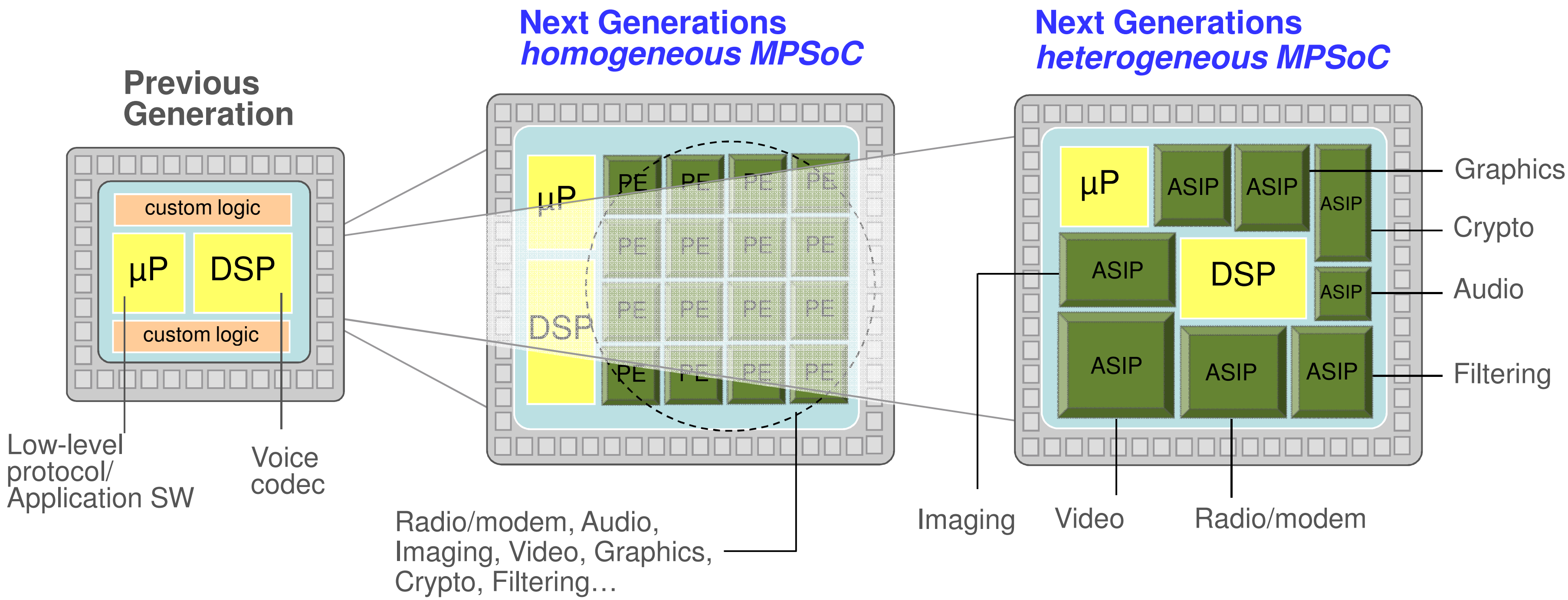
- You could create your own processor just for your application as an Application-Specific Instruction-set Processor (ASIP)
  - Could get exactly the cost/power/performance point you want
  - But, designing a processor takes time
    - Think of the man years put into designing the next generation pentium chips (100s of man-years)

“Rolling out your own” processor

- You could create your own processor just for your application as an Application-Specific Instruction-set Processor (ASIP)
  - Another option:
    - Some companies provide tools to allow you to customize a base processor for a given application
    - No need to design a processor from scratch
    - But sometimes the degree of customization possible is limited
  - The following slides are taken from a keynote address at ASAP and highlight things you need to consider when designing an ASIP

