面向二十一世纪的嵌入式系统设计技术

第三讲：
软硬件协同设计技术
Hardware-Software Codesign

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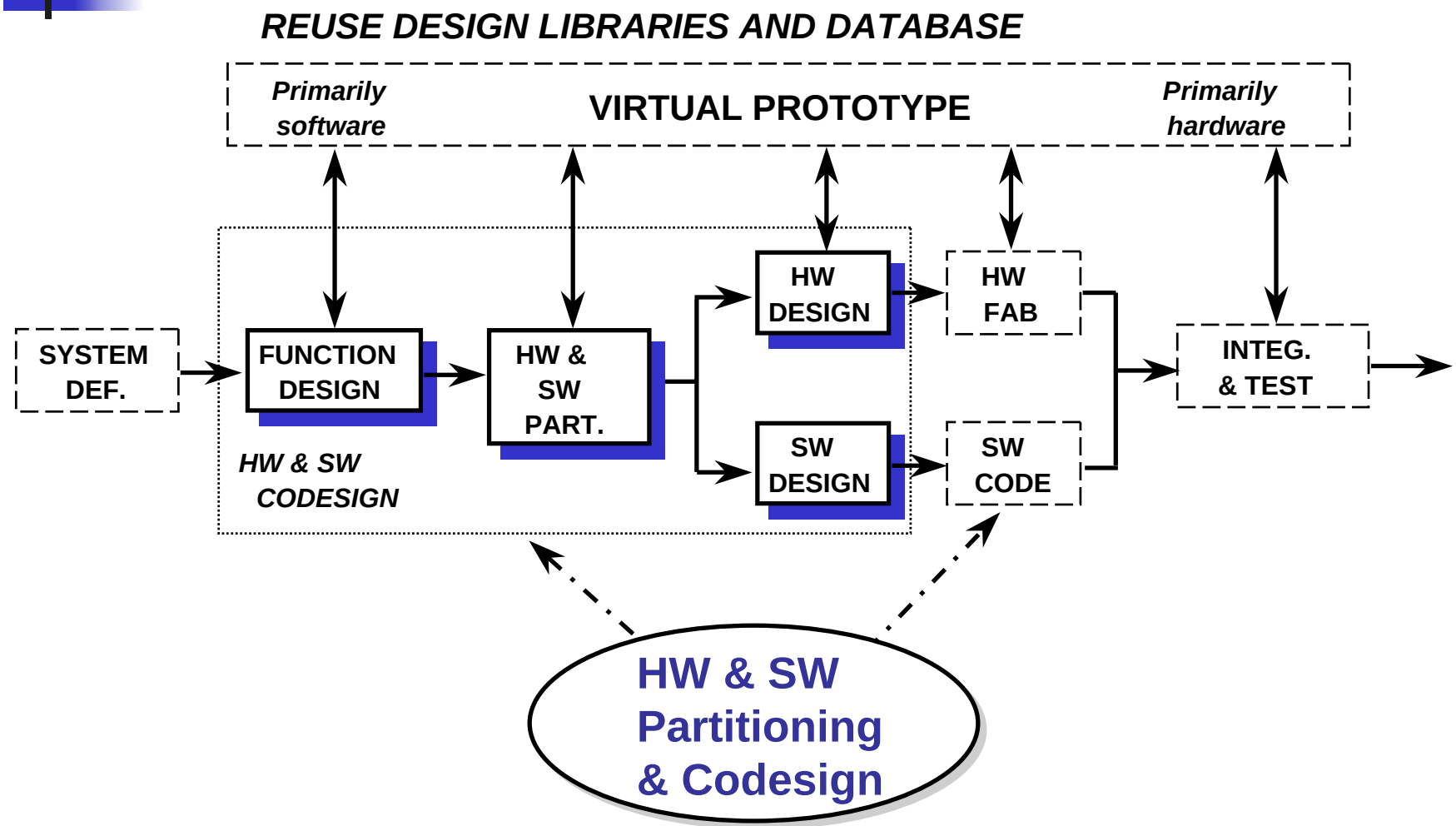
软硬件协同设计定义与主要概念

