A RF Hardware Abstraction-based Methodology for Front-End Design in Software-Defined Radios

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Outline

- Introduction
- Hardware abstraction
- Our HA-based design approach for RF/MW domain: an overview
- Our HA-based design approach for RF/MW domain: from theory to practice
- Summary

Introduction

1. Communications: a world in turmoil !
2. RF design: a delicate job!
3. Design: which methodology for the future?

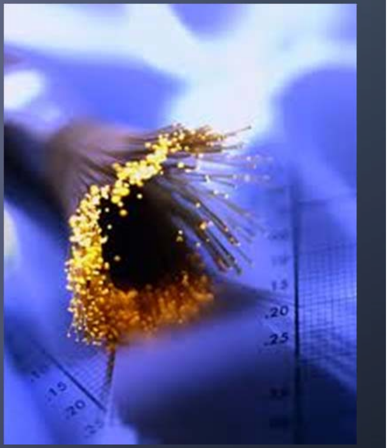
Communications: a world in turmoil !

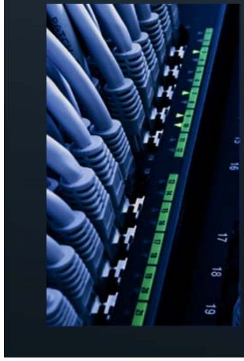
Communications: A continuously evolving sector

- Various standards
- Different Quality of Service (QoS) / Applications
- Network convergence

New paradigms:

- Software-Defined Radio (SDR)
- Cognitive Radio (CR)
- End-to-End Reconfigurability (E2R)
- …





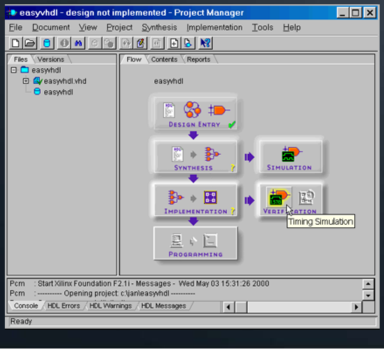
RF Design: a delicate job!

Design Methodology:

- Remarkable advances in digital design
  - Circuit / functionalities' Synthesis
  - Availability of automation tools / well elaborated design environments
  - Various design approaches, …
- Analog (such as RF / microwave) design stagnates!
  - Design is often manual (/ semi-manual) and handcrafted,
  - RF design is technology-dependent,
  - Designs are generally non adaptive et rarely non reusable, …

➔ Effective design needs are emerging:

- An agile, flexible and adaptive design approach is needed!



