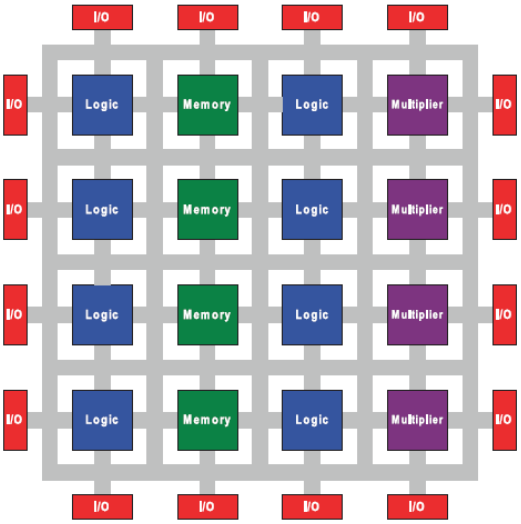
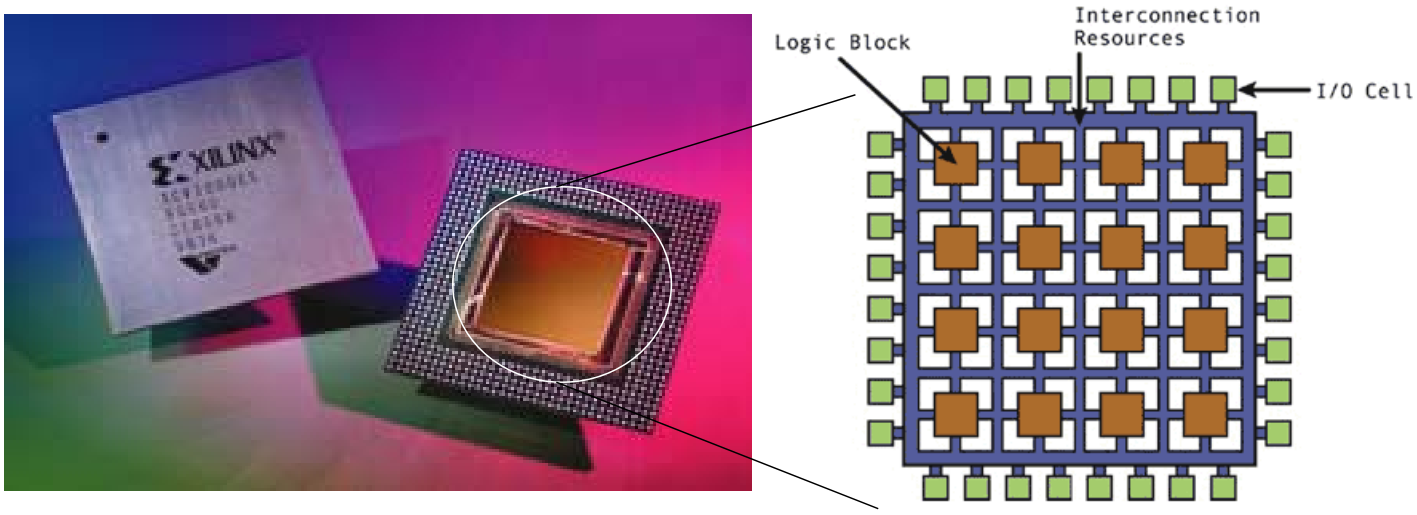
Classification and Evolution of Field Programmable Logic Devices

Topics

- Distinction from ASIC
- Classification & evolution of FPLDs
- FPLD markets



Field-Programmable Gate Array (FPGA)



Field-Programmable Devices

- *User-configurable* ICs.
- They are standard parts, not designed for any particular application.
- Unlike traditional ASIC, logic function is specified by the user *after* the device is manufactured.

- They are programmed/configured by the users to implement their designs *at their own sites*.
- *Instant configuration* (in minutes) at users' site.

Advantages of Field-Programmable Logic Devices

- Short turnaround time for new designs
- Low startup cost
- Low inventory cost
- Low risk
- Allow easy design changes

How to make a chip that can realize different circuits and configurable?

What are the essential elements that make up any circuit?

What do you expect within a FPLD?

大量的

1. Substantial amounts of uncommitted combinational logic.

logic gate

FF 2. Contain flip-flops/latches.

wire 3. Programmable interconnections between the combinational logic, flip-flops, and chip input/outputs.

