A brief history of Programmable Logic

University of Colorado **Boulder**

Let’s look at the history of programmable logic devices to give us some perspective on PLDs in general, and FPGAs in particular.

What is Programmable Logic?

The first programmable logic was a

PROM (programmable Read only Memory), followed quickly by

PLAs (Programmable Logic Array) and

PALs (Programmable Array Logic).

We will explain the difference between these in the following pages.

FPGAs are a subset programmable logic devices.
Here's a brief history of the development of programmable logic devices.

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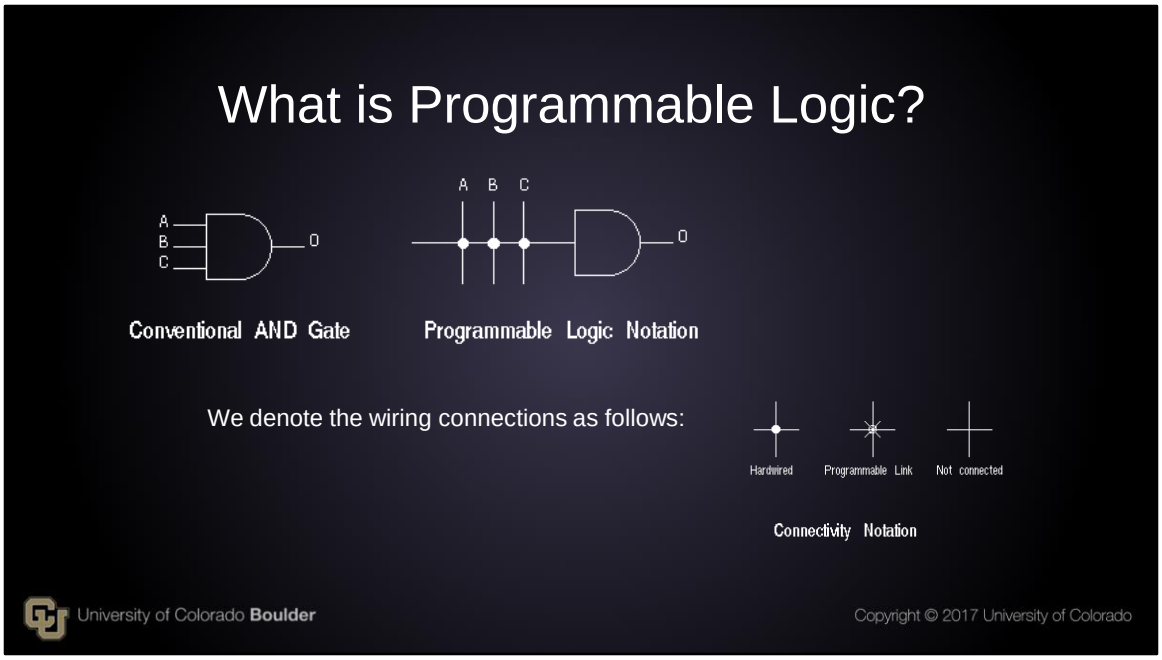


Insert Reference http://web.engr.oregonstate.edu/~sllu/fpga/lec1.html

Programmable Logic is as easy as ABC

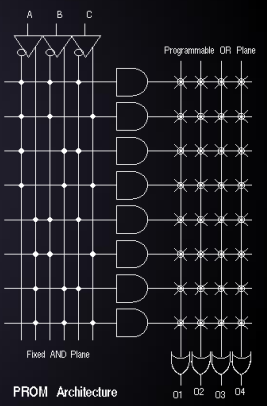
The desire to have programmable hardware has been in existence ever since the very beginning of digital hardware.
We can realize any logic equation in a two-level sum of product format.
Let us denote the AND logic in a format which is easy for us to illustrate the AND-OR planes.
To the left is a traditional notion for a three input AND gate.
To the right is the notion we will adopt for two-level programmable logic blocks.