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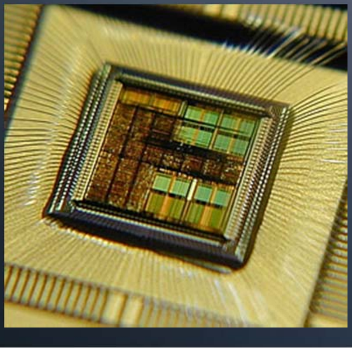
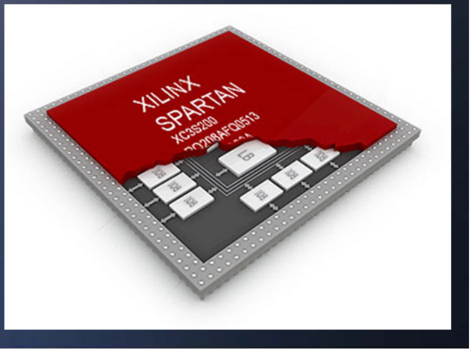
Pcm    : Start Xilinx Foundation F2.1i - Messages -  Wed May 03 15:31:26 2000
Pcm    : ---------- Opening project: c:\jan\easyvhdl ----------
```



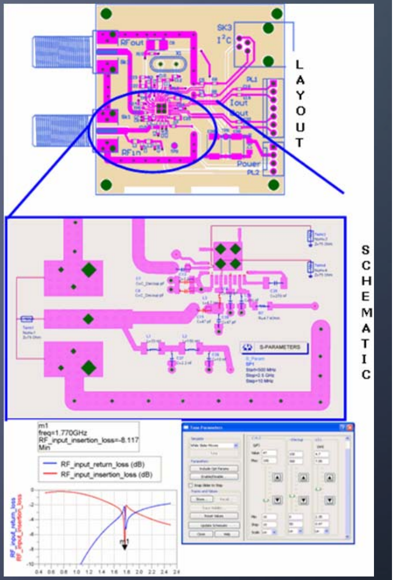


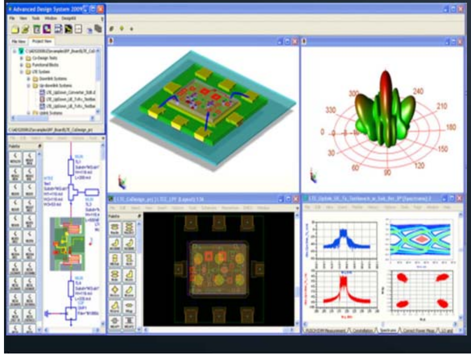
RF Design: which methodology for the future?

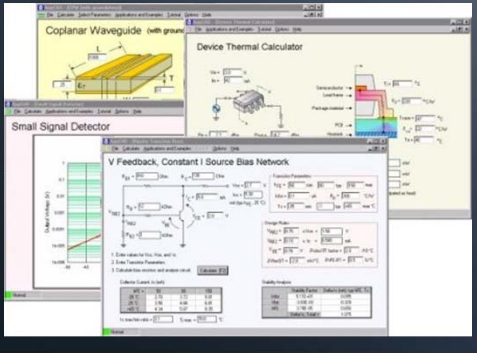
The new design methodology should be:

- Agile et adaptive (adaptable to the product line)
  - ↘ the design constraints (modeling / functional description)
- Automated (enhancing productivity)
  - Masks the technology details,
  - Includes a smart process able to automatically select the implementation
- Flexible
  - Allow previous designs reuse, and
  - Capture data all over the design cycle steps (validation 👍)

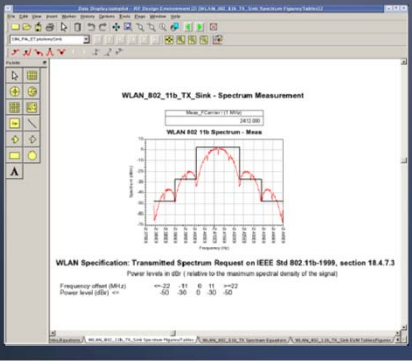
➔ A basic concept is needed: Hardware Abstraction







Coplanar Waveguide (with ground
Device Thermal Calculator
Small Signal Detector
V Feedback, Constant I Source Bias Network



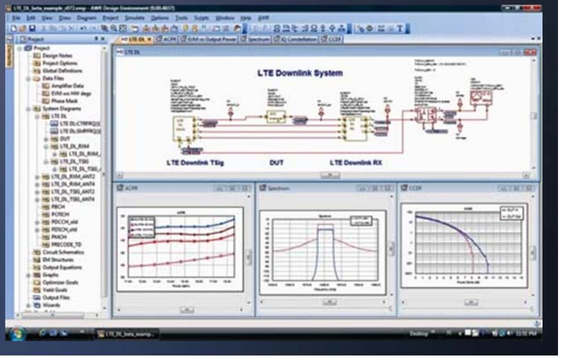
WLAN_802_11b_TX_Sink - Spectrum Measurement

WLAN 802 11b Spectrum - Meas