- 软硬件协同设计定义
  - The meeting of system-level objectives by exploiting the trade-offs between hardware and software in a system through their concurrent design
- 主要概念
  - Concurrent（并发）： hardware and software developed at the same time on parallel paths
  - Integrated（交互）： interaction between hardware and software developments to produce designs that meet performance criteria and functional specifications

嵌入式系统快速原型设计过程

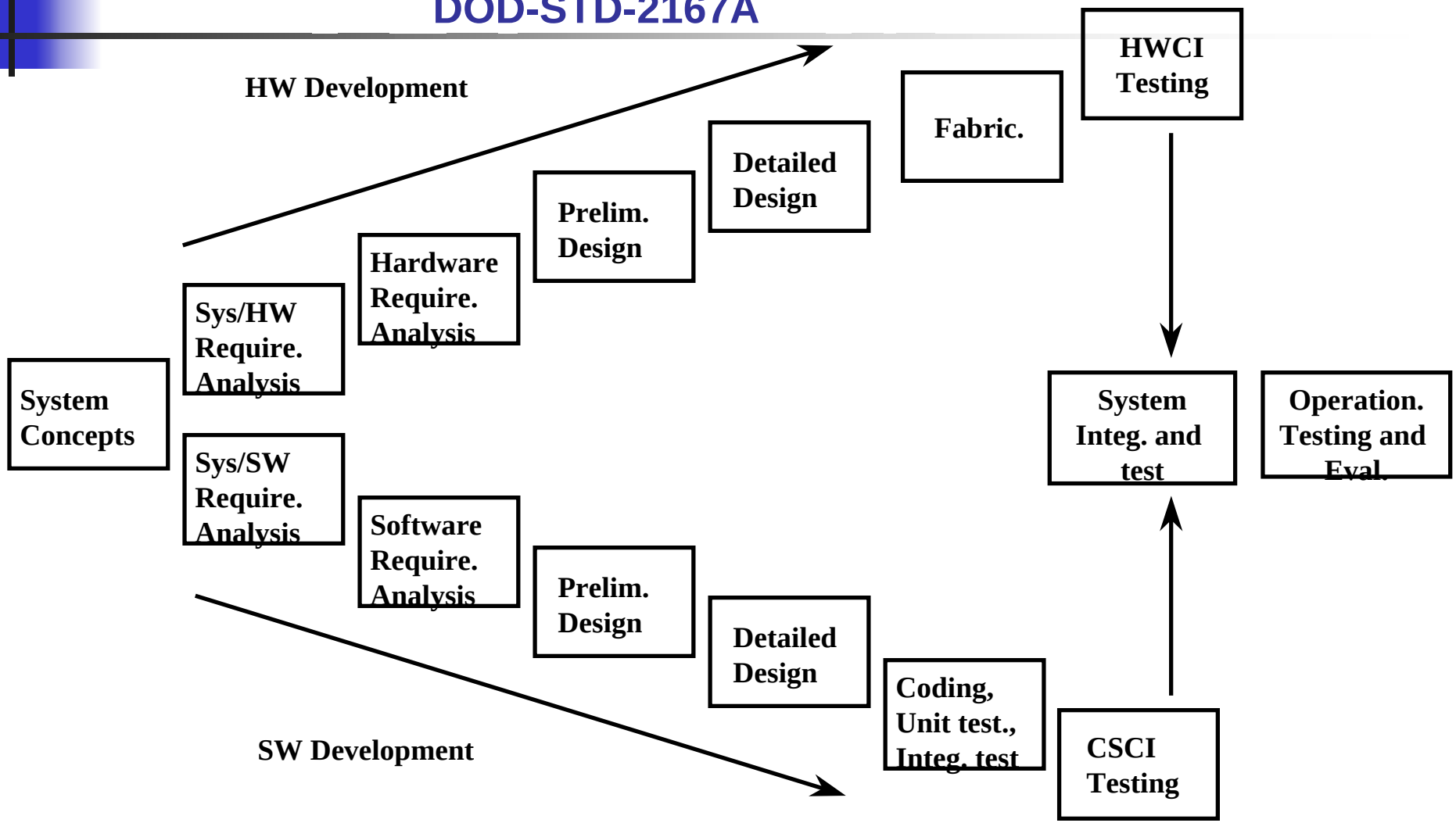


嵌入式系统快速原型开发的基本要素

- 系统定义（需求分析）
- 软硬件划分
  - 结构规划 – 处理器类型, 软硬件之间的接口类型, 等.
  - 划分目的 – 满足系统速度,延迟, 体积,成本等方面的要求.
  - 划分策略 - **high level partitioning by hand, automated partitioning using various techniques, etc.**
- 调度
  - **Operation scheduling in hardware**
  - **Instruction scheduling in compilers**
  - **Process scheduling in operating systems**
- 软硬件设计过程中的建模

