FPGA Logic Cells and Architecture

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Overview

- An FPGA contains a large number of logic cells. Each logic cell can be configured to implement a certain set of functions.

- Each logic cell has a fixed number of inputs and outputs.

- Logic cells used in FPGAs
  - Multiplexer based logic cells (e.g. Actel FPGAs)
  - Memory based logic cells (e.g. Xilinx FPGAs)
A multiplexer-based logic module is typically composed of a tree of 2-to-1 MUXes.
Multiplexer Logic as Function Generators

- **Shannon's Expansion Theorem**

  \[ F(a) = a \cdot F(a=1) + a' \cdot F(a=0) \]

  - \( F(a=1) \) represents the function evaluated with \( a=1 \)
  - \( F(a=0) \) represents the function evaluated with \( a=0 \)

  - example

    \[ F(a) = (b \cdot (a+c) + d \cdot a')' \]
    \[ = a \cdot b + a' \cdot (b \cdot c + d)' \]

- **Implement \( F(a) \) using multiplexers**

  ![Diagram of multiplexer](image-url)
Actel ACT2 and ACT3 Logic Modules

- Flip-flop can be incorporated into a multiplexer-based logic module to implement sequential logic.
Memory Based Logic Cells

- A memory based logic cell is also called look-up table (LUT) based logic cell (memory is the LUT).
- Any function of up to K variables can be implemented by a k-input LUT (memory).
- D flip-flops can be included in LUT based logic cells to implement sequential circuits.
Implement Function $Y = a \cdot b + b \cdot c'$

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Truth Table
Xilinx XC3000 Configurable Logic Block
Altera FLEX Logic Element
How to Build a LUT

Source: Altera white paper: FPGA Architecture
Determining the Optimal Size of LUT

- Small size LUT increases the level of logic implementation and, hence, increases circuit delay.
- Large size LUT increases silicon area and cost since some of their inputs are not used in logic implementation.

Source: Altera white paper: FPGA Architecture
Example: Xilinx Virtex II

Block SelectRAM™ resource

Dedicated multipliers

Programmable interconnect

Configurable Logic Blocks (CLBs)

I/O Blocks (IOBs)

Clock Management (DCMs, BUFGMUXes)

Source: Xilinx Basic FPGA Architecture
Adding Analog Flavor to Programmable Devices

- Some latest FPGA devices also contain programmable analog components to provide single-chip solutions for mixed-signal applications:
- Example: Actel SmartFusion

Source: www.actel.com