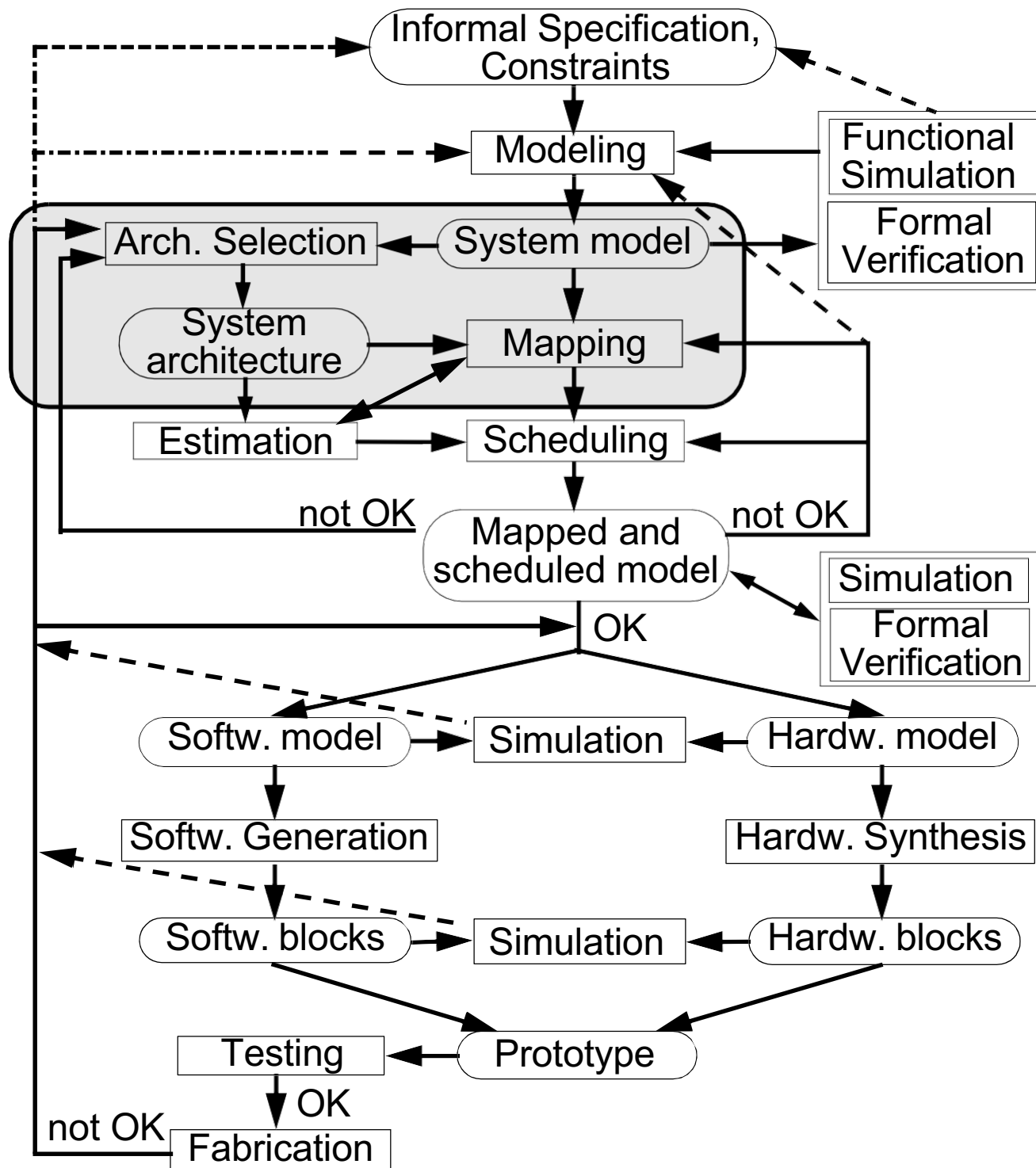


ARCHITECTURES AND PLATFORMS

1. **Architecture Selection: The Basic Trade-offs**
2. **General Purpose vs. Application-Specific Processors**
3. **Processor Specialisation**
4. **ASIP Design Flow**
5. **Tool Support for Processor Specialisation**
6. **Application Specific Platforms**
7. **IP-Based Design (Design Reuse)**
8. **Reconfigurable Systems**



Architecture Selection and Mapping

- **Select underlying hardware structure on which to run the modelled system.**
- **Map the functionality captured by the system over the components of the selected architecture.**

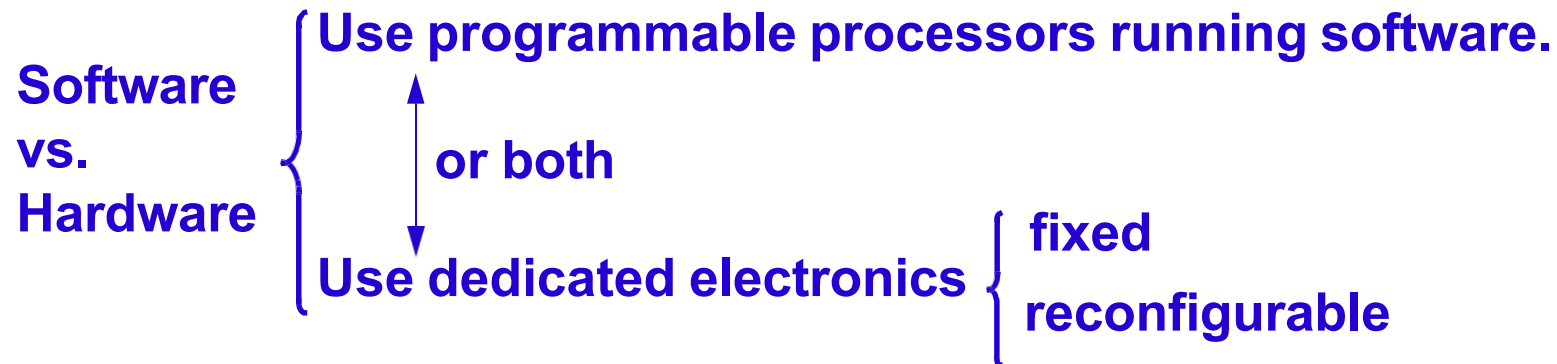
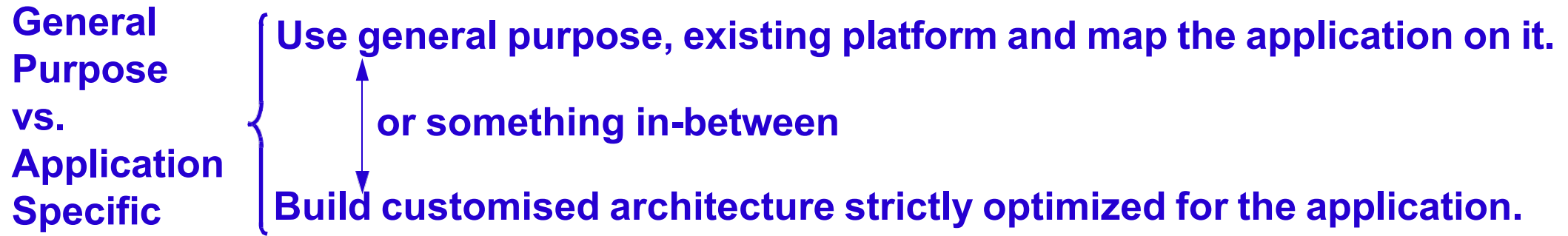
Functionality includes processing and communication.