What is Programmable Logic?

In fact the first "programmable logic" is a PROM. The PROM has a fixed AND Plane (product terms) which is the address decoding logic. The OR plane (Sum terms) is programmable through the change of memory contents. This is an 8x4 PROM

Using this, we could implement the logic function Output1 = ABC by storing in the first column of the PROM 0b00000001.

Then only when A, B, and C are all ones will output O1 be a one.



PROM Architecture

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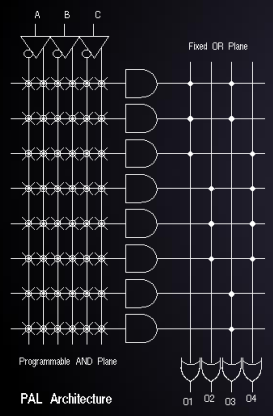

In the same way, we could make the OR plane fixed and make the AND plane programmable.

The following figure illustrates the general approach of a PAL which has a fixed OR plane but has a programmable AND plane. PAL devices are very popular and they are still used in many designs, with common part numbers like 22V10 or 16R8.

Further development lead to CPLDs, which were devices with multiple PALs in the same package with registered outputs and an interconnecting programmable fabric. CPLD = Complex Programmable Logic Device. See https://www.altera.com/solutions/technology/system-design/articles/_2013/in-the-beginning.tablet.html for history of the CPLD.

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In the same way, we could make the OR plane fixed and make the AND plane programmable. In fact this is a more efficient architecture since most of the logic functions we are interested has limited number of production terms. The following figure illustrates the general approach of a PAL which has a fixed OR plane but has a programmable AND plane. PAL devices are very popular and they are still used in many designs, with common part numbers 22V10 or 16R8.
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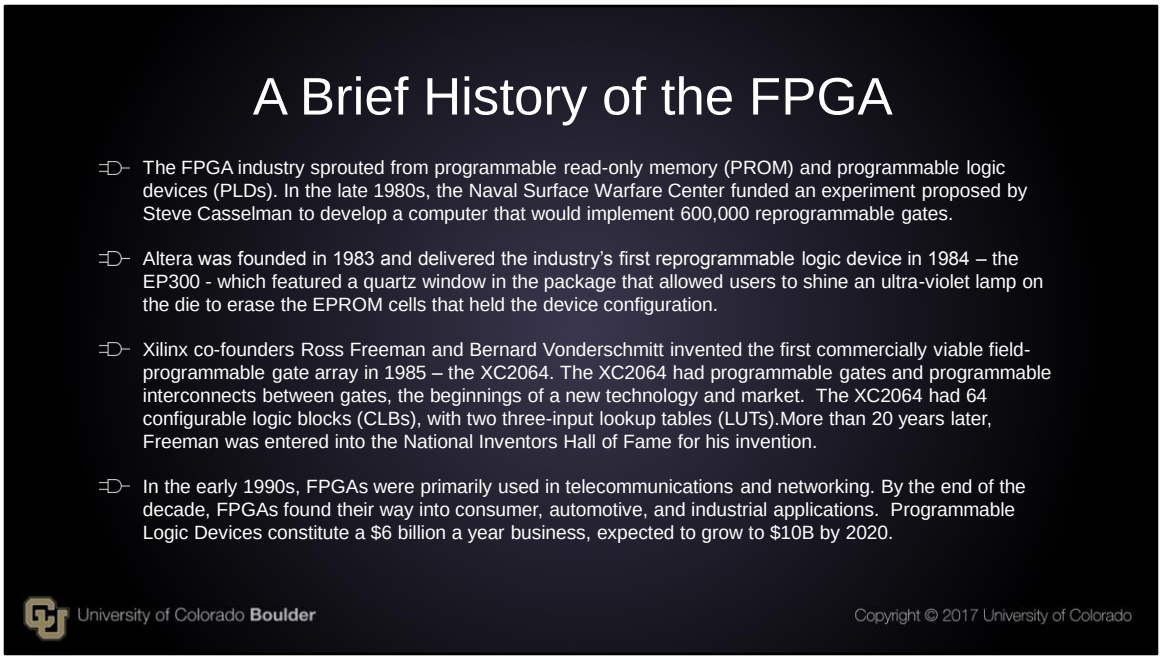
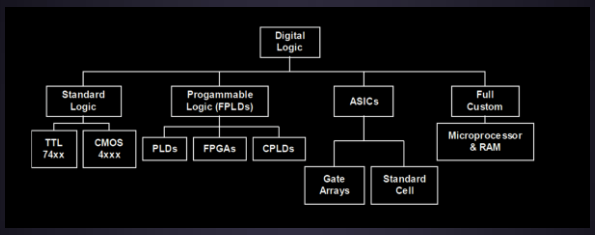