传统的嵌入式系统设计模型

DOD-STD-2167A



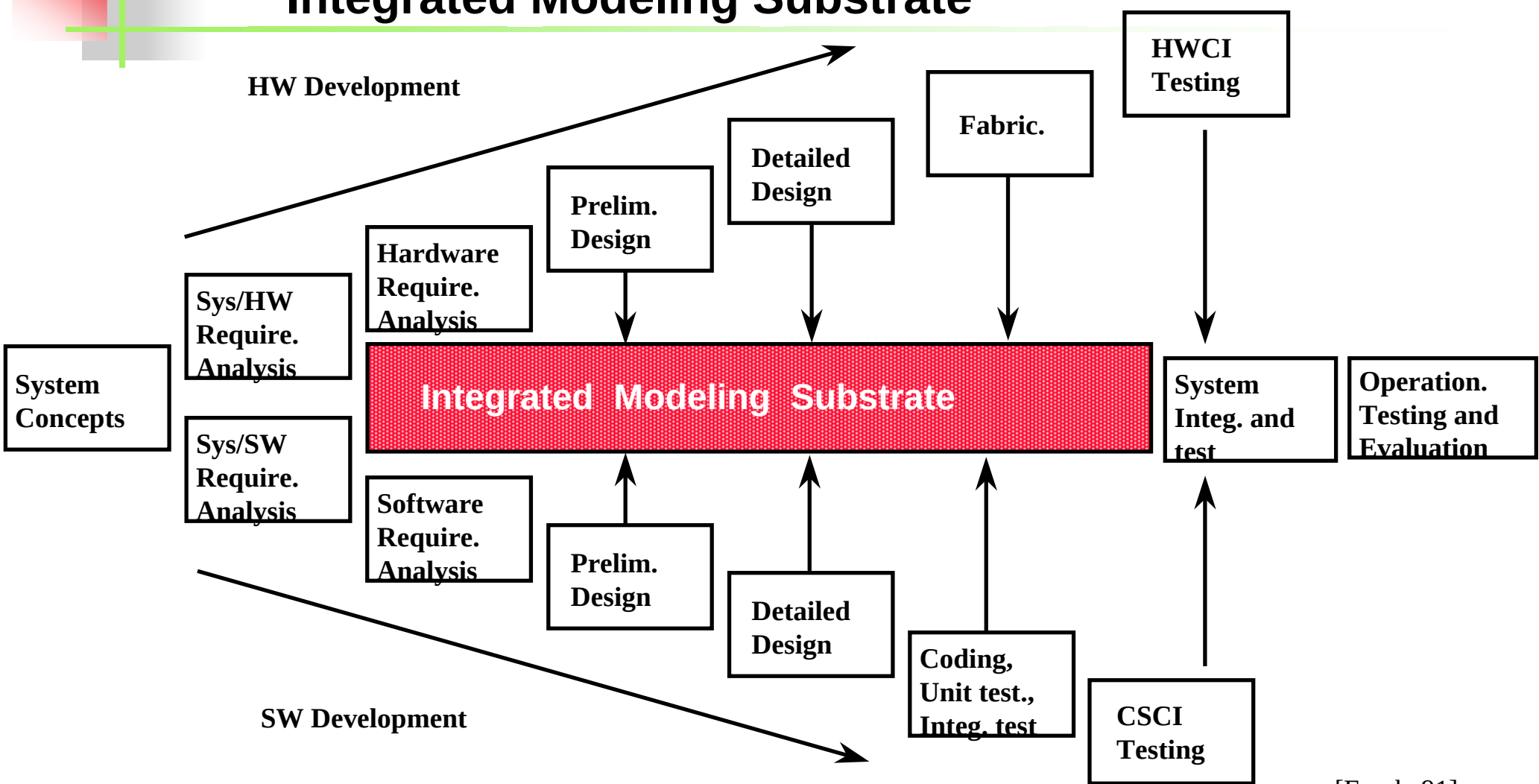
传统的嵌入式系统设计过程

- 传统软硬件设计过程的基本特征：
  - 系统在一开始就被划分为软件和硬件两大部分
  - 软件和硬件独立进行开发设计
  - **“Hardware first” approach often adopted**
- 隐含的一些问题：
  - 软硬件之间的交互受到很大限制
    - 软硬件之间的相互性能影响很难评估
  - 系统集成相对滞后，**NRE**较大
- 因此：
  - **Poor quality designs**（设计质量差）
  - **Costly modifications**（设计修改难）