ASIPs in Multi-Core SoC

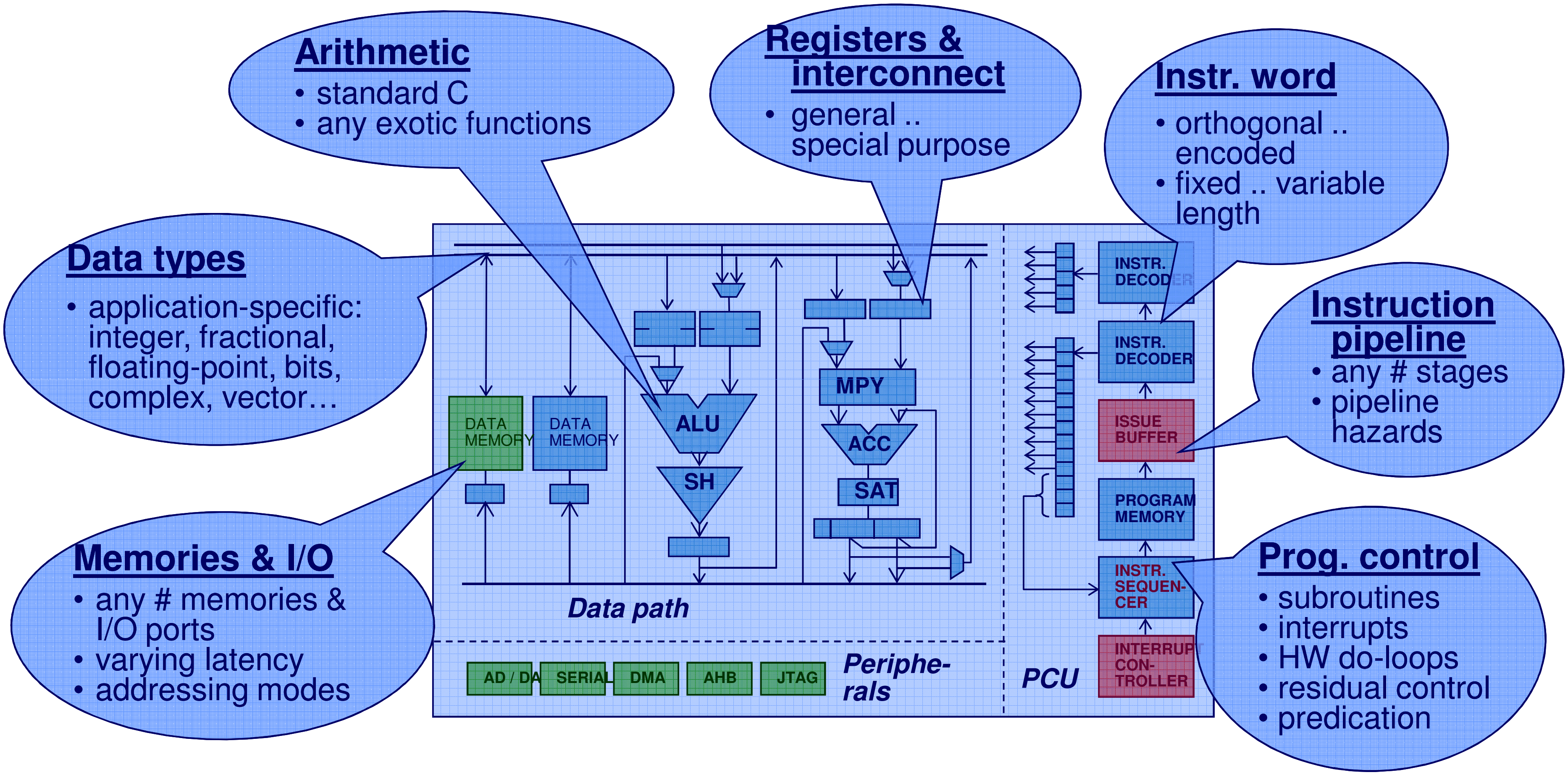
- System-on-Chip becomes Sea-of-Cores



- Heterogeneous best for deep submicron power challenge
  – Each ASIP optimised for its function: minimal logic, balanced parallelism
  – Local communication
  – Power gating based on system requirements