Here's a brief history of the FPGA.
The FPGA industry sprouted from programmable read-only memory (PROM) and programmable logic devices (PLDs). In the late 1980s, the Naval Surface Warfare Center funded an experiment proposed by Steve Casselman to develop a computer that would implement 600,000 reprogrammable gates.
Altera was founded in 1983 and delivered the industry's first reprogrammable logic device in 1984 – the EP300 - which featured a quartz window in the package that allowed users to shine an ultra-violet lamp on the die to erase the EPROM cells that held the device configuration.[9]
Xilinx co-founders Ross Freeman and Bernard Vonderschmitt invented the first commercially viable field-programmable gate array in 1985 – the XC2064. The XC2064 had programmable gates and programmable interconnects between gates, the beginnings of a new technology and market. The XC2064 had 64 configurable logic blocks (CLBs), with two three-input lookup tables (LUTs).More than 20 years later, Freeman was entered into the National Inventors Hall of Fame for his invention.
In the early 1990s, FPGAs were primarily used in telecommunications and networking. By the end of the decade, FPGAs found their way into consumer, automotive, and industrial applications. Programmable Logic Devices constitute a $6 billion a year business, expected to grow to $10B by 2020.

What's this programmable logic stuff anyway?



- Programmable Logic is just one part of the pantheon of digital logic devices.
- Standard Logic has much more breadth than is depicted here, includes additional
- TTL families (LVTTL, etc.) additional CMOS families (HC, LVC, etc.) and biCMOS
- (BCT, HCT, etc.) and differential logic (ECL, LVDS, etc.)

J. Hamblen, T. Hall, M. Furman, "Programmable Logic Technology", in *Rapid Prototyping of Digital Systems*, New York: Springer, 2008, p. 56

This definition is from Hamblen's book.

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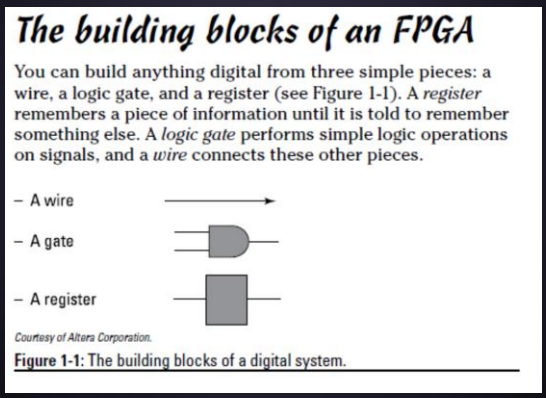
What's this programmable logic FPGA stuff anyway?



The building blocks of an FPGA

You can build anything digital from three simple pieces: a wire, a logic gate, and a register (see Figure 1-1). A *register* remembers a piece of information until it is told to remember something else. A *logic gate* performs simple logic operations on signals, and a *wire* connects these other pieces.