  - **Schedule slippages**（研制周期不能有效保障）

传统设计过程中的尖锐矛盾

- 随着设计复杂程度的提高，软硬件设计中的一些错误将使开发过程付出昂贵的代价
- “Hardware first” approach often compounds software cost because software must compensate for hardware inadequacies

软硬件设计过程发展方向——协同设计



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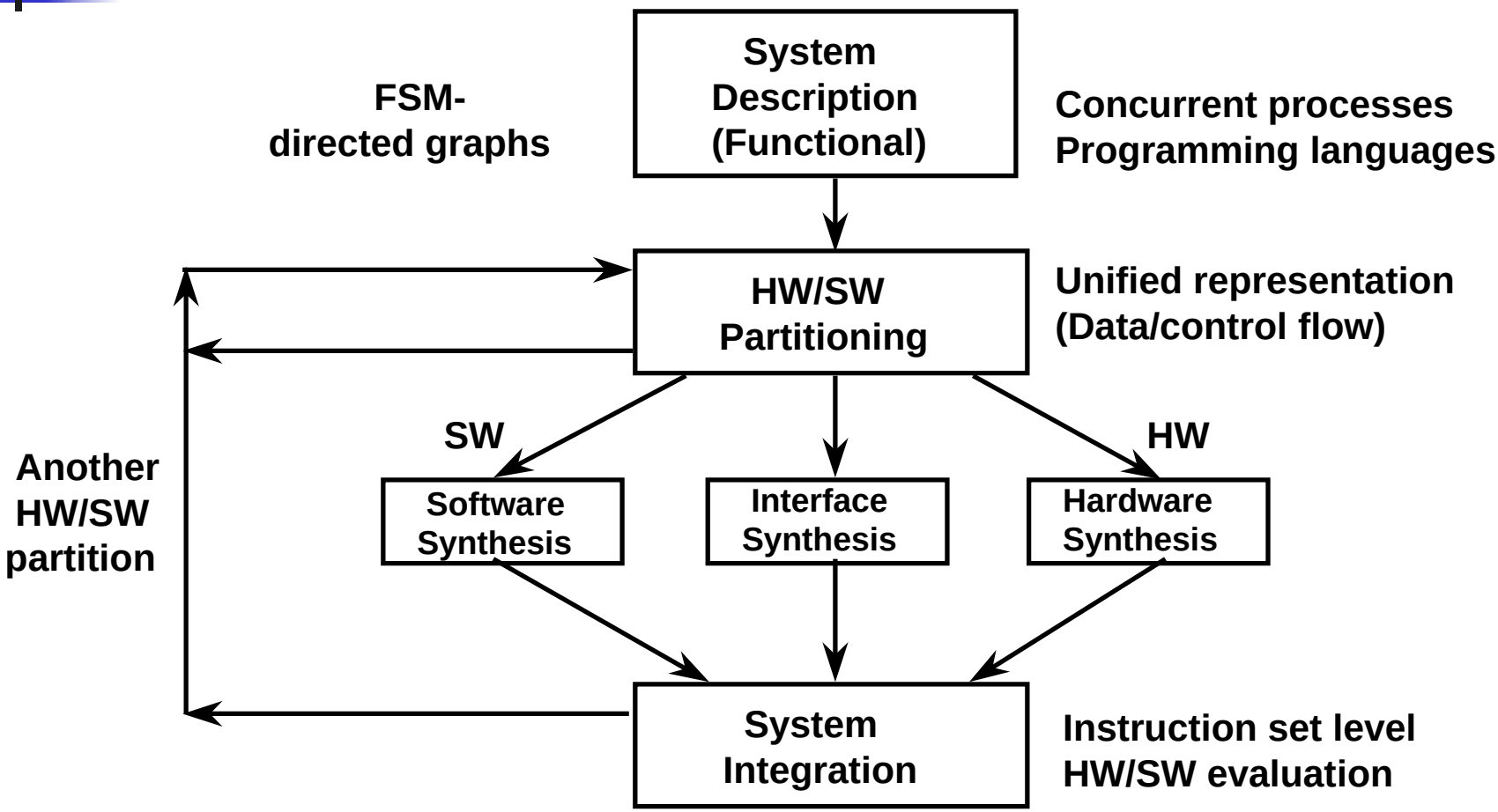
软硬件协同设计的基本需求