From Keynote at ASAP 2008 by Gert Goossens from Target the ASIP Company

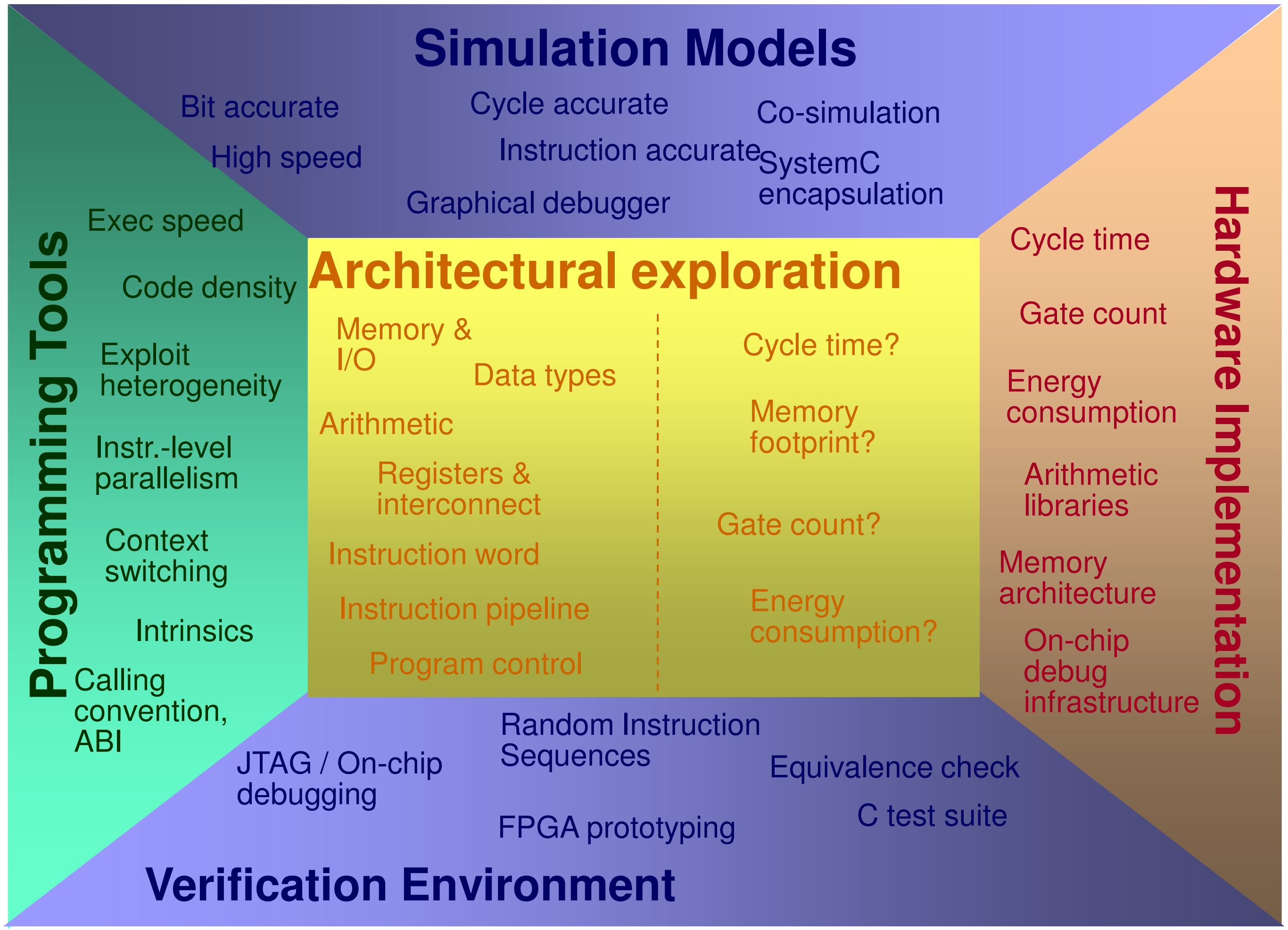
Architectural variation of ASIPs



• True architectural exploration: opportunity & challenge…

From Keynote at ASAP 2008 by Gert Goossens from Target the ASIP Company

ASIP Designer's Challenges



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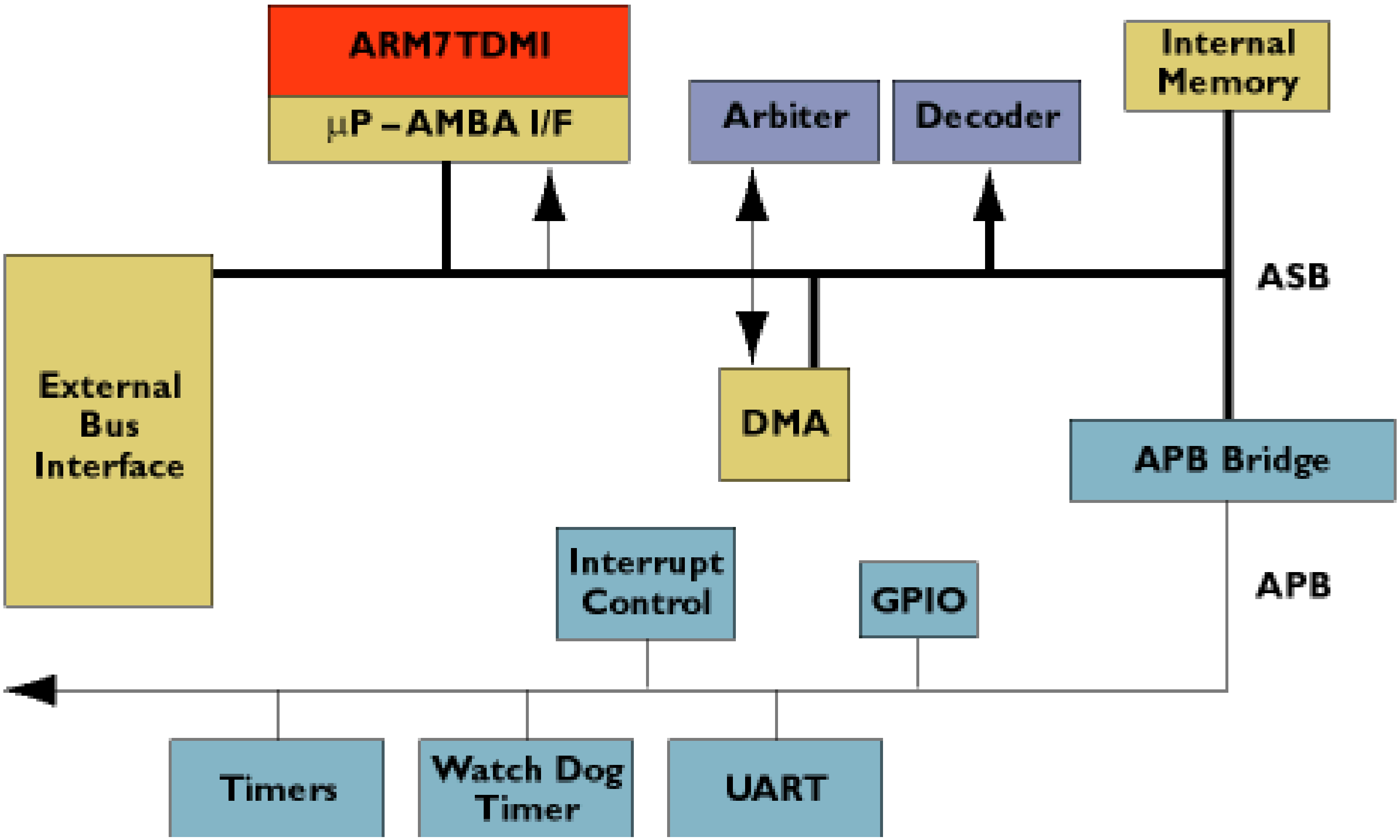
