

COMP2611: Computer Organization

Single-cycle datapath and control

Single Cycle Datapath

Review of the control signals

- the two hardware control units
- the effects of the control signals

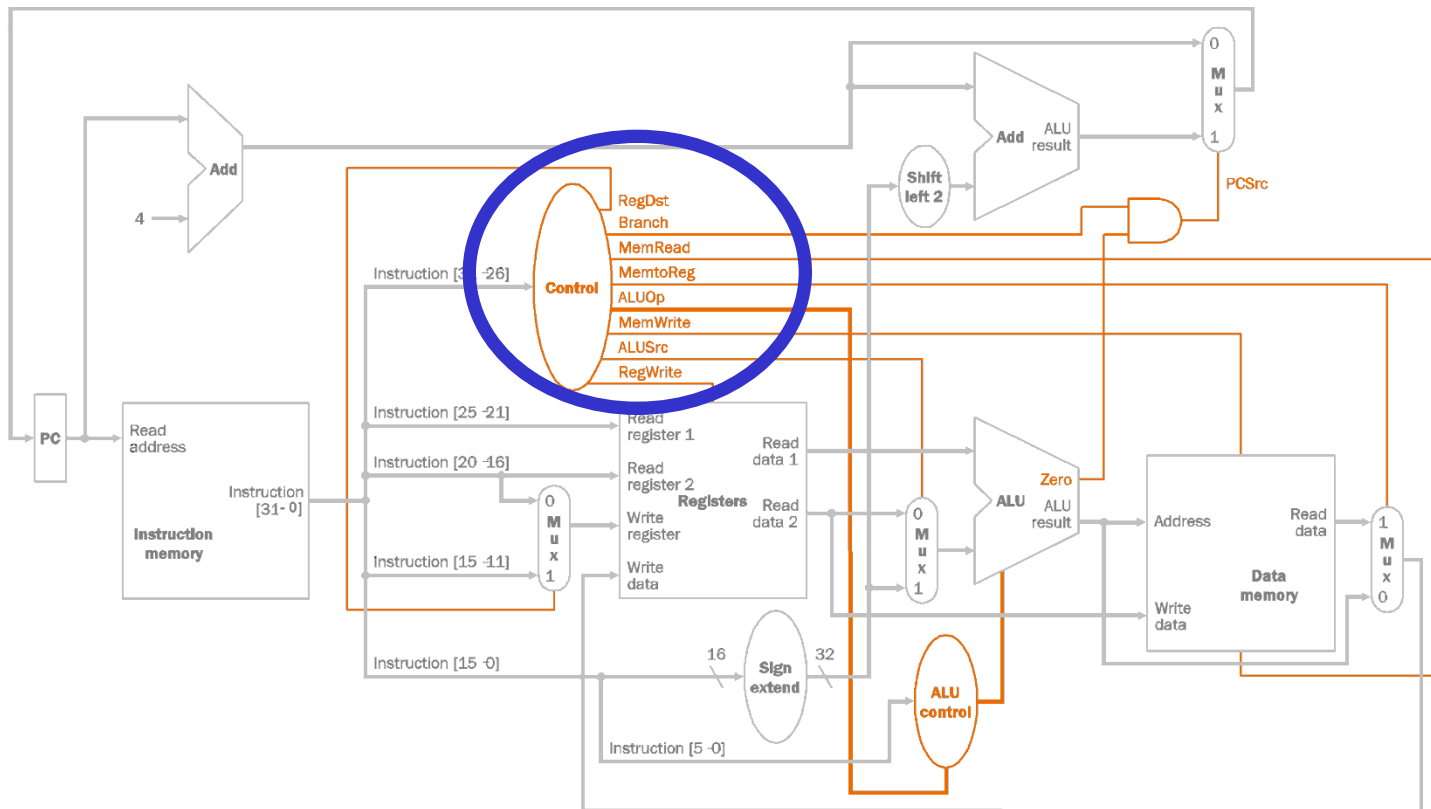
Sample execution of an instruction

- instruction fetch, decoding, executing, memory referencing and writing back

Exercises

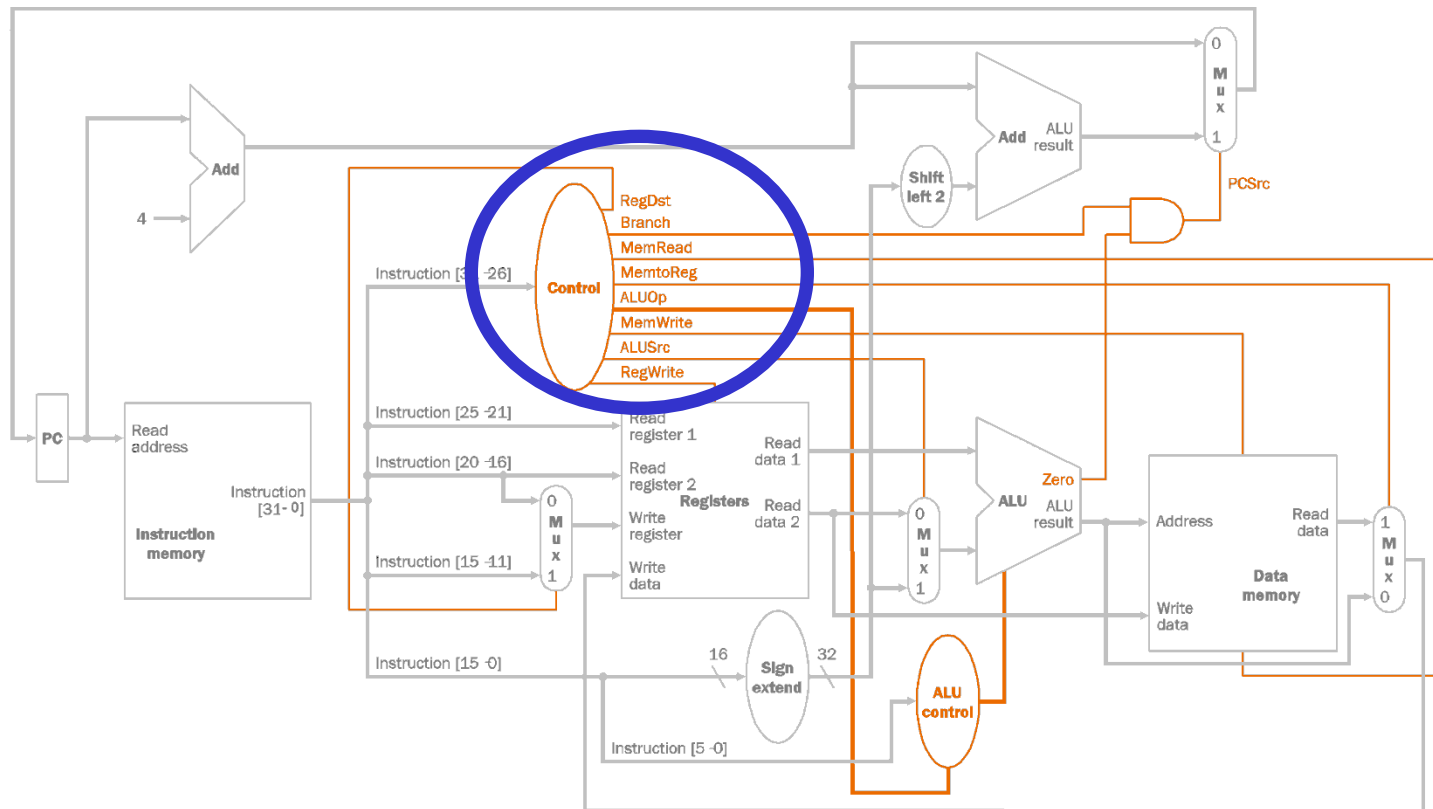
Review of the Control signals

Signal name	Effect when deasserted	Effect when asserted
RegDst	The register destination number for the write register comes from rt field (bits 20-16)	The register destination number for the write register comes from rd field (bits 15-11)
Branch + Zero	When both signals are asserted, PCSrc will be asserted	When either one is deasserted, PCSrc will be deasserted
MemRead	None	Enable read from memory. Memory contents designated by the address are put on the read data output
MemtoReg	Feed the write data input of the register file with the output from the ALU	Feed the write data input of the register file with output from the memory



