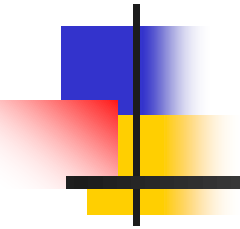
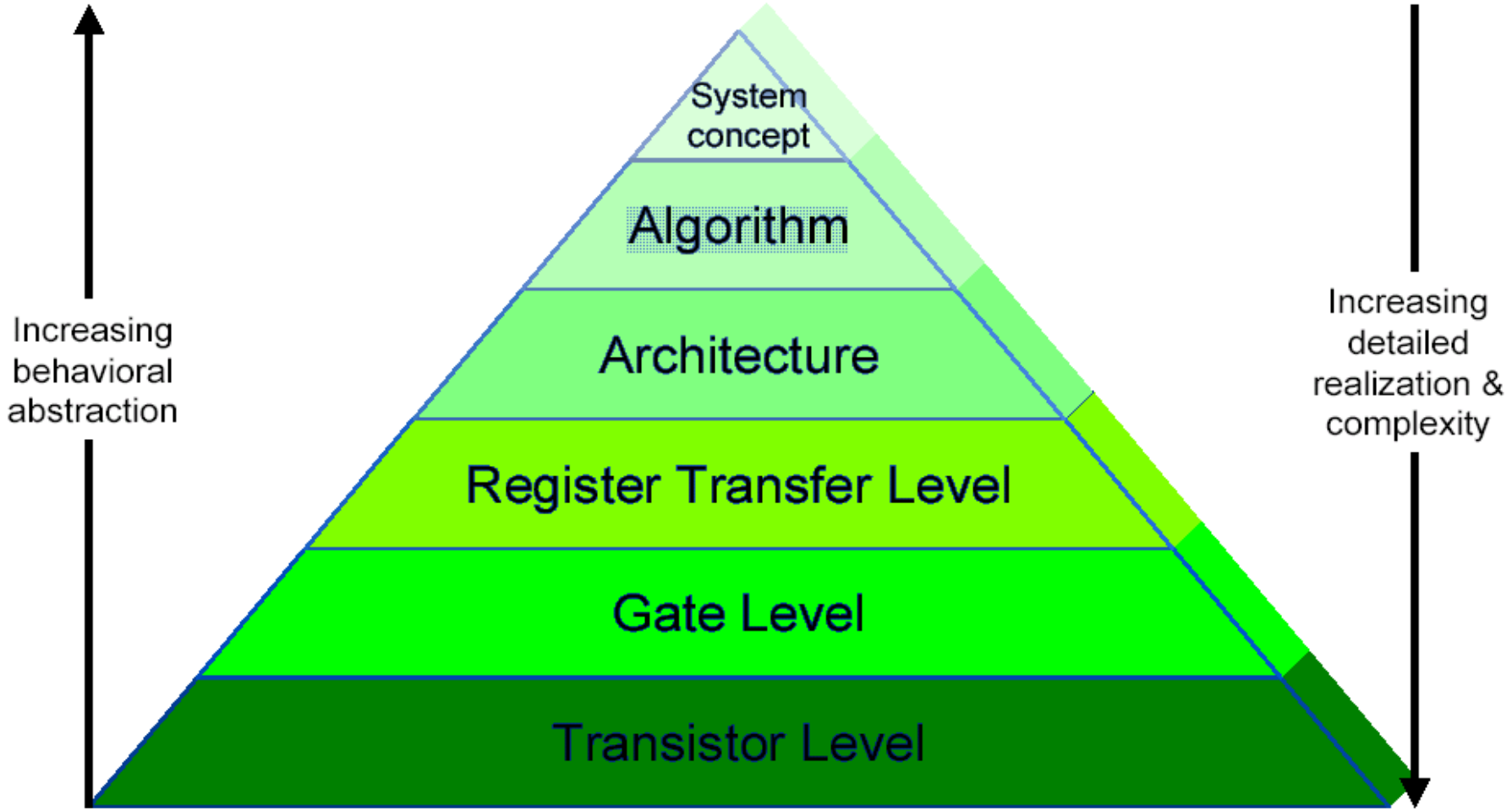
數位IC設計

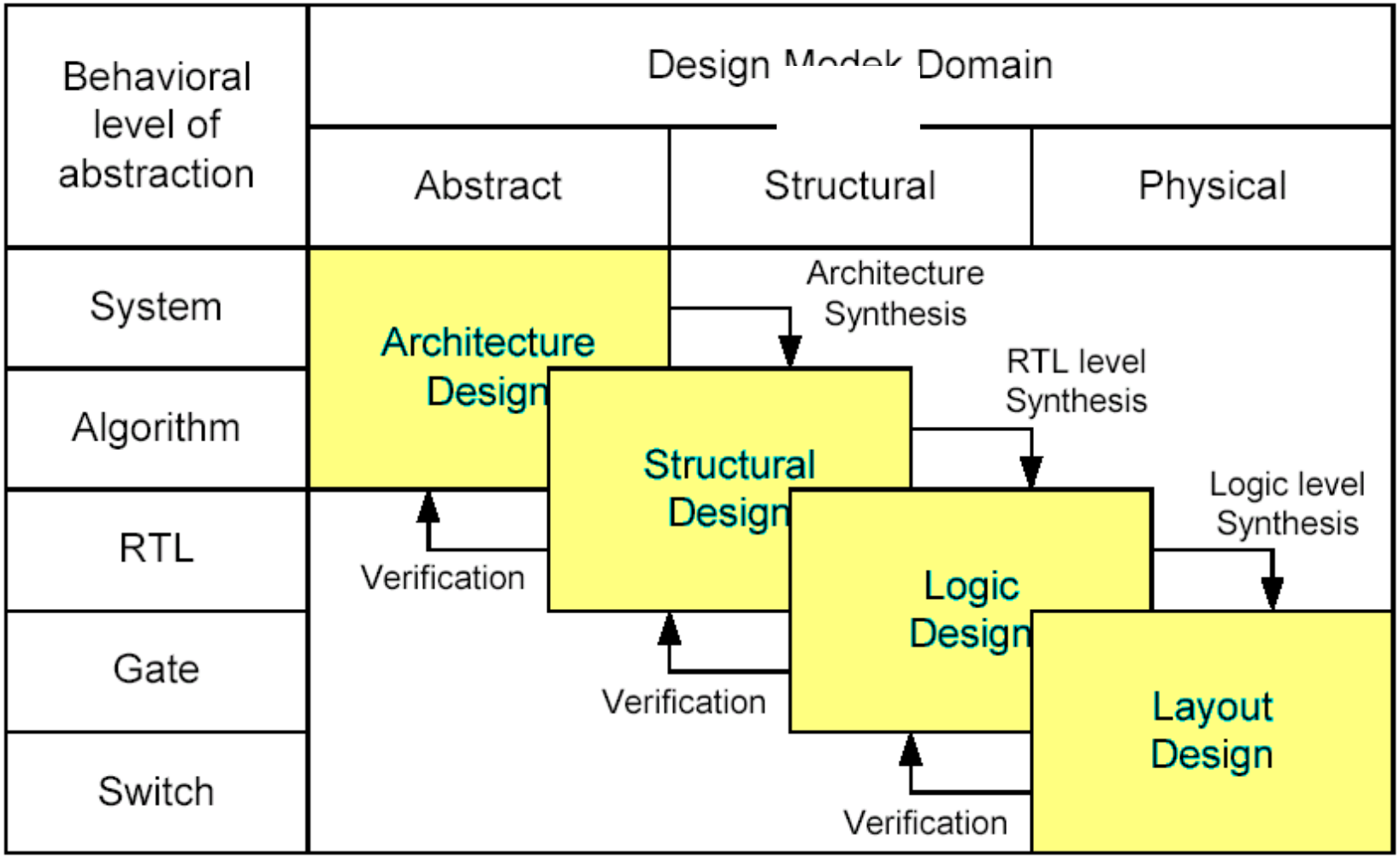


Semi Custom Design Flow

Top-Down Design Methodology



Design Domain



Register Transfer Level -- RTL

Cell-Based Design Flow (1/2)

