

This information might be useful. For any instruction that might need it, assume the instruction is located in memory at 0x4000.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADD	0	0	0	1	DR			SR1			0	0	0	SR2		
ADD	0	0	0	1	DR			SR1			1	imm5				
AND	0	1	0	1	DR			SR1			0	0	0	SR2		
AND	0	1	0	1	DR			SR1			1	imm5				
BR	0	0	0	0	n	z	p	PCoffset9								
LD	0	0	1	0	DR			PCoffset9								
LDI	1	0	1	0	DR			PCoffset9								
LDR	0	1	1	0	DR			BaseR			offset6					
LEA	1	1	1	0	DR			PCoffset9								
TRAP	1	1	1	1	0	0	0	0	trapvect8							

1. What does the LC3 instruction 0 1 0 1 1 1 0 0 1 0 0 0 0 1 1 0 do?

AND operation
 AND R6, R2, R6
 R6 = R2 and R6; a bit-wise AND operation

2. Write the bit pattern for the LC3 instruction to add R2 to R3, storing the result in R6.

0001 110 010 000 011 or
 0001 110 011 000 010

3. What does the instruction 0 0 1 0 0 1 0 1 1 0 1 0 1 1 1 1 do in the LC3?

Loads something from memory into R2 from the PC location plus x1AF
 See page 125

4. What does the instruction 0 1 1 0 0 0 1 0 1 0 0 1 1 1 0 1 do in the LC3?

Loads something into R2, using the R2 and the offset x1D
 See page 127

5. Write the bit pattern for an LC3 instruction which causes the program counter to jump forward 23 locations if the “positive” status register is set.

0000 001 000010111

6. For the LC3, what causes the Z,P, and N status registers to change? When are they altered?

They are changed when a value gets stored into a register. The number stored is checked to see if it's zero, positive, or negative.

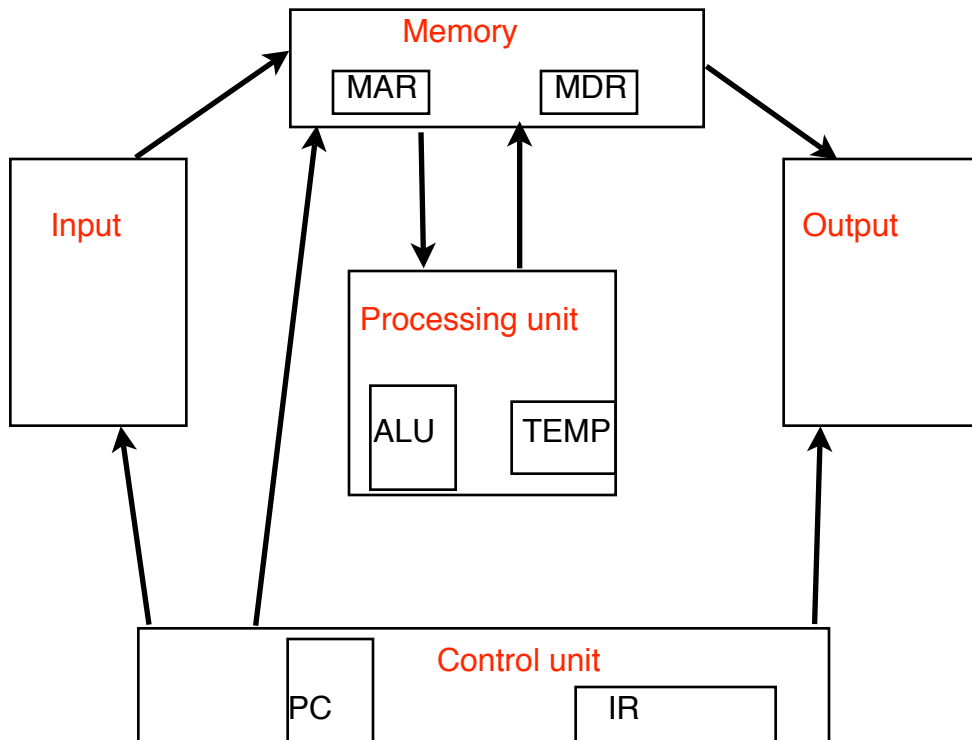
7. Suppose we have a 12-bit address bus. How many locations in memory can we access?

$2^{12} = 4096$

8. Suppose someone tells you they're going to build a microprocessor with 9 registers. Why would this not be a smart (efficient) thing to do?

We'll need 4 bits to represent each register -- but we're using only 9 of the 16 possible combinations. It would be better to either add more registers (using the address bits), or to reduce to 8 registers.

9. Fill in the names for each of the boxes for this picture:



10. On a TRAP instruction, what happens with PC and R7?

The PC is copied into R7

11. Suppose you have a sequential circuit that has three bits to store the machine state in. How many different states are possible?

There are 8 possible states

12. Suppose you design a state machine that needs 5 states (absolutely no way to get it to four). You start working on the logic for the circuit using a Karnaugh map (remember those from the last exam?). With only 5 states, what would be unusual in your Karnaugh map that might let you do a better job of simplifying the circuit?

The 3 unused states are "don't cares" for the Karnaugh map. We can use them to be either 0 or 1.

13. What does sign extension mean?

The first bit of a binary number is duplicated, to extend it to a longer number. For example, the 4-bit binary number 0011 (three) can be extended to 16 bits as 0000000000000011. The 4-bit number 1111 (minus 1) can be extended in the same way -- just duplicate the first bit.

14. What is the default color for the console window of the LC3 simulator?

I was expecting "blue" but a lot of people are seeing white on the PC version of the simulator. So -- either blue or white is fine.

15. Using a conditional branch instruction, how far away from the current program counter can you jump?

Branch has 9 bits, which gives a range of -256 to 255.

16. What does the assembly instruction AND R2,R4,#0 do?

Clears (sets to zero) R2.

It will also set the status registers for P and N to zero, and Z to 1 (this part is not required for a correct answer -- but if the student notices this, they should get a pink balloon with a gold star or something.)

17. Write a few lines of assembly language that results in $R0 = R1 - R2$.

```
NOT R2, R2
ADD R2, R2, 1
ADD R0, R1, R2 ; There are probably a couple of OK variants for this
```

18. Write a few lines of assembly language that will print out "Hello World." It might be useful to know that the operating system has a PUTS function, that is TRAP #22.

```
LEA R0, HELLO
PUTS ; or TRAP #22
; Might expect a halt here

HELLO .SRINGZ "Hello World."
```

19. Name two of the LC3 addressing modes (and only name two of them -- putting down 20 things and hoping some of them are right is not allowed!).

Reasonable answers (pick any two) are
 PC-relative
 Indirect
 Base+Offset
 Immediate

20. What numbers are in registers R1, R2, and R3 when the following code finishes?

```
LD R1, A
LD R2, B
AND R3, R3, #0
X ADD R3, R3, R2
ADD R1, R1, #-1
BRp X
HALT
A .FILL 8
B .FILL 9
```

R3 should have 72 ($8 * 9$)
 R2 should have 9 (it never gets changed)
 R1 should have 0 (it gets decremented every time until zero)