CSCI 210: Computer Architecture
Lecture 25: Datapath

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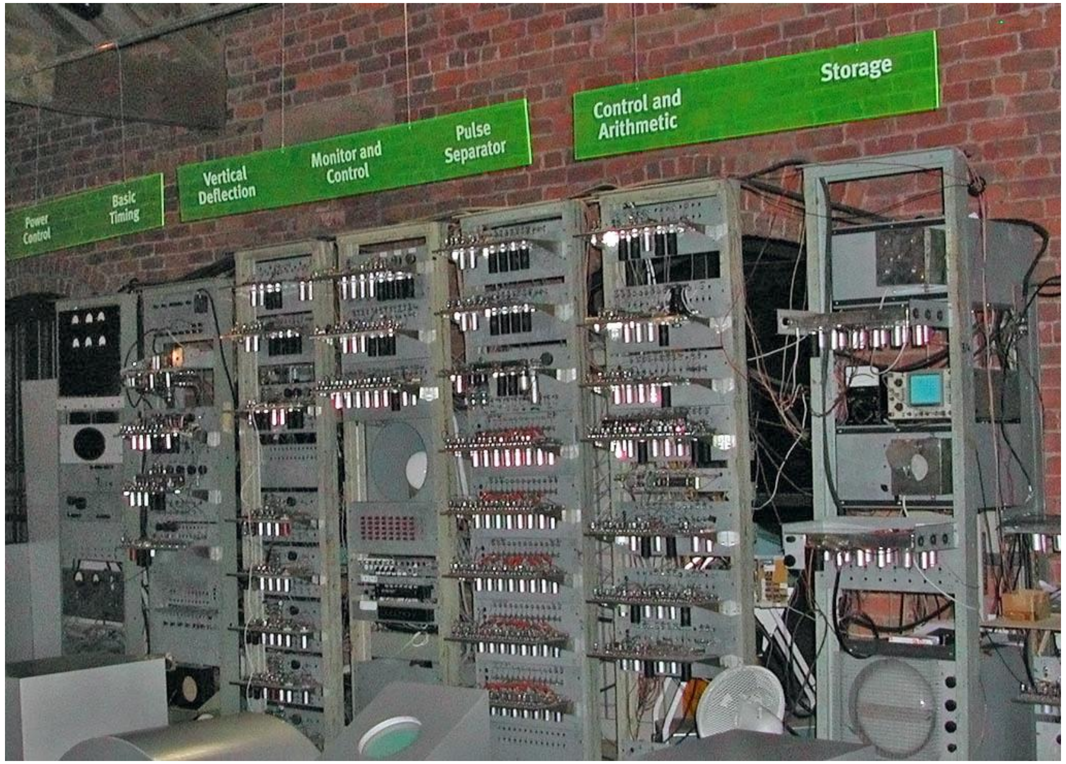
Slides from Cynthia Taylor

Today’s Class

- The datapath!

CS History: The Manchester Baby



- First stored-program computer
- Ran its first program on June 21, 1948
- Designed as a testbed for the first random-access memory
- Only arithmetic operations were addition and subtraction
- Its first program calculated the highest proper divisor of 2^{18} (262,144), by testing every integer from 2^{18} downwards
- This program was 17 instructions and took 52 minutes to run

The Processor: Datapath & Control

- We're ready to look at an implementation of MIPS simplified to contain only:
  - memory-reference instructions: `lw,  sw`
  - arithmetic-logical instructions: `add,  sub,  and,  or,  slt`
  - control flow instructions: `beq`

Generic implementation

- Fetch
  - Use the program counter (PC) to supply instruction address
  - Get the instruction from memory
  - Update the program counter to the next instruction
- Decode instruction
  - Read registers
  - Read the instruction to decide how to execute
- Execute
  - Perform necessary data manipulation
  - Write to registers

To fetch an instruction, what hardware do we need?

- Fetch
  - Use the program counter (PC) to supply instruction address
  - Get the instruction from memory
  - Update the program counter to the next instruction