Architecture Selection

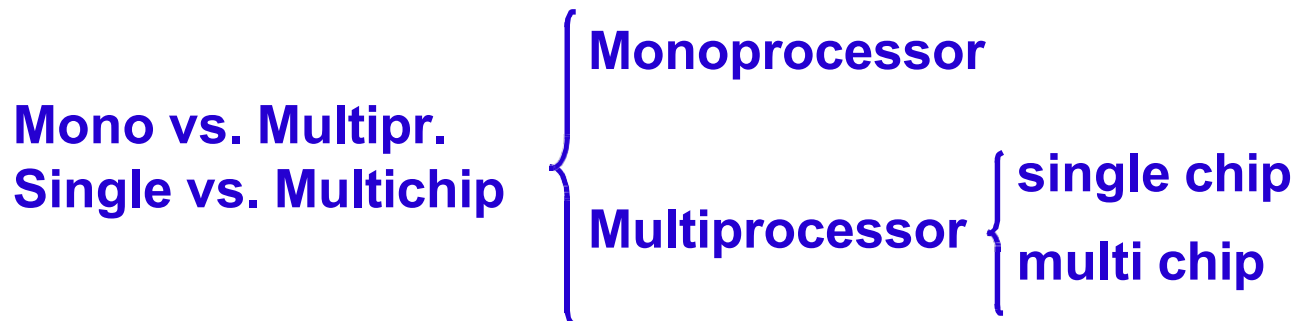
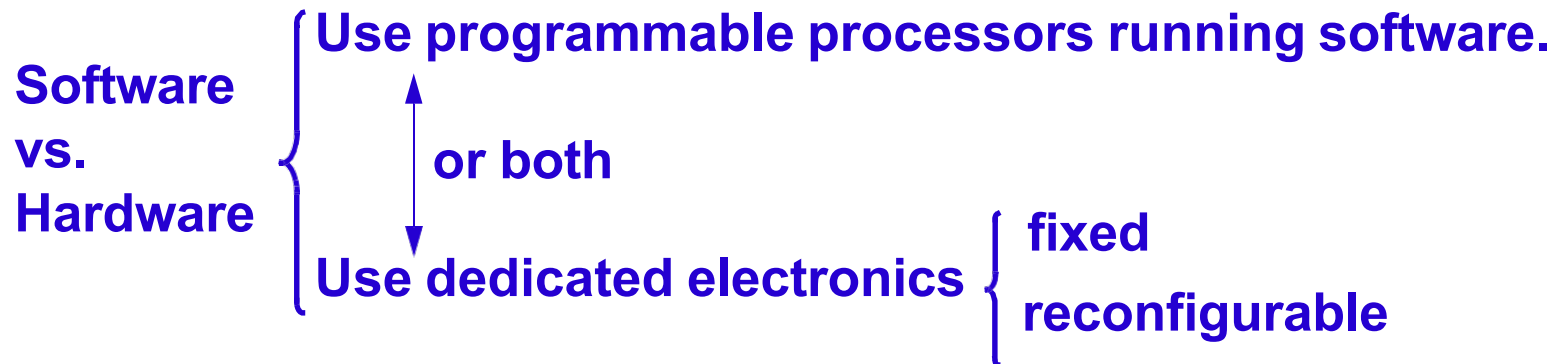
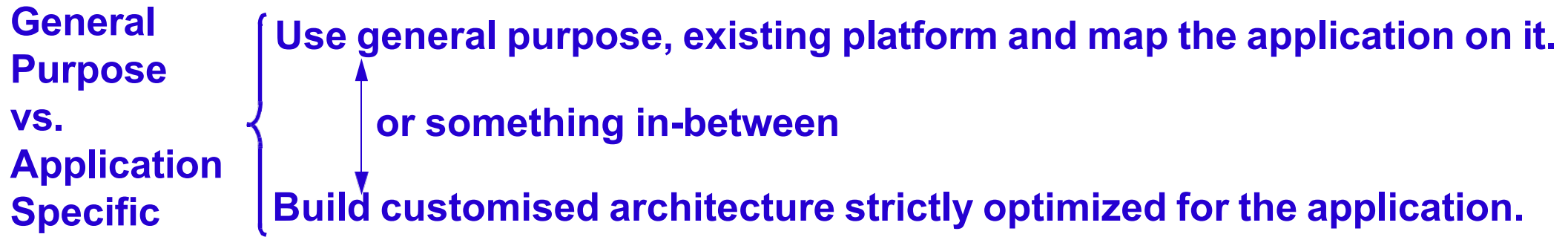
**General
Purpose
vs.
Application
Specific**



Architecture Selection



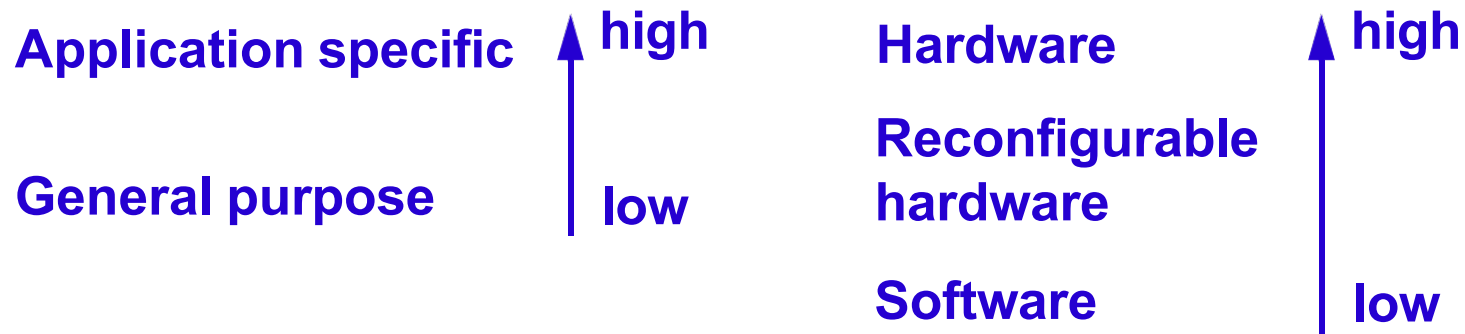
Architecture Selection



Architecture Selection

The trade-offs:

- Performance (high speed, low power consumption)



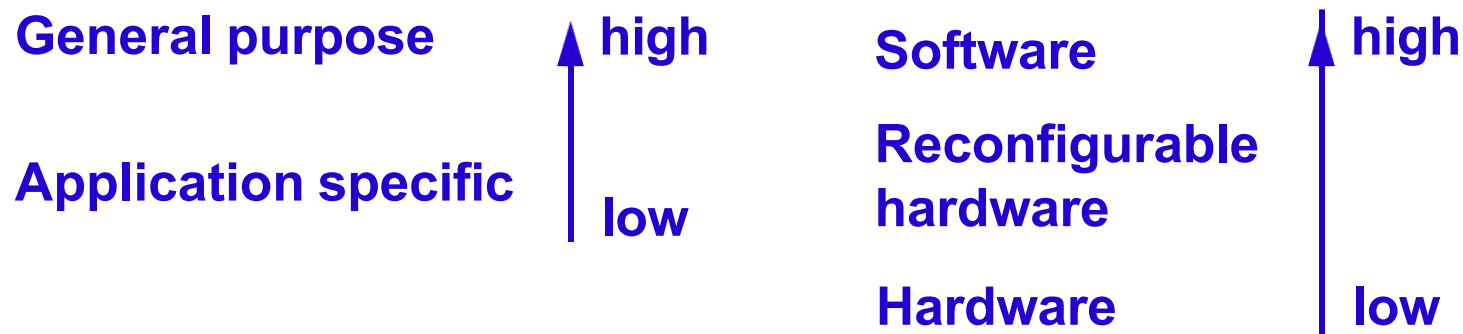
Architecture Selection

The trade-offs:

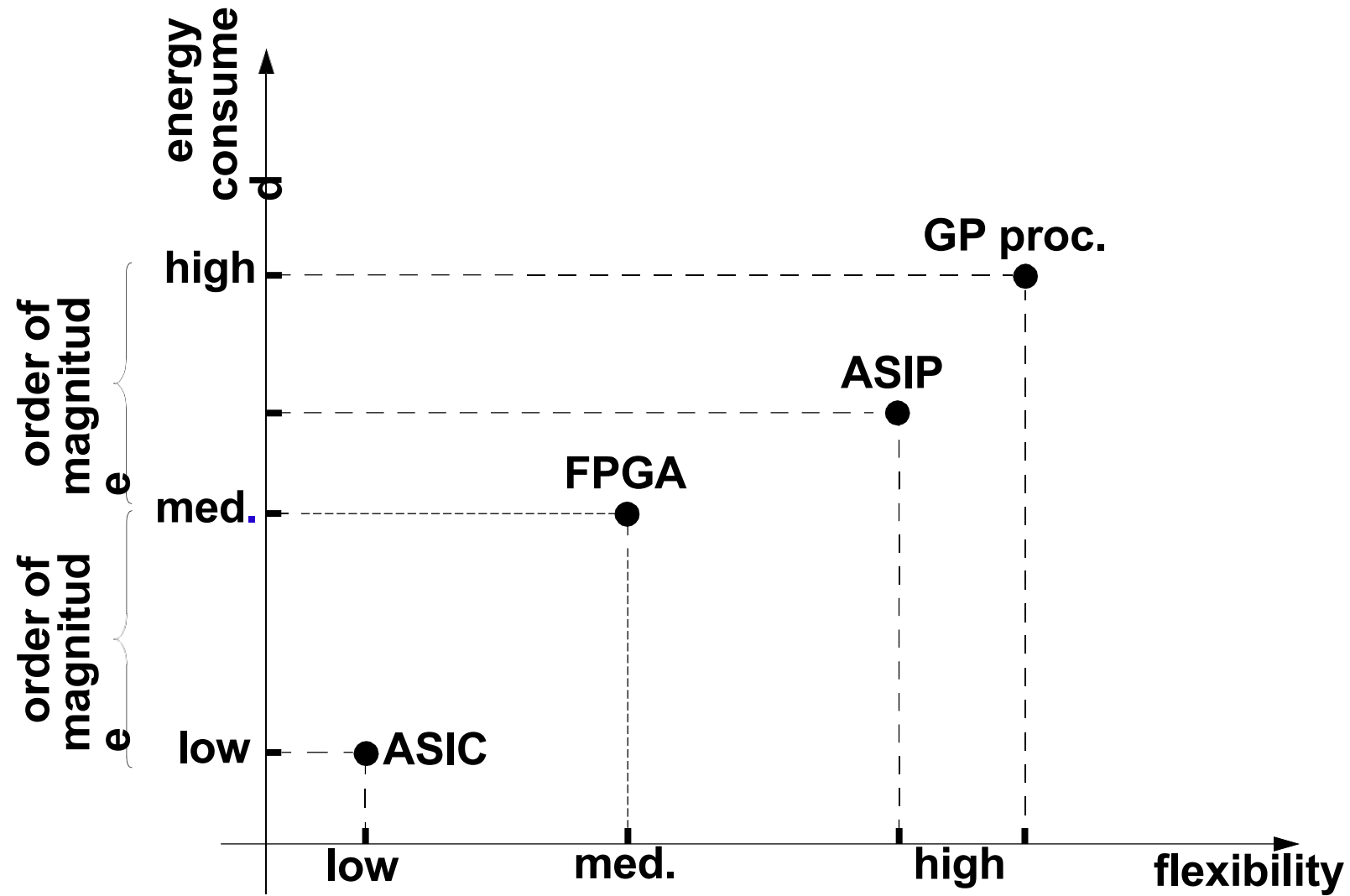
- Performance (high speed, low power consumption)