Flexible Processor Examples

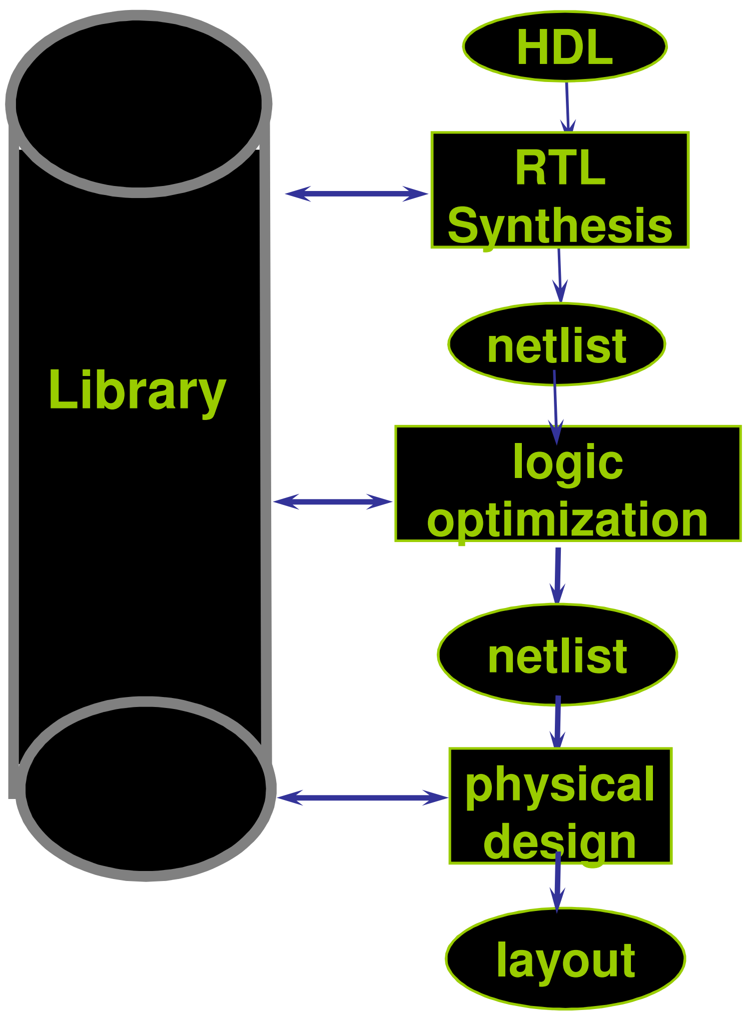
- ARM allows for configurability via AMBA bus
- Offers ``prime cell'' peripherals which hook into AMBA Peripheral Bus (APB)
  - UART
  - Real Time Clock
  - Audio Codec Interface
  - Keyboard and mouse interface
  - General purpose I/O
  - Smart card interface
  - Generic IR interface

