CS3410 Project 1 Design Document

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Introduction

Our MIPS processor will follow a five stage pipeline as discussed in class. Each stage will be blocked off with registers storing necessary data. Instructions will proceed through one stage of the pipeline per clock cycle. The overall diagram of how the stages are laid out is as follows:

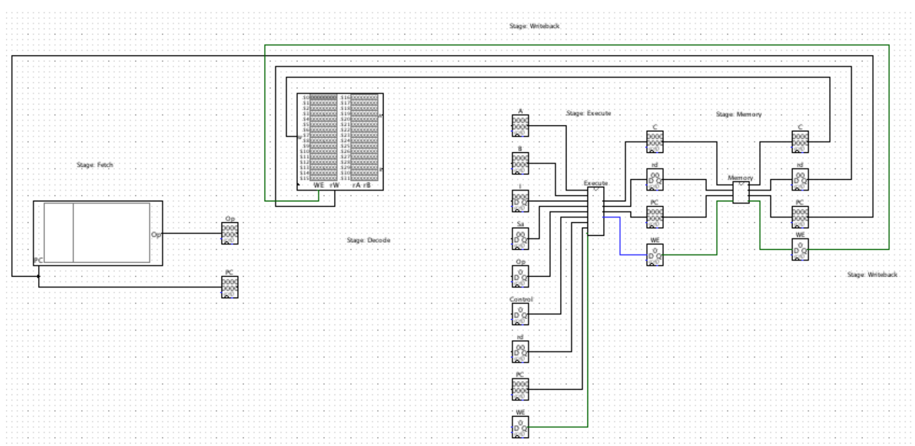

Figure 1: The layout of the MIPS pipeline in five stages.

This is merely a design diagram. While we will implement the pipeline processor in the overall layout and sub circuits shown, very few wires are currently connected. The fetch, decode, and execute stages are not yet implemented, although space for them has been allocated.

Fetch

This stage Fetches the next instruction from the instruction memory and updates the program counter. Both the instruction and PC+4 are passed into the register so that the next stage (Decode) has access to that information.

To calculate PC+4, we split off the lower two digits of the PC, use the +1 incremented to increment the remaining 30 bits, and rejoin them into one 32 bit bus.

The Fetch stage will also include a multiplexer to select between PC+4 and jump/branch targets, for Project 2.

Decode

This stage uses the bits in the instruction to determine several different values:

It determines the immediate value for immediate operations (this value is computed regardless of whether or not the operation is an immediate operation - it is selected for using a multiplexer in the next stage).

It determines which registers to read from (and reads those registers).

It determines a shift amount and op-code to send to the ALU.

It also determines jump and branch amounts (though these values are not used).

The registers at the end of this stage will store certain data for the next stage including the values of the read registers, PC+4, jump and branch targets, the immediate value, the shift amount, the op code, the write enable bit, and the register to write to. There are also two extra control bits indicating the presence of a set less than operation and whether it is signed or unsigned, one more indicating whether this is an immediate or register operation, and two dealing with the three conditional move or load operations.

We include a simplified truth table to show how the decoding logic will work. Op[6] refers to the op-code, the first 6 bits of the operation. Func[6] refers to the final 6 bits of the operation. The ALU[4] is the 4-bit control signal passed directly into the ALU.

OPCODE	OP[6]						FUNC[6]						ALU[4]			
ADDI	0	0	1	0	0	1	x	x	x	x	x	x	0	0	1	x
ANDI	0	0	1	1	0	0	x	x	x	x	x	x	1	0	0	0
ORI	0	0	1	1	0	1	x	x	x	x	x	x	1	0	1	0
XORI	0	0	1	1	1	0	x	x	x	x	x	x	1	1	0	0
SLTI	0	0	1	0	1	0	x	x	x	x	x	x	x	x	x	x
SLTIU	0	0	1	0	1	1	x	x	x	x	x	x	x	x	x	x
ADDU	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	x
SUBU	0	0	0	0	0	0	1	0	0	0	1	1	0	1	1	x
AND	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
OR	0	0	0	0	0	0	1	0	0	1	0	1	1	0	1	0
XOR	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	0
NOR	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	0

This represents a limited subset of the supported operations, and a limited subset of control bits. The decode logic takes in the 12 bits described above outputs 7 bits of control logic used in the execute stage as well as a 4 bit opcode. The logic functions and the meaning of these bits are as follows:

WE is a bit that is set if the given operation may write to a register. Note that this bit is set regardless of whether or not the operation actually does write to a register (consider the operation MOVN) - that is computed in the execute stage. The logic for WE is $(\sim op5)(\sim op4)op3 + \sim(op0op1op2op3op4op5) \sim ((\sim f5)(\sim f4)f3(\sim f2)(\sim f1))$

LUI is a bit which determines if the operation is an LUI operation. It is used to select the proper immediate value. The logic for LUI is $op2op1op0$.

