SISTEMI EMBEDDED

Embedded Systems

SOPC Design Flow

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Definition(s) of Embedded Systems

- **Systems with embedded processors**
  - Hamblen, Hall, Furman, "Rapid Prototyping Of Digital Systems," *Springer 2008*
- **One or more computers are used as components**
  - Ashenden, "Digital Design: An Embedded Systems Approach Using Verilog," *Elsevier 2008*
- **A physical system that employs computer control for a specific purpose, rather than for general-purpose computation**
  - Hamacher, Vranesic, Zaky, Manjikian, "*Computer Organization And Embedded Systems," McGraw Hill 2012*
- **Device that includes a programmable computer but is not itself intended to be a general-purpose computer**
  - Wolf, "Principles of Embedded Computing System Design," *Elsevier 2008*

Embedded Systems (1)

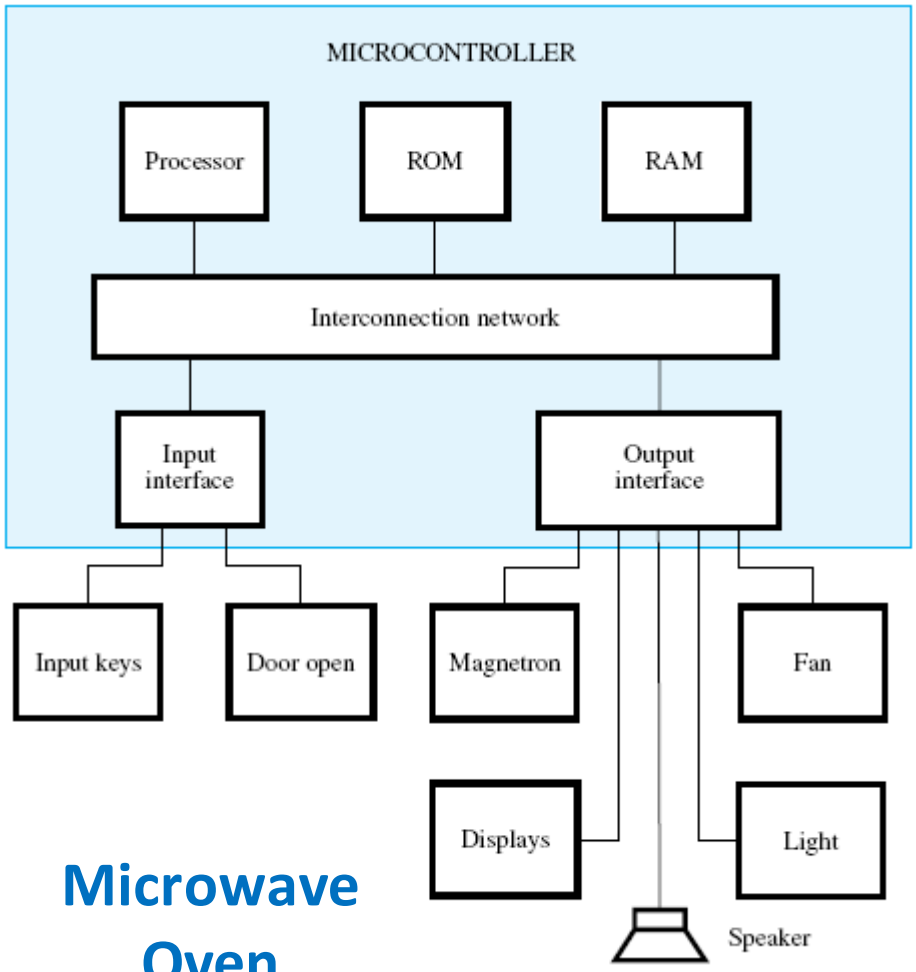
- Not easy to find a precise definition. But we can identify some prominent features:
  - Contain a computer which is **not** general-purpose
  - Are part of a larger device/equipment/plant that they control
  - Are application-specific and single functioned; functions are a-priori known and executed repeatedly
  - Need to be optimized for cost, size, energy consumption,…
  - May have Real time and safety requirements
  - Typically have minimal user interface

Embedded Systems (2)