WLAN Specification: Transmitted Spectrum Request on IEEE Std 802.11b-1999, section 18.4.7.3

Power levels in dBr (relative to the maximum spectral density of the signal)

Frequency offset (MHz)	<=-22	-11	0	11	>=22
Power level (dBr) <=	-50	-30	0	-30	-50



Hardware Abstraction

1. Understand Hardware Abstraction
2. Advantages of Hardware Abstraction
3. Hardware Abstraction in Some Domains

Understand Hardware Abstraction

Hardware Abstraction (HA) is a paradigm that consists of **masking the physical details of the platform**, allowing to the designer **to focus on the effects** rather than the details resulting from the direct manipulation of the hardware platform. It is a a fashion to **describe the functionality** without the manipula- of the equipment intrinsic architecture.

1- Mask the physical details

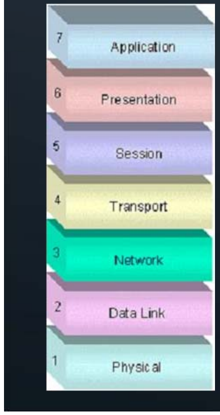
2- Focus on the system's response

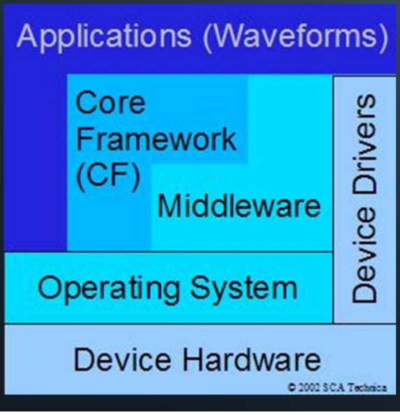
3- Elaborate a functional view

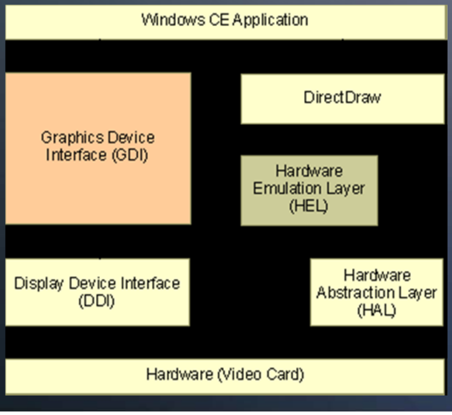
Advantages of the hardware Abstraction

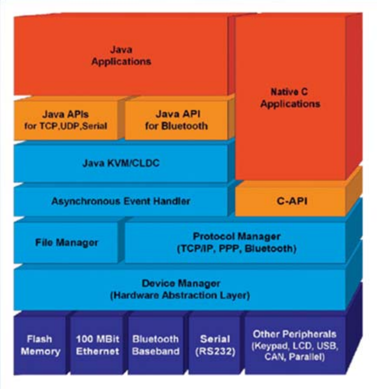
- Allows the encapsulation of parts / and details unnecessary for the design
- Enhances the uncoupling of the function from the physical platform