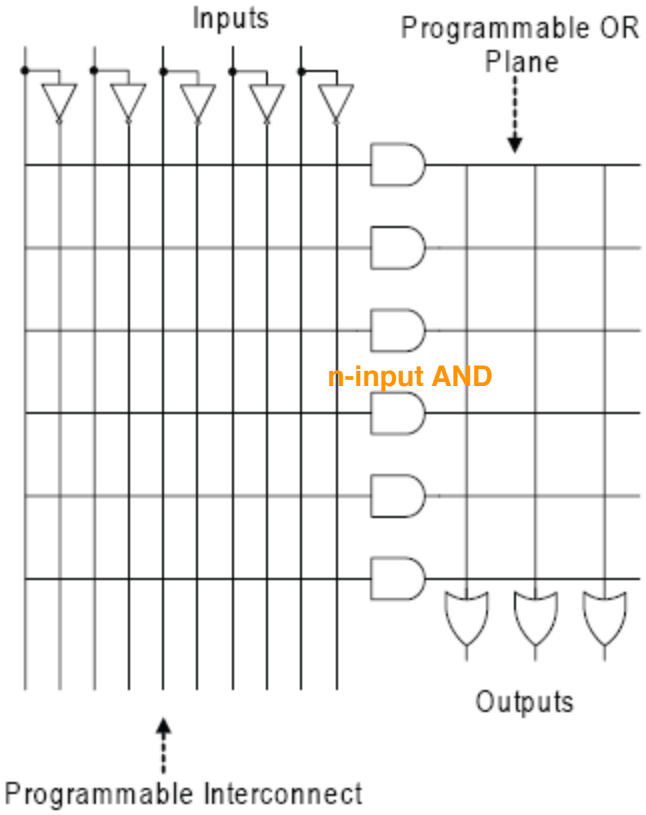
Types of Field-Programmable Devices

- *Simple Programmable Logic Devices* (SPLDs)
- *Complex Programmable Logic Devices* (CPLDs)
- *Field-Programmable Gate Arrays* (FPGAs)

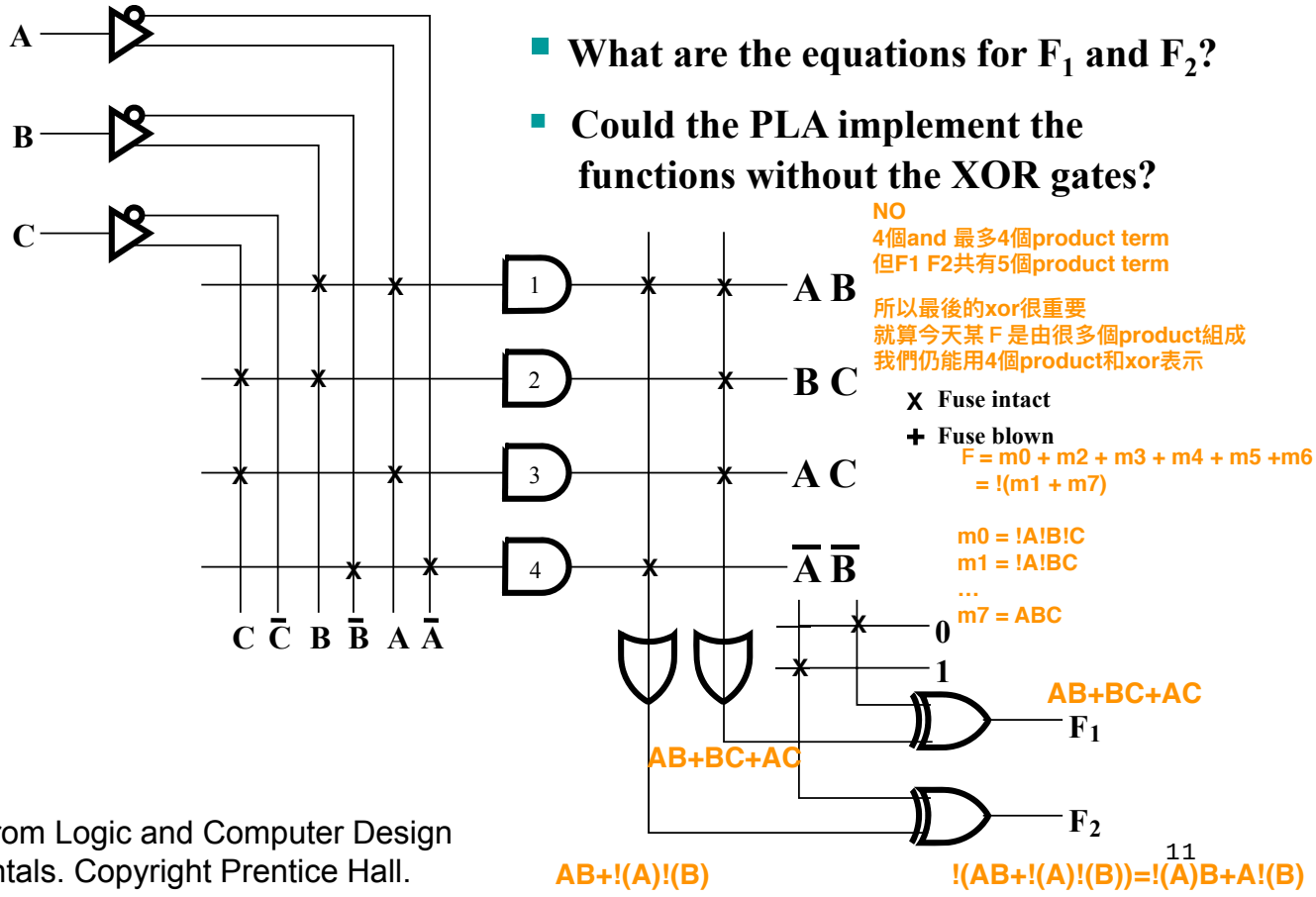
Programmable Logic Array (PLA)

- A simple programmable logic device (SPLD).
- The first programmable logic device introduced in the early 1970s by Philips.
- Use a *2-level logic* structure to implement programmed logic.
- Based on idea that logic functions can be realized in *sum-of-products* form.
- A programmable array of AND gates feeding a programmable array of OR gates.

PLA Structure



Function Implementation by PLA



- What are the equations for F_1 and F_2?
- Could the PLA implement the functions without the XOR gates?