- 统一的软硬件描述方式
  - 软硬件支持统一的设计和分析工具（技术）
  - 允许在一个集成环境中仿真（评估）系统软硬件设计
  - 支持系统任务在软件和硬件设计之间的相互移植
- 交互式软硬件划分技术
  - 允许多个不通的软硬件划分设计进行仿真和比较
  - 辅助最优系统实现方式决策
  - Partitioning applied to modules to best meet design criteria (functionality and performance goals)

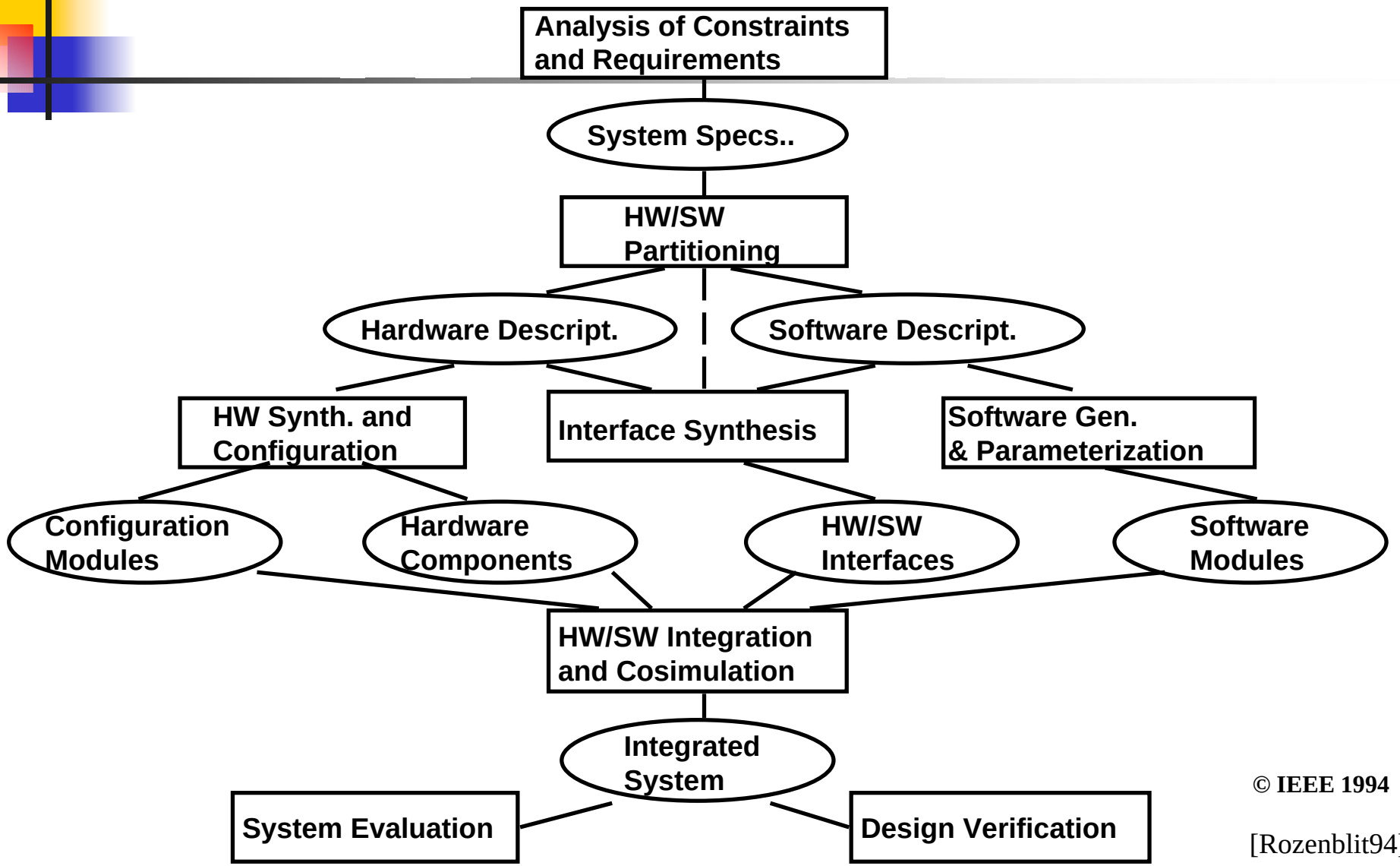
软硬件协同设计的基本需求 (cont.)