- Flexibility (how easy it is to upgrade or modify)



Architecture Selection



General Purpose vs. Application Specific Processors

- Both GP processors and ASIPs (application specific instruction set processors) can be RISCs, CISCs, DSPs, microcontrollers, etc.
 - GP processors
 - Neither instruction set nor microarchitecture or memory system are customised for a particular application or family of applications
 - ASIPs
 - Instruction set, microarchitecture and/or memory system are customised for an application or family of applications.



Results in better performance and reduced power consumption.

What Makes an ASIP “Specific”?

■ Instruction set (IS) specialisation

- Exclude instructions which are not used
 - reduces instruction word length (fewer bits needed for encoding);
 - keeps controller and data path simple.
- Introduce instructions, even “exotic” ones, which are specific to the application: combinations of arithmetic instructions (multiply-accumulate), small algorithms (encoding/decoding, filter), vector operations, string manipulation or string matching, pixel operations, etc.
 - reduces code size \Rightarrow reduced memory size, memory bandwidth, power consumption, execution time.
 - increases speed.

What Makes an ASIP “Specific”?

- Function unit and data path specialisation

- Once an application specific IS is defined, this IS can be implemented using a specific data path and specific function units.

- Adaptation of word length.
- Adaptation of register number.
- Adaptation of functional units

Highly specialised functional units can for string matching and manipulation, pixel operation, arithmetics, and even complex units to perform certain sequences of computations (co-processors).

What Makes an ASIP “Specific”?

■ Memory specialisation

- ❑ Number and size of memory banks.
- ❑ Number and size of access ports.
 - They both influence the degree of parallelism in memory access.
 - Having several smaller memory blocks (not one big) increases parallelism and speed, and reduces power consumption.
 - Sophisticated memory structures can increase cost and bandwidth requirement.
- ❑ Cache configuration:
 - separate instruction/data?
 - associativity
 - cache size
 - line size

What Makes an ASIP “Specific”?

- **Interconnect specialization**
 - **Interconnect of functional modules and registers.**
 - **Interconnect to memory and cache.**
 - **How many internal buses?**
 - **What kind of protocol?**
 - **Additional connections increase the potential of parallelism.**

What Makes an ASIP “Specific”?

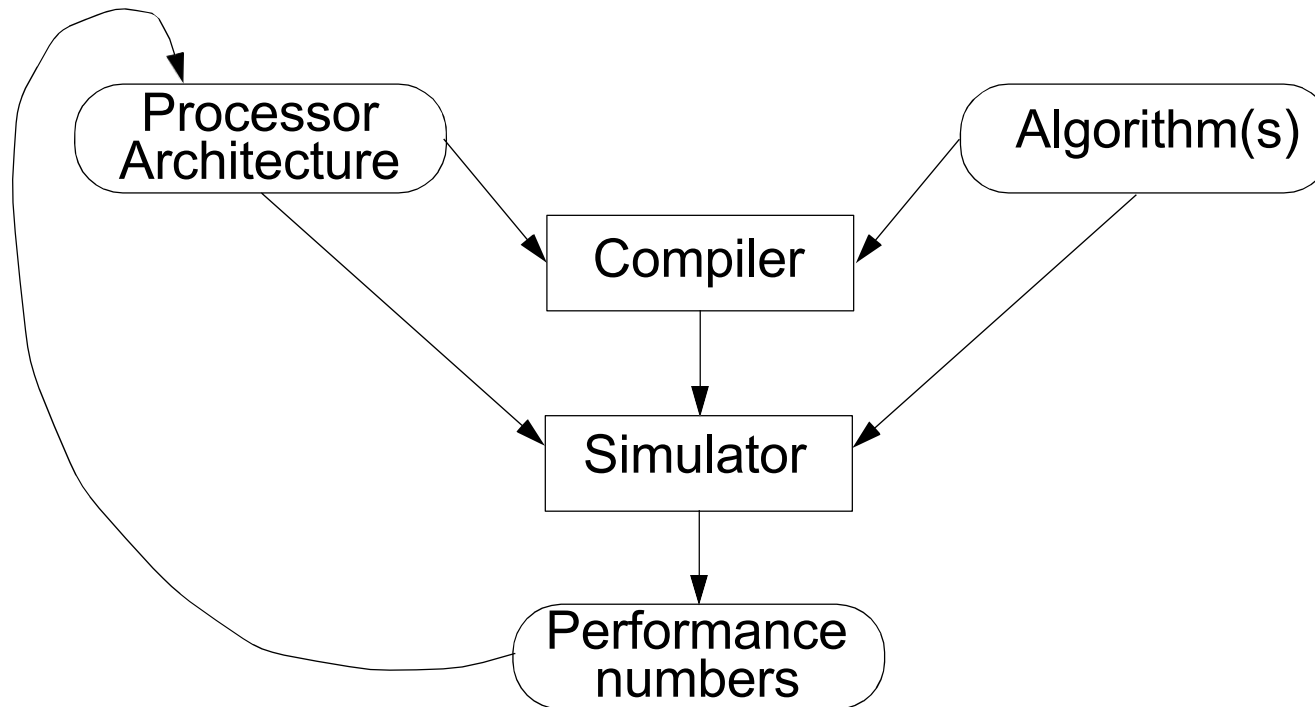
■ Interconnect specialization

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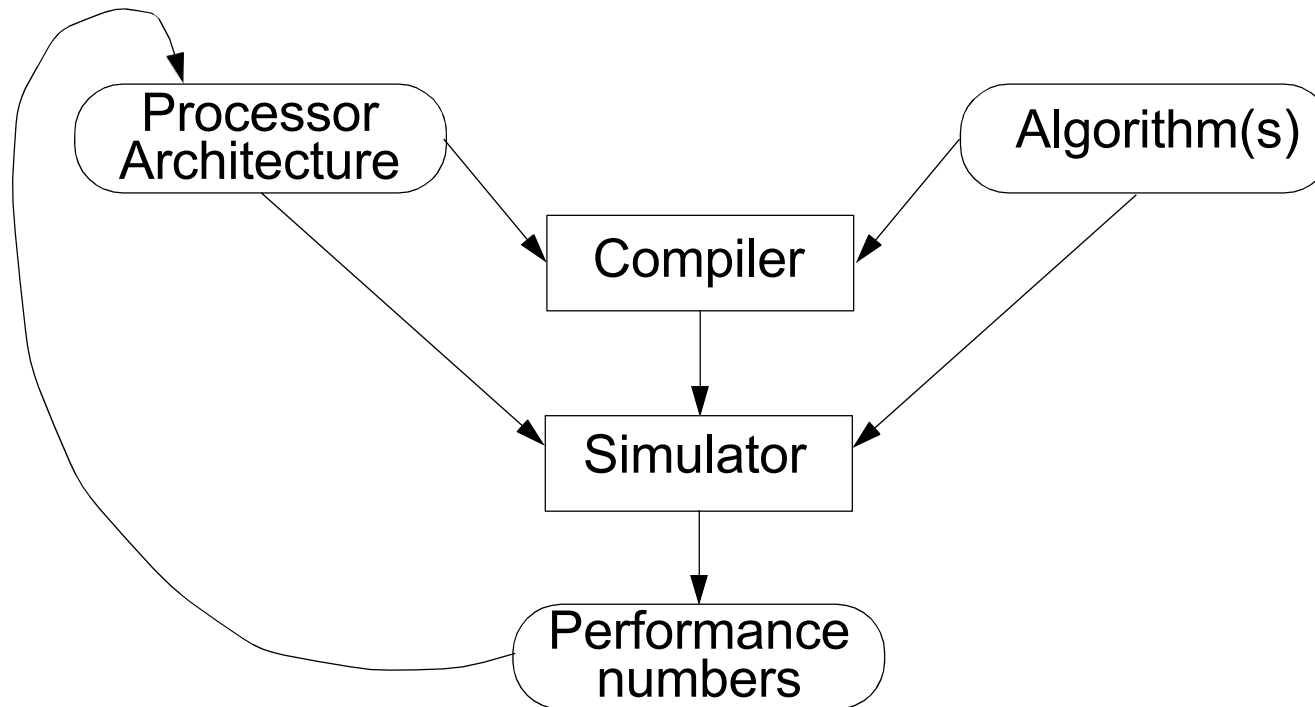
■ Control specialisation

- ❑ Centralised control or distributed (globally asynchronous)?
- ❑ Pipelining?
- ❑ Out of order execution?
- ❑ Hardwired or microprogrammed?