- Allows a multi-level / hierarchical description of the system
- May enhance the design automation and implementation
- Allows the development of standardized interfaces
- Reduces the system complexity (black box concept)
- Allows the clear definition of the specifications of each system component
- Enhances the integration of tiers technologies

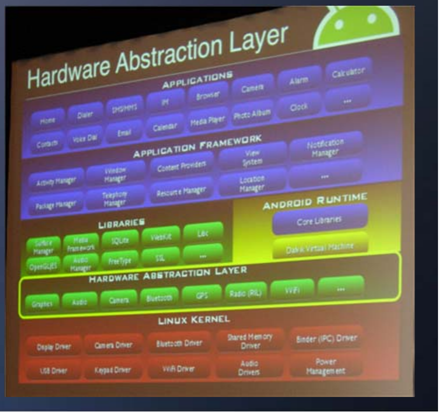
➔ Hardware Abstraction (HA): a useful concept in various domains






Windows CE Application
Graphics Device Interface (GDI)
DirectDraw
Hardware Emulation Layer (HEL)
Display Device Interface (DDI)
Hardware Abstraction Layer (HAL)
Hardware (Video Card)


Java Applications
Native C Applications
Java APIs for TCP,UDP,Serial
Java API for Bluetooth
Java KVM/CLDC
Asynchronous Event Handler
C-API
File Manager
Protocol Manager (TCP/IP, PPP, Bluetooth)
Device Manager (Hardware Abstraction Layer)
Flash Memory
100 MBit Ethernet
Bluetooth Baseband
Serial (RS232)
Other Peripherals (Keypad, LCD, USB, CAN, Parallel)

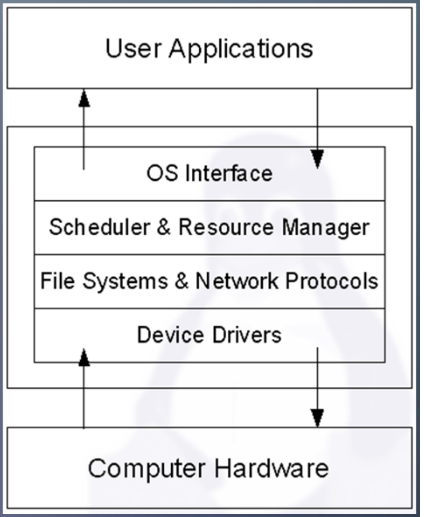


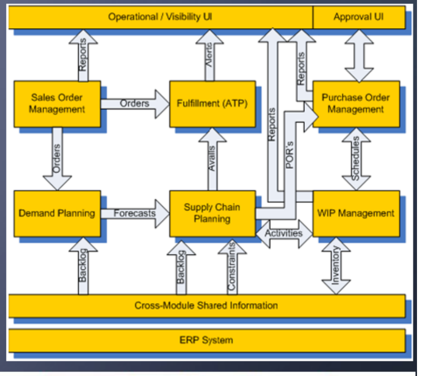
Hardware Abstraction in some domains (1)

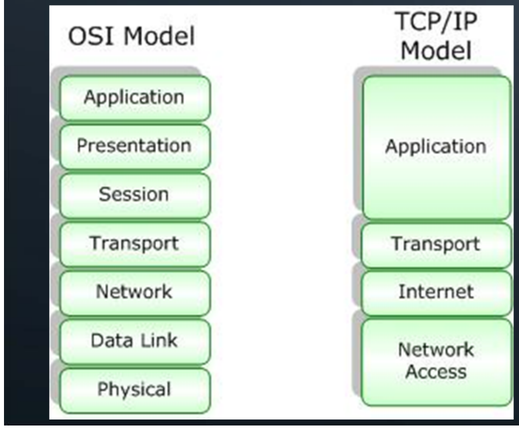
Computer Domain:

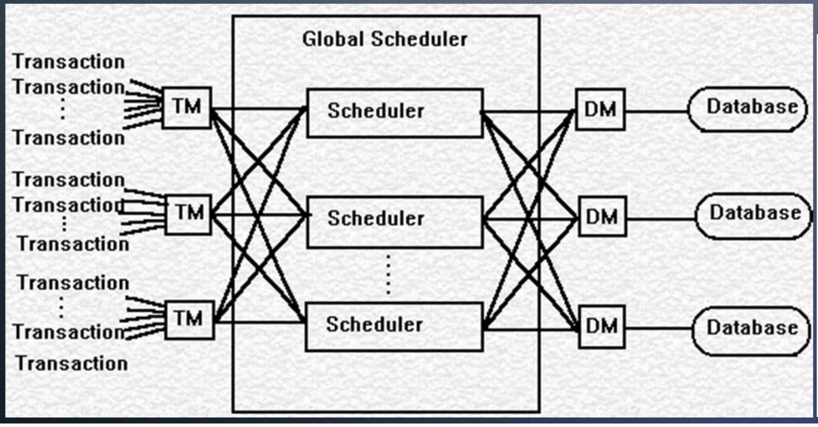
