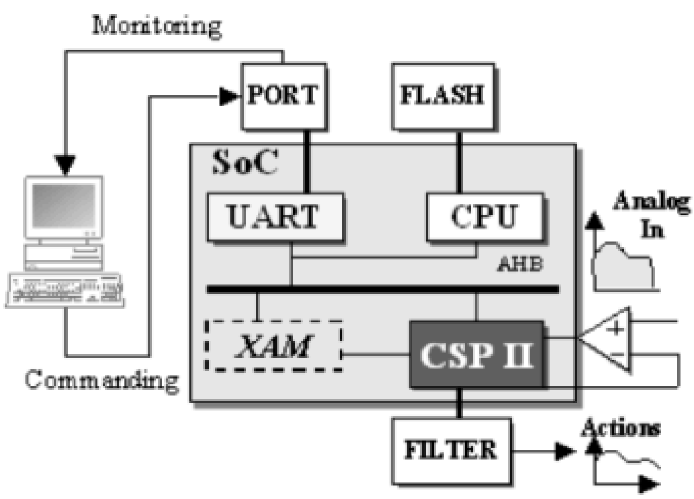
Team_2
Task_7

System-on-Chip (SoC) Design for Embedded Real-Time Control Applications

INTRODUCTION

The development of System-on-Chip (SoC) solutions for embedded real-time (RT) control applications integrates diverse functionalities onto a single FPGA platform. This approach incorporates a general-purpose processor, a specialized application-specific processor (CSP II), and standard external communication interfaces. The SoC design supports re-programmability, high-speed operation, and adaptive real-time control capabilities, consolidating all digital electronics into a single device and minimizing external logic requirements. Automated software libraries facilitate system programming by simulating control models and transforming control equations into native processor instructions. Key areas of focus include SoC architectures, hardware/software co-design, and optimization for numerical precision to meet stringent sample rate demands typical in real-time control systems.

ARCHITECTURE



The architecture integrates all digital electronics into a single FPGA, minimizing external logic.

1. Control Kernel:

- Central to the system, manages all control aspects.
- Includes an AMBA compliant bus facilitating communication between a general-purpose microprocessor and the CSP II (Control System Processor II).
- CSP II handles high-speed control execution, incorporating Successive Approximation Converter (SAC) units and Pulse Width Modulation (PWM) units for analog input and output.
- Executes control tasks such as sensor input conversion, control law execution, and sending actions to the system.

2. Adaptation Management:
- Runs concurrently with control execution.
- Managed by the CPU, which periodically monitors control state variables stored in the CSP II.
- Computes new coefficients based on variable values.
- Optionally supported by the XAM (eXtended Adaptation Unit) for complex, high sample rate calculations; otherwise, a C-based algorithm runs on the CPU.

3. Communication Section:
- Provides essential support for general data transfer with external devices.
- Includes a UART core for serial communication, ensuring compatibility with common applications.

FEATURES

1. Integration of Functional Blocks: SoC design aims to integrate all necessary functional blocks onto a single chip.

2. Real-Time Capability: Embedded systems for real-time control require deterministic behavior, where tasks are completed within specified time constraints.

3. Low Power Consumption: Many embedded applications operate on battery power or have strict power constraints.

4. Scalability and Flexibility: The ability to scale the SoC design allows it to adapt to varying application requirements and future upgrades.

5. Reliability and Safety: Embedded systems often operate in critical environments where reliability and safety are paramount.

SOFTWARE TOOLS:

- MATLAB-based Automation:
  - MATLAB automates the entire process of designing, simulating, and programming the SoC.
  - It facilitates hardware/software co-design by integrating control law simulation and generating necessary programming files.

- Offline and Online Tools:
  - Offline Suite:Converts control equations into native code for the CSP II processor and facilitates cycle-accurate simulation. It also creates C files for the ARM processor to direct system actions.
  - Online Java-based Tool: Enables real-time control and graphical monitoring of the system. It allows for system command execution and provides visual feedback on controller state variables, system inputs/outputs, etc. This tool also alerts users to critical values nearing thresholds during operation.

CONCLUSION:

In summary, this project aims to create a single-chip solution for complex embedded real-time control applications. It automates system programming and optimization with software libraries, simplifying tasks for control engineers. System operation and monitoring are also automated through a GUI. The CSP II, the main control unit, is continuously enhanced with new features. Testing and refinement are conducted using an Altera Development Board, while a magnetic levitation vehicle serves as a compelling demonstration of the SoC design's capabilities in practical settings.

REFERENCES

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