The control logic bits $C0 - C4$ determined several different pieces of information. First, if the operation was either a MOVN or a LUI op, if it was one of the 2, $C0$ was 1, otherwise it was 0. Second, $C1$ held 1 if the op was a move op, 0 otherwise. $C2$ determined the sign of an SLT/SLTI op (0 for unsigned, 1 for signed). $C2$ was also 1 if the operation was a variable shift. $C3$ was 1 if the operation was a SLT/SLTI op, otherwise it was 0. Finally, $C4$ determined whether the operation was an immediate or a register operation. Note I do not include the logic here as it is rather complex. To see the logic, analyze the Decode circuit.

All of these bits were used in the execute stage to select for the correct operation/inputs through multiplexers. The $4-$bit opcode was passed into the ALU as it determined which ALU operation was to be computed.

Note that on page 5 of this design doc you can view the Decode stage of the pipeline.

Execute

This section sign-extends the immediate value and selects whether to use register B or the immediate value in the operation. Then, it performs the given ALU operation.

This result is then combined with some additional logic (comparators in the case of SLT or MOVZ for instance) and the result of the operation is outputted.

Scroll down to page 6 to view the execute stage.

The execute circuit has hazard detection in the top left, arithmetic computation and control in the top right, and write enable and target register computations at the bottom. Moving is conditional, so we compute the conditions and the controls that say whether we're moving into the write enable. The destination register is stored in a different part of the original operation for immediate arithmetic.

We implement data hazard detection using forwarding, with a dedicated hazard detection sub circuit. There will be no control or memory hazards in Project 1, because we do not support branching, jumping, or memory operations. Therefore, the correct data will be stored in pipeline registers farther ahead, and we can easily use forwarding to resolve all hazards.

The registers at the end of this stage will store PC+4, the result of the ALU operation, the write enable bit, and the register to write to.

Memory

This section will be a pass-through stage. There will not be any logic here, though it will be blocked off by registers so all operations have to spend a cycle in this stage. The registers at the end of this stage store the same values as the registers at it's beginning, for Project 1.

Writeback

This section will only write the results of the register and immediate operations that we have to implement. It will not write the bits read from memory (as these operations will not be implemented).