ASIP Design Flow

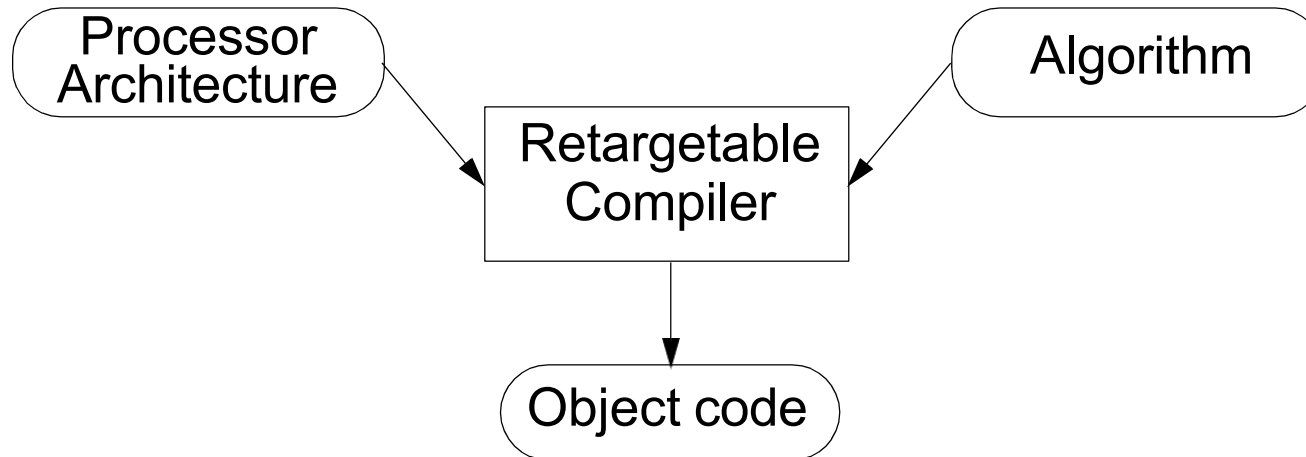


ASIP Design Flow



- In order to be able to generate a specialised architecture you need:
 - ❑ Retargetable compiler
 - ❑ Configurable simulator

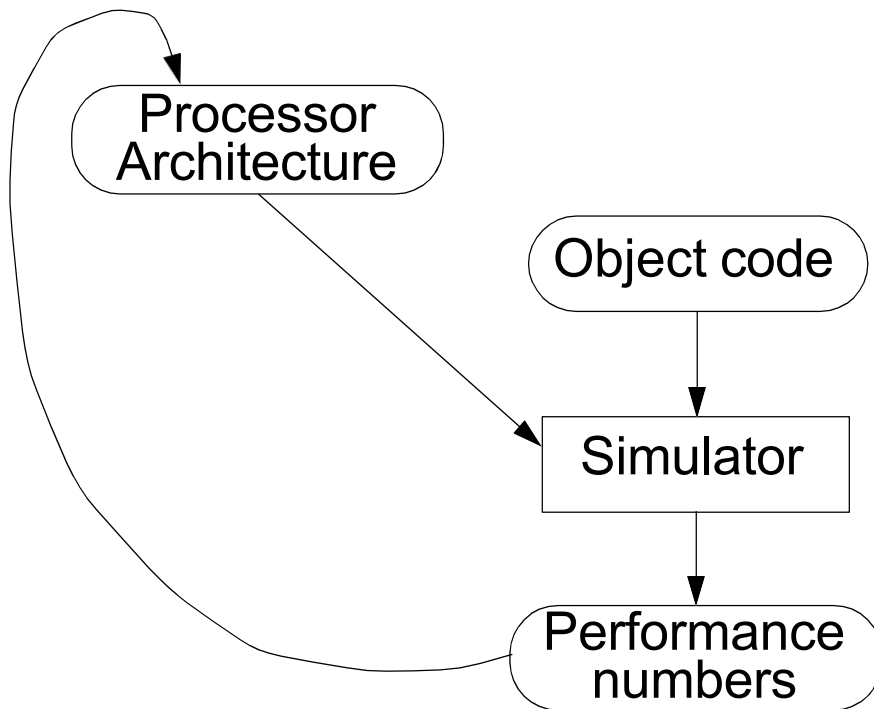
Retargetable Compiler



- ***An automatically retargetable compiler can be used for a range of different target architectures.***

The actual code optimization and code generation is done by the compiler, based on a description of the target processor architecture. This description is formulated in a, so called, “architecture description language”.

Configurable Simulator



- Such a simulator can be configured for a particular architecture (based on an architecture description)
- The most important output produced by the simulator is performance numbers:
 - ❑ throughput
 - ❑ delay
 - ❑ power/energy consumption

Application Specific Platforms

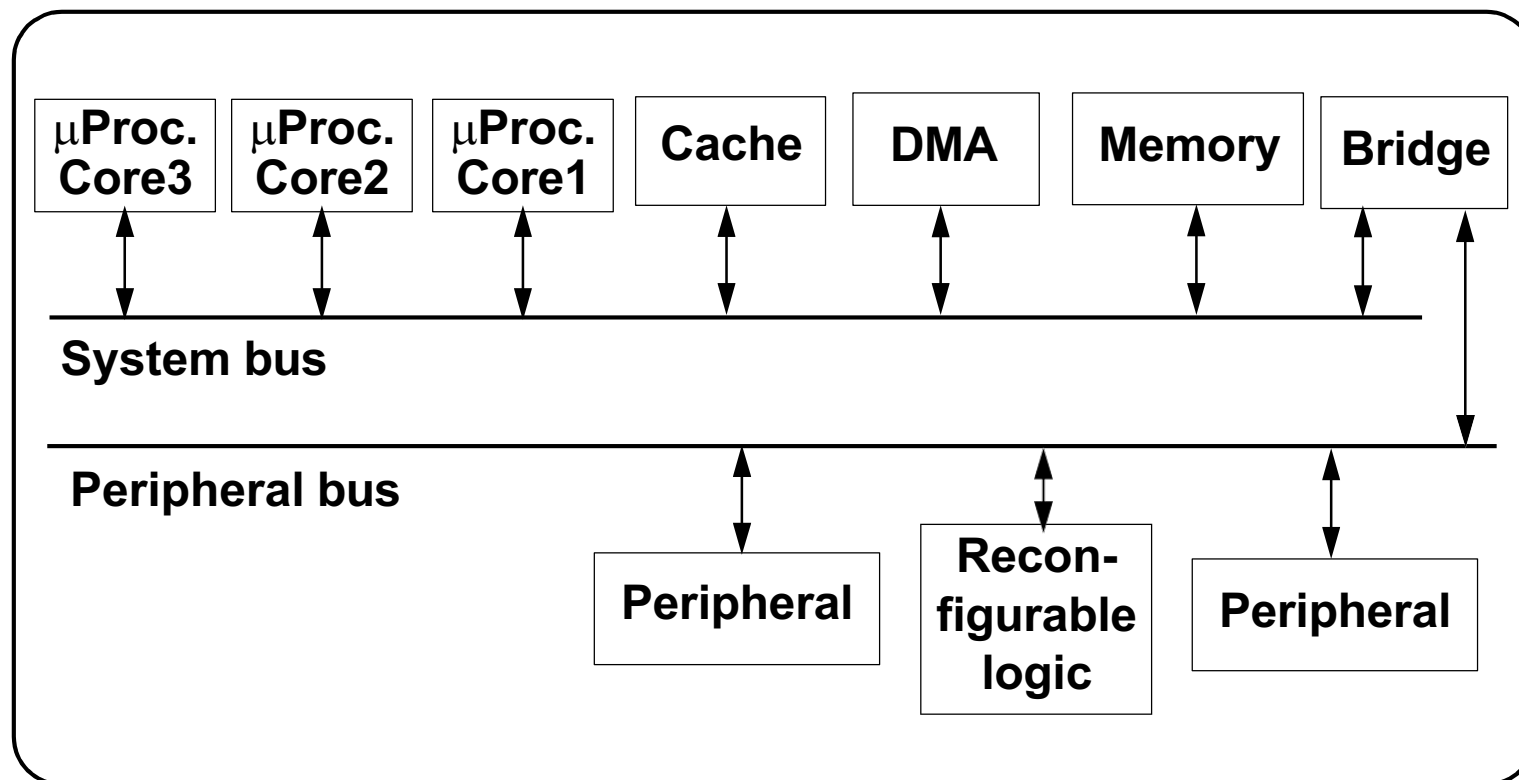
- Not only processors but also *hardware platforms* can be specialised for classes of applications.