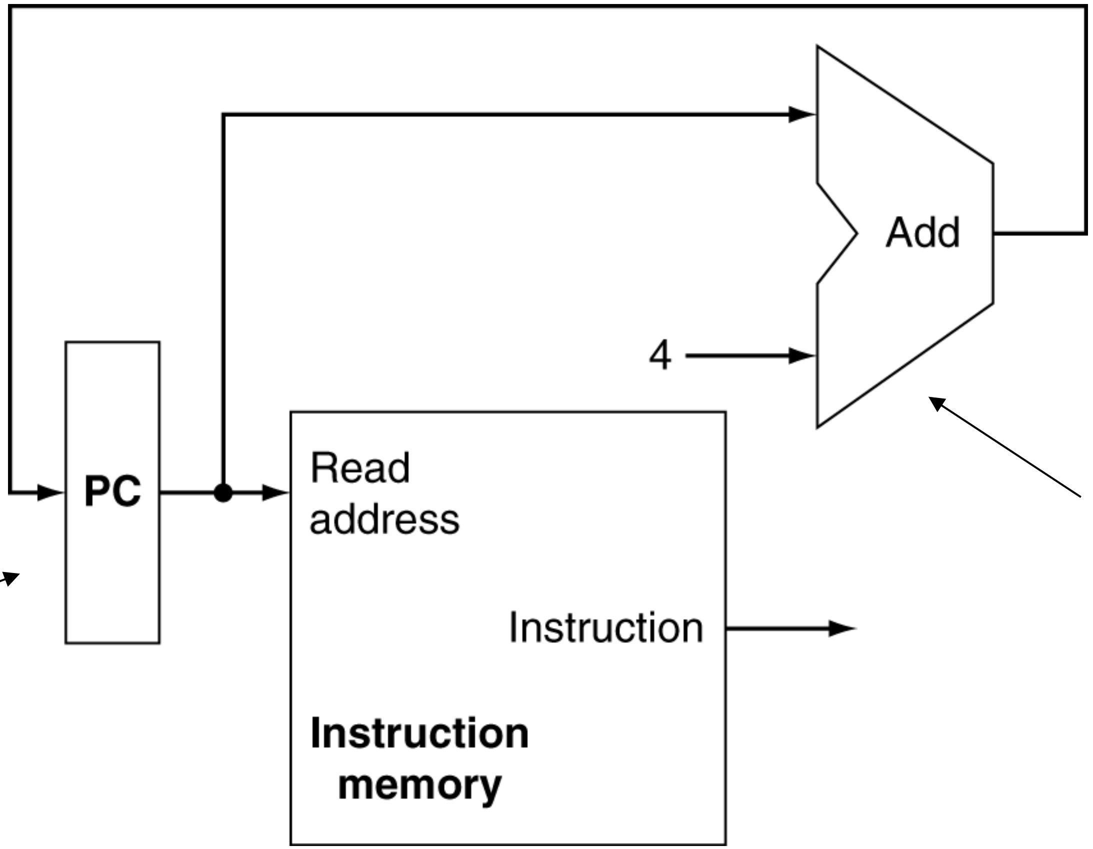
A. Register(s), Memory

B. Register(s), Adder, Memory

C. Register(s), ALU, Memory

D. More than this

Instruction Fetch



32-bit register

Increment by 4 for next instruction

Generic implementation

- Fetch
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  - Update the program counter to the next instruction
- Decode instruction
  - Read registers
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Registers for instructions

- add $t0, $t1, $t2 needs to read the values of registers $t1 and $t2 and write to register $t0
- lw $t0, 4($t8) needs to read one register and write one register
- sw $t0, -8($s0) needs to read two registers and write zero registers

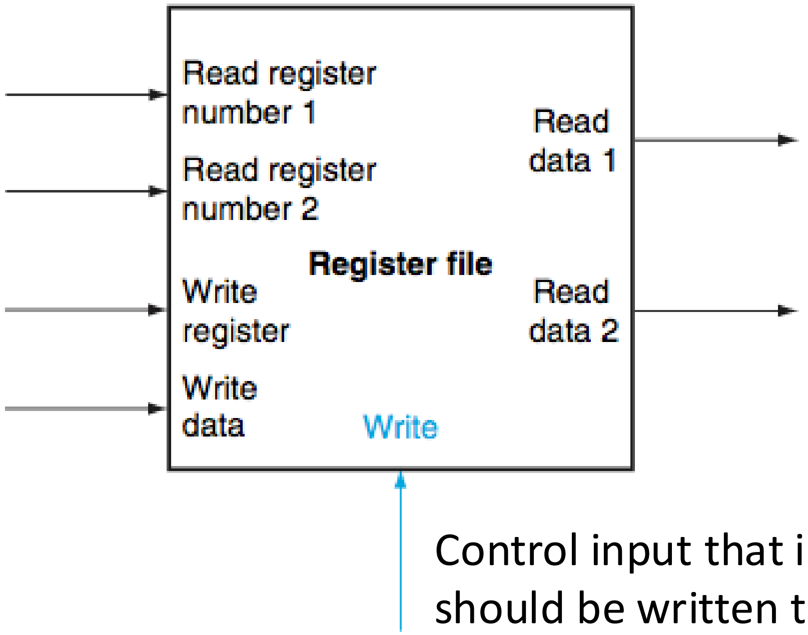
Interface for the register file

- We need the ability to read from up to 2 registers and write up to 1 register

Interface:

- Three 5-bit register select inputs (rs, rt, rd)
- Two 32-bit data outputs (data in rs and rt)
- One 32-bit data input (data to write to rd)
- One 1-bit control input (should input data be written to rd or not)

Register File



Control input that is 1 if the write data should be written to the register specified by write register

	6 bits	5 bits	5 bits	5 bits	5 bits	6 bits
R-type	**opcode**	**rs**	**rt**	**rd**	**sa**	**funct**

Generic implementation

- Fetch
  - Use the program counter (PC) to supply instruction address
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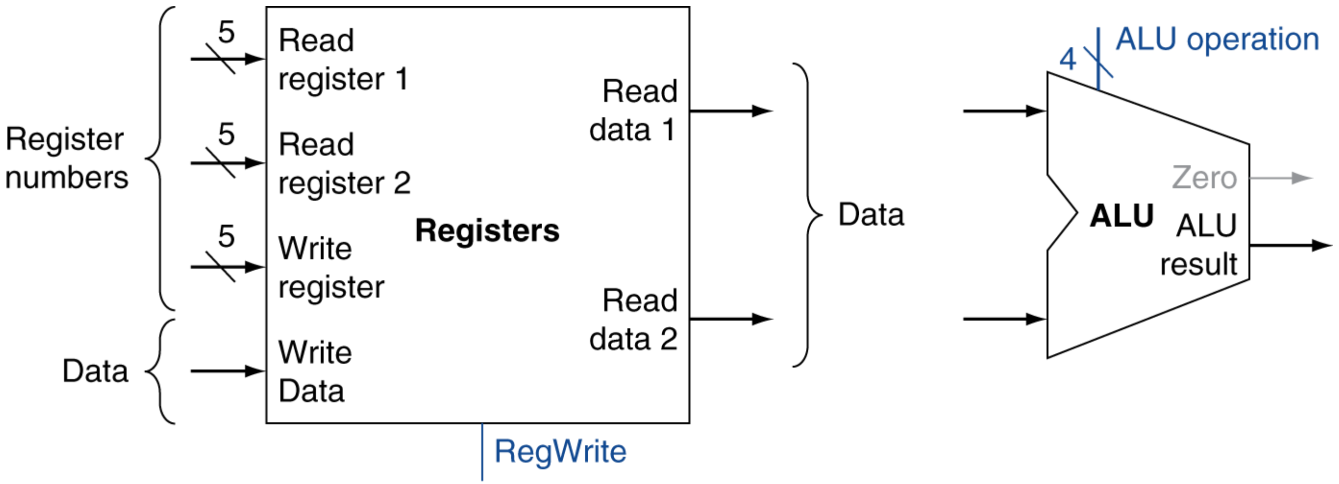
R-Format Instructions