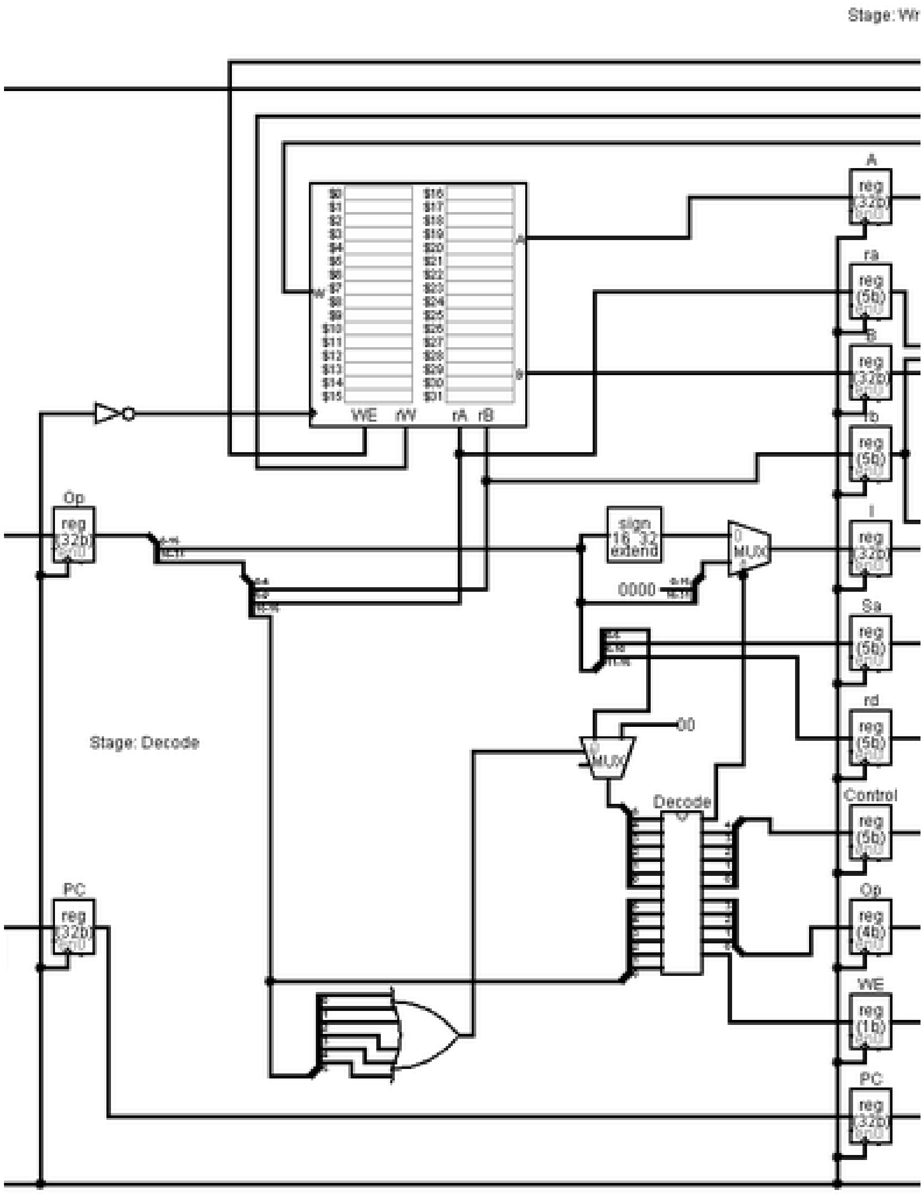

Figure 2: The Decode pipeline stage

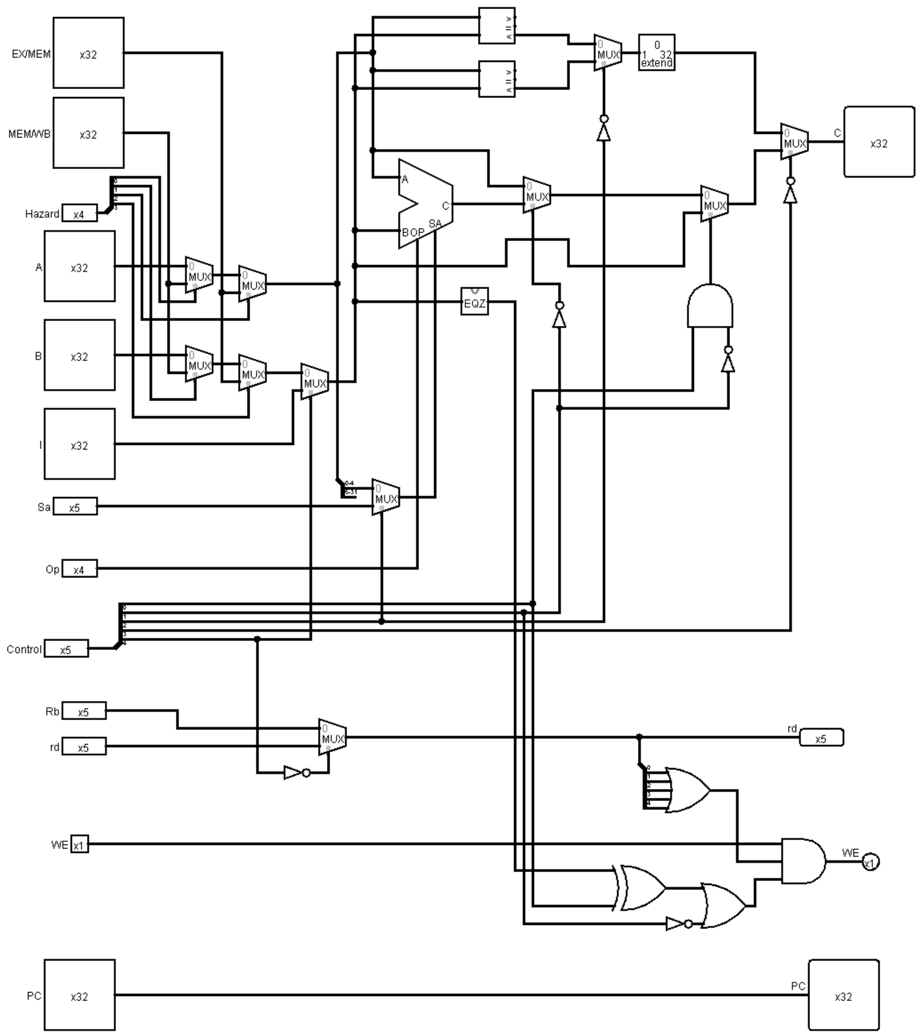

Figure 3: The Execute pipeline stage