Semi Custom Design

a. Product specification

b. Modeling with HDL

c. Synthesis (by using suitable standard cell)

d. Simulation and verification

e. Physical placement and layout

-- implemented with suitable tools

f. Tape-out (real chip) -- implemented by suitable Fab companies

g. Testing -- implemented by suitable tools and mechanisms

more flexible, shorter design cycle, suitable for smaller production

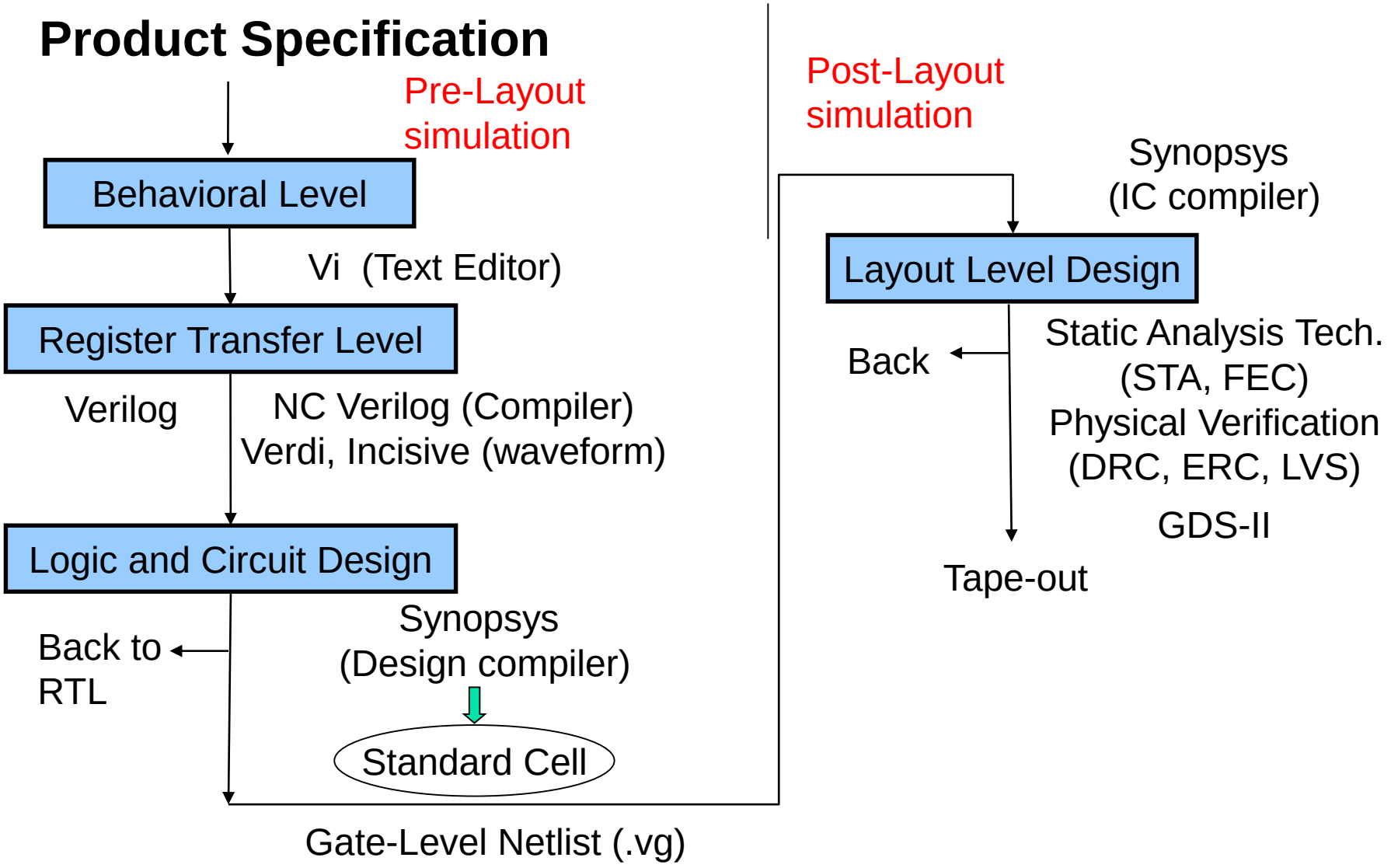
Two different solutions :

PLD → FPGA or CPLD — Xilinx, Altera

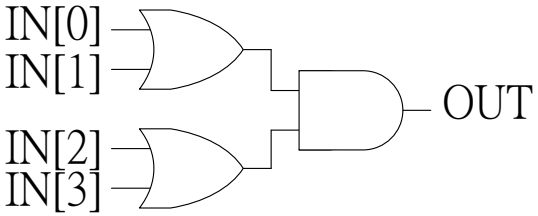
Standard cell → Real ASIC chip — Fab (TSMC, UMC, ..)

less flexible, long design cycle, larger-scale production to reduce price

Cell-Based Design Flow (2/2)



Hardware Description Language (1/3)

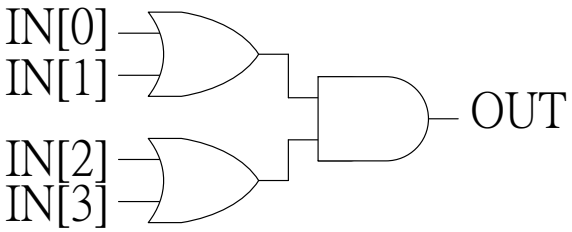


Structural description

```
1. module OR_AND_STRUCTURAL(IN,OUT);

2. input     [3:0]    IN;
3. output             OUT;
4. wire      [1:0]    TEMP;

5. or u1(TEMP[0], IN[0], IN[1]);
6. or u2(TEMP[1], IN[2], IN[3]);
7. and (OUT, TEMP[0], TEMP[1]);

8. endmodule
```

Register Transfer Level -- RTL

Hardware Description Language (2/3)



- Behavioral description

```
1. module OR_AND_BEHAVIORAL(IN, OUT);

2. input  [3:0]   IN;
3. output         OUT;
4. reg            OUT;

5. always @(IN)
6. begin
7.   OUT = (IN[0] | IN[1]) & (IN[2] | IN[3]);
8. end
9. endmodule
```

Register Transfer Level -- RTL

Hardware Description Language (3/3)

- 3 to 8 decoder

E	In[2]	In[1]	In[0]	Out
0	X	X	X	00000000
1	0	0	0	00000001
1	0	0	1	00000010
1	0	1	0	00000100
1	0	1	1	00001000
1	1	0	0	00010000
1	1	0	1	00100000
1	1	1	0	01000000
1	1	1	1	10000000

Behavioral description

```
1.  module Decoder_Behavioral (E, In, Out);
2.  Input      E;
3.  input    [2:0]        In;
4.  output   [7:0]        Out;
5.  reg      [7:0]        Out;
```

```
always @(E or In)
begin
  if(!E)
      Out = 8'h00;
  else
      begin
          case(In)
              3'b000: Out = 8'h01;
              3'b001: Out = 8'h02;
              3'b010: Out = 8'h04;
              3'b011: Out = 8'h08;
              3'b100: Out = 8'h10;
              3'b101: Out = 8'h20;
              3'b110: Out = 8'h40;
              default: Out = 8'h80;
          endcase
      end
end
endmodule
```