NO
4個and 最多4個product term
但F1 F2共有5個product term

所以最後的xor很重要
就算今天某 F 是由很多個product組成
我們仍能用4個product和xor表示

X Fuse intact
+ Fuse blown

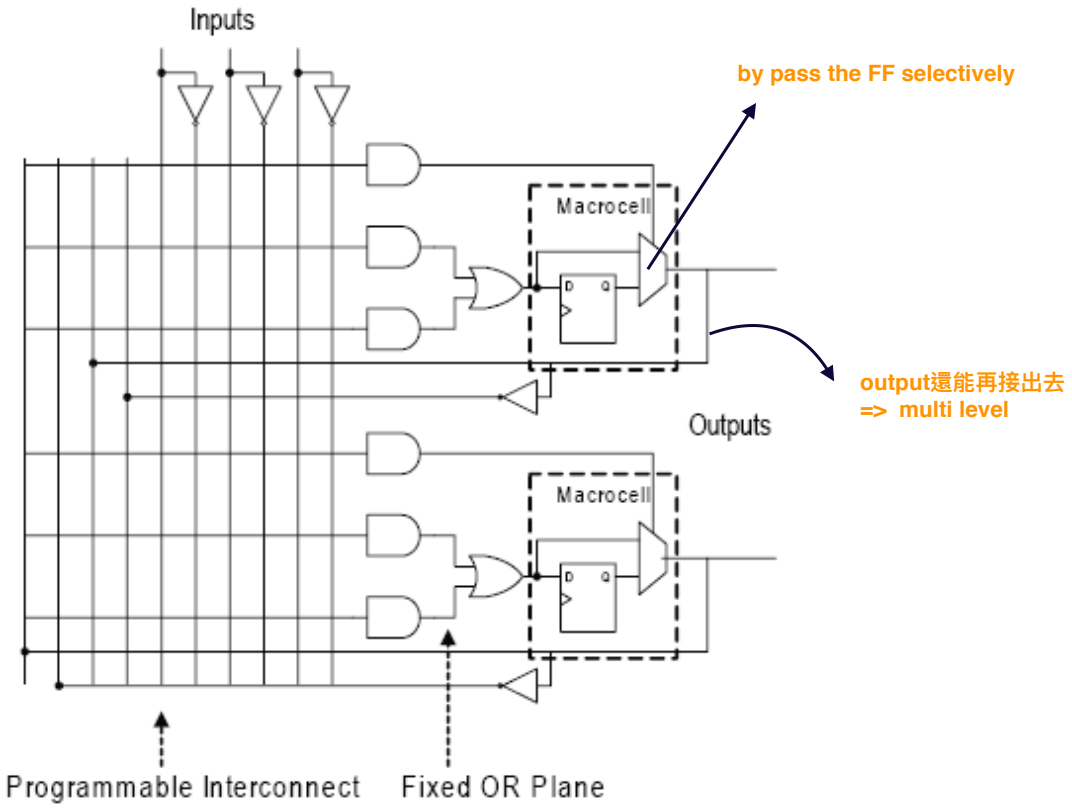
F = m0 + m2 + m3 + m4 + m5 +m6
= !(m1 + m7)

m0 = !A!B!C
m1 = !A!BC
…
m7 = ABC

Programmable Array Logic (PAL)

- Introduced to overcome the weaknesses of PLAs (programmable switches were hard to fabricate correctly and introduced significant propagation delays).
- A programmable array of AND gates feeding a fixed array of OR gates.
- PAL usually contains flip-flops connected to the OR gate outputs to implement sequential circuits. (*Macrocell:* an OR gate combined with a flip-flop and extra circuitry in a PAL.)
- PLAs and PALs are useful for implementing small digital circuits, typically ≤ 32 combined inputs and outputs.

PAL Structure



Function Implementation by PAL

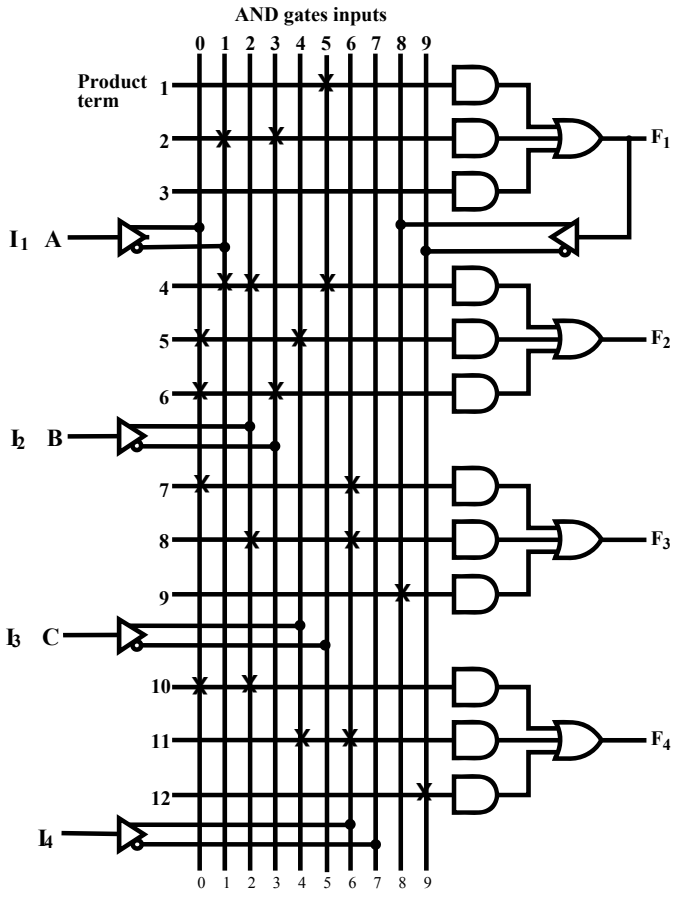
- 4-input, 4-output PAL with fixed, 3-input OR terms
- What are the equations for F1 through F4?

