ENGR 2323 Digital Design Lab
Digital Logic Technologies

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Digital logic designs can be implemented in many ways such as: standard logic, programmable logic, and full custom integrated circuits.

Discrete Logic

Discrete logic is traditional off the shelf integrated circuits. They are typically SSI (2-8 gates per chip) or MSI devices (up to a few hundred gates per chip). The devices have a fixed operation (hardwired inputs and outputs) defined by the manufacturer. For example, a 74HCT00 is a quad 2-input NAND gate.

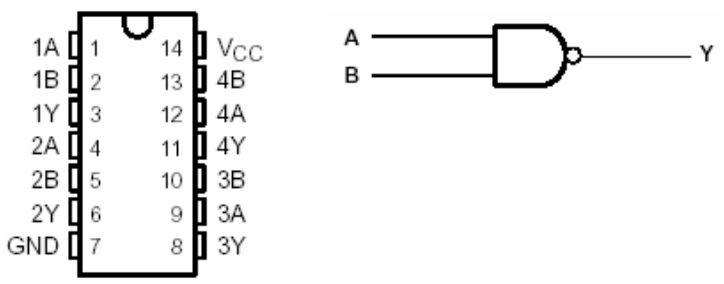

Figure 1. Quad 2-input NAND

FPGA

Field programmable gate arrays (FPGAs) are digital integrated circuits (ICs) that contain configurable (programmable) blocks of logic along with configurable interconnects between these blocks. Design engineers can configure, or program, such devices to perform a tremendous variety of tasks [1]. The FPGA industry flourished from programmable logic devices (PLDs). Recently, VLSI CMOS has played a crucial role in placing millions of transistors on a single chip, providing digital system designers with an ability to implement a vast number of gates with complex functionality on a single IC. A typical FPGA may contain millions of logical gates.

A FPGA is mainly composed of many programmable logic modules, which are connected by crisscrossing distributed programmable interconnect lines to form extremely complex logic circuits. It is more suitable for the realization of multi-level logic functions and has a higher integration density and application flexibility.

A basic FPGA architecture consists of thousands of fundamental elements called configurable logic blocks (CLBs) surrounded by a system of programmable interconnects, called a fabric, that routes signals between CLBs. Input/output (I/O) blocks interface between the FPGA and external devices. An individual CLB is made up of several logic blocks. A lookup table (LUT) is a characteristic feature of an FPGA. An LUT stores a predefined list of logic outputs for any

combination of inputs: LUTs with four to six input bits are widely used. Standard logic functions such as multiplexers (mux), full adders (FAs) and flip-flops are also common [2].

PLD

PLDs are devices whose internal architecture is predetermined by the manufacturer but are created in such a way that they can be configured by engineers in the field to perform a variety of different functions. In comparison to an FPGA, however, these devices contain a relatively limited number of logic gates, and the functions they can be used to implement are much smaller and simpler. At the other end of the spectrum are ASICs and ASSPs that can contain hundreds of millions of logic gates and can be used to create incredibly large and complex functions. [1].

ASIC

ASICs are virtually any chip that performs a predefined task. Since ASICs are created for a specific task, modification of its design is almost impossible at the later phase of the designs of ASICs. ASICs provide higher performance and higher densities in the chip for very large complex designs thus they are expensive. ASICs provide for flexibility for mixed signal designs but may introduce increased cost and schedule delays. However, modifications to the design are impossible late in the design process. Testing and debugging of ASIC is much more difficult and the volume of production of ASICs need to be enough sometime to come close to break even cost of production and thus is not suitable for many designs.

DE10-standard Developmental Board

Several companies manufacture FPGAs including Intel, Xilinx, Lattice Semiconductor, and Microchip Technology among others.

The DE10-standard Development board, shown in Figure 1, is built around an Intel System-on-Chip (SoC) FPGA. The Cyclone® V FPGA on the DE10-standard board is a low cost, low power, and small form factor (as small as 11 by 11 mm^2) solution. The Cyclone V is typically used in high-volume applications [3].

The Cyclone V SoC FPGA on the DE10-standard integrates a dual-core ARM Cortex-A9 processor, memory interfaces, DSP blocks, and embedded memory on a single chip. The board also has high-speed DDR3 memory, video and audio capabilities, ethernet networking, and more [4].