Design Flow Using ModelSim

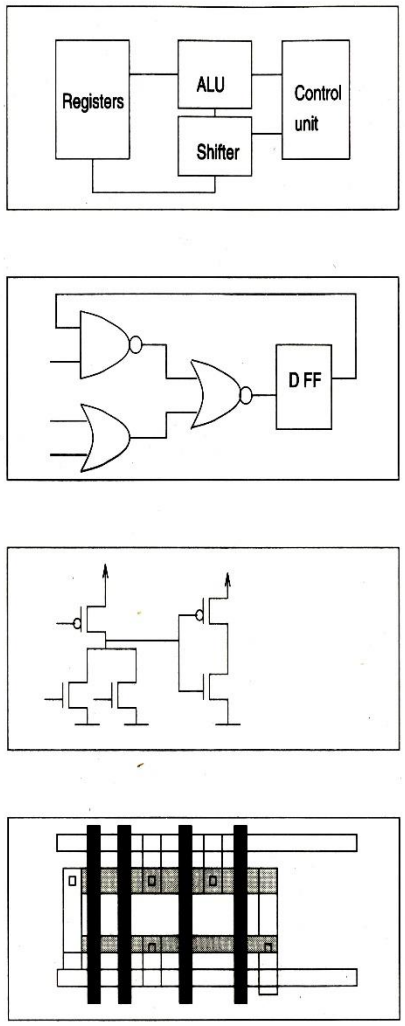
Functional design

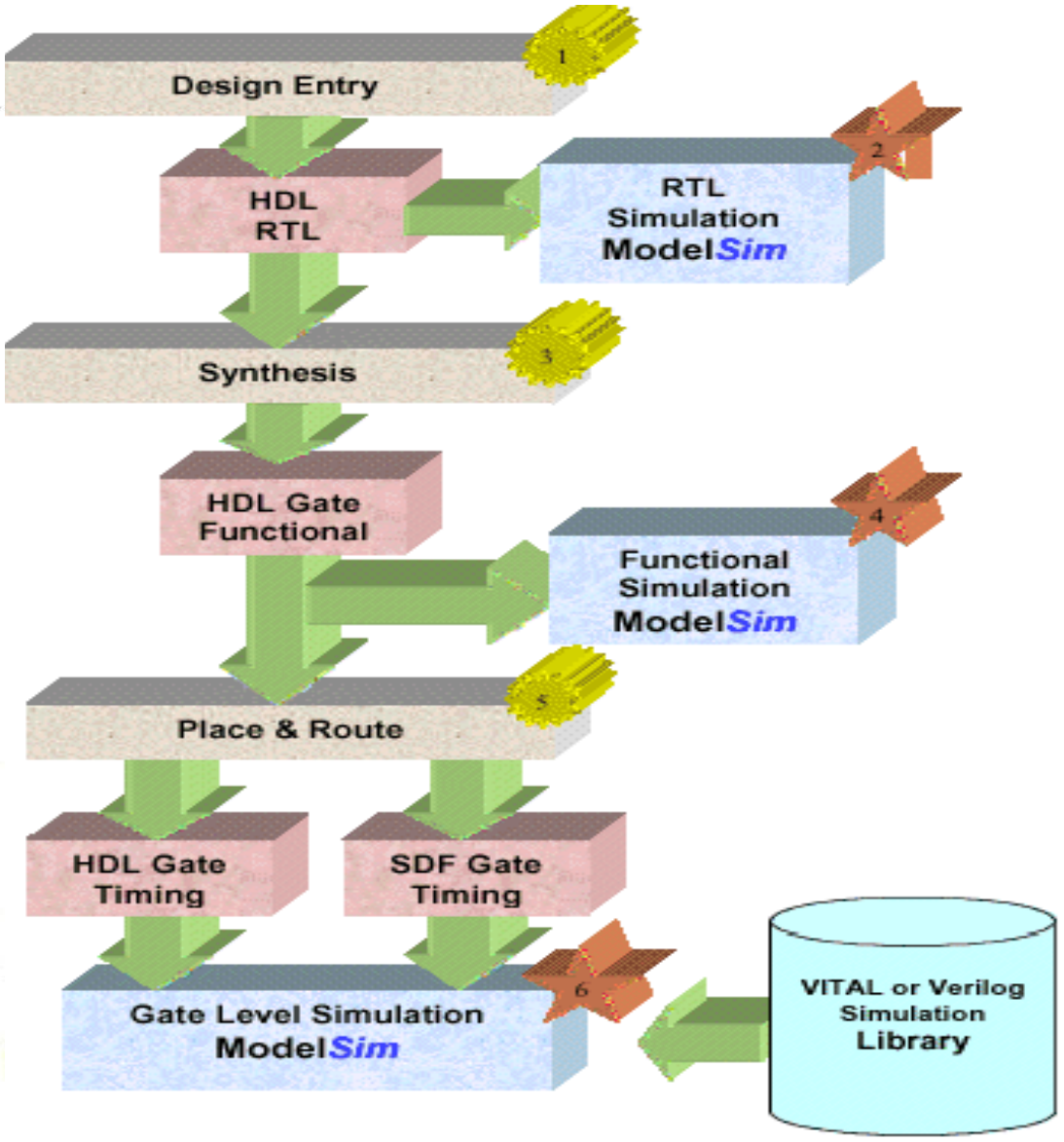
HDL

Logic design

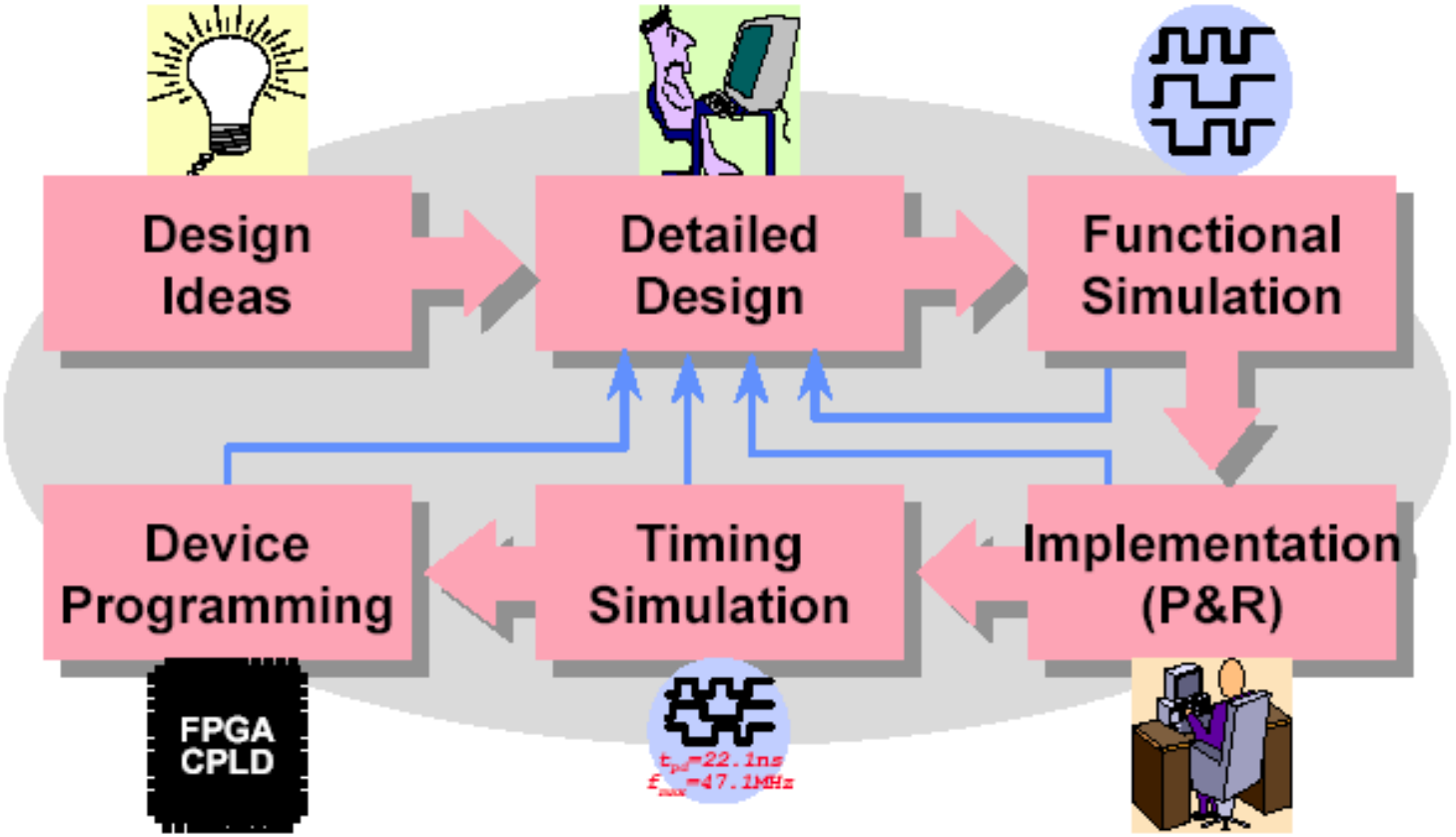
Circuit design

Physical design





FPGA/CPLD Design Flow



Note: What is the difference between standard-cell design and FPGA/CPLD design ? 何者相同?何者不同? Flow, tool, cost, time, …

Design Ideas

- Main design consideration
  - Design feasibility?
  - Design spec.?
  - Cost?
  - FPGA or standard-cell ASIC?
  - FPGA vendor?
  - Device family?
  - Development time?

Programmable Logic Device

- PLD (Programmable Logic Device)依其架構及密度可分成三類:
  - SPLD（Simple Programmable Logic Device)
  - CPLD（Complex Programmable Logic Device)
  - FPGA (Field Programmable Gate Array)

SPLD

- SPLD（Simple Programmable Logic Device):
  - 邏輯閘約在數百閘左右
  - IC腳位在28pin以內
  - Bipolar process，只能作單次燒錄，資料無法抹除
  - GAL process，多次燒錄，可縮短設計時程

CPLD

- CPLD（Complex Programmable Logic Device)
  - 邏輯閘在800～5000之間