F1 = $\overline{A}\ \overline{B} + \overline{C}$

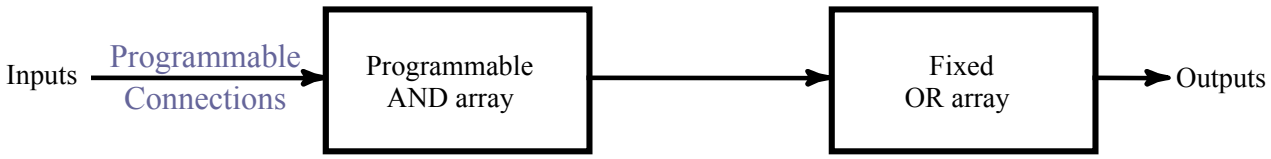
F2 = $\overline{A}B\ \overline{C} + AC + AB$

F3 =

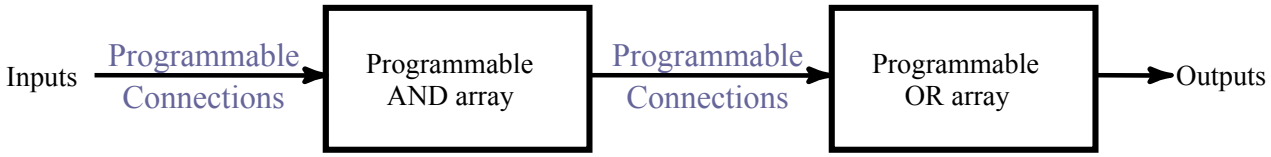
F4 =



PAL and PLA Comparison



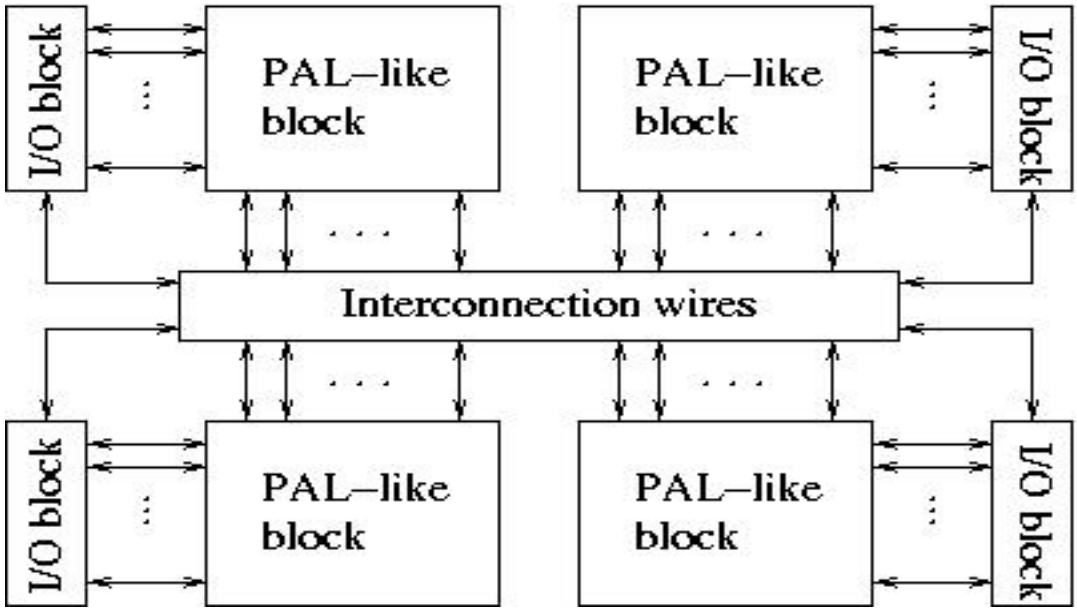
(a) Programmable array logic (PAL) device



(b) Programmable logic array (PLA) device

How to get larger capacity?

Complex Programmable Logic Device (CPLD)



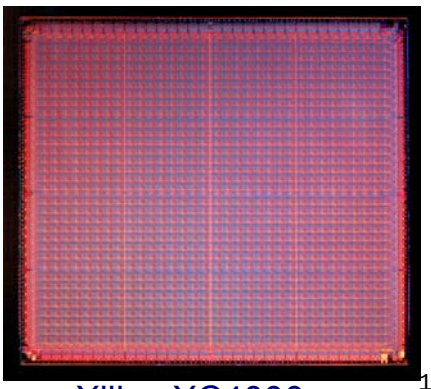
Complex Programmable Logic Device

- Combines multiple PAL-like blocks with programmable interconnect network.
- Provides much larger capacity than SPLDs.

