Project #2

Simulation of CPU, Cache, Bus, and Memory Datapath

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**II. Executive Summary**

This report goes over what project the group was assigned with, how the group went about designing and implementing the project by making certain assumptions, backing up those assumptions with correct output data. The report finishes with a longer conclusion and all the related code attached.

**III. Introduction**

Write policy descriptions

**IV. Design**

The group decided after lots of discussion to split all of the required pieces of structure into separate modules and then combine them into an overall dataflow. This allowed for each individual component to be thoroughly tested. The overall dataflow can be seen below as well as in the appendix.



Figure X: Datapath design of cache/memory system

Based on the figure above, the black lines are mostly data lines, and the orange lines are control inputs for specific block. There are six main blocks where a majority of the functionality takes place.

The ICache block is 256-Byte word-addressable cache (implemented as a 64x32 array, 2048 bits) The cache is directly mapped from memory so the following formula was used to calculate the index of the cache.

(1)

This block takes in the Instruction Address (Program Counter) from the test bench program, as well as a flag, IHC, to test the different functionality of either an Icache Hit or Icache Miss. Since we implemented a write through policy, on a cache hit we take the word value from cache and update it to memory. Upon a instruction miss in cache, the data will be fetched from memory. Since the Write Allocate strategy was implemented, a block of memory was put back in the cache to update it. The data is then correct and outputted. The mux on the top is to select either from the memory (ICache Hit) or from the cache after a block update (ICache Miss). The access time for the ICache operation is just 1 cycle (10 ns).

The Bus block is simply to model the bus delay. Since the specifications of the bandwidth of the bus stated, 32 words/cycle, the assumption was made that the bus will delay a full cycle when 32 words or less are put on the bus. Since the most that will put across the bus is a memory block (8 words) this assumption works.

The memory Block is 1024 Bytes of Byte-addressable storage (implemented as a 1024x8 array). The memory then has addresses from 0x0 0x3FF. When there is an ICache Hit, a word is brought into the memory to perform a word update, when there is an ICache Miss the Block of memory at the inputted address is outputted and write allocated back to cache to update the values in cache. After the correct instruction is retrieved from either the cache or memory, the Op-Code is inputted into the CPU Block. The memory has a port access time of 5 cycles/word for reads, and an additional memory read time of 3 cycles/word for a total of 8 cycles/word for reading. The memory has a port access time of 3 cycles/word for writes, and an additional memory write time of 4 cycles/word for a total of 7 cycles/word for writing.

The CPU is a simple block, based on the Op-code inputted from the instruction cache/memory process it will determine a couple output signals. The instructions that needed to be implemented are shown below:

|  |  |
| --- | --- |
| Common Name | Register Names |
| lw $s1, 200 ($t3) | lw R17,200(R11) |
| sw $s3, 100 ($t4) | sw R19,100(R12) |
| add $s3, $t3, $t2 | add R19,R11,R10 |
| beq $s5, $t6, 400 | beq R21,R14,0[400-PC] |
| bne $s5, $t6, 500 | bne R21,R14,0[500-PC] |
| lui $s6, 40 | lui R22,40 |

There are two types of instructions implanted ALU/Branch Instructions and Memory Access functions. The last four on the list above are the ALU/Branch instructions. These only require the use of register values. The Op-codes are determined to match specific instructions. For the beq and bne instructions in the CPU the ALU\_DONE flag will be set. For the other two, the register value will be updated with the proper value (add, lui). The Initial values of the register can be seen below.

|  |  |  |  |
| --- | --- | --- | --- |
| Register Number | Initial value | Register Number | Initial value |
| Reg 8 | 0x00000008 | Reg 17 | 0x00000017 |
| Reg 9 | 0x00000009 | Reg 18 | 0x00000018 |
| Reg 10 | 0x00000010 | Reg 19 | 0x00000019 |
| Reg 11 | 0x00000011 | Reg 20 | 0x00000020 |
| Reg 12 | 0x00000012 | Reg 21 | 0x00000021 |
| Reg 13 | 0x00000013 | Reg 22 | 0x00000022 |
| Reg 14 | 0x00000014 | Reg 23 | 0x00000023 |
| Reg 15 | 0x00000015 | Reg 24 | 0x00000024 |
| Reg 16 | 0x00000016 | Reg 25 | 0x00000025 |

This will give the following results for the Add and LUI.

|  |  |
| --- | --- |
| Register Names | Results |
| add R19,R11,R10 | R19 <= 0x00000021 |
| lui R22,40 | R22<= 0x00280022 |

These two instructions, like the branch instructions will output the ALU\_DONE flag to signal that this branch is complete. For Load Word the ALU calculates the Data Address, sets the R\_W flag to 1 to signal a read, D\_Type flag to signal for the data memory access, and finally the Register number where the data in the memory will be loaded into the register. For Store Word the ALU calculates the Data Address, sets the R\_W falg to 0 to signal a write, D\_Type flag to signal for the data memory access, and the data in Register 19 (which is initially 0x19).

The DCache datapath will only be run through when there is a data memory access. This is only for the instructions Load word and Store Word, and signaled from the CPU as the D\_Type signal. The DCache block is 128-Byte word-addressable cache (implemented as a 32x32 array). The cache is directly mapped from memory so the following formula was used to calculate the index of the cache.

(2)

Once the correct value of the block is reached on a read hit (DCache Hit and Load Word), it will update the word in memory and output that data at the memory address, finally updating the value in the register file. On a read miss (DCache Miss and Load word), it will find the correct value in memory, and write allocate a memory block back to the DCache, updating 8 words in the DCache. On a write hit (DCache Hit and Store Word), the DCache will write Data value output from the ALU to the DCache, then it will be updated in memory. On a write miss (DCache Miss and Store Word), the DCache will store the correct value in memory, and then write allocate a block of memory back to the DCache.

**V. Implementation**

**VI. Results**

**VI. Discussion**

**VII. Conclusions**

**Attachments**

Each individual program’s code will be attached, the individual test benches for the components won’t be necessary, since the overall test bench works without issue.