  - IC腳位高於28pin
  - 44pin以上IC的封裝以PLCC為主
  - CMOS設計技術
  - 多次燒錄抹除

FPGA

- FPGA:(Field Programmable Gate Array)
  - 使用和CPLD不同的架構設計方式
  - 以暫存器居多，其密度在5K以上
  - 腳位數多
  - Routing複雜，非固定式，延遲時間較長

- FPGA的架構
  - SRAM Base -可重覆燒錄但需外部電源維持資料
  - Anti-fuse -只有一次燒錄，提供較佳保密性

Configurable VLSI

- Advantages
  - Short time-to-market
  - Low tooling costs
  - Low penalty on design changes
  - Low testing cost
  - Product advantage (new process, .35, .25, .18, .13)
- Disadvantages
  - capacity
  - cost
  - speed

Altera Devices

- Products
  - MAX3000/5000/7000/9000 devices family
  - FELX6K/8K/10K devices family
  - APEX20K devices family
  - ACEX1K …..
- Workbench
  - MaxplusII & QuartusII
  - FPGA express, Leonard Spectrum

Xilinx Devices

- Products
  - XC9500/4000,CoolRunner(XPLA3) ,Spartan,Vertex …..
- Workbench
  - Foundation & ISE
- **Virtex Architecture**

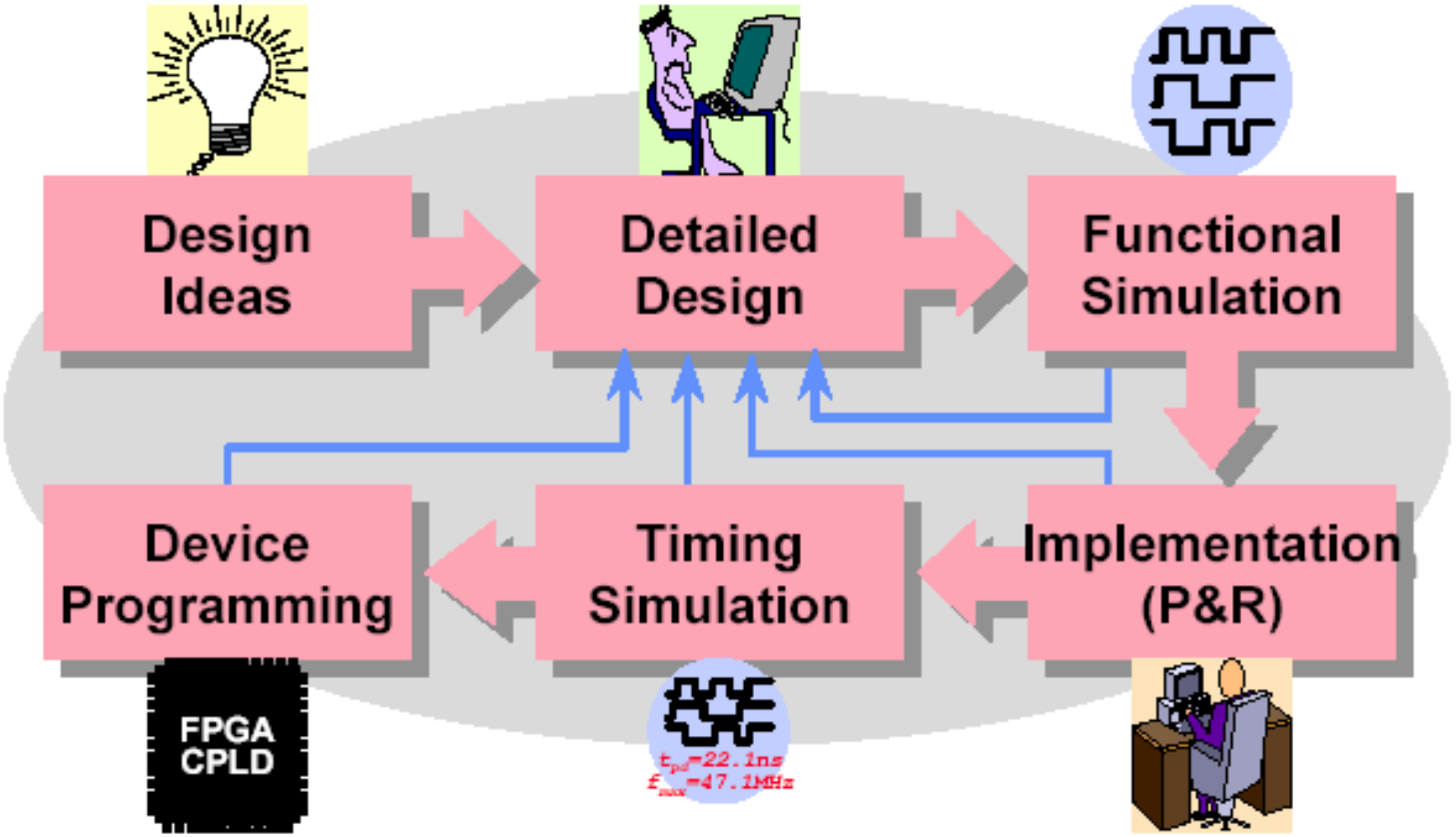
Gate-array like architecture, Configurable logic blocks