- Read two register operands
- Perform arithmetic/logical operation
- Write register result



a. Registers

b. ALU

	6 bits	5 bits	5 bits	5 bits	5 bits	6 bits
R-type	**opcode**	**rs**	**rt**	**rd**	**sa**	**funct**

Data memory

- sub $t0, $t1, $t2 does not read or write memory
- lw $t0, 0($s0) reads 32-bits from memory
- sw $t0, 0($s0) writes 32-bits to memory

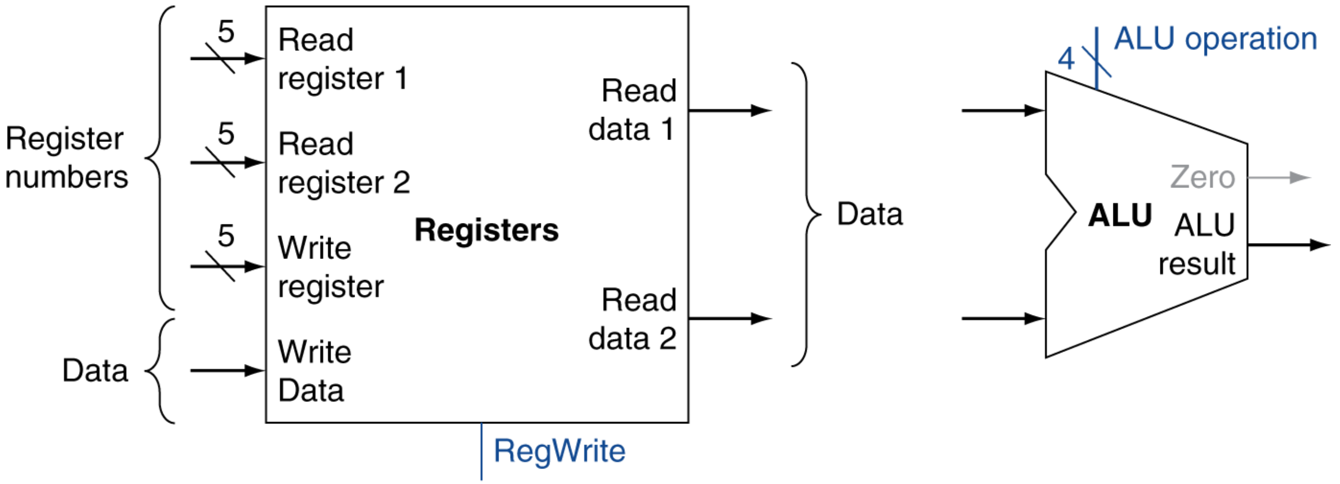
Which of these describes our interface for data memory? What do we need for lw 0($t3), $t2 or sw 4($t5), $t4

	Data Inputs	Data Outputs	Select inputs	Control inputs
A	One 32-bit input	One 32-bit output	One 5-bit input	2 bits
B	Zero inputs	One 32-bit output	Two 5-bit inputs	2 bits
C	One 32-bit input	One 32-bit output	One 32-bit input	2 bits
D	One 32-bit input	One 32-bit output	One 32-bit input	1 bit
E	One 32-bit input	One 32-bit output	One 5-bit input	1 bit

Data is what we read from/write to memory,
Select is the address we're reading/from writing to
control is what operation the data memory does (e.g., load or store)

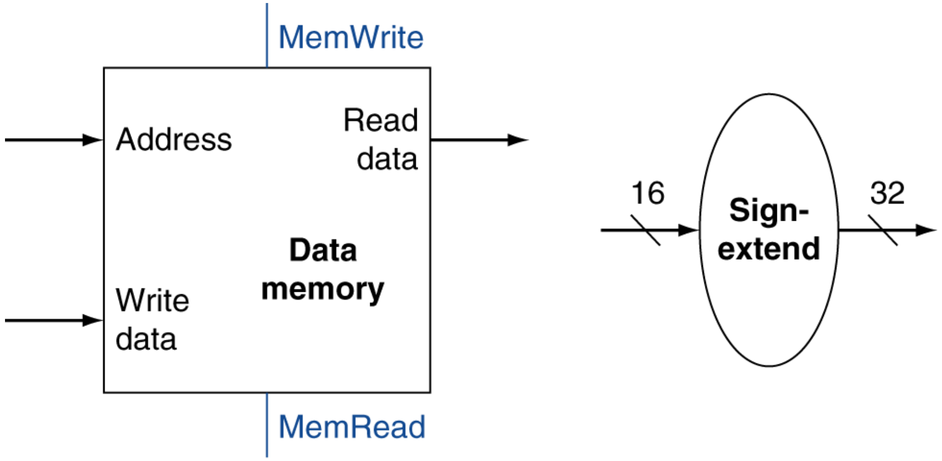
Load/Store Instructions

- Read register operands
- Calculate address using 16-bit offset
  - Use ALU, but sign-extend offset
- Load: Read memory and update register
- Store: Write register value to memory