basic idea for SPLD/CPLD is sum of product
but not for FPGA

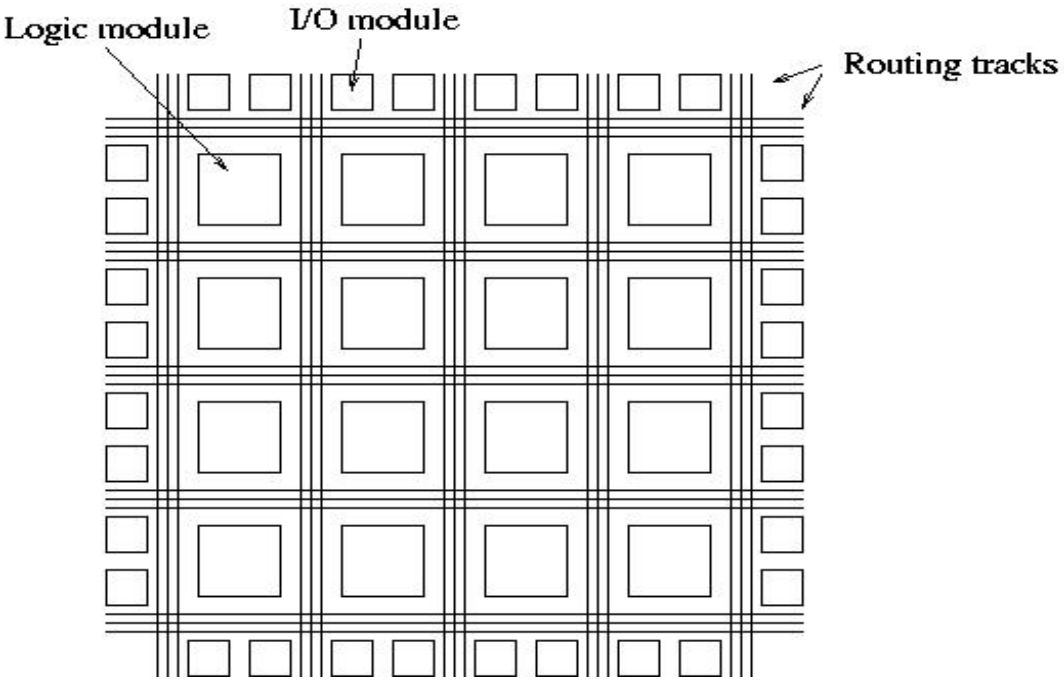
Field-Programmable Gate Array (FPGA)

- A high-capacity programmable logic device providing multi-level logic.
- Introduced in 1985 by Xilinx.
- Classic FPGA consists of an *array of programmable logic blocks* surrounded by programmable interconnect.

