ASIC vs FPGA

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ASIC

Application-**S**pecific **I**ntegrated **C**ircuit

- What are ASICs?
- Design
- General usage
- Practical application

What are ASICs?

- Integrated Circuits (ICs) that are made for a **specific purpose** [1]
  - Efficient
- Hardware is fixed in production, cannot be changed by customer
  - Design is expensive
- Range of different ASICs
  - From ASICs made only from customer's own design to the use of pre-made logic cells [2]

Design

- Full-custom design
  - Every transistor is custom designed and placed by the customer [3]
- Semi-custom design
  - Like the full-custom design, but with standard blocks (e.g. SRAM)
- Standard-cell ASIC
  - ASIC implemented with standard cells of the manufacturer (boolean logic functions: AND, OR, XOR, ...) [4]
  - Can be found in standard-cell library

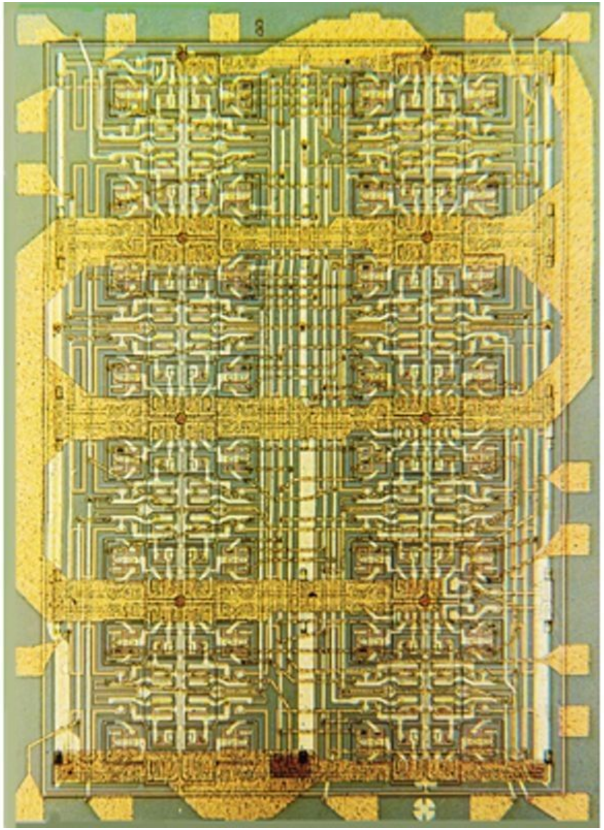

Fig. 1: Custom designed ASIC (Fairchild 4500, 1967) [13]

General usage

- General: new products that will be produced in high numbers
  - Initial costs high, but cheaper with every piece manufactured
- Use cases for high-efficiency
- Little space available

Practical application

- Toys
- Video codecs
- USB chargers
- Network switch
- Cryptographic algorithms (crypto mining)

FPGA

Field **P**rogrammable **G**ate **A**rray

- What are FPGAs?
- Design
- General usage
- Practical application

What are FPGAs?

- Hardware can be reconfigured by customer [5]
  - Flexible
  - Exception: Antifuse technology
- Less expensive due to less specialized hardware
- Hardware is configured via lookup tables (LUTs)
  - LUTs are configured with SRAM [6]

Design

- Gate arrays were used in ASIC design [7]
    - Pre-made repeating patterns of memory, logic and bus elements
    - Wires connected on the basis of customer's design
- Now: Configurable Logic Blocks (CLBs)
    - Contains LUT and flip-flop
    - The LUT can be programmed with volatile memory (SRAM)
    - Boolean functions make logic possible
- IO-Blocks and networks between CLBs

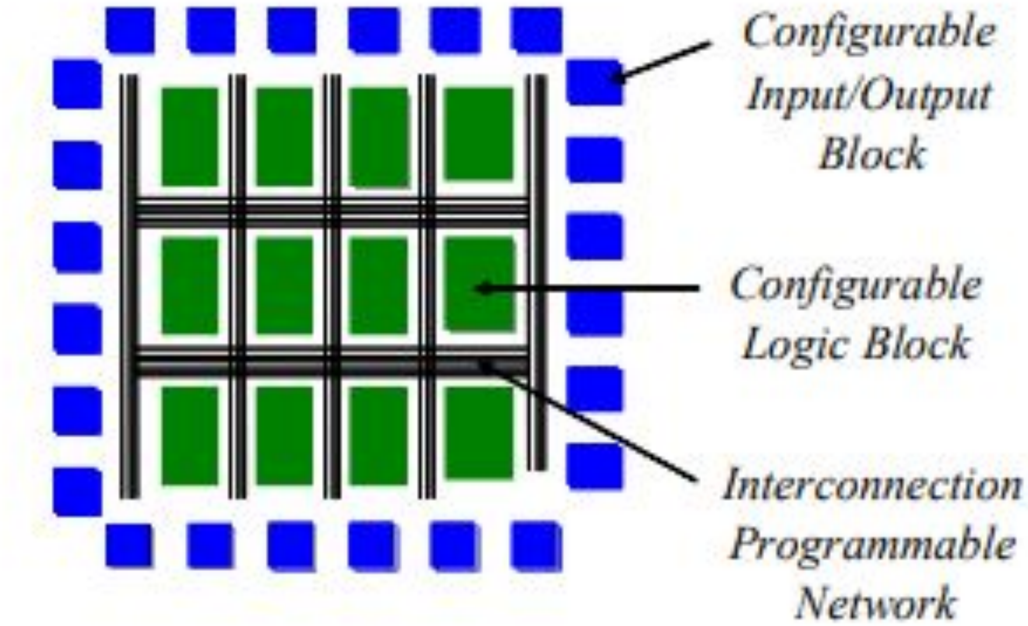

Fig. 2: Generic FPGA architecture [6]

General usage

- Small and medium sized product lines
- Use cases where hardware needs to be adjusted often
    - Design and test phase of ASICs
- Replicas of other hardware
    - Old hardware no longer produced

Practical application

- Many small-scale applications
- Machine learning applications
  - Hardware can be optimized ➔ performs better than CPUs/GPUs
- Replication of old gaming consoles
  - Also spare parts that are no longer in production
- Aerospace technologies [8]
- Education :)

Pros & cons & differences

of ASICs and FPGAs

Quick overview

ASIC

- Build for a single purpose
- Expensive to design
- Very fast

FPGA

- Hardware can be reprogrammed
- Cheaper to buy
- Slower than ASICs

Pro & Cons

- FPGAs make dynamic changes possible
  - Easier testing and design
  - Less time to implement
  - Adjustable to new environments
- ASICs are more efficient [9]
  - Faster (FPGAs are about 3 times slower)
  - Less energy usage (FPGAs use about 12 times more power)
  - Higher gate density (FPGAs use 25 to 55 times more space)

Other differences

- FPGAs need to load the hardware design every time it restarts [7]
  - LUTs values are stored in volatile memory (SRAM)
- ASICs are less sensitive to radiation or electric charge [10]
  - If hard wired and not software controlled
  - One time programmable (Antifuse) FPGAs are less affected [11]
- ASICs are hard to counterfeit [12]

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