I/O blocks 16 signal standards, Block RAM

On-chip memory for higher performance

Clocks & delay-locked loop, Interconnect resources

FPGA/CPLD Design Flow



Note: What is the main difference between cell-based design and FPGA/CPLD design ? 何者相同?何者不同? Flow, tool, cost, time, …

Detailed Design (1/2)

- Choose the suitable architecture
  - Algorithm, spec. to architecture mapping
  - Parallel, pipeline, serial, DA, …..
- Choose the design entry method
  - Schematic
    - Gate level design
    - Intuitive & easy to debug
  - HDL (Hardware Description Language), Verilog & VHDL
    - Descriptive & portable
    - Easy to modify
    - RTL (register transfer level) coding
  - Mixed HDL & schematic

Detailed Design (2/2)

- Manage the design hierarchy
  - Design partitioning
    - Chip partitioning
    - Logic partitioning
  - Use vendor-supplied libraries or parameterized libraries to reduce design time
  - Create & manage user-created libraries (circuits)

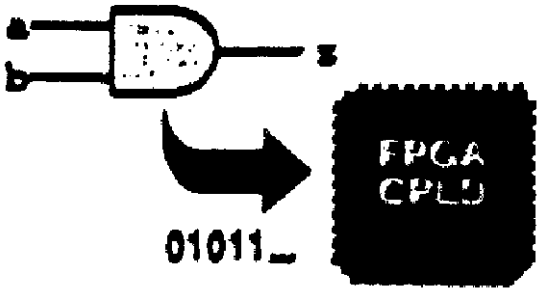
Functional Simulation

- Preparation for simulation
  - Generate simulation patterns
    - Waveform entry
    - HDL testbench
  - Generate simulation netlist

- Functional simulation
  - To verify the functionality of your design only
- Simulation results
  - Waveform display
  - Text output
- Challenge
  - Sufficient & efficient test patterns

Design Implementation (1/2)

- Implementation flow
  - Natlist merging, flattening, data base building
  - Design rule checking
  - Logic optimization
  - Block mapping & placement
  - Net routing
  - Configuration bitstream generation



Design Implementation (2/2)

- Implementation results
  - Design error or warnings
  - Device utilization
  - Timing reports
- Challenge
  - How to reach high performance & high utilization implementation?

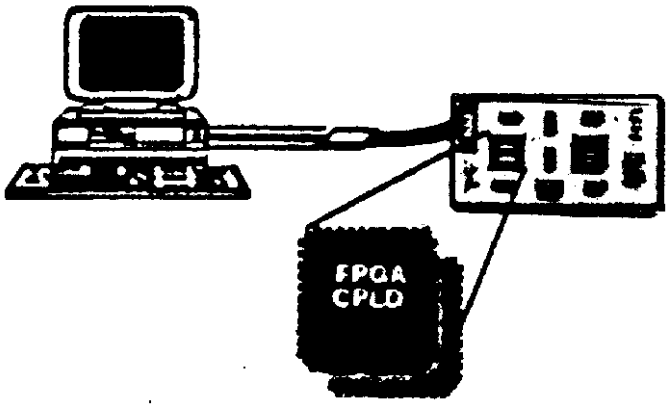
Timing Analysis & Simulation

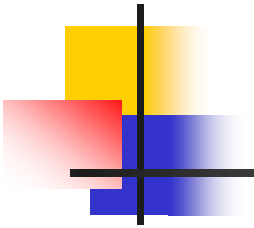
- Timing analysis
  - Timing analysis is static, i.e., independent of input & output patterns
  - To examine the timing constraints
  - To show the detailed timing paths
  - Can find the critical path

- Timing simulation
  - To verify both the functionality & timing of the design

Device Programming (1/2)

- Choose the appropriate configuration scheme
  - SRAM-basedFPGA/CPLD devices
    - Downloading the bitstream via a download cable
    - Programming onto a non-volatile memory device & attaching it on the circuit board
  - OTP, EPROM, EEPROM or Flash-based FPGA/CPLD devices
    - Using hardware programmer
    - ISP



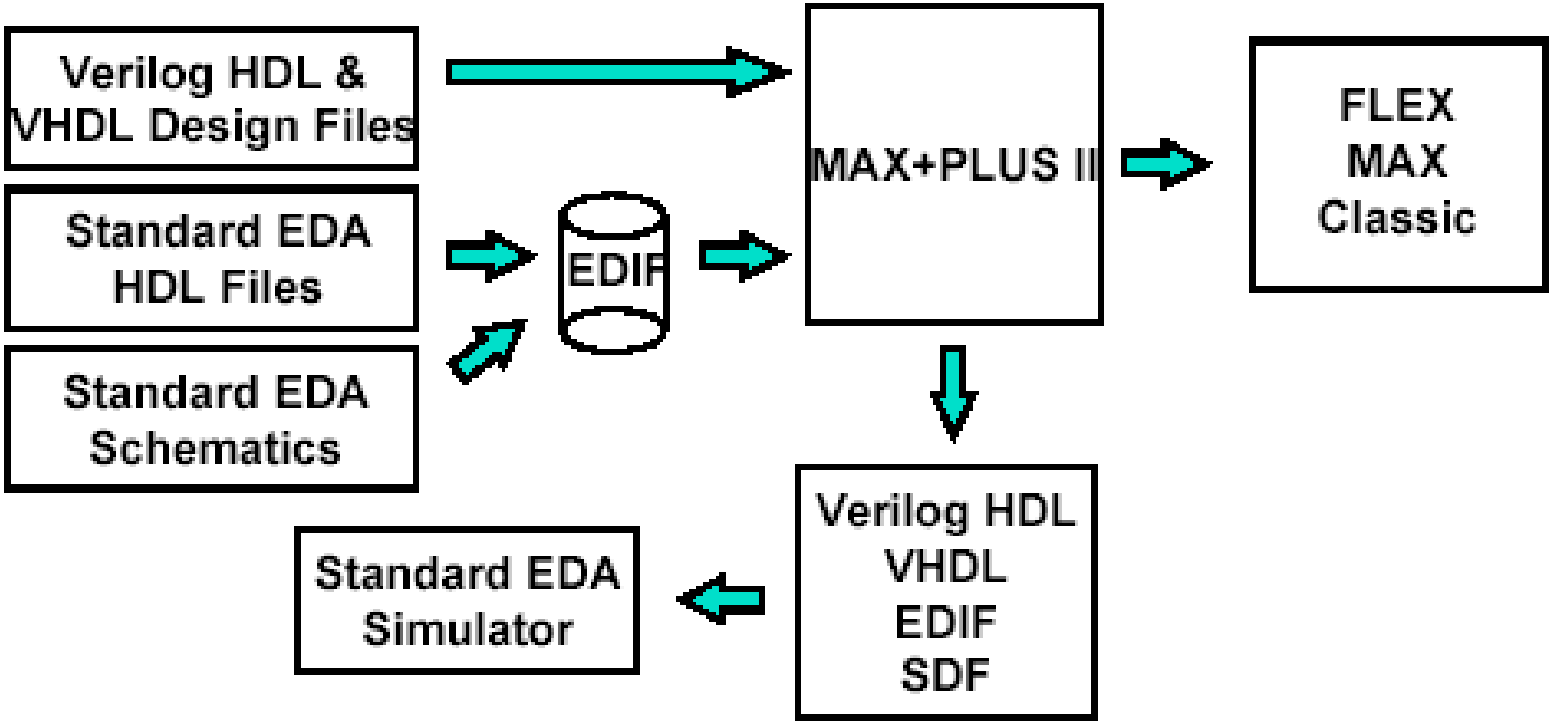


Device Programming (2/2)