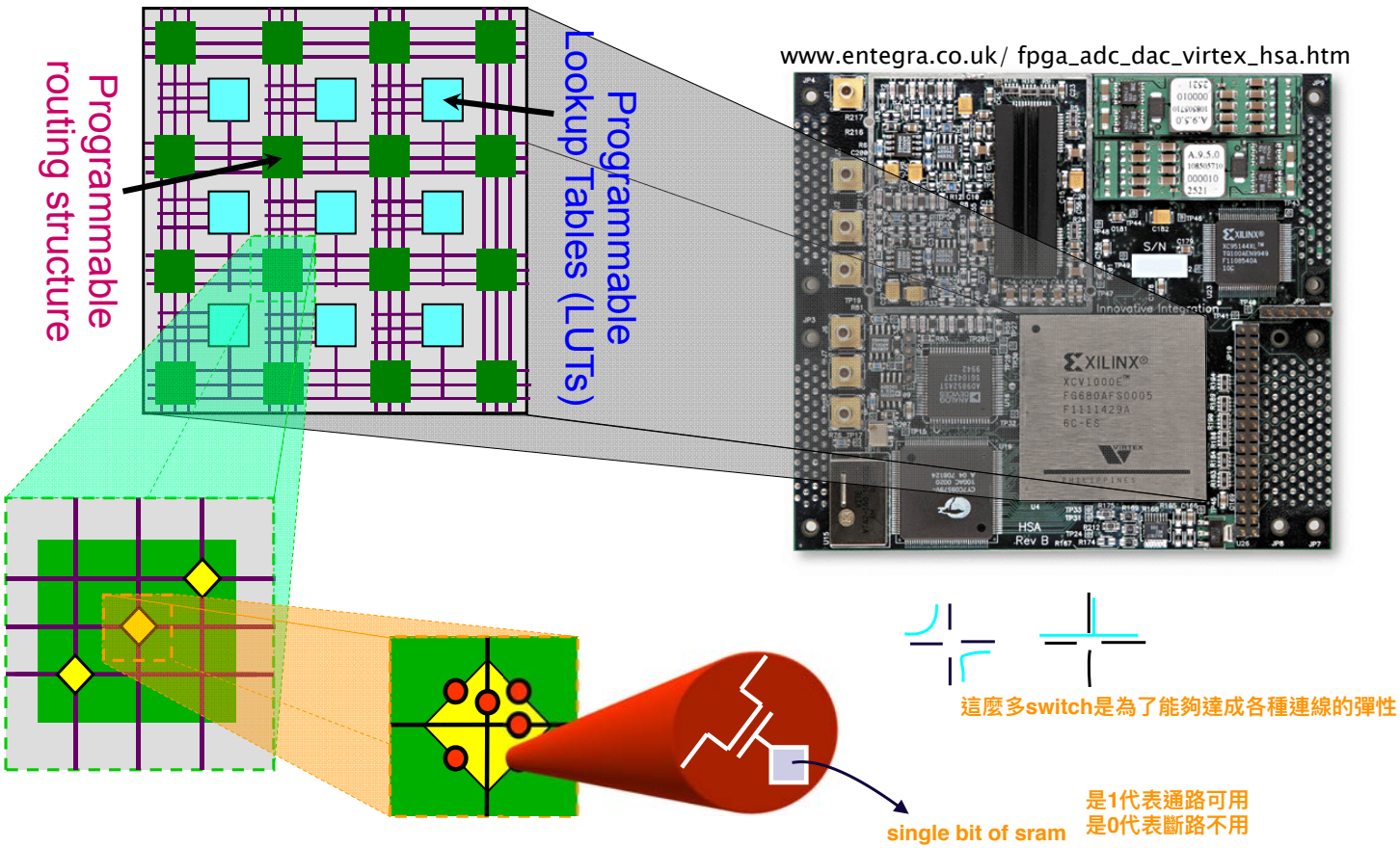


Xilinx XC4000ex

Field-Programmable Gate Array



SRAM-Based FPGA



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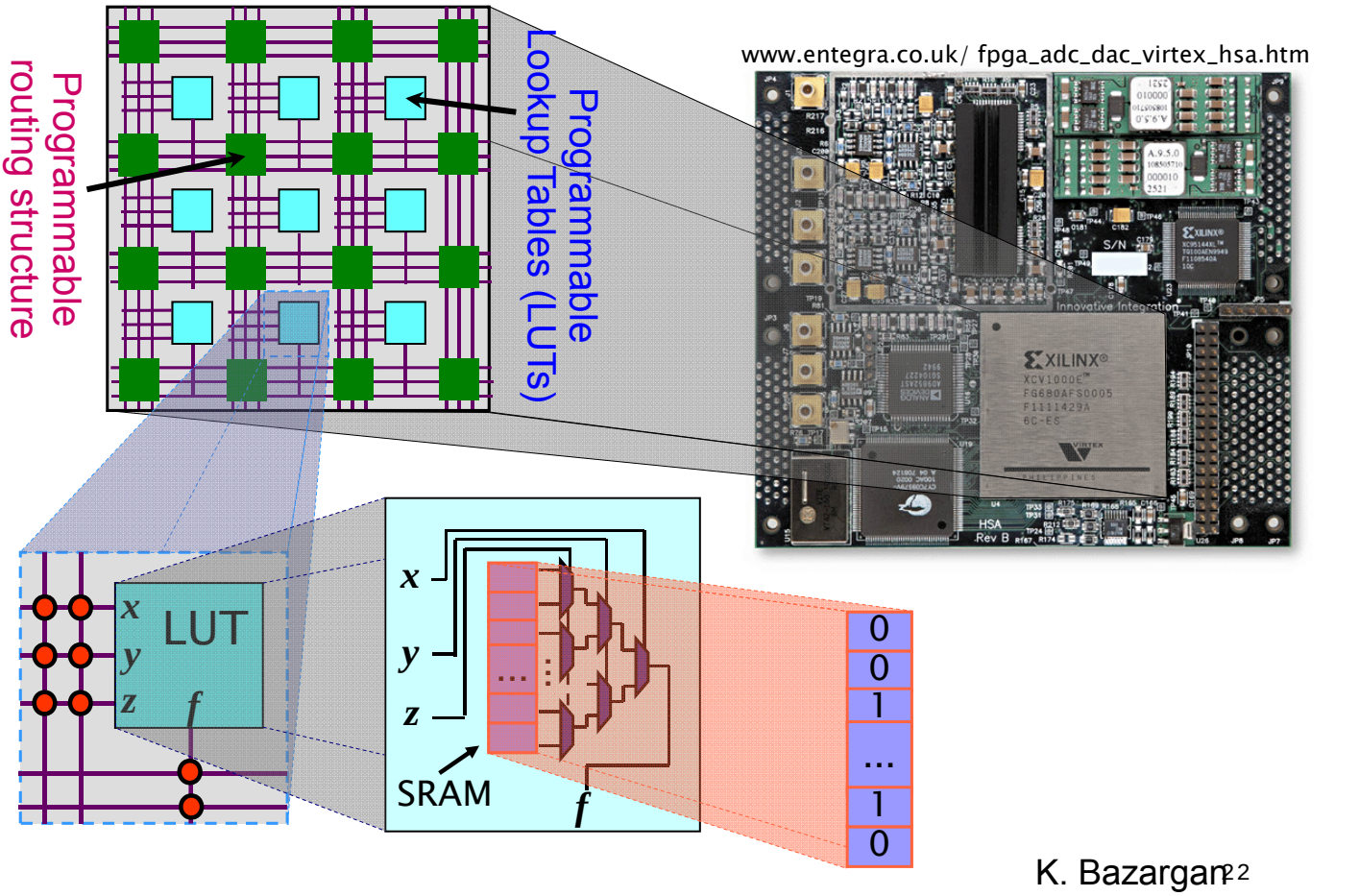


Microprocessor vs Custom Chip vs FPGA

ie. ASIC

- Microprocessor
  - Rely on software to implement functions
  - Slowest, most power-hungry
  - Re-programmable (load different software)
- Custom Chip
  - Designed for a particular purpose
  - Fastest, most power-efficient
  - Not re-programmable
- FPGA
  - Not designed for any particular function
  - In between microprocessor and custom chip in speed and power
  - Re-programmable (most)

