

Lecture #18 Worksheet, Answer Master

Fill in blanks to answer questions below. Then email this sheet to your TA.

1. Define computer architecture.

Computer architecture refers to the design of the computer, the relationship of the arithmetic unit to memory and to the various peripherals, and the choice of instructions which the computer supports.

2. Lecture 18 covers the so-called ALU (or “datapath,” in the Patterson and Hennessy textbook). What is the purpose of the ALU?

The ALU processes data to produce numerical or logical results.

3. The ALU is primarily composed of an adder/subtractor circuit and some related units. Name at least three other processing elements in the ALU.

The ALU contains, in addition to the adder/subtractor elements, a shifter, a multiplier, a comparator (which also uses the adder), AND, OR, and other logical circuits, and the register block, to hold operands and results.

4. The ALU contains adder elements in bit-slice form, in addition to AND and OR circuits. What other familiar element is included in each bit-slice?

A multiplexer, to choose the desired result.

5. What do we call the components that carry data to the ALU and back from the register block?

Data and address buses.

6. Notice that a square blue block is used to represent memory in the ALU diagrams, a green rectangle represents the Program Counter register, and a trapezoid on its side represents an adder—and also an ALU. Why does the trapezoid with a notch represent both ALU and adder circuits?

Because the ALU is essentially an adder as well as other things, so the symbol stands for both.

7. The diagram on slide 10 shows how the Program Counter points to the memory address of the next instruction. Why is an adder included?

The adder updates the PC address so that it points to the next instruction to be accessed.

8. As noted, the ALU also is represented by a trapezoid.

a. What is its extra output bit?

The single output bit is to signal when a compare instruction is successful.

b. The register block has four input and two output buses. Name them.

Inputs: Read data 1 ID, Read data 2 ID, dest. register ID, write data bus.

Outputs: Read data from reg. 1, read data from reg. 2.

9. Slide 12 shows the register block hookup to the ALU. Where does the ALU result go?

Back to a register in the register block.

10. Slide 13 introduces data memory. What is the difference between data

memory and instruction memory.

Nothing except the paths, which are different.

11. Slide 14 illustrates the sign extender. Why do we need a sign extender?

You cannot add a 16-bit signed number to a 32-bit signed number without sign extension.

12. Slides 15 & 16 show the paths for data to/from memory. How is this different from the path of instructions into the CPU?

Data can only be loaded into the register block or stored from the register block. Instructions go directly into the CPU, where they are decoded.

13. Branch instructions compare two values and make a decision to execute the instruction after the branch or go elsewhere in the program. Define the “elsewhere” (branch) address based on the current program counter.

The branch address is contents of program counter plus the immediate in the instruction. That is, $[\text{branch address}] = [\text{PC}] + \text{immediate}$.

14. Why is the sign-extended immediate shifted left two digits or spaces to make the branch new address?

The immediate is the number of instructions (words) from the current address to the branch address. But a word is 4 bytes, and each byte has its own address, so the CPU must multiply by 4 to get the real instruction address.

15. Explain how the actual jump address is created from the 26-bit field in the

jump instruction.

The 26-bit field is left-shifted twice to create a byte address (same reason as for branch), then the top four bytes of the Program Counter are added to make up the 32-bit address.

16. Why is the jump instruction executed so rapidly?

The instruction does not involve the ALU or any other circuitry in the CPU—it is simply left shifted two and the upper bits inserted.

17. Why are multiplexers added to the register block and ALU inputs?

Multiple data sources feed the ALU and register block inputs, so the CPU must be able to switch between them.

18. Define the components of read and write addresses in data memory.

Read or write memory addresses are the sum of the load/store immediate and the contents of the Rs (source register) contents.

19. Slide 24 shows the two memory elements, which are the same memory, but use different paths. Although data memory only goes to the register block, it turns out that part of the instruction goes to the register block as well. What part of the instruction is that?

The source/destination registers in the instruction must be transmitted to the register block, in order to identify operands and the operation destination.

20. Define the two inputs to the Program Counter multiplexer.

(1) The program counter input ($[PC] + 4$), and (2) the new branch address increment (sign-extended, left-shifted-2 immediate).

21. Why is the CPU called a “single-cycle CPU?”

Because one instruction is executed during each full clock cycle.

22. Review slide 31 and be sure that you can answer all the questions shown, then check your answers on slide 32.