- Operating Systems
  - Drivers, middleware layers, …
- Databases
  - Data access logical levels, multi-level databases
- Networking
  - Communication layers and protocols (TCP/IP stack, OSI Model, …)
- Software Design
  - Modular design, Model-driven architecture (MDA), …

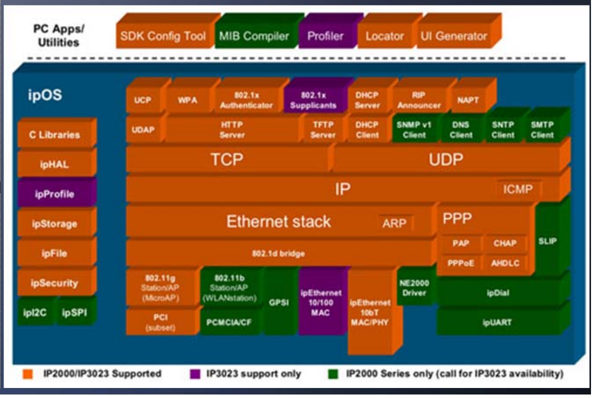
➔ HA has sustained remarkable progress in this domain


User Applications
OS Interface
Scheduler & Resource Manager
File Systems & Network Protocols
Device Drivers
Computer Hardware



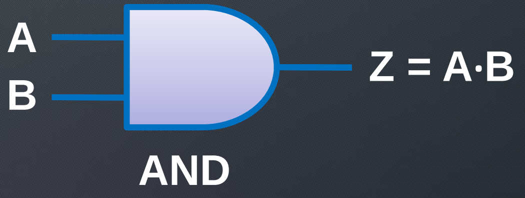






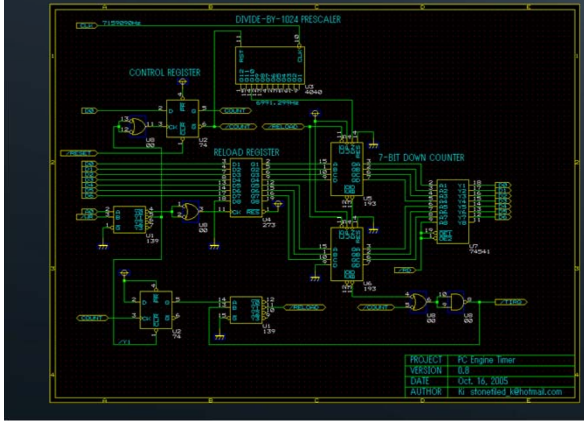
Hardware Abstraction in some domains (2)

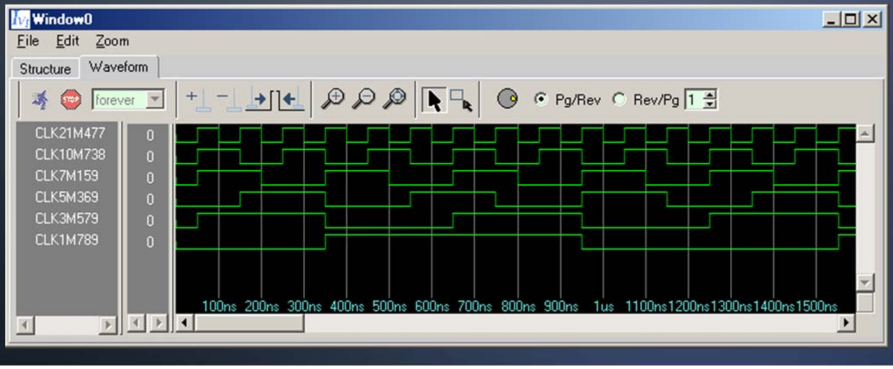
Microelectronics Domain:



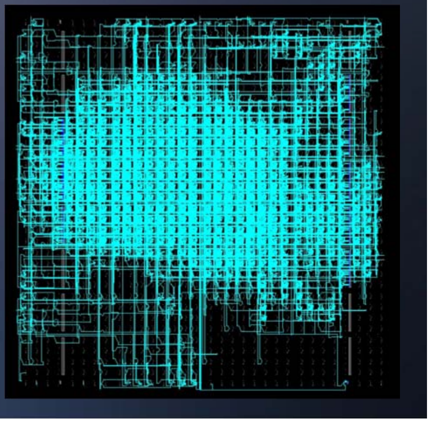
- VLSI Design
  - Cell concept (behavior defined by formal logical equations, inputs and outputs),
  - A cell captures the functionality defined by the model,
  - Hierarchical design of cells…
- Design of programmable circuits (FPGA, PLA, …)
  - High-level hardware description language (e.g. VHDL / Verilog) ensures the functional description of the system,
  - Then, the circuit is synthesized in an automated fashion.

➔ HA allowed the development of IP cores, SoCs, …