Rapidly Increasing Logic Capacity

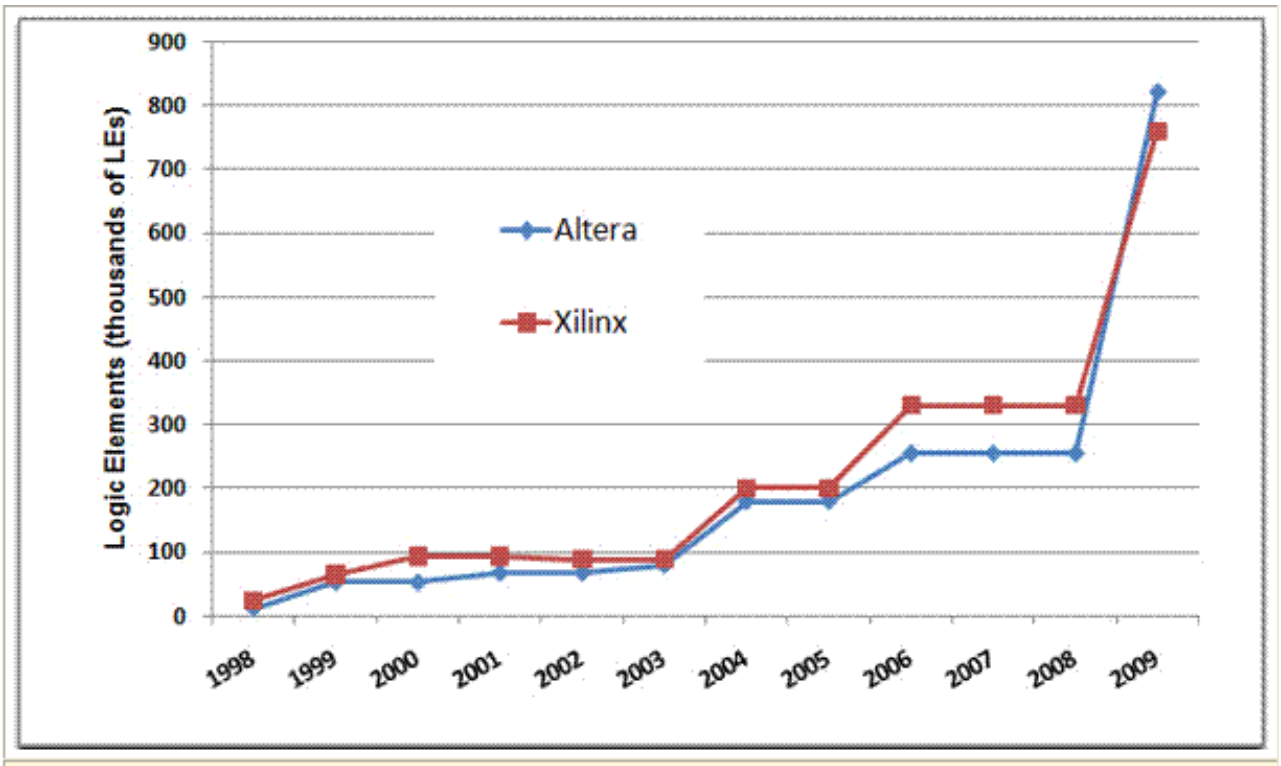
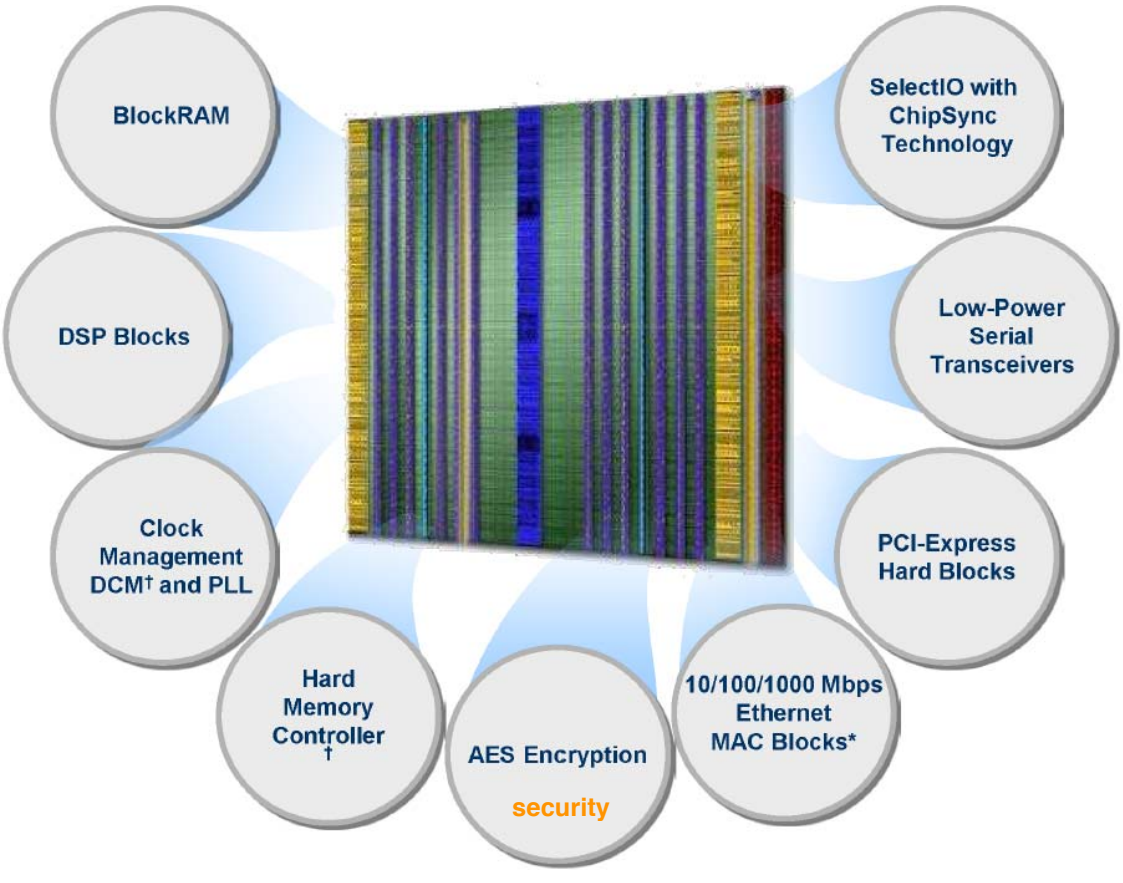