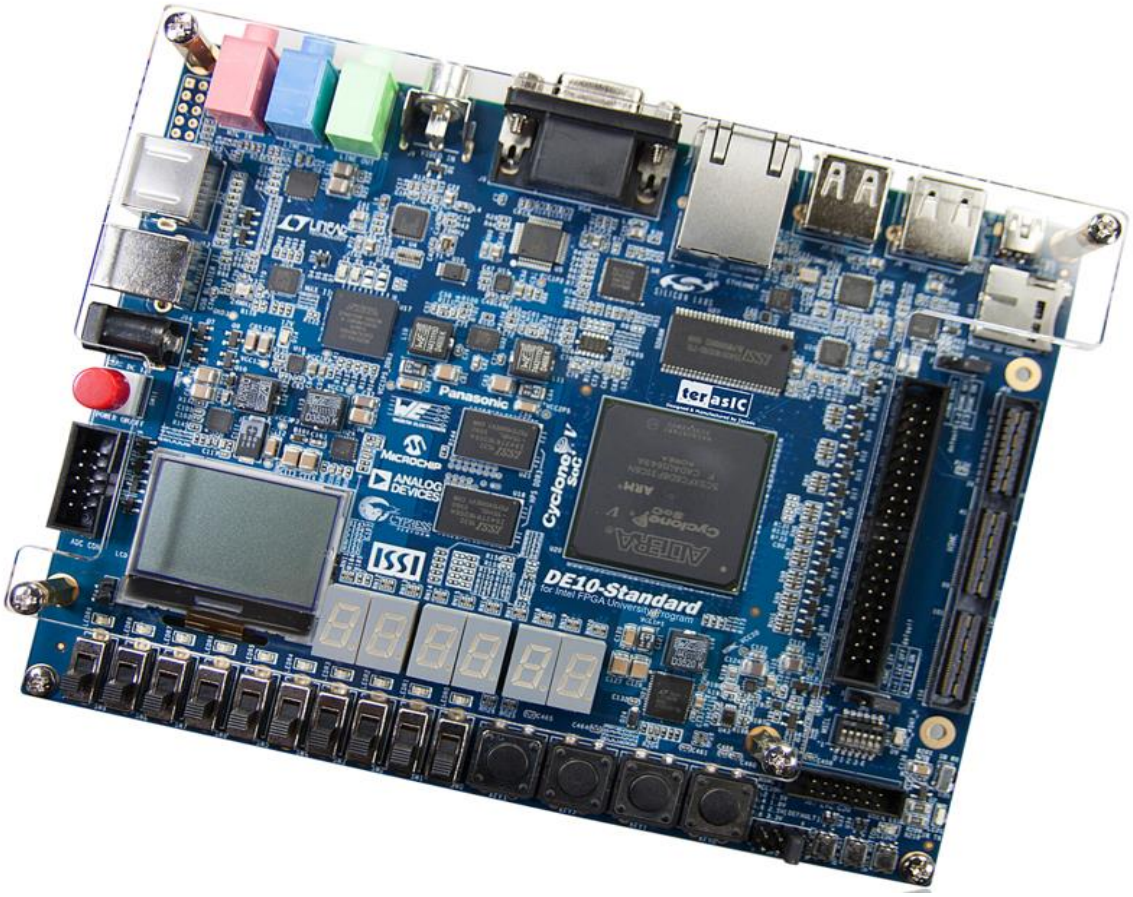

Figure 1: Intel's DE-10 Standard board.

Intel Quartus Prime Lite Software
Intel provides computer aided design (CAD) software named Quartus that allows users to design digital circuits. Quartus supports both functional and timing simulation and programming FPGAs to implement designs.

Design Using Quartus and FPGAs
Design Entry: circuit is entered into CAD software using schematics or hardware description language (HDL).

Design Synthesis: the CAD software (like Intel Quartus Prime) is used to partition and map the design to the function blocks of the programmable device.

Functional Simulation: simulation to ensure that design logic is correct.

Timing Analysis and Simulation: verifies that the design meets any timing specifications and constraints.

Production: design is downloaded into the FPGA, perform final tests of the design

References

[1] FPGAs Instant Access - 1st. ed. by Clive Maxfeild - Pub: Newnes, ISBN-13: 978-0750689748
[2] Retrieve from https://en.wikipedia.org/wiki/Field-programmable_gate_array
[3] Retrieve from www.intel.com
[4] Retrieve from www.de10-standard.terasic.com

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