The platform will define a certain communication infrastructure (buses and protocols), certain processor cores, peripherals, accelerators commonly used in the particular application area, and basic memory structure.

Application Specific Platforms

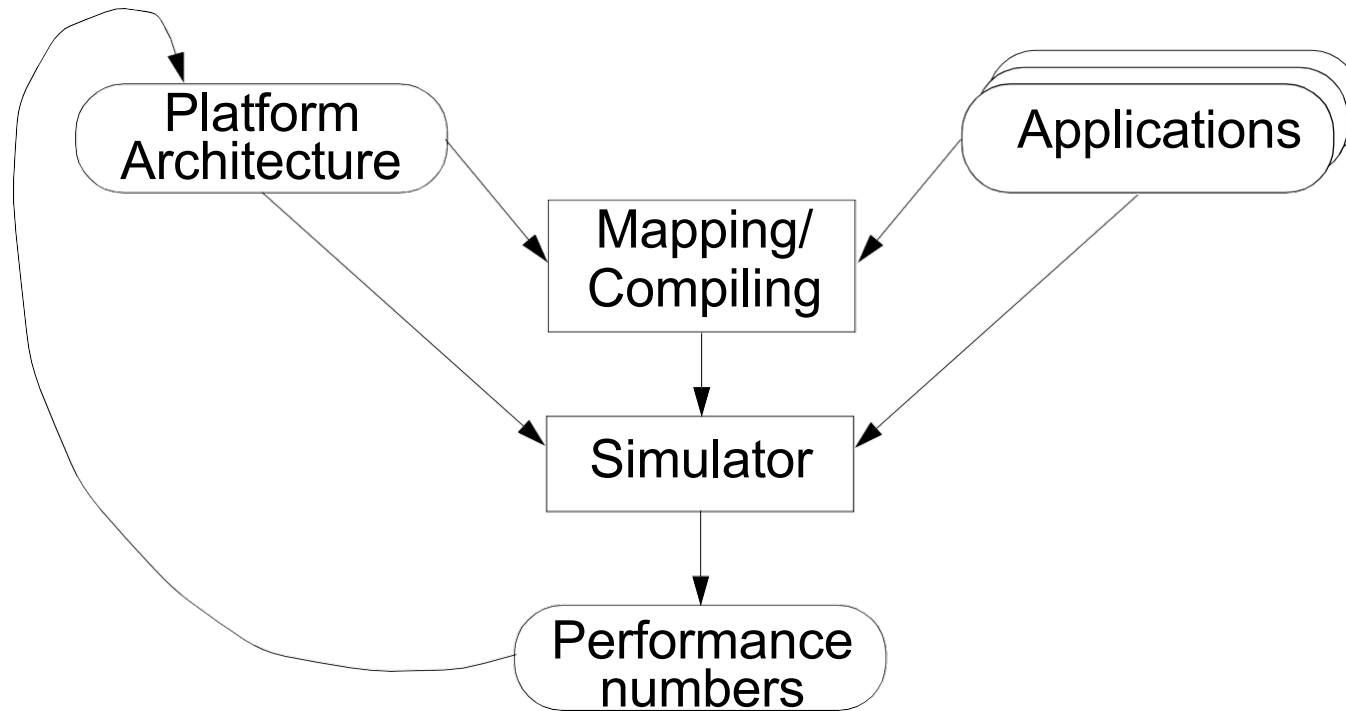
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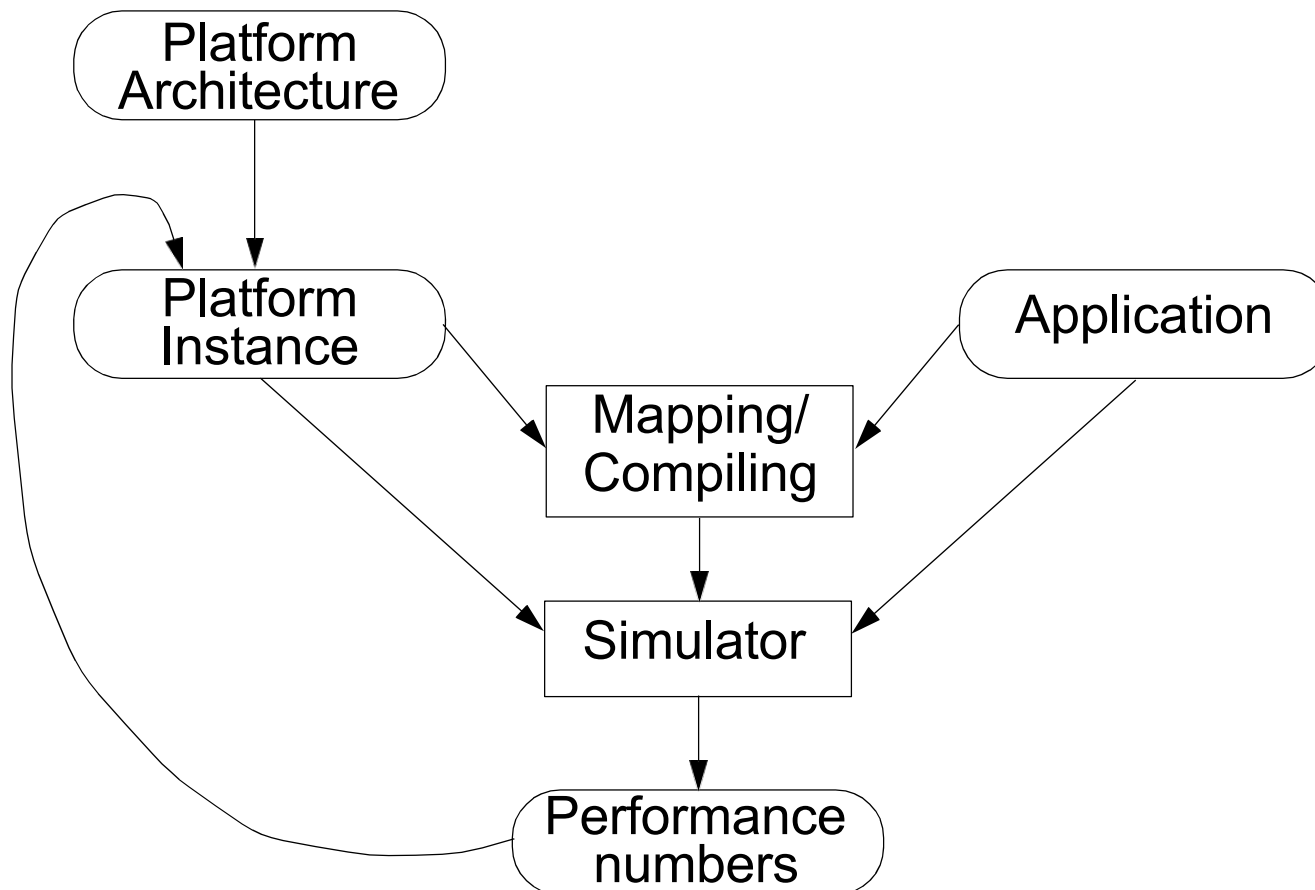
Application Specific Platforms

Design space exploration for platform definition:



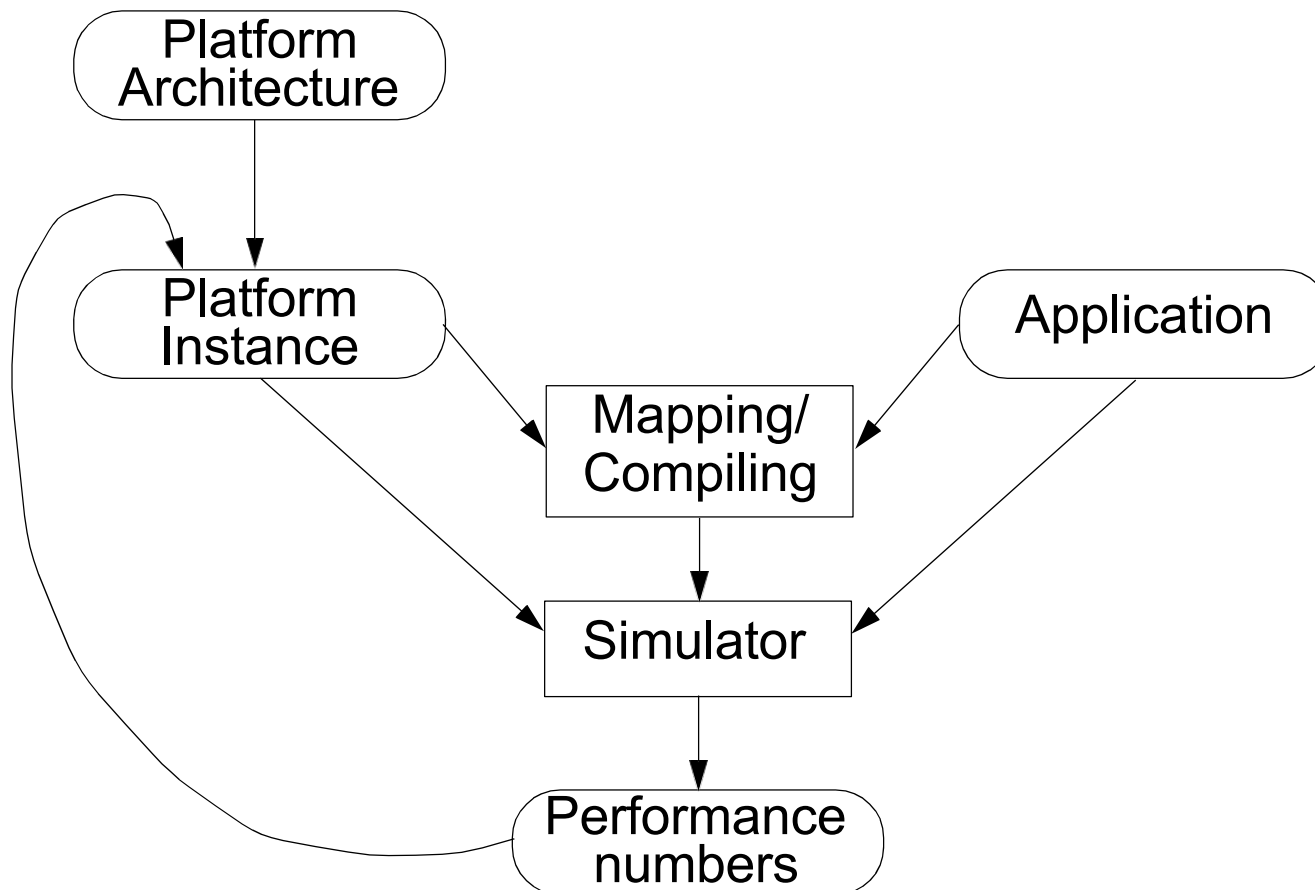
Instantiating a Platform

- Once we have an application, the chip to implement on will not be designed as a collection of independently developed blocks, but will be *an instance of an application specific platform*.



Instantiating a Platform

- Once we have an application, the chip to implement on will not be designed as a collection of independently developed blocks, but will be *an instance of an application specific platform*.



- The hardware platform will be refined by
 - determining memory and cache size;
 - identifying the particular cores, peripherals;
 - adding specific ASICs, accelerators;
 - determining the amount of reconfigurable logic.

System Platforms

- What we discussed about are hardware platforms.
- The hardware platform is delivered together with a software layer:
hardware platform + software layer = *system platform*.
 - Software layer:
 - real-time operating system
 - device drivers
 - network protocol stack
 - compilers
 - The software layer creates an abstraction of the hardware platform (an application program interface) to be seen by the application programs.

IP-Based Design (Design Reuse)

- The key concept in order to increase designers' productivity is *reuse*.

In order to manage the complexity of current large designs we do not start from scratch but reuse as much as possible from previous designs, or use commercially available pre-designed *IP blocks*.

IP: intellectual property.

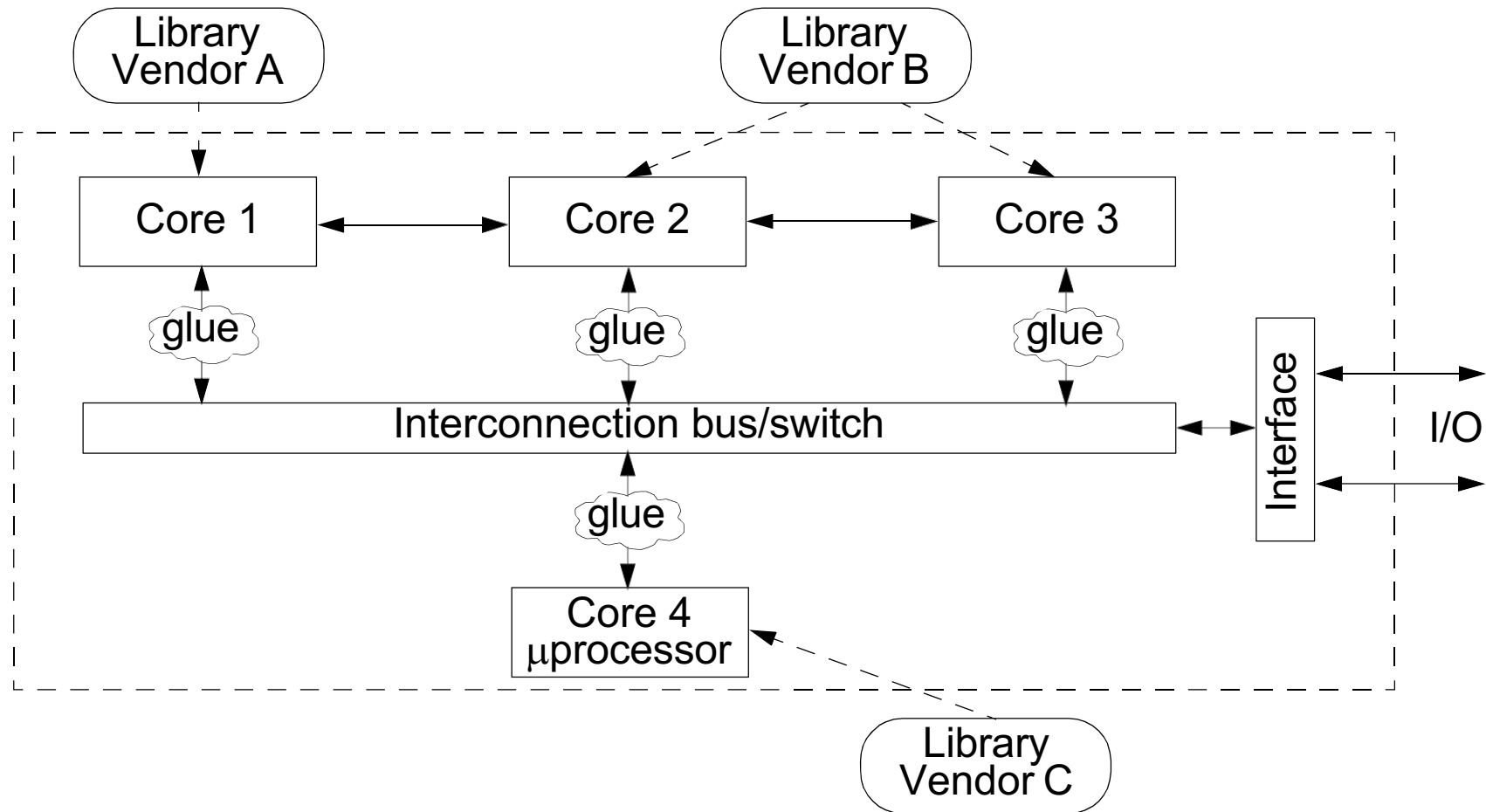
- Some people call this *IP-based design*, *core-based design*, reuse techniques: The process of producing a system design by reusing existing components.

IP-Based Design

What are the blocks (cores) we reuse?

- ❑ interfaces, encoders/decoders, filters, memories, timers, microcontroller-cores, DSP-cores, RISC-cores, GP processor-cores.
- ❑ A *core* is a design block which is larger than a typical RTL component.

IP-Based Design



Types of Cores

- Hard cores: are fully designed, placed, and routed by the supplier.



A completely validated layout with definite timing



rapid integration



low flexibility

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rapid integration



low flexibility

- Firm cores: technology-mapped gate-level netlists.



less predictability



flexibility during
place and route

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A completely validated layout with definite timing



rapid integration



low flexibility

- Firm cores: technology-mapped gate-level netlists.



less predictability



flexibility during
place and route

- Soft cores: synthesizable RTL or behavioral descriptions.



much work with
integration and
verification.



maximal flexibility

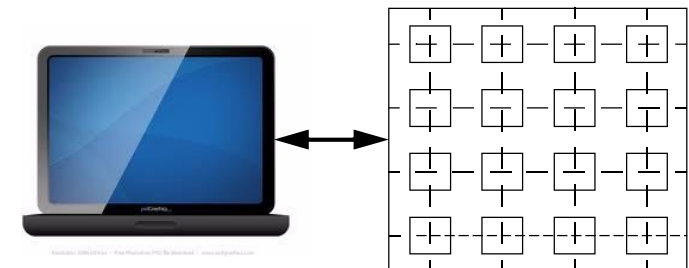
Reconfigurable Systems

■ Programmable Hardware Circuits:

- They implement arbitrary combinational or sequential circuits and can be configured by loading a local memory that determines the interconnection among logic blocks.
- Reconfiguration can be applied an unlimited number of times.