Figure 1. Largest FPGA announced (by equivalent 4-input Logic Elements - LEs).

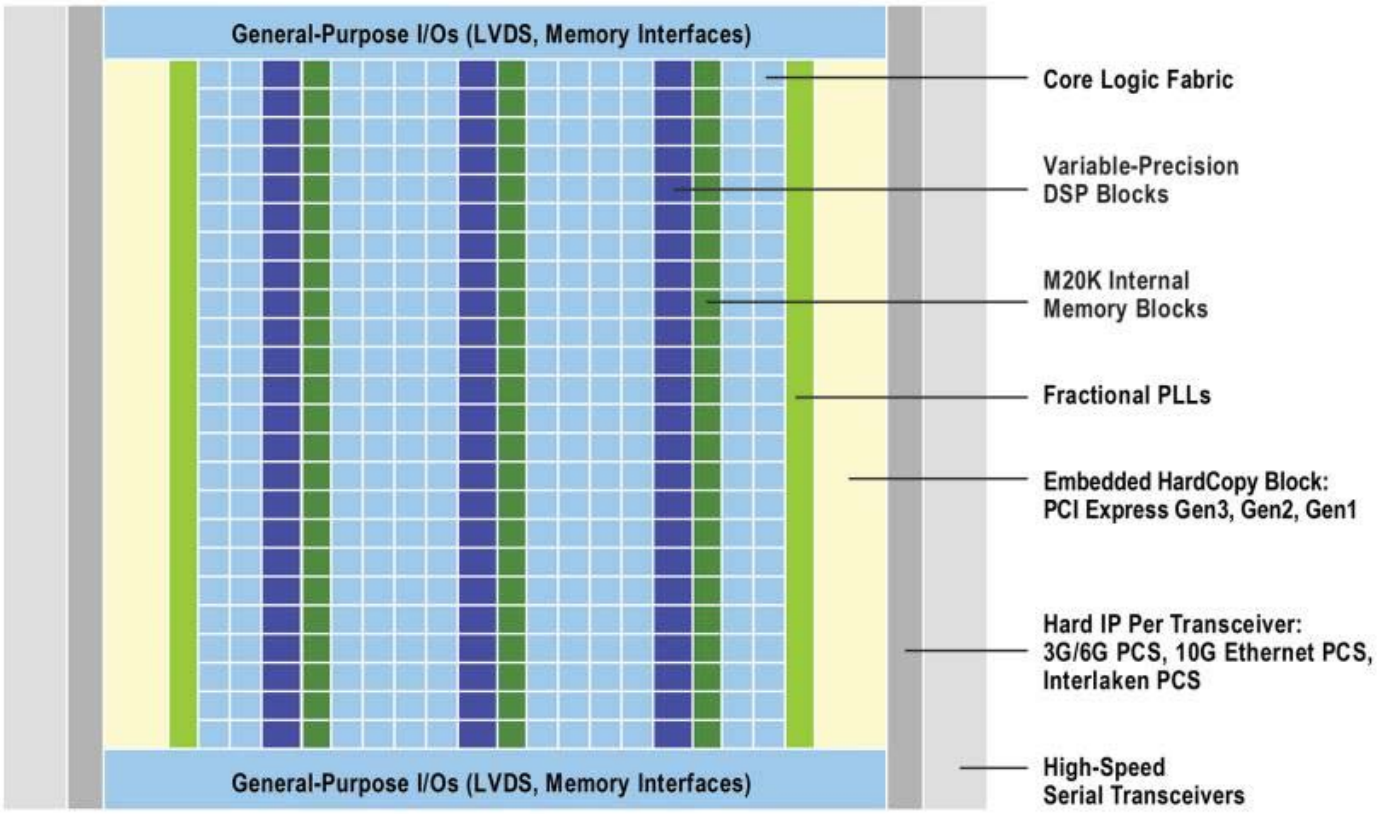
Today's FPGAs

- Additional resources: embedded memory blocks, fast carry logic chains, DSP blocks
- Versatile programmable I/Os
- Some even contain: 1 or more processors
- Applications: audio, video, wireless, industrial equipments, network components, medical, automotive, etc.
- Vendors offer a variety of FPGAs catering for different markets

Advanced Features of Today's FPGAs



Advanced Features of Today's FPGAs



SoC FPGA

- Xilinx's Zynq families and Intel's SoC FPGAs
  - with 1 or more ARM cores