FPGA
How do they work?

ETI135, Advanced Digital IC Design

Anders Skoog, Stefan Granlund 21-02-2012

Content

• What is a FPGA?
• How FPGAs work
• Manufacturers
• Distributed RAM
• History
• FPGA vs ASIC
• FPGA and Microprocessors
• Alternatives to FPGAs

What is a FPGA?

• Field-Programmable Gate Array
• Digital logic chips that can be reconfigured so that they perform a logic function
• Programmed with HDL languages e.g. VHDL or Verilog

FPGA
Typical applications

• Aerospace & Defense
• Automotive
• Medical/Scientific
• Storage & servers
• Wired & wireless communications
How FPGAs work

FPGA Design

- Block structure
- CLB (Configurable Logic Block)
- RAM
- IOB
- DSP
- Microprocessors
- Multipliers

Logic-Cell

Smallest part in FPGA

Consists at least of
- Lookup Table (4-6 inputs)
- D-flipflop
- MUX

Behaviour to duplicate

3-input AND & OR

Lookup on FPGA
How FPGAs work

Cont

Several Logic cells then gets interconnected

Logic Cells can be connected to slices

Several Slices form a CLB

Interconnections between blocks is managed with Switch Matrices
How FPGAs work

Configuration of FPGA

- The FPGA clears (initializes) the internal configuration memory
- Configuration data is loaded into the internal memory
- The user-application is activated by a start-up process

Example of VHDL-code
Design Flow

1. Describe function in HDL or Schematic
2. Simulate
3. Synthesize and create netlist
4. Simulate with netlist
5. Place and Route
6. Simulate/verify Place and Route
7. Generate binary files
8. Upload to FPGA via JTAG interface or to an external memory device

IP-Cores

- IP-Cores are a reusable unit of logic, cell, or chip layout design that is the intellectual property of one party.
- Soft cores: HDL code or as a Netlist
- Hard cores: ASICs embedded on FPGA
- FFT, AC97, ARM processors, MIPS, MP3 codec
- OpenCores.org

Manufacturers

Major manufacturers (80% of market):
- Xilinx (over 50% of market)
- Altera

Other manufacturers:
- Lattice semiconductor
- Actel
- SiliconBlue
- QuickLogic

Xilinx vs Altera

Design philosophy

Xilinx:
Tries to include as many features as possible, at the cost of increasing the complexity of the FPGA.

Altera:
Include the features most people use, to keep the complexity down.
Xilinx vs Altera
RAM-implementation

- Xilinx and Altera use "big" RAM-blocks
- Xilinx uses "Distributed RAM" for small RAMs
- Altera mixes smaller and bigger blocks of RAM

Distributed RAM

- Xilinx patented technology
- Turns a Logic-cell into a small 16-bit RAM, ROM or FIFO shift register

History
FPGA patent

- Invented by Ross Freeman
- Patent filed in 1984 describing basic FPGA functions

"Patent No. 4,870,302 -- Each configurable logic element in the array is in itself capable of performing any one of a plurality of logic functions depending upon the control information placed in the configurable logic element. Each configurable logic element can have its function varied even after it is installed in a system by changing the control information placed in that element."

Ref. [2]

History
First commercially viable FPGA

- XC2064
- 1985
- By co-founders of Xilinx Ross Freeman and Bernard Vonderschmitt
- 64 CLB with two 3-input lookup tables
- Today: Virtex 7 ~150 000 CLB with four 6-input lookup tables

Ref. [2][3]
FPGA vs ASIC
FPGA advantages
- Simpler design cycle
- No "non recurring expenses"
- More predictable project cycle
- Reprogrammable
- Shorter time to market, 9 months compared to 2 years

Ref. [5]

FPGA vs ASIC
ASIC advantages
- Dynamic power: ASIC 12 x less than FPGA
- Area: ASIC 40 x less than FPGA
- Speed: ASIC 3.2 x faster than FPGA
- Full custom capability
- Lower unit cost

Ref. [6]

FPGA vs ASIC
What to choose?
ASIC
- High volume products
- Low power products
- High speed

FPGA
- Low to medium volume products
- Needs to be flexible
- Short development time

FPGAs and Microprocessors
- Combining Serial and parallel processing
- Reconfiguring FPGA at "run-time"
- Loading firmware at Power on
FPGAs and Microprocessors

- Hardware processor embedded in FPGA
  - PowerPC
  - ARM Cortex-M3
  - Atmel
- Soft processor core
  - MicroBlaze
  - Nios II

CPLD

- Alternative to FPGA
  - Macrocels with logic-gates and flip-flops
  - Non-volatile configuration memory
  - Constant signal delay
  - Not as flexible as FPGAs
  - Less number of gates than a FPGA

References

Text

- [3] "FPGA Comparison Table", 17-02-2012,
  http://www.eecg.toronto.edu/~jayar/pubs/kuon/kuonfpga06.pdf
- [5] Karthikeya "FPGA Vs ASIC Design: A Strategic Comparison"
  http://electronicsbus.com/fpga-vs-asic-design-verification-comparison/
- [7] Spartan-3E FPGA Family Data Sheet (v3.8), August 26, 2009
References

References

1. Anders Skoog, 16-02-2012

2. Stefan Granlund, 20-02-2012

3. Stefan Granlund, 20-02-2012


5. Spartan-3E FPGA Family Data Sheet (v3.8), August 26, 2009, page 29


7. [B7] Spartan-3E FPGA Family Data Sheet (v3.8), August 26, 2009, page 22


15. [B15] Altera ACCEX 1K Data sheet ver. 3.4, may 2003, page 8