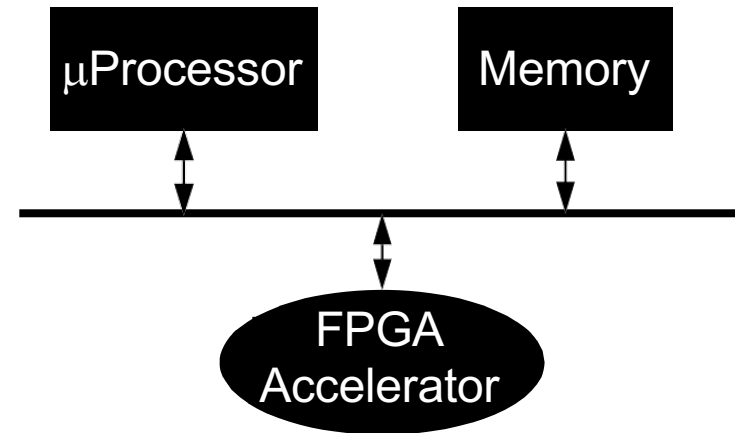
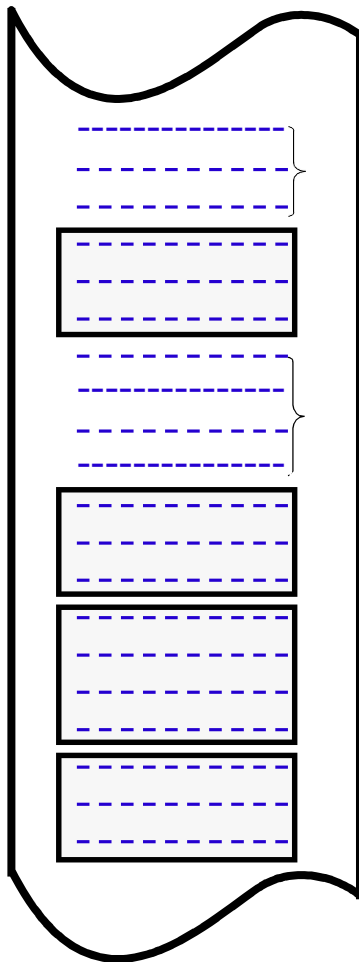
■ Main applications:

- Software acceleration
- Prototyping



Reconfigurable Systems

Dynamic reconfiguration:

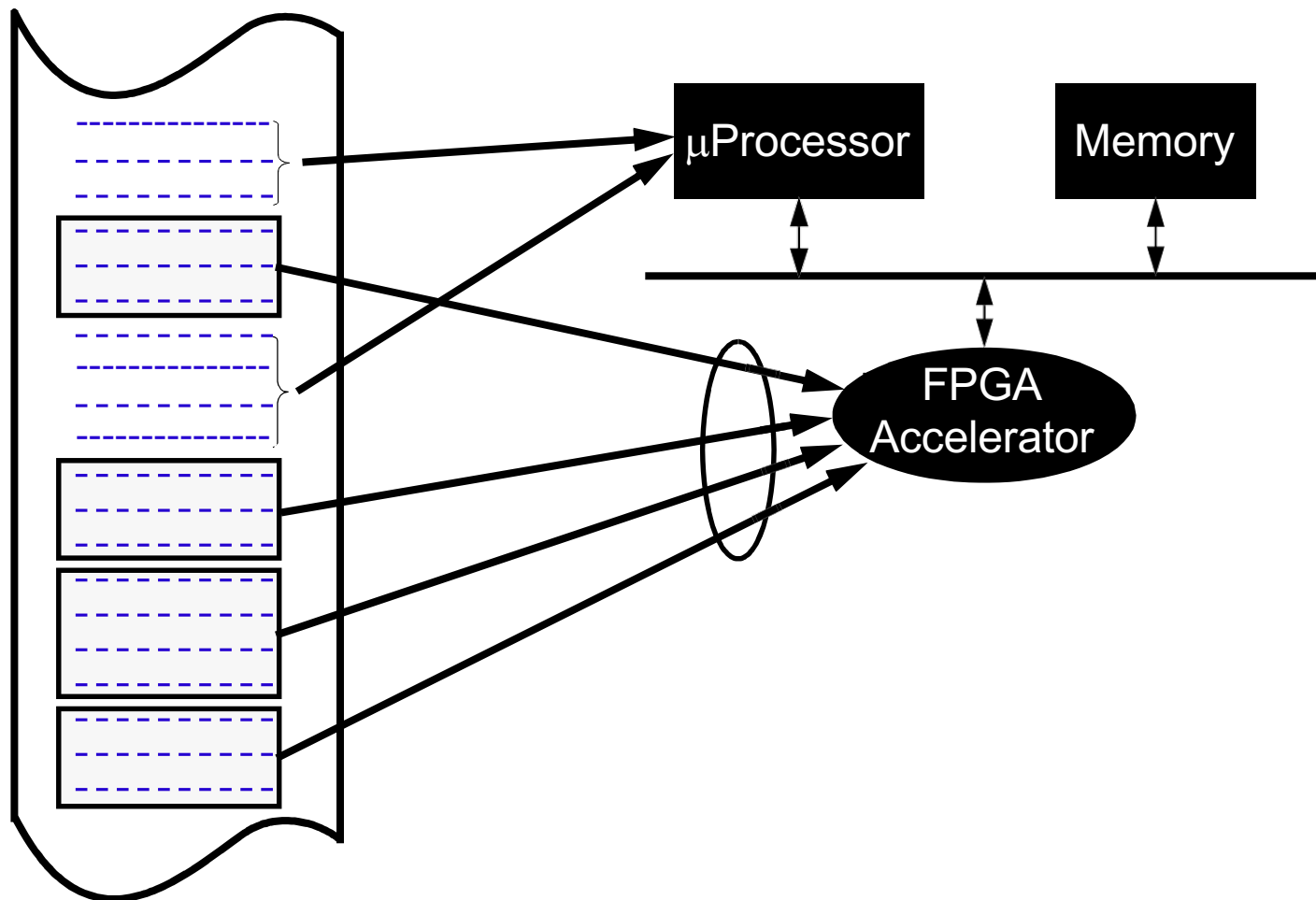


Reconfigurable Systems

Dynamic reconfiguration:

■ Spatial partitioning:

What goes into software(μ Processor) and what into hardware (FPGA)?