- http://www.arm.com/Pro+Peripherals/PrimeCell/index.html

An ARM plus your choice of peripherals



Can be even more flexible…

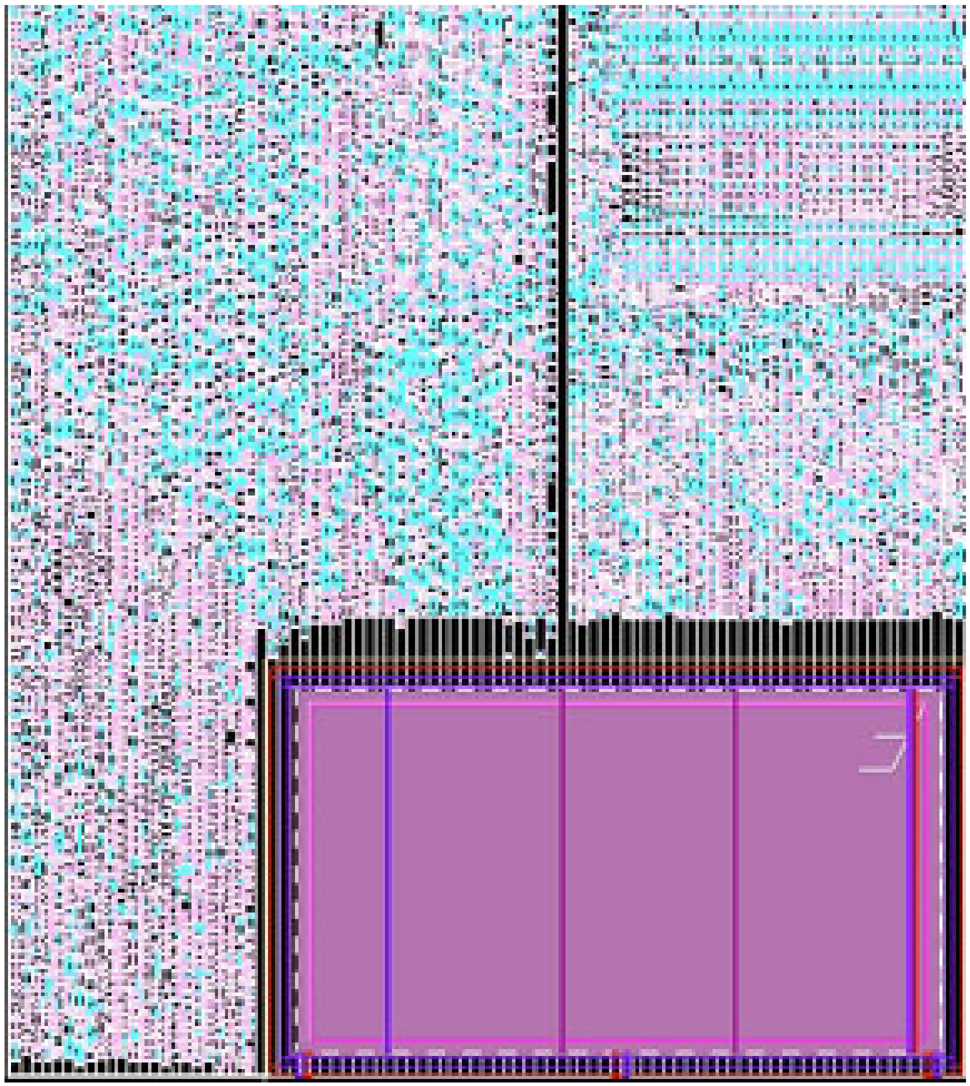


Synthesis of a processor core from an RTL description allows for:

- Lots more configurability

Examples:
- ARM7
- Motorola Coldfire
- Tensilica Xtensa

ARM7



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