Fundamentals of SoC (System on Chip)

1. What is a System on Chip (SoC)?

- A single chip combines:
    - CPU (central processing)
    - Memory (RAM/ROM)
    - I/O Ports (connectivity)
    - GPU (graphics)
    - DSP (audio/video processing)
    - Power Management
    - Additional features: Wi-Fi, Bluetooth, security modules

Benefits

- Space-saving: miniaturizes device hardware
- Energy efficient: less power draw
- High performance: fast data transfer
- Cost effective: lowers manufacturing costs
- Reliability: fewer failure points

Common Applications

- Smartphones
- Wearables (smartwatches)
- IoT devices
- Embedded automotive/TV systems

Challenges

- Complex design/fabrication
- Heat management
- Low flexibility post-fabrication

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2. Types of SoCs

- Microcontroller-based SoC
    - For simple control and IoT applications
    - Low power, efficient
- Microprocessor-based SoC

    - Runs operating systems; higher processing
    - Used in phones, tablets
- Application-specific SoC
    - Custom for graphics, AI, networking, industry

SoC Design Flow

- Define requirements
- System-level modeling
- Component selection
- Integration and testing

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3. VSDBabySoC Architecture

Major Components

- RVMYTH (RISC-V CPU):
    - Open-source, simple, customizable
    - Handles digital processing and analog handoff
- Phase-Locked Loop (PLL):
    - Generates stable, synchronized system clocks
    - Prevents timing mismatches
- Digital-to-Analog Converter (DAC):
    - Converts processed data to analog signals
    - Allows output to audio/video devices

Key Operations

- Initialization and Clocking:
    - Input triggers PLL to lock frequency
    - PLL synchronizes CPU and DAC timing
- Data Processing:
    - CPU's r17 register cycles through output values
    - DAC receives data for analog conversion
- Analog Output:

- Converted analog data saved as OUT
- Ready for external device input—TV, phone, etc.

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4. Component Details

Phase-Locked Loop (PLL)

- Purpose: Synchronize output frequency/phase to a reference input
- Core Parts:
  - Phase Detector
  - Loop Filter
  - Voltage-Controlled Oscillator (VCO)
- Functions:
  - Minimize clock distribution delays/jitter
  - Manage multiple frequency needs on chip
  - Handle frequency tolerance/stability/aging

Digital-to-Analog Converter (DAC)

- Function: Converts digital binary (multi-bit input) to analog output
- Types:
  - Weighted Resistor DAC
  - R-2R Ladder DAC
- Usage in VSDBabySoC: 10-bit resolution for high-fidelity analog signaling

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5. Why Use On-Chip PLL?

- Reduces clock delays across chip (critical for performance)
- Handles multiple clock requirements with high stability and accuracy
- Improves synchronization despite external clock jitter or deviations

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6. Why Digital-to-Analog Circuits Matter

- Essential bridging technology for connecting digital systems to analog world
- Enables audio/video outputs and sensor interfacing in embedded systems

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7. Learning Outcomes

Fundamentals of SoC (System on Chip)

- Master SoC integration—combining RISC-V processing, clock management, and analog output
- Understand practical challenges and solutions in digital-analog interfacing
- Foundation for experiment and innovation in open-source hardware using Sky130 technology