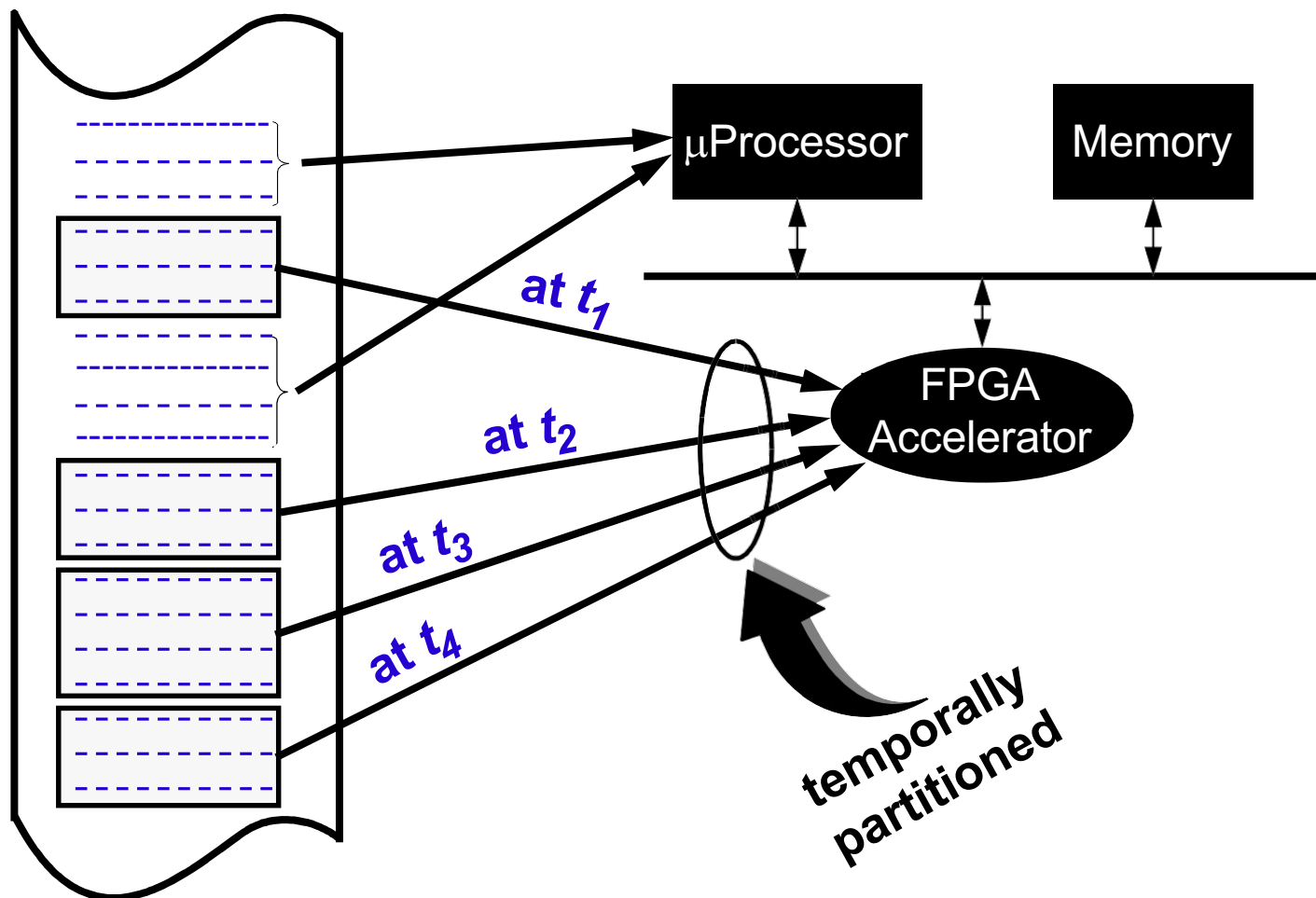


Reconfigurable Systems

Dynamic reconfiguration:

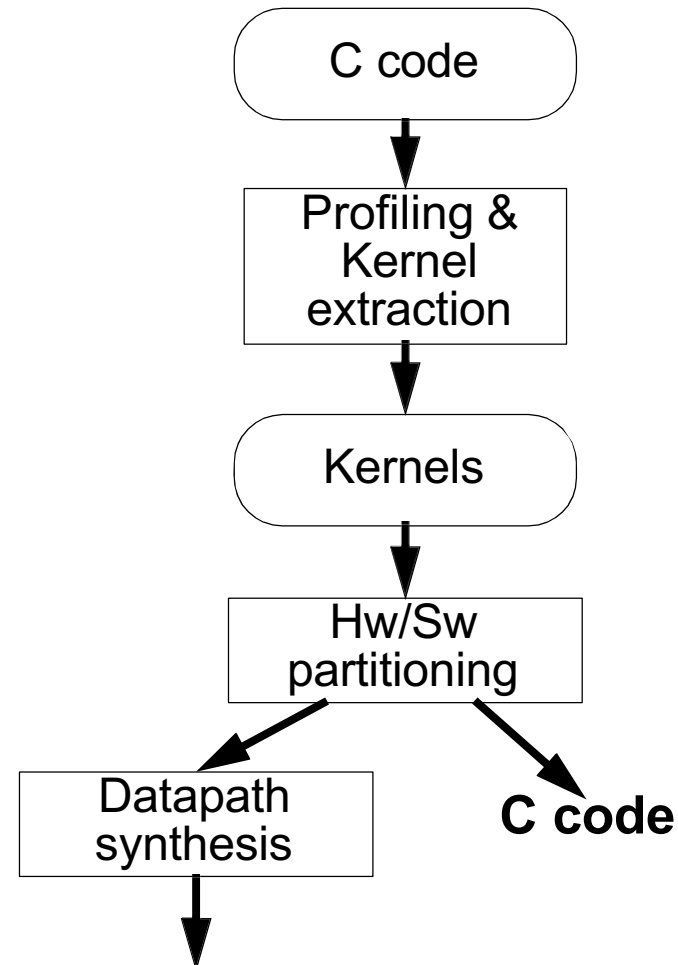
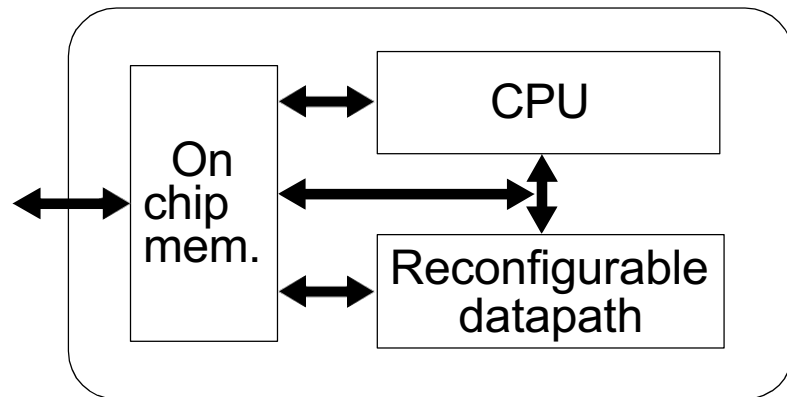
■ Temporal partitioning:

At which moment to download which module into the FPGA?

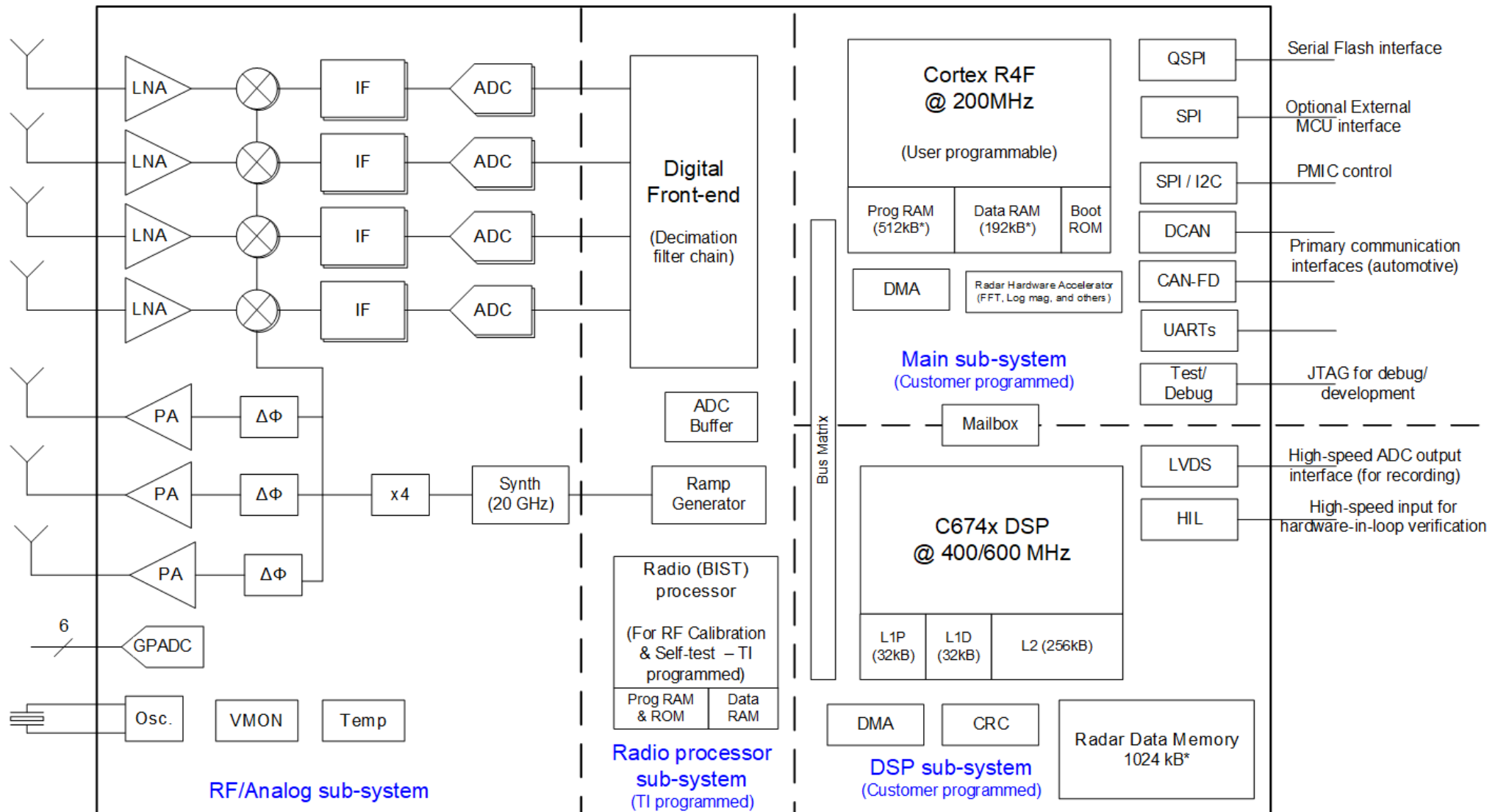


Reconfigurable Systems

System on Chip with reconfigurable datapath:



Example from Texas Instruments (Radar ASIP platform)



* Up to 512kB of Radar Data Memory can be switched to the Main R4F program and data RAMs

Example from Texas Instruments (Radar ASIP platform)

Different platform instantiation with higher-speed interfaces (Ethernet), Security, and Lock Step CPU