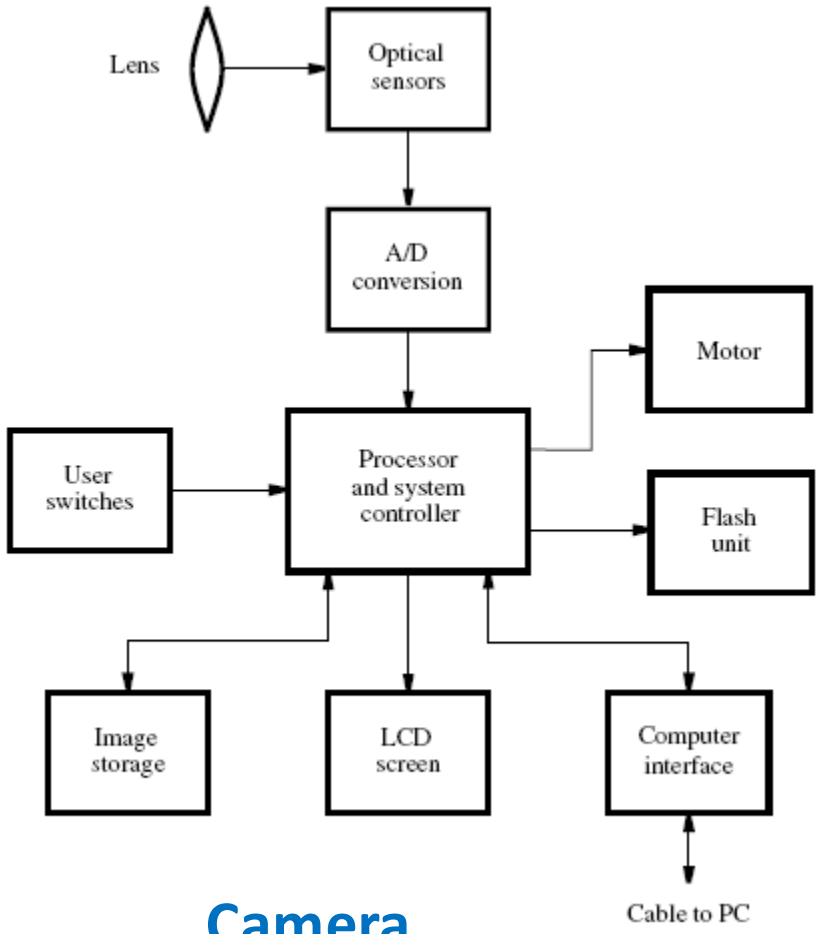
- Are very pervasive in our daily life:
  - Household appliances, cars (ABS, EPS,…), ATMs, printers, scanners, cameras, videogames, TVs, smart watches, alarm systems, “smartphones”, “tablets”,…
- Every year billion of new embedded computers
  - 100 embedded computers every one general-purpose computer

Application Examples (1)

Application Examples (2)