- 完整的软硬件模型基础
  - Supports evaluation at several stages of the design process
  - Supports step-wise development and integration of hardware and software
- 正确的验证方法
  - 确保系统设计达到目标要求

典型的软硬件协同设计过程



经典的软硬件协同设计方法



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软硬件协同设计的优势

- 在设计初始阶段就可进行软硬件交互设计和调整
  - Provides continual verification throughout the design cycle（贯穿整个设计周期）
  - Separate HW/SW development paths can lead to costly modifications and schedule slippages
- 关键技术（如可编程逻辑综合技术、器件接口和功能模型描述）的进步 使得软硬件交互设计变得简单起来

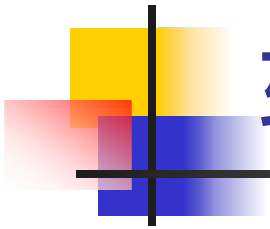
软硬件协同设计技术的现状

- 主要问题:
  - Lack of a standardized representation
  - Lack of good validation and evaluation methods
- 可能的解决方案:
  - Extend existing hardware/software languages to the use of heterogeneous paradigms
  - Extend formal verification techniques to the HW/SW domain
  - 基于FPGA的嵌入式系统设计——SOPC设计

软硬件协同设计基本步骤

HW-SW system involves

- **Specification**（设计描述）
- **modeling** （设计建模）
- design space exploration and partitioning
- synthesis and optimization（综合与优化）
- **Validation**（设计验证）
- **implementation** （设计实现）



软硬件协同设计基本步骤

Specification（设计描述）

- List the functions of a system that describe the behavior of an abstraction clearly with out ambiguity.

Modeling（设计建模）

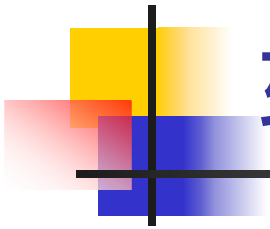
- Process of conceptualizing and refining the specifications, and producing a hardware and software model.

软硬件协同设计基本步骤

Validation:

Process of achieving a reasonable level of confidence（置信度） that the system will work as designed.

- Takes different flavors per application domain（根据应用领域而不同）: cosimulation for performance and correctness（性能与功能的协同仿真）

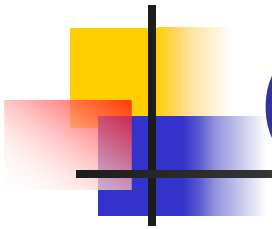


软硬件协同设计基本步骤

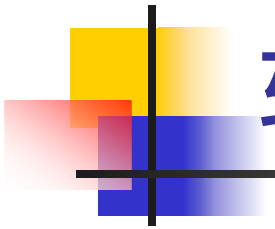
Implementation:

Physical realization of the hardware (through synthesis) and of executable software (through compilation).