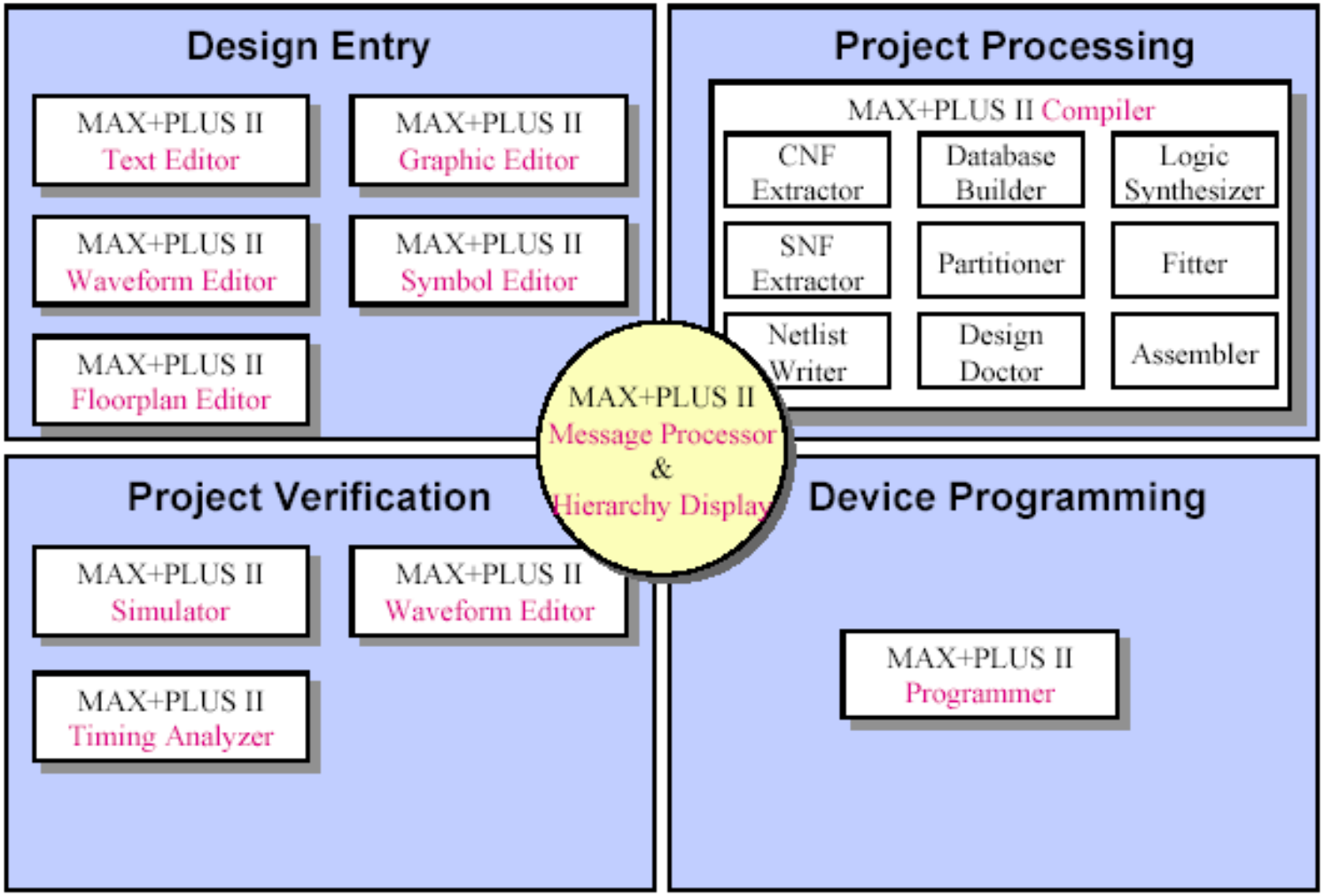
- Finish the board design
- Program the device
- Challenge
  - Board design
  - System considerations

Altera Design Flow (Max-Plus II)

- Operate seamlessly with other EDA tools



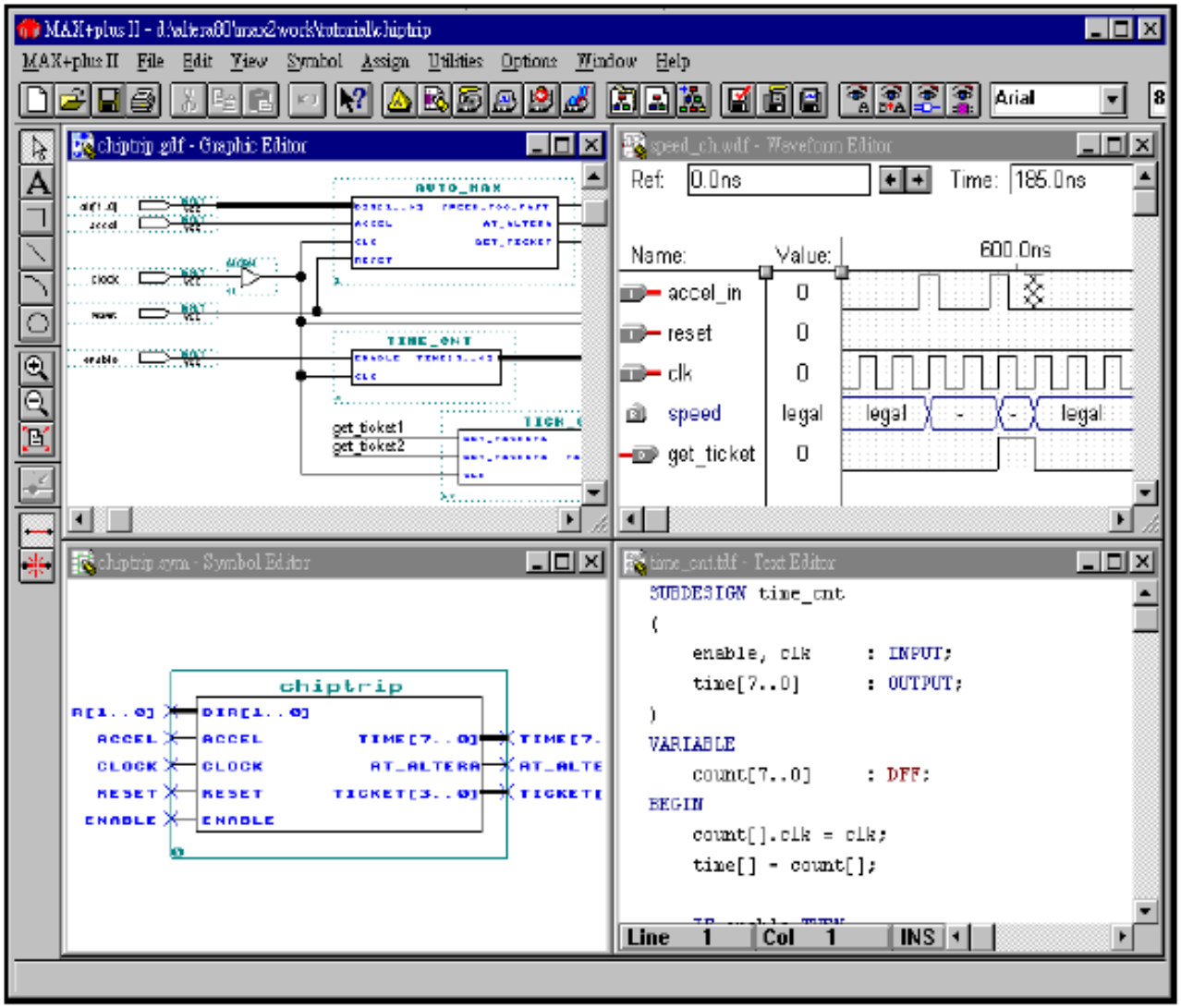
MAX+PLUS II Altera Fully-Integrated Development System