a. Registers

b. ALU

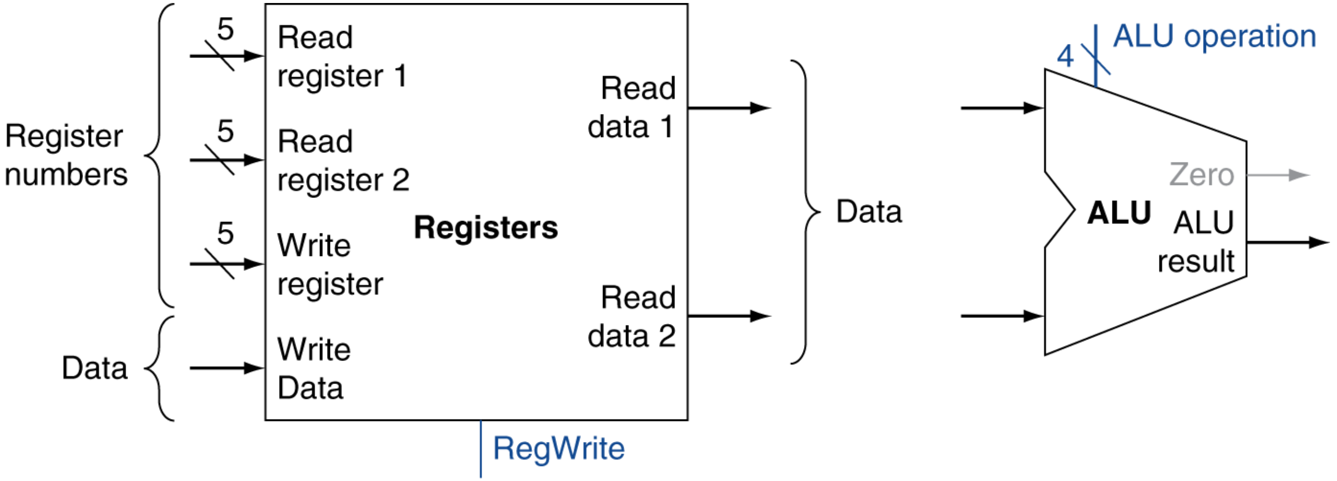


a. Data memory unit

b. Sign extension unit

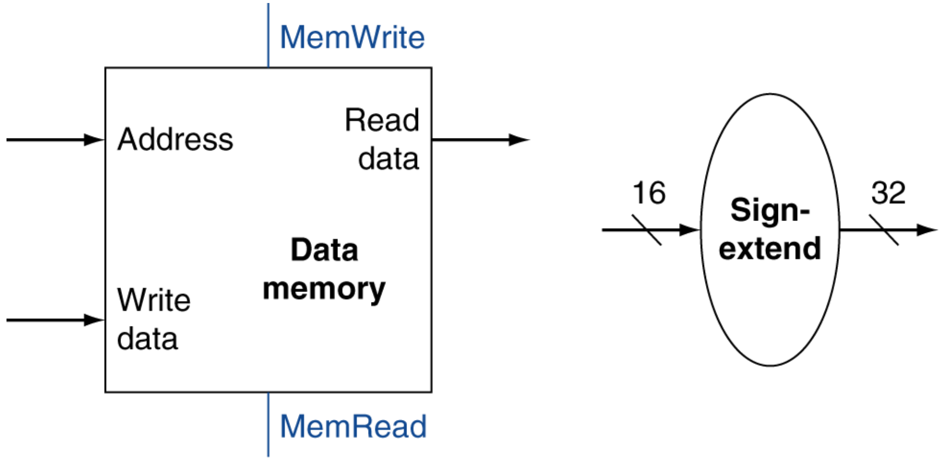
opcode	rs	rt	immediate

Memory



a. Registers

b. ALU



a. Data memory unit

b. Sign extension unit

opcode	**rs**	**rt**	**immediate**

Which is true about the ALU and the register file in MIPS?

A. The ALU *always* performs an operation before accessing the register file

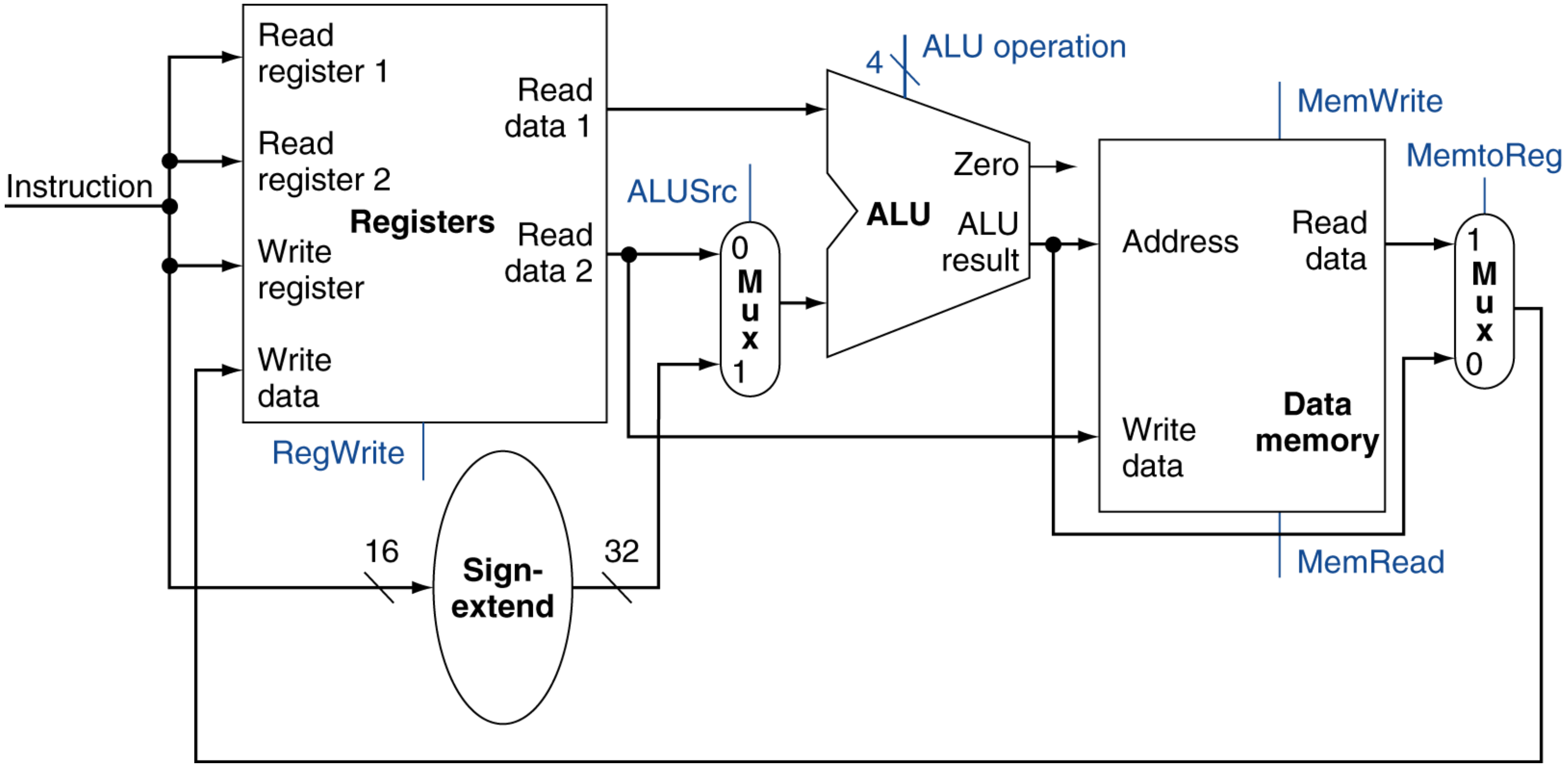
B. The ALU *sometimes* performs an operation before accessing the register file

