

Residency Project: Designing and Implementing a Microprocessor Using Gem5 Simulation Software

Objective:

In this part of the final project, you will apply your understanding of low-power and energy-aware microprocessor design principles by designing and implementing a microprocessor using the gem5 simulation software. Your project will include defining the architecture, implementing the design, simulating performance, and optimizing for energy efficiency. The final submission will demonstrate your ability to translate theoretical knowledge into practical application and will include both a detailed report and a presentation.

Project Overview:

This part of the final project challenges you to utilize gem5, a widely-used computer architecture simulator, to design and implement a low-power microprocessor. You will define the architectural specifications, implement the design, conduct simulations to evaluate performance and power consumption, and optimize your design based on the results. The culmination of your efforts will be a comprehensive project report and an oral presentation demonstrating your microprocessor design's efficacy and energy efficiency.

Project Phases:

Phase 1: Architecture Definition and Design (Deliverable 1)

Tasks:

1. Define Microprocessor Architecture:

- Choose a target application or use case for your microprocessor (e.g., IoT device, mobile processor, embedded system).
- Define the key architectural features (e.g., instruction set, pipeline depth, cache hierarchy, power management features).

2. Design Low-Power Features:

- Incorporate energy-efficient design techniques (e.g., dynamic voltage and frequency scaling, clock gating, power gating).
- Justify your design choices based on industry practices and recent research.

Deliverable 1 Requirements:

A written report (4 pages, excluding references and title page, APA format) detailing:

- Target application and key architectural features.
- Low-power design techniques implemented.
- Justification for design choices.

Phase 2: Implementation Using Gem5 (Deliverable 2)

Tasks:

1. Setup Gem5 Environment:
 - Install and configure gem5 on your development environment.
 - Familiarize yourself with gem5's components and scripting capabilities.
2. Implement Microprocessor Design:
 - Translate your architectural specifications into gem5 configurations.
 - Implement the defined low-power features within gem5.
3. Validate Implementation:
 - Run preliminary simulations to ensure the correctness of your implementation.
 - Debug and refine your design as necessary.

Deliverable 2 Requirements:

A detailed implementation guide (4 pages, excluding references and title page, APA format) including:

- Installation and configuration steps for gem5.
- Step-by-step implementation process.
- Preliminary simulation results and validation procedures.

Phase 3: Performance and Power Simulation (Deliverable 3)

Tasks:

1. Design Simulation Experiments:
 - Define metrics for performance and power consumption (e.g., instructions per cycle, energy per instruction).
 - Design experiments to measure these metrics under various workloads.
2. Conduct Simulations:
 - Run simulations using gem5 to collect data on performance and power consumption.
 - Compare the results with benchmarks or theoretical expectations.
3. Analyze and Optimize:
 - Analyze the simulation results to identify bottlenecks and inefficiencies.
 - Implement optimizations to improve energy efficiency without significantly compromising performance.

Deliverable 3 Requirements:

A simulation and optimization report (4 pages, excluding references and title page, APA format) including:

- Description of simulation experiments and metrics.
- Detailed simulation results.
- Analysis of results and optimization steps taken.
- Final performance and power consumption metrics.

Final Report and Presentation (Deliverable 4)

Tasks:

1. Compile Comprehensive Final Report:

- Integrate all previous deliverables into a cohesive final report.
- Ensure the report includes a comprehensive literature review, architectural design, implementation details, simulation results, and optimizations.

Deliverable 4 Requirements:

A comprehensive final report (12-16 pages, excluding references and title page, APA format) including:

- Integrated content from Deliverables 1, 2, and 3.
- Discussion on the overall impact and future research directions.

A 15-minute oral presentation (slides and script) summarizing your project.