Design Entry (1/2)

- MAX+PLUS II design entry tools
  - Graphic Editor & Symbol Editor
    - For schematic designs
  - Text Editor
    - For AHDL, Verilog HDL, and VHDL designs
  - Waveform Editor
  - Floorplan Editor
  - Hierarchy Display

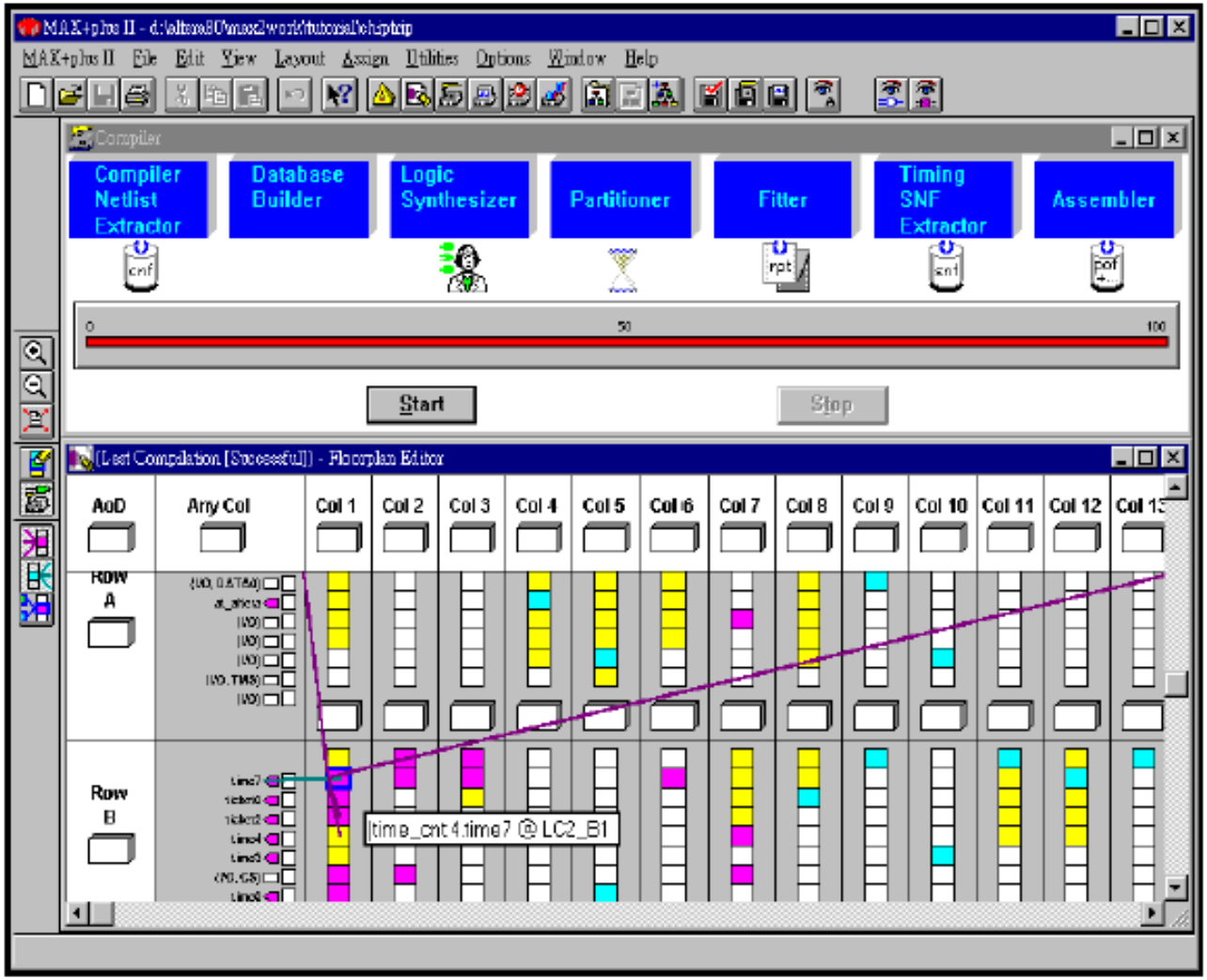
Design Entry (2/2)



Project Processing (1/2)

- MAX+PLUS II tools for project processing (implementation)
  - MAX+PLUS II Compiler
  - MAX+PLUS II Floorplan Editor
    - For pin, logic cell location assignments
  - Message Processor
    - For error detection & location

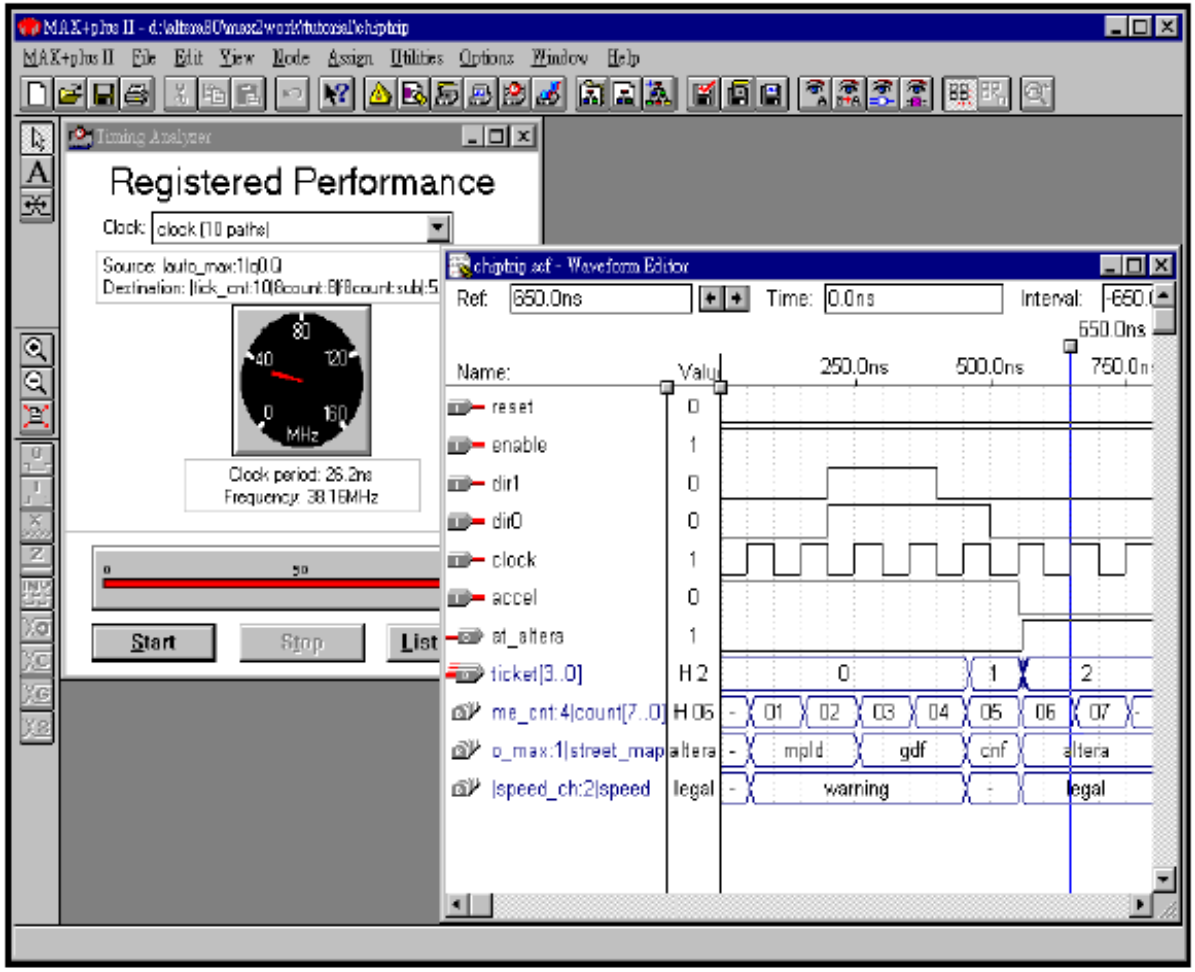
Project Processing (2/2)