C. The register file is *always* accessed before performing an ALU operation

D. The register file is *sometimes* accessed before performing an ALU operation

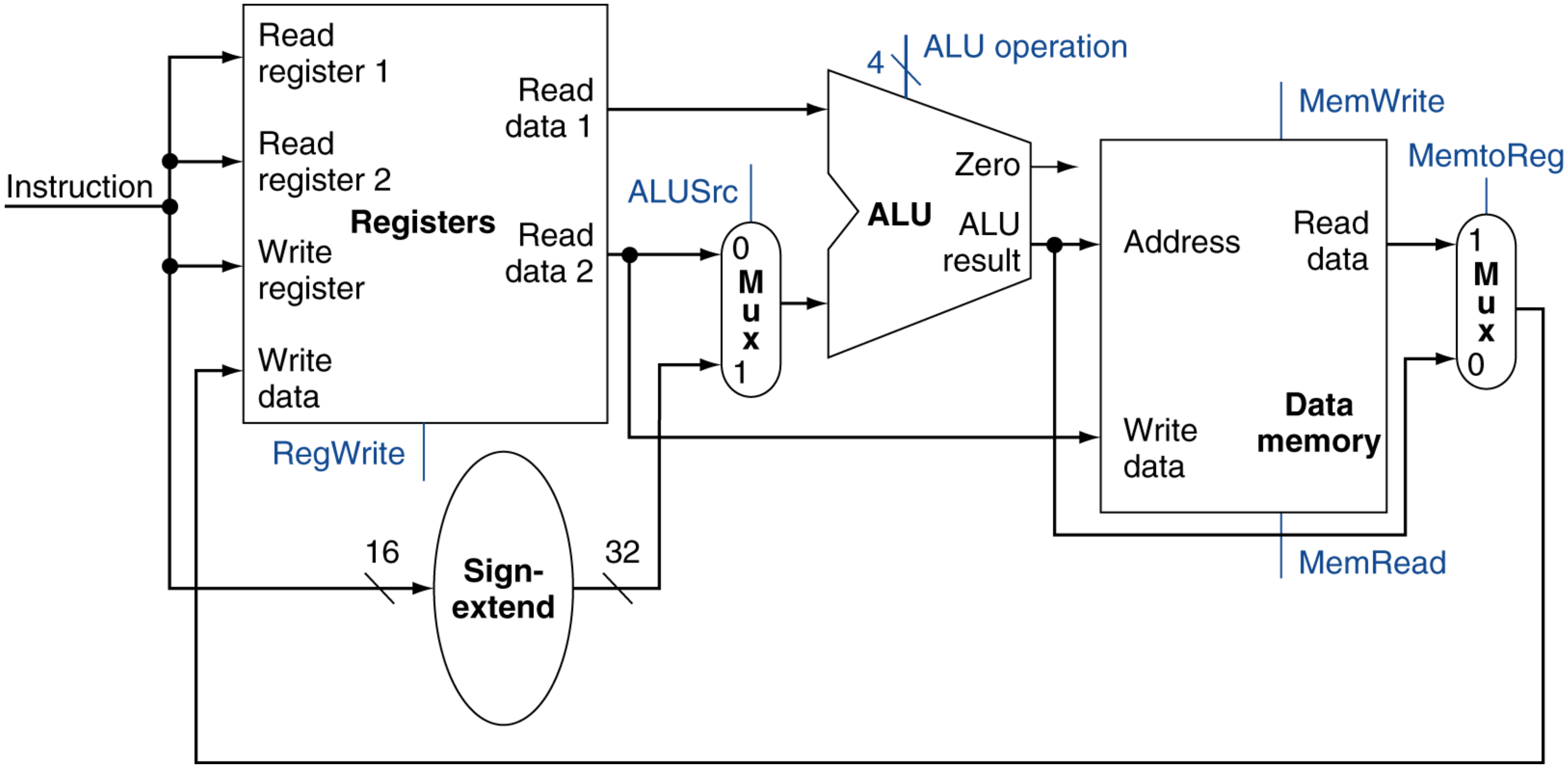
E. None of the above.