– A wire

– A gate

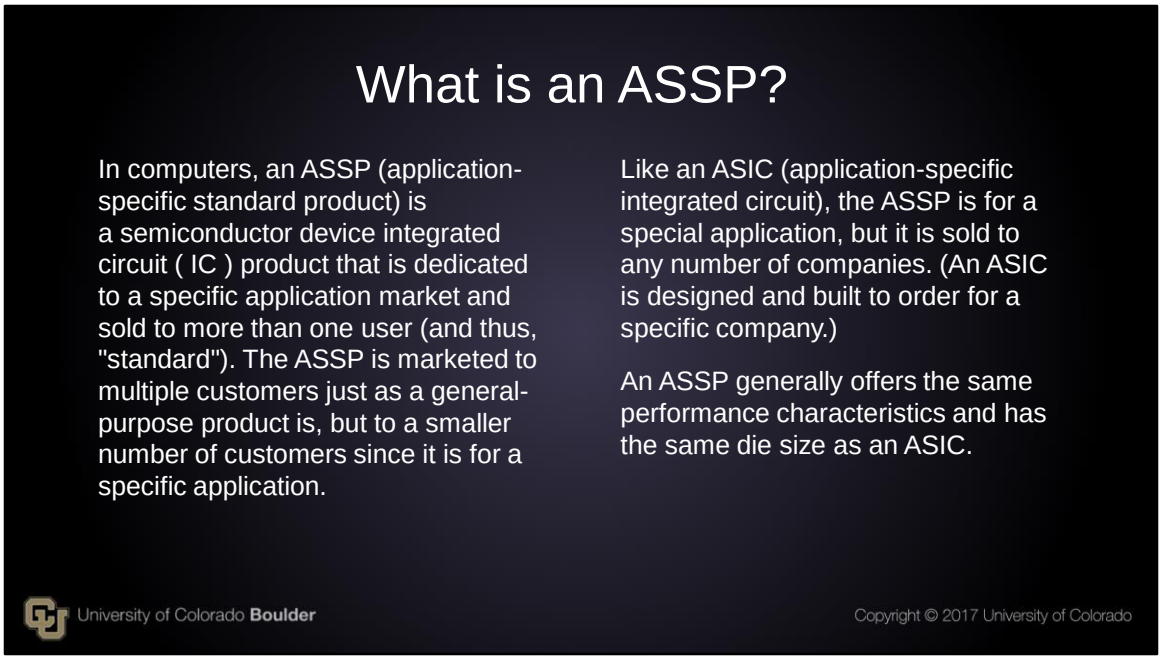
– A register

Courtesy of Altera Corporation.

Figure 1-1: The building blocks of a digital system.

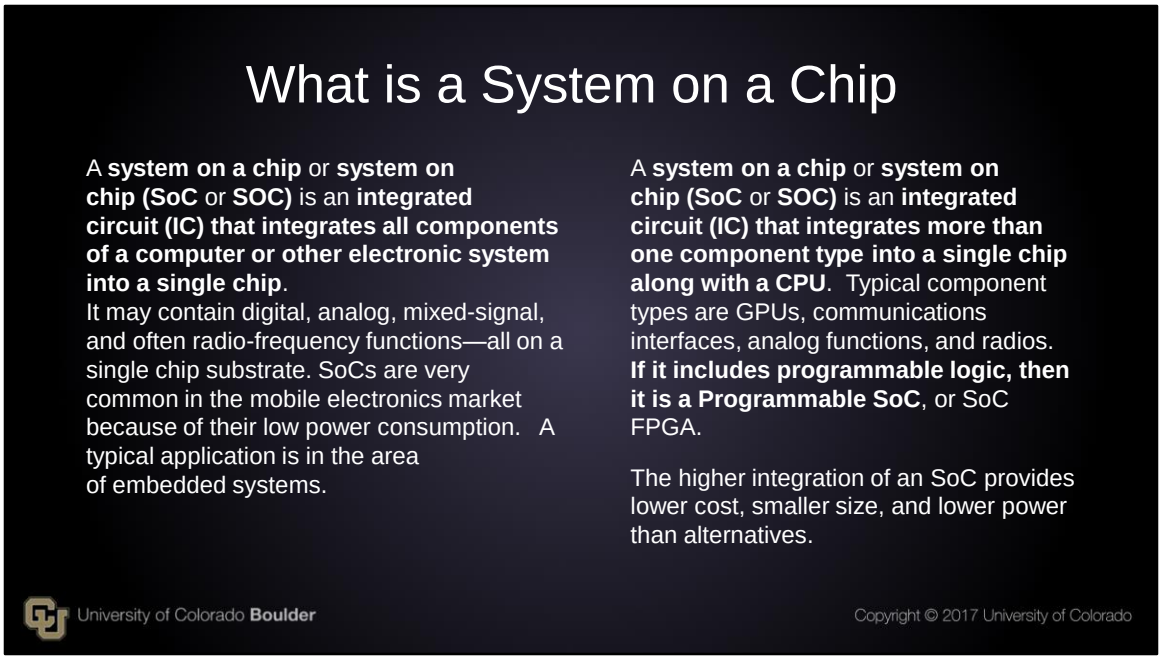
https://www.altera.com/products/fpga/new-to-fpgas/resource-center/learn.tablet.html