Project Verification (1/2)

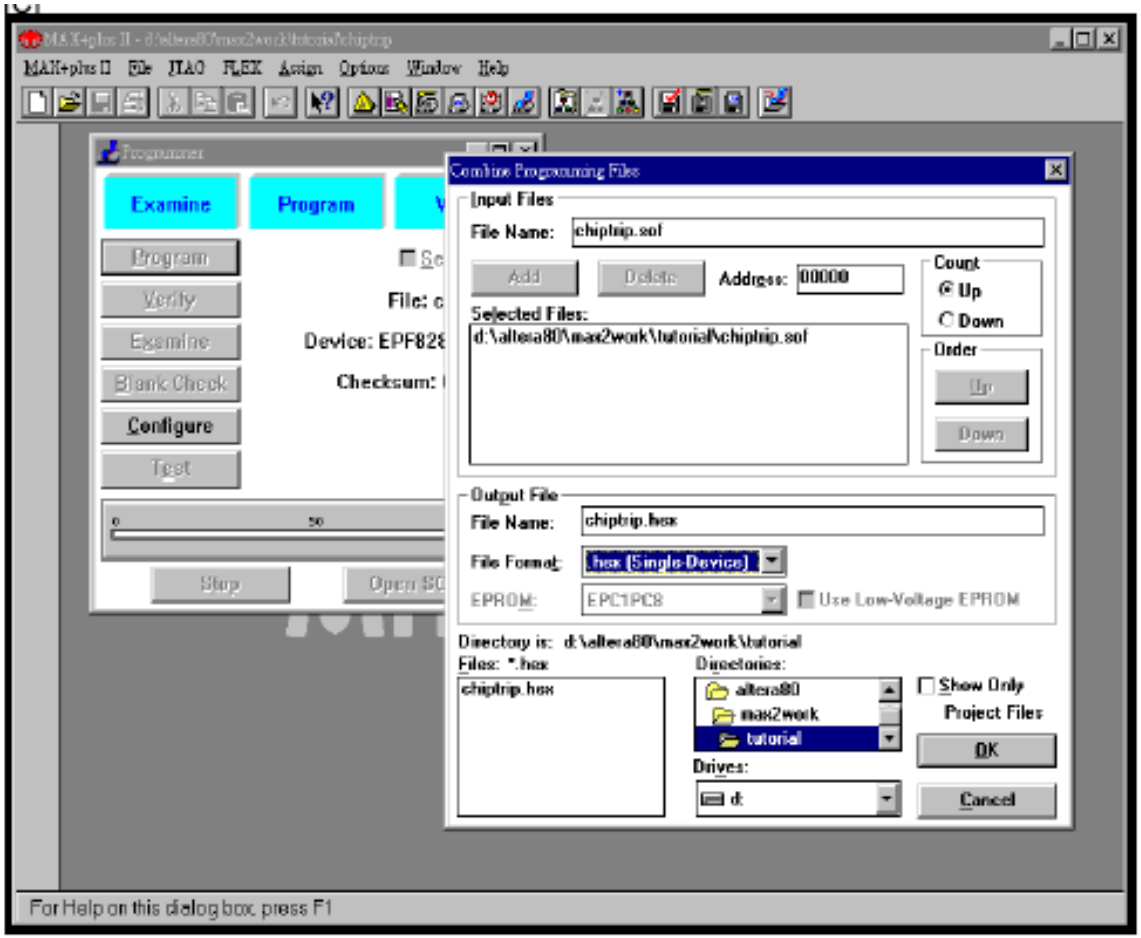
- MAX+PLUS II tools for project verification
  - MAX+PLUS II Simulator
  - MAX+PLUS II Waveform Editor
  - MAX+PLUS II Timing Analyzer

Project Verification (2/2)



Device Programming

- MAX+PLUS tool for device programming
  - MAX+PLUS II Programmer



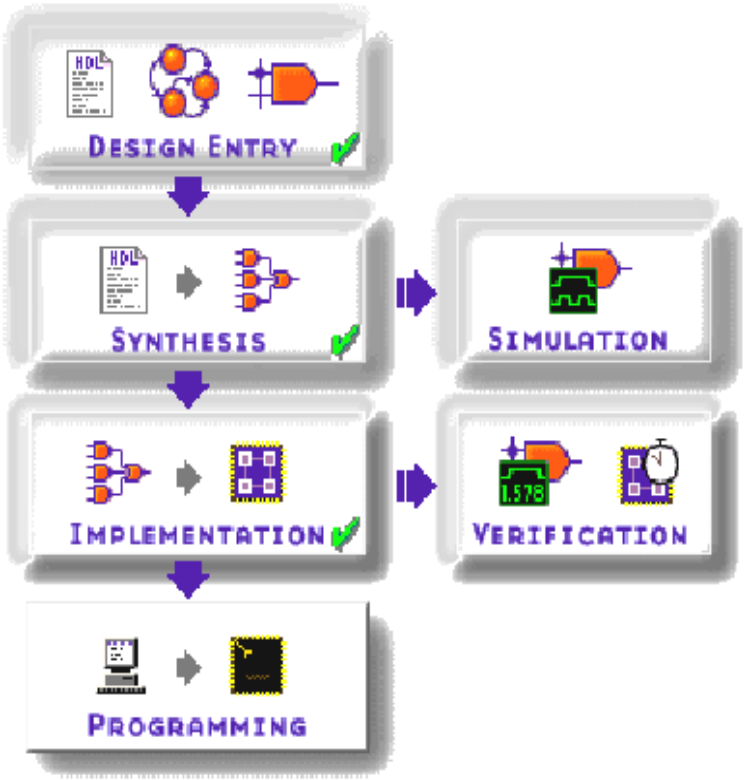
MAX+PLUS II Features (1/2)

- MAX+PLUS II, Altera's fully integrated design environment (jump to page 4)
  - Schematic, text (AHDL, VHDL, and Verilog HDL), waveform design entry & hierarchy display
  - Floorplan editing
  - RC, logic synthesis & fitting, timing-driven compilation
  - Multi-device partitioning
  - Automatic error location

MAX+PLUS II Features (2/2)

- Functional simulation, timing simulation, and multi-device simulation
- Timing analysis
- Programming file generation & device programming
- EDA interface : industry-standard library support, EDA design entry & output formats (EDIF, Verilog & VHDL)
- On-line help

Xilinx Design Flow (Foundation)



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(3) http://www.cic.edu.tw/~steven/stratix.htm/

(4) http://www.altera.com/literature/ds/acex.pdf

(5) 教育部P&L聯盟-FPGA系統設計實務(摘自陳漢臣老師部份)