R-Type/Load/Store Datapath



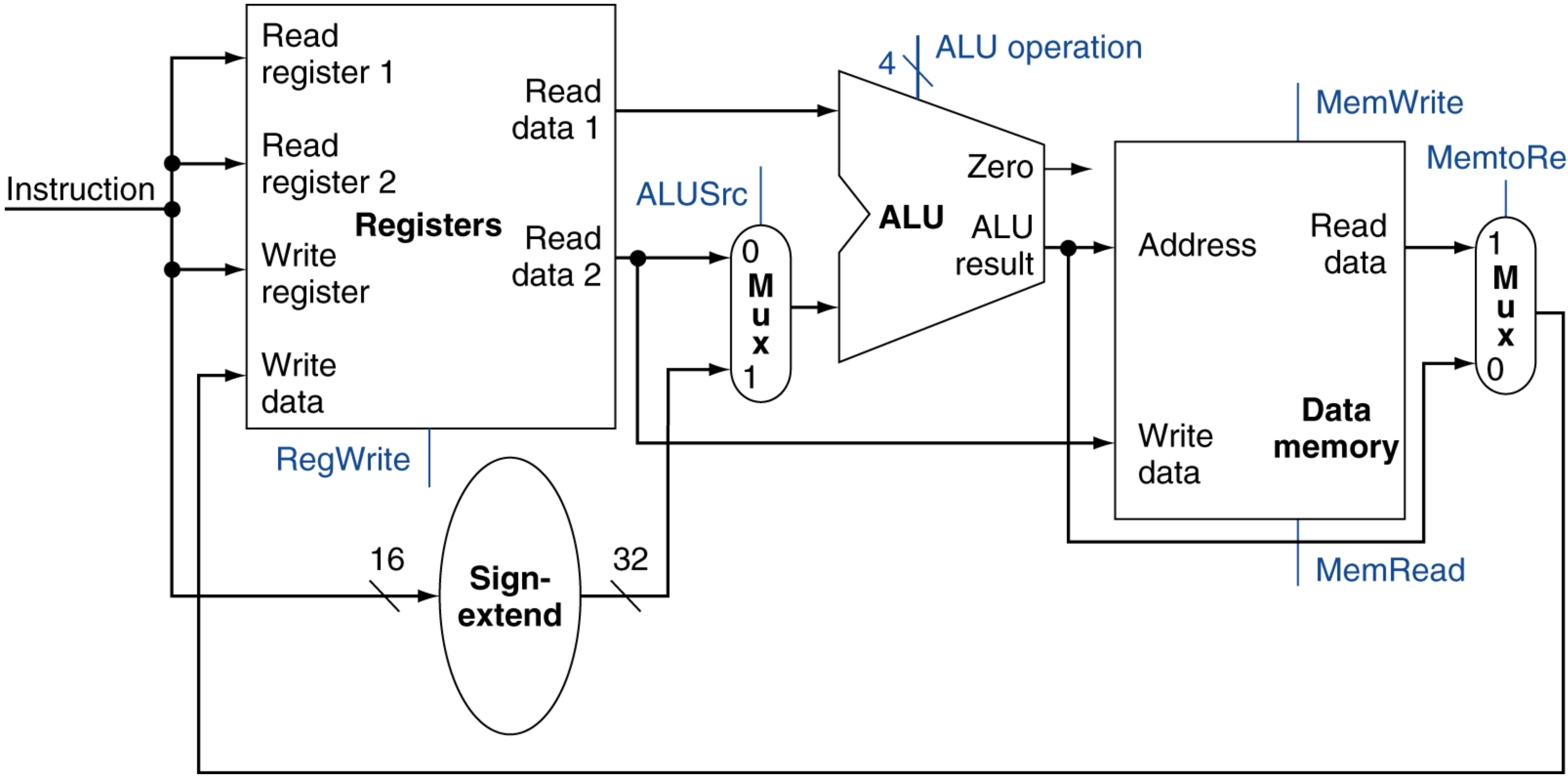
Add $t0, $t0, $t1

$t0 is register 8, $t1 is register 9
$t0 holds 5
$t1 holds 6



lw $t1, 4($t0)

$t0 is register 8, $t1 is register 9
$t0 holds 0x07AB8110
0x07AB8114 holds 12



Branch Instructions

- Read register operands
- Compare operands
  - Use ALU, subtract and check Zero output
- Calculate target address
  - Sign-extend offset
  - Shift left 2 bits (word offset)
  - Add to PC + 4
    - Already calculated during instruction fetch

What do we need to add Conditional Branch Instructions to our datapath?

