**ELC 5313: Advanced Computer Architecture**

**Fall 2025**

**Lab 3: Register File and Instruction Queue**

**Introduction and Scope**

In this lab, you will begin implementing the front-end of an out-of-order execution pipeline. Specifically, you will complete two key components:

1. **Instruction Queue (IQ)** – manages instruction fetching, issuing, execution tracking, and completion.
2. **Register File (Registers)** – provides register read and write functionality while supporting register renaming for out-of-order execution.

Together, these modules form the foundation for Tomasulo’s Algorithm — allowing instructions to issue and execute dynamically while preserving data dependencies.

In a basic in-order processor, each instruction must wait for previous instructions to complete before executing. Tomasulo’s algorithm removes this bottleneck by introducing:

* **Reservation stations (RS):** temporary storage for instructions waiting for operands or execution units.
* **Register renaming:** eliminates false data dependencies by mapping architectural registers to reservation stations.
* **Instruction queue:** holds instructions as they move from fetch to issue and beyond.

The **instruction queue** manages when instructions are fetched, when they are ready to issue to available reservation stations, and when they can be removed after execution completes.  
The **register file** is responsible for tracking the latest producer (reservation station) for each register and providing operands when they are ready.

**Schedule**

* **Week 1 (today):**
  + Register module completion
* **Week 2:**
  + Instruction Queue module completion

You are welcome to work ahead.

**Provided Files**

* registers.sv
* resgisters\_tb.sv
* .instruction\_queue.sv
* Instruction\_queue\_tb.sv

**Module 1: Registers**

**Big Picture**

This module is similar to the *register file* from Computer Organization but extended for out-of-order execution.

1. **Reading operands:**  
   Each instruction can read two source registers (A\_address and B\_address). If a register’s value is ready, it is output directly. If it’s not ready because a reservation station is still computing it, the module outputs the reservation station number instead and marks the output as invalid.
2. **Deferring writes:**  
   Unlike the in-order register file, the destination register is not updated immediately. Instead, the register file stores the *reservation station number* that will eventually produce that register’s new value.
3. **Updating after execution:**  
   When a reservation station completes, it writes back the produced value to any registers that were waiting on it.

**Tasks**

1. Operand Fetch (Negative Clock Edge)

2. Register Update (Positive Clock Edge)

**Expected Behavior**

When simulated:

* Instructions that read from ready registers output their actual values.
* Instructions waiting on data from reservation stations output the RS identifiers.
* Once the producing RS completes and writes back, the register file automatically updates with the new value.

A screenshot of a computer

AI-generated content may be incorrect.

**Module 2: Instruction Queue**

**Big Picture**

The **instruction queue** controls instruction flow between the fetch stage and the reservation stations.  
It tracks instruction status through multiple stages:

| **Stage** | **Description** |
| --- | --- |
| Fetch | Instruction is loaded from memory into the queue |
| Issue | Instruction is sent to a reservation station |
| Execute | Instruction is actively running in an execution unit |
| Write Back | Instruction has completed and can retire |

**Tasks**

1. Fetch Block

2. Issue Block

3. Issue Completion Block

4. Execute Start Block

5. Write Back Block

6. Instruction Removal Block

**Expected Behavior**

When simulated:

* Instructions will continuously fetch from memory into the queue.
* When the adder is available, one instruction will issue each cycle.
* As reservation stations confirm execution, instructions update their status and are eventually removed.
* The queue contents should dynamically reflect instruction flow through fetch → issue → execute → write-back → retire.

A screenshot of a computer program

AI-generated content may be incorrect.

**Deliverables**

1. registers.sv – completed module.
2. Instruction\_queue.sv – completed module.
3. Screenshots of each waveform simulation showing correct register redirection and instruction flow, and status updates. Separate waveforms for each module. (Include these in your lab report).
4. Lab Report: Your report should give details about the work distribution within the group (who did what), milestones in your work, and your implementation decisions (why did you choose the way you did it, and/or how did you do that).

**Grading Rubric**

* **Lab Report** (50 pts)
  + Complete report. Clear documentation about work distribution and process. Contains simulation waveforms that demonstrate proper behavior of both modules with clear waveform evidence; shows correct data flow, redirection, and instruction status update.
* **Register Module Functional** (20 pts)
  + Correct implementation of operand fetch, redirection logic, and register updates.
* **Instruction Queue Module** (20 pts)
  + Correct implementation of fetch, issue, execute, write-back, and instruction removal.
* **Code clarity & comments** (10 pts)
  + Descriptive names and comments explaining design choices.

**Due Date**

**10/22/2025** (Submit individually via Canvas). You can work in pairs for this lab.