FPGAs are simpler in concept than other PLDs. They consist of only 3 elements: a wire, a gate, and a register, or flip-flop. The chip is made of an array of gates and flip-flops with wires that can connect them together in patterns. These patterns create the logic for larger functions, like counters, timers, state machines, ALUs, and even whole CPUs. Creating the interconnecting pattern is the heart of FPGA design.



http://whatis.techtarget.com/definition/ASSP-application-specific-standard-product

In computers, an ASSP (application-specific standard product) is a semiconductor device integrated circuit (IC) product that is dedicated to a specific application market and sold to more than one user (and thus, "standard"). The ASSP is marketed to multiple customers just as a general-purpose product is, but to a smaller number of customers since it is for a specific application.
Like an ASIC (application-specific integrated circuit), the ASSP is for a special application, but it is sold to any number of companies. (An ASIC is designed and built to order for a specific company.)
An ASSP generally offers the same performance characteristics and has the same die size as an ASIC.



https://en.wikipedia.org/wiki/System_on_a_chip

The ultimate expression of logic devices is the system on a chip
Here are 2 definitions for SoC, or system on a chip, which are becoming more common as time goes on.

A **system on a chip** or **system on chip** (**SoC** or **SOC**) is an integrated circuit (**IC**) that integrates all components of a computer or other electronic system into a single chip. It may contain digital, analog, mixed-signal, and often radio-frequency functions—all on a single chip substrate. SoCs are very common in the mobile electronics market because of their low power consumption.[1] A typical application is in the area of embedded systems.

A **system on a chip** or **system on chip** (**SoC** or **SOC**) is an integrated circuit (**IC**) that integrates more than one component type into a single chip along with a CPU. Typical component types are GPUs, communications interfaces, analog functions, and radios. If it includes programmable logic, then it is a Programmable SoC, or SoC FPGA.

The higher integration of an SoC provides lower cost, smaller size, and lower power than alternatives.

What is an FPGA Summary

- Field Programmable Gate Arrays, FPGAs, are programmable logic devices made of gates, registers and routing wires connected together in a pattern that can be programmed after the device is deployed. Creating the interconnecting pattern is the heart of FPGA design.
- Programmable Logic Devices (PLDs) include simple PLDs like PROMs and PALs, complex PLDs (CPLDs), FPGAs, and SoC FPGAs. PLDs are a subset of all logic devices, and FPGAs are a subset of PLDs.
- FPGAs compete with Applications Specific Integrated Circuits (ASICs) and Application Specific Standard Products (ASSPs), successfully displacing these in many applications. When it comes to digital devices, FPGAs are the future.