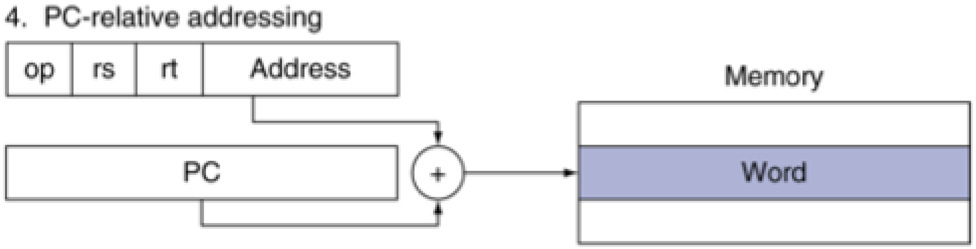
A. ALU

B. Registers and an ALU

C. Registers, ALU and Memory

D. Registers, an ALU and an Adder

beq $t2, $t3, 0x4F35



Read register operands

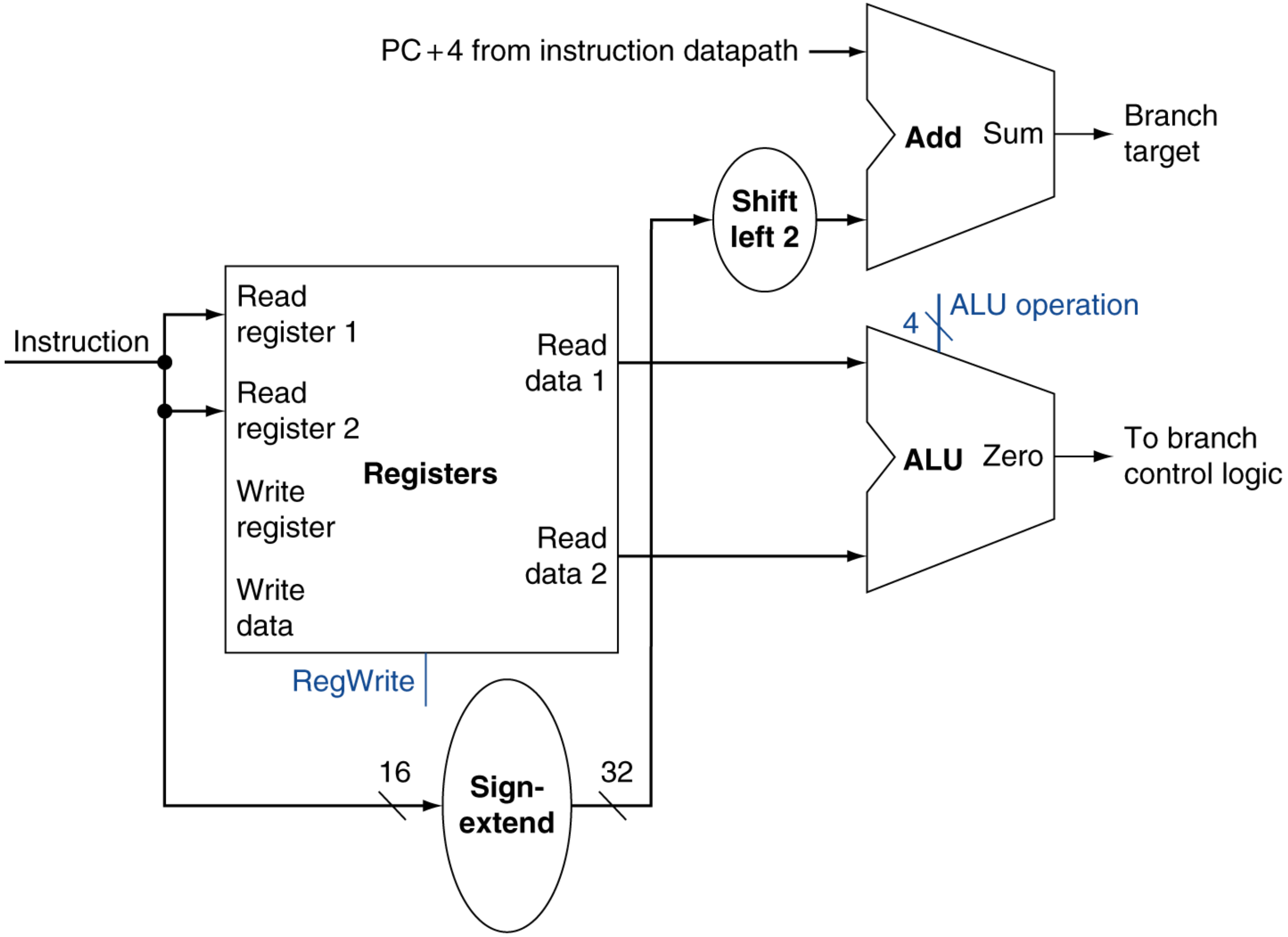
Compare operands

- Use ALU, subtract and check Zero output

Calculate target address

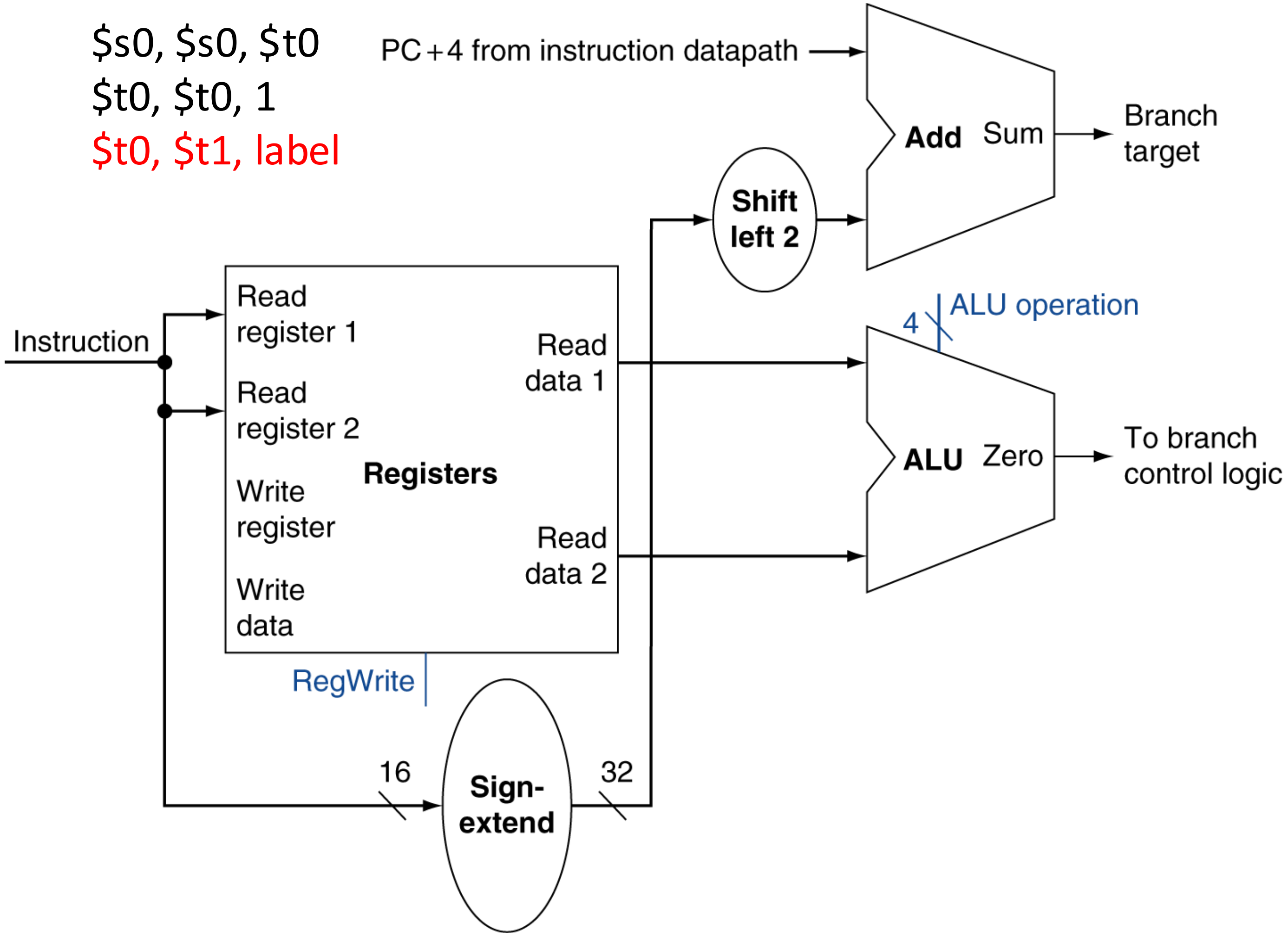
- Sign-extend offset
- Shift left 2 bits (word offset)
- Add to PC + 4
  - Already calculated during instruction fetch

