Performance Analysis

Comparing multi-cycle vs single cycle UST-3400 processor designs

To compare the single cycle and multi-cycle simulators, four assembly programs were created. Each program focused on one or two instructions by using many of them. The instructions groups were *add/nand, lw/sw, beq, and jalr*. Creating more than one program shows the difference between the simulators depending on the instruction. These programs were run on both the single cycle and multi-cycle simulators and their total instructions and cycles were recorded. The simulators will be compared using the speedup between the two. Below is how speedup is calculated using the performance of each simulator.

Speedup = perf(A) / perf(B) = exec(B) / exec(A) = n

- exec = IC * CPI * t_{clk}
    - IC = total instruction count
    - CPI = average cycles per instruction
    - t_{clk}= clock cycle time

The speedup is the improvement one simulator has over the other. It says how many times faster a simulator is.

The performance analysis for each program on both simulators is below. The single cycle clock is 9 times slower than the multi-cycle clock so its clock speed will be multiplied by 9.

add and nand instructions

Multi-cycle

IC = 703
Cycles = 1821
Average CPI = Cycles / IC = 1821 / 703 = 2.59
Exec = IC * CPI * t_{clk} = 703 * 2.59 * t_{clk} = 1820.77 * t_{clk}

Single cycle

IC = 703
Cycles = 703
CPI = Cycles /IC = 703 / 703 = 1
Exec = 703 * 1 * 9t_{clk} = 6327 * t_{clk}

Speedup = perf(A) / perf(B) = exec(B) / exec(A) = 6327 / 1820.77 = **3.47**

The multi-cycle simulator is 3.47 times faster than the single cycle simulator for add and nand instructions.

lw and sw instructions

Multi-cycle

IC = 703
Cycles = 4221
Average CPI = Cycles /IC = 4221 / 703 = 6.00
Exec = IC * CPI * t_{clk} = 703 * 6.00 * t_{clk} = 4218 * t_{clk}

Single cycle

IC = 703
Cycles = 703
CPI = Cycles / IC = 703 / 703 = 1
Exec = 703 * 1 * 9t_{clk} = 6327 * t_{clk}

Speedup = perf(A) / perf(B) = exec(B) / exec(A) = 6327 / 4218 = **1.5**

The multi-cycle simulator is 1.5 times faster than the single cycle simulator for lw and sw instructions.

beq instruction

Multi-cycle

IC = 703
Cycles = 2621
Average CPI = Cycles /IC = 2621 / 703 = 3.73
Exec = IC * CPI * t_{clk} = 703 * 3.73 * t_{clk} = 2622.19 * t_{clk}

Single cycle

IC = 703
Cycles = 703
CPI = Cycles / IC = 703 / 703 = 1
Exec = 703 * 1 * 9t_{clk} = 6327 * t_{clk}

Speedup = perf(A) / perf(B) = exec(B) / exec(A) = 6327 / 2622.19 = **2.41**

The multi-cycle simulator is 2.41 times faster than the single cycle simulator for beq instructions.

jalr instruction

Multi-cycle

IC = 703
Cycles = 1421
Average CPI = Cycles /IC = 1421 / 703 = 2.02
Exec = IC * CPI * t_{clk} = 703 * 2.02 * t_{clk} = 1420.06 * t_{clk}

Single cycle

IC = 703
Cycles = 703
CPI = Cycles / IC = 703 / 703 = 1
Exec = 703 * 1 * 9t_{clk} = 6327 * t_{clk}

Speedup = perf(A) / perf(B) = exec(B) / exec(A) = 6327 / 1420.06 = **4.46**

The multi-cycle simulator is 4.46 times faster than the single cycle simulator for jalr instructions.

Results

Overall the multi-cycle simulator is much faster than the single cycle simulator. It is on average 2.96 times faster than the single cycle simulator. This is what was expected. The single cycle clock speed is set to the time of the slowest instruction while the multi-cycle clock speed is set to the fastest instruction. The single cycle clock is 9 times slower so it doesn't get as many instructions done as the multi-cycle simulator.