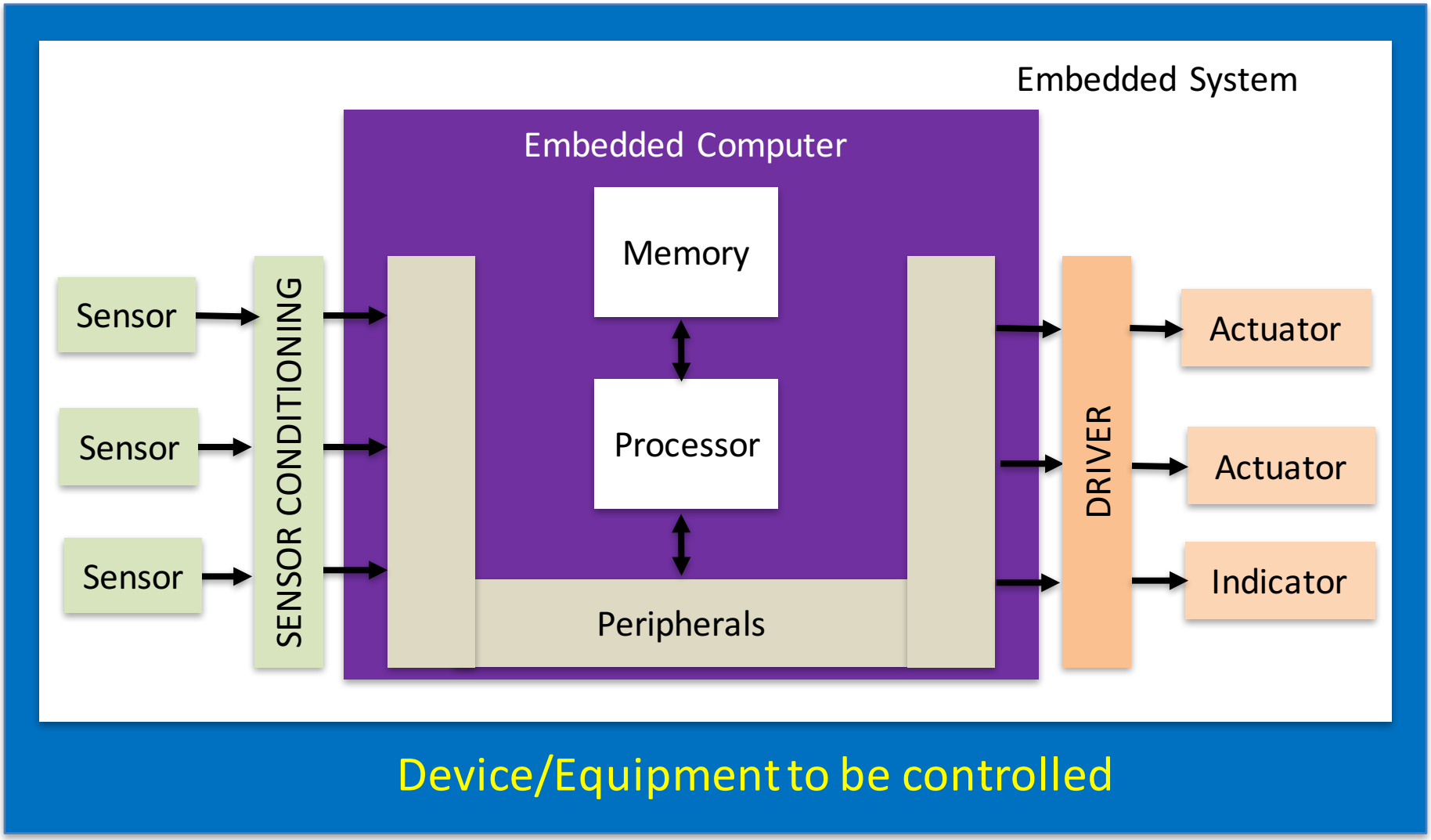


Microwave Oven



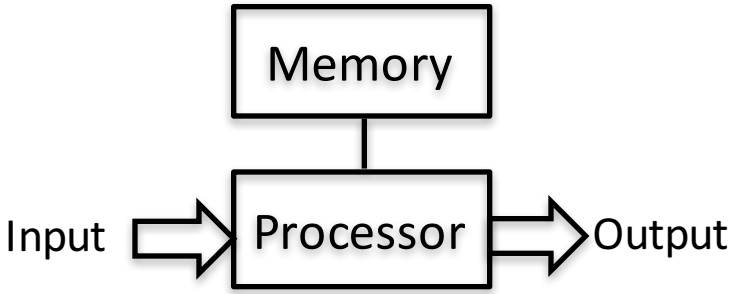
Camera

Embedded System Block Diagram



An embedded system is a computer system that is **not** general-purpose like a personal computer

Main building blocks:



- Processor(s)
- Memories: FLASH, EEPROM, SRAM, SDRAM, DDRAM
- Peripherals: GPIO, Timer/Counter, PWM, Communication interfaces (SPI, I^2C, CAN,…), A/D, D/A,…
- …
- and definitely some “specific” SOFTWARE

An embedded system is a computer system that is **not** general-purpose like a personal computer

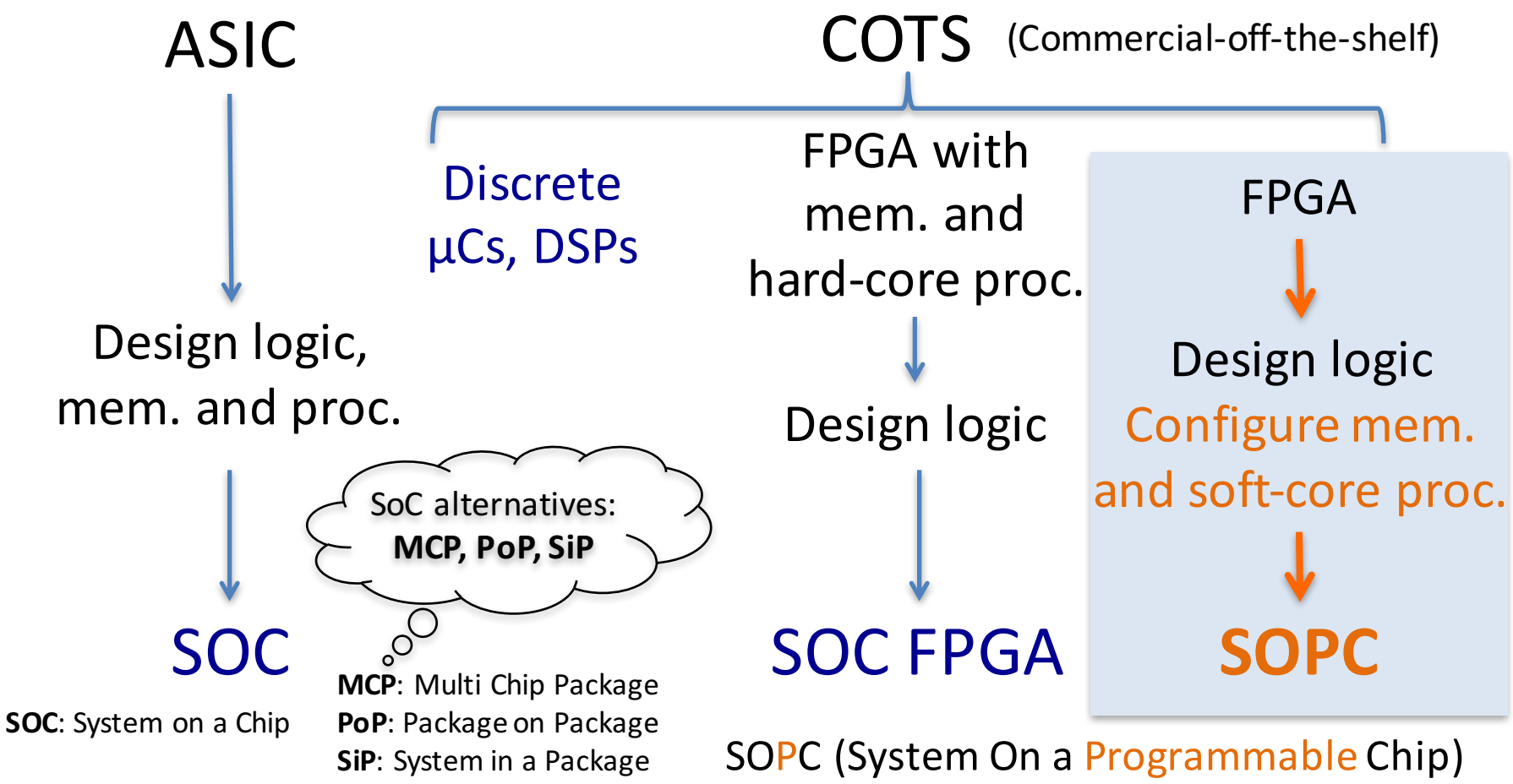
Main design constraints:

- Development cost (*Non-Recurring Engineering* cost)
- Production cost
- Power consumption
- Physical size

- Their relative importance varies from one embedded system to another

An embedded system is a computer system that is **not** general-purpose like a personal computer

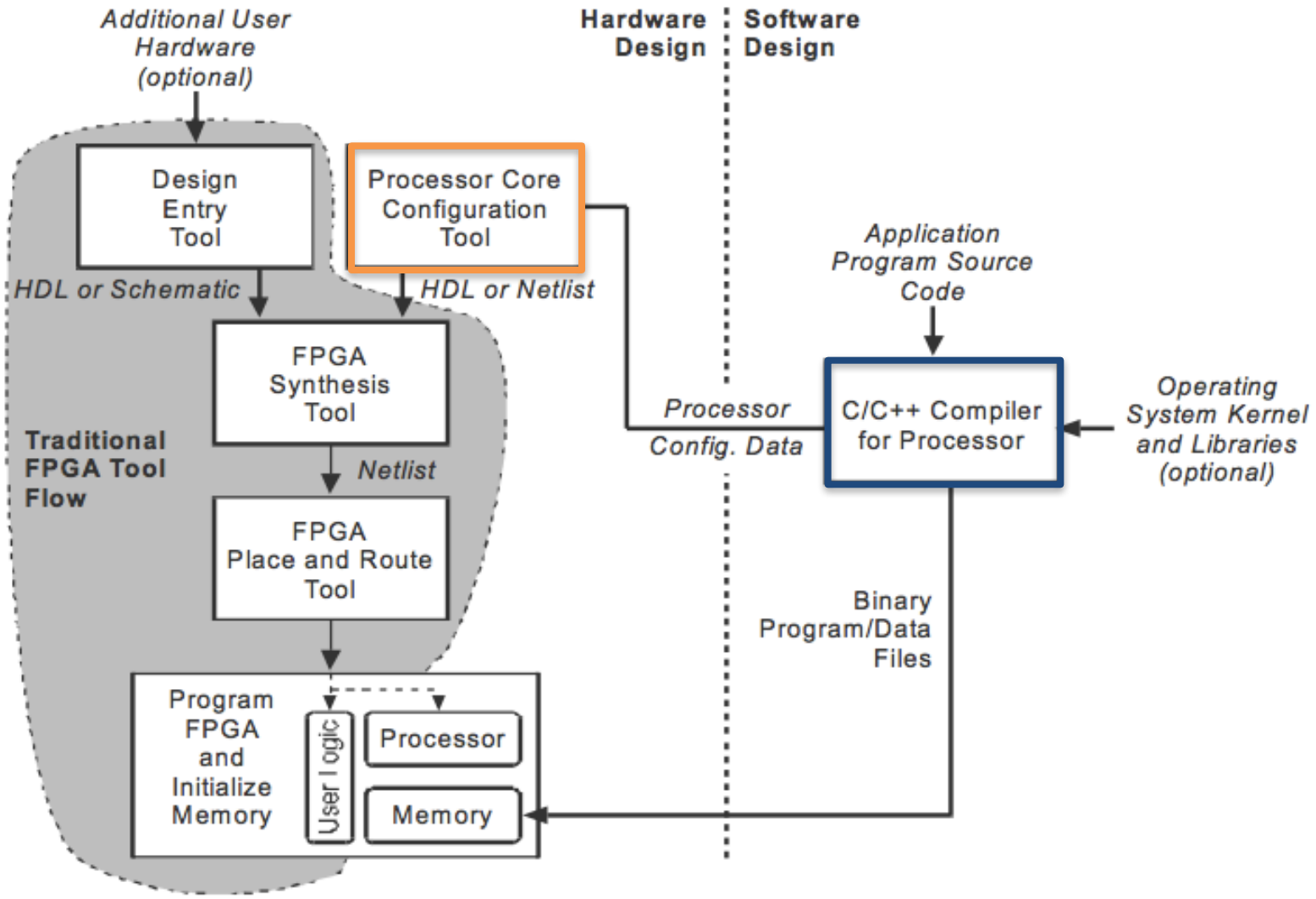
Hardware design options:



System-on-Programmable-Chip

- Configure soft-core processor:
  - Core configuration
    - Core version (E.g. economy, standard, fast for Altera Nios II)
    - Instruction/Data Cache, Pipeline Stages, JTAG Debug Modules, Custom Instructions, etc.
  - Peripheral configuration (what and where)
    - Peripheral selection
      - Standard peripherals from Altera and third-party vendors: GPIOs, Timers, Serial Communication Interfaces, Memory Interfaces, etc.
      - Custom peripherals
    - Address mapping

SOPC Design Flow



J. O. Hamblen et al. "Rapid Prototyping of Digital Systems – SOPC Edition", Springer, 2008

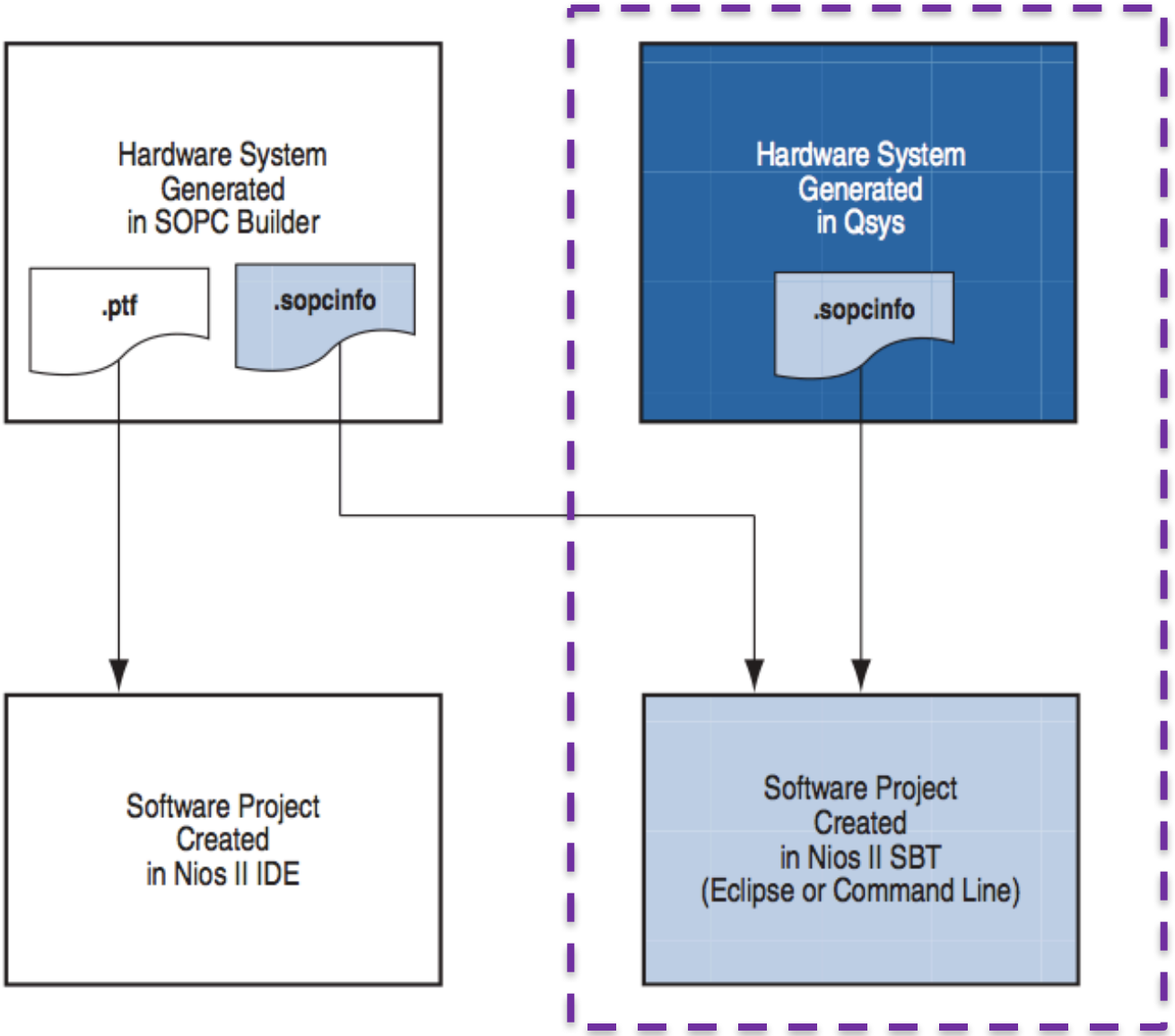
Altera's **CAD** tools

- Logic Design: **Quartus II**
  - Nios II Configuration and **Computer** integration: **Qsys**
  - **Qsys** generates the HDL description of the **Computer**
- Logic Simulation: **ModelSim-Altera**
- Software Development:
  Nios II Embedded Design Suite (EDS) – Eclipse
- DE2: Development & Education board
  - Cyclone II EP2C35F672C6 (33216 LE; 105 M4K)

	Nios II/e	Nios II/s	Nios II/f
#LE	600-700	1200-1400	1400-1800
#M4K	2	2 + cache	3 + cache

Nios II versions:
economy
standard
fast

Nios II HW/SW Design Flow



Nios II SBT Design Flow

- Creating a project
  - Nios II Application and BSP from Template
    - Target hardware information (.sopcinfo, CPU)
    - Project template
    - Board Support Package (BSP)
- Code editing (.c, .h)
- Building the Project (.elf)
- Configuring the FPGA
  - Quartus II programmer (.sof)
- Running/ Debugging the Project on Nios II
  - Run/Debug configurations

Board Support Package (BSP)

- Library and header files (e.g. system.h) specific to the target processor
- Automatically generated through .sopcinfo and CPU
- Hides memory map, available devices, device implementation and processor configuration
  - Device drivers
  - Hardware Abstraction Layer (HAL)
  - RTOS: Micrium MicroC/OS-II