```
CLK21M477   0
CLK10M738   0
CLK7M159    0
CLK5M369    0
CLK3M579    0
CLK1M789    0
```



Hardware Abstraction in some domains (3)

Software-Defined Radio Domain:

- Software Communication Architecture (SCA – JTRS)
  - CORBA / IDL
- Government Reference Architecture
  - Modem Hardware Abstraction Layer (MHAL)
  - Open System Interface (OSI)

Other Initiatives

- Matlab Simulink
- Software-Based Communication Components (OMG)
- Open Wireless Architecture

Radio-frequency (RF) / Microwave (MW): (limited and incomplete initiatives)

- UML Profile for Software Radio – OMG

➔ Further efforts have to be deployed in order to enhance the contribution of HA in the design schemes of RF/MW systems

The Proposed HA Strategy in RF and Microwave Domain: An overview

1. Model-driven Engineering (MDE)
2. Our HA Strategy: Basic Concepts
3. The Proposed HA-based Design Approach
4. How to enhance the abstraction approach?
5. And if we combine these concepts?

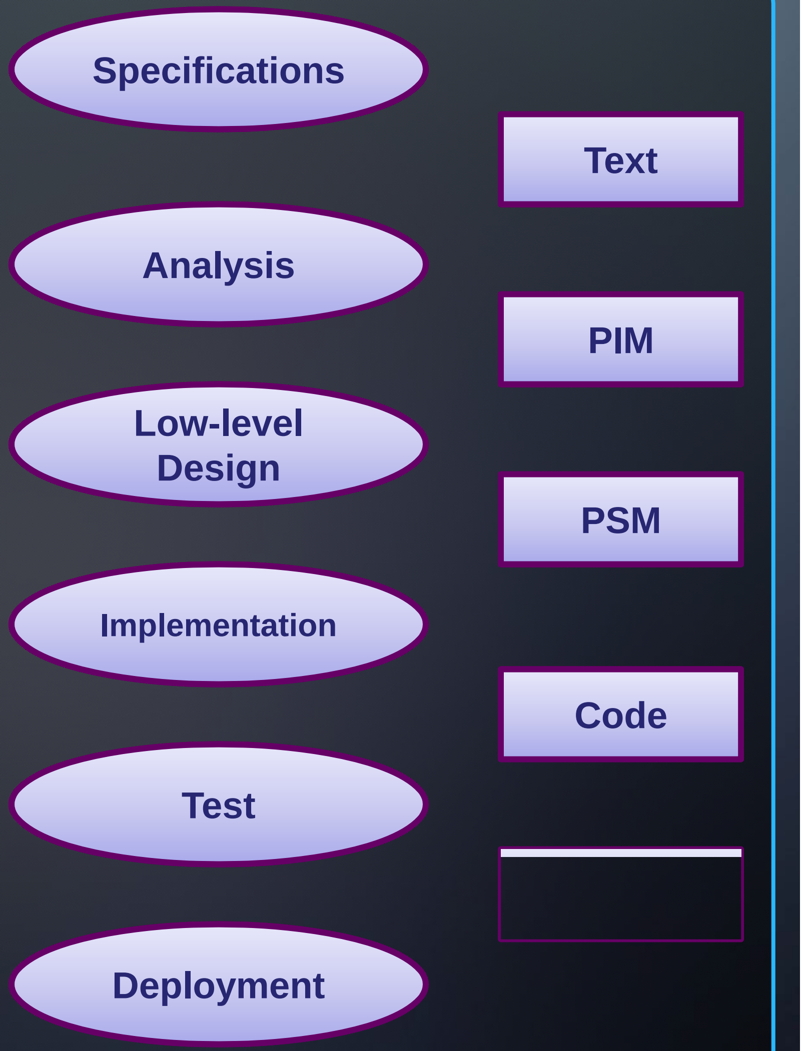
Model-driven Engineering

Model-driven Engineering (MDE): a software design approach:

- Platform-Independent Model (PIM)
- Platform-Specific Model (PSM)
- Model Transformations

Model-driven Architecture (MDA): an initiative of the OMG built around several standards

- UML (Unified Modeling Language)
- SysML (Systems Modeling Language)
- OCL (Object-Constraint Language)
- XMI (XML Metadata Interchange)
- …


Specifications
Text
Analysis
PIM
Low-level Design
PSM
Implementation
Code
Test
Deployment