Branch Instructions



Branch Instructions

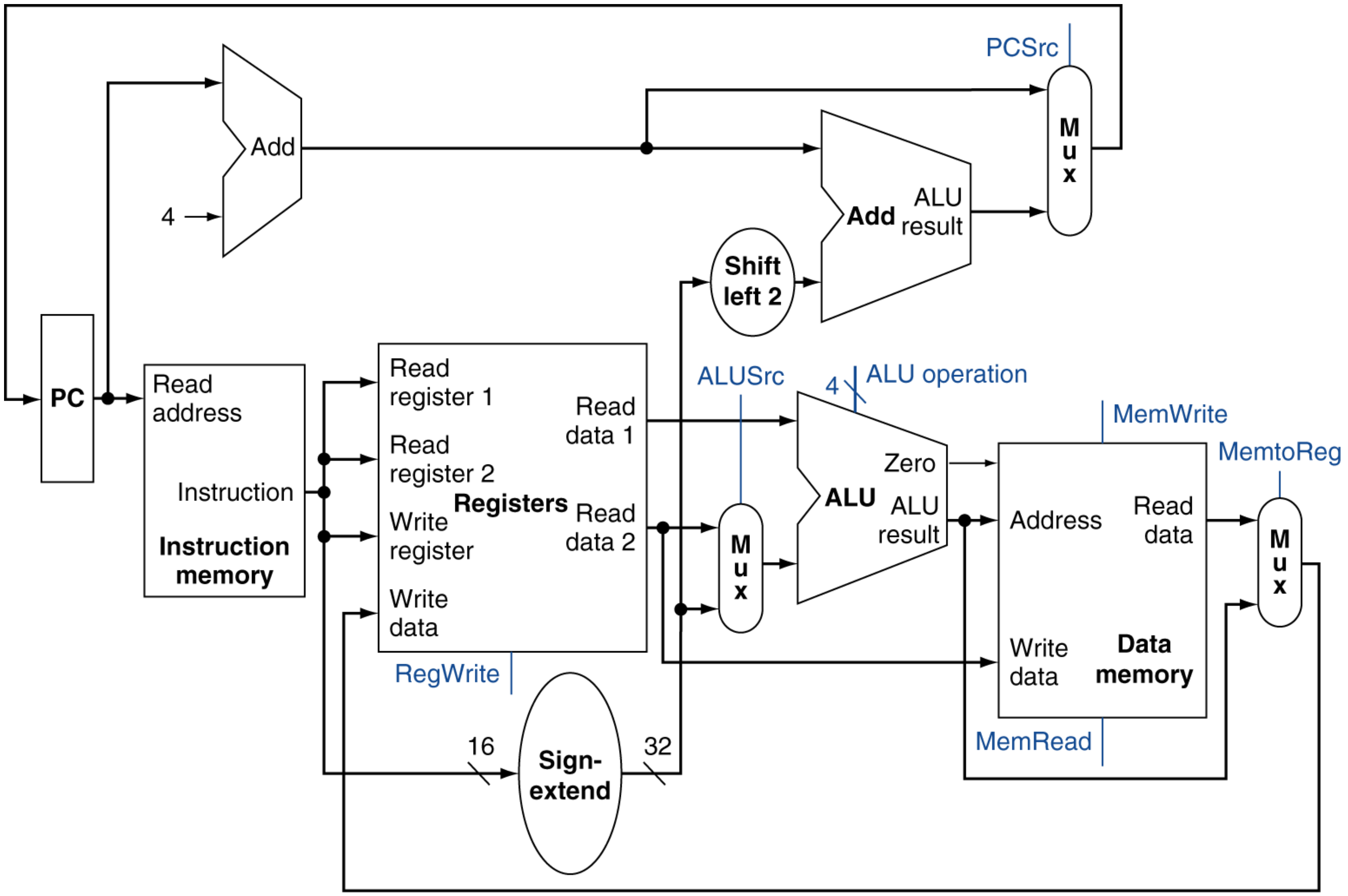
0x4045A130	label:	add	$s0, $s0, $t0
0x4045A134		addi	$t0, $t0, 1
0x4045A138		beq	$t0, $t1, label



op = 0x04	rs = 8	rt = 9	imm = 0xFFFD

$t0 holds 5
$t1 holds 5

Datapath (still simplified a bit)



Reading

- Next lecture: Data path
  - Section 5.2