协同设计中的软硬件划分与调度 (where and when)

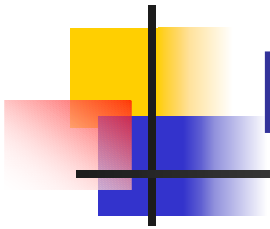


- A hardware/software *partitioning* represents a physical partition of system functionality into application-specific hardware and software.
- *Scheduling* is to assign an execution start time to each task in a set, where tasks are linked by some relations.



软硬件协同设计工具

- Mentor的Seamless
- Cadence的……



Bonus

- 讨论实例：嵌入式网络视频播放器
- （1）协同设计问题
- （2）硬件设计实现

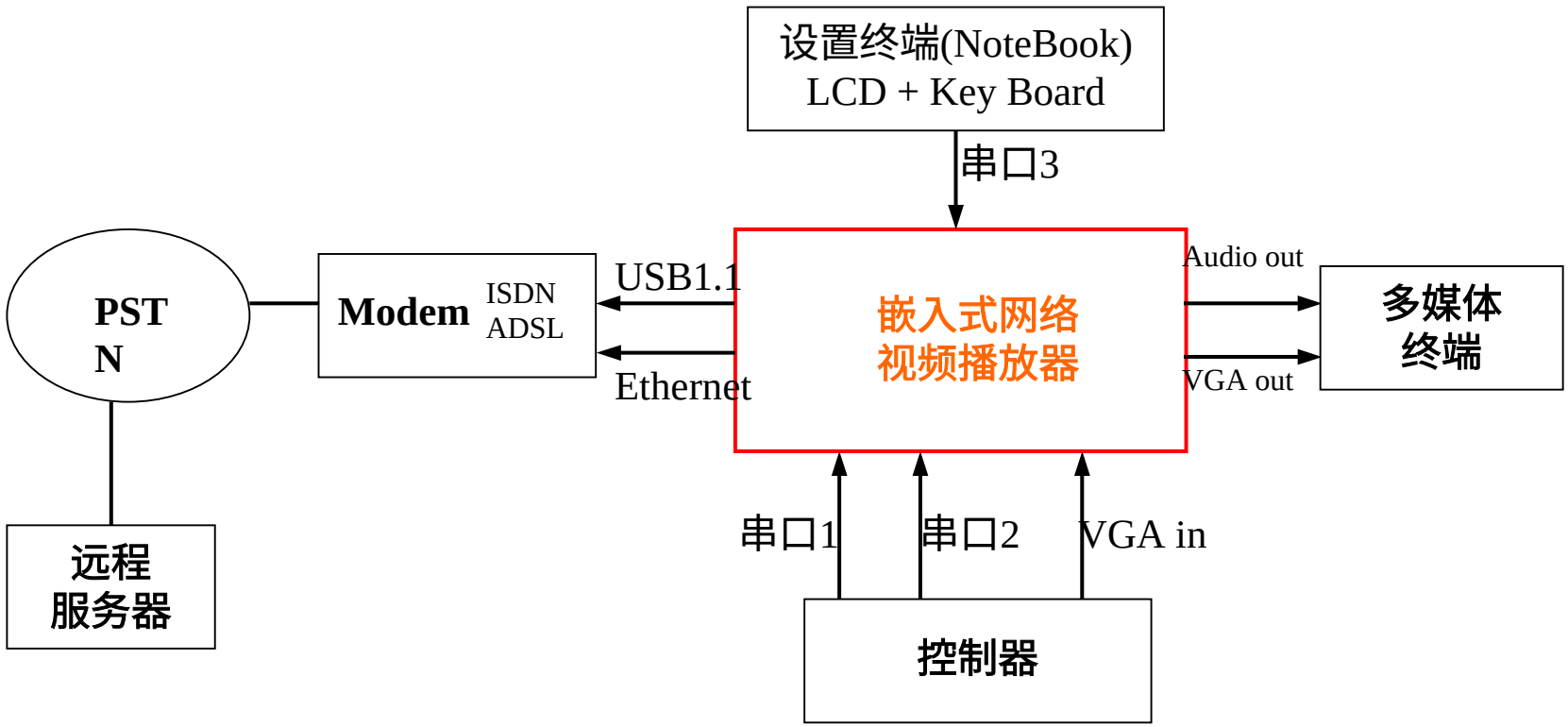


图1 嵌入式网络视频播放器外部接口示意图

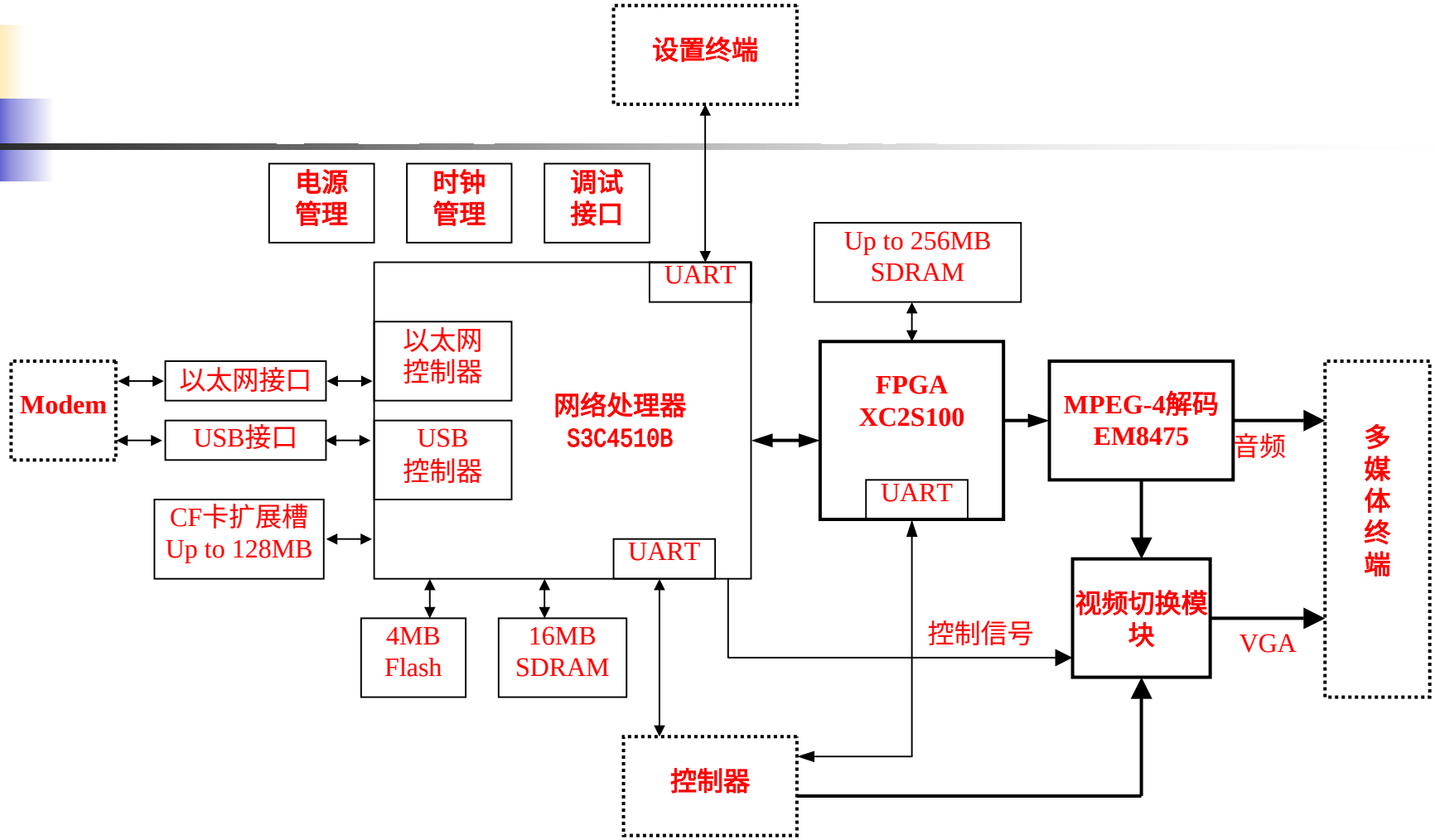


图2 嵌入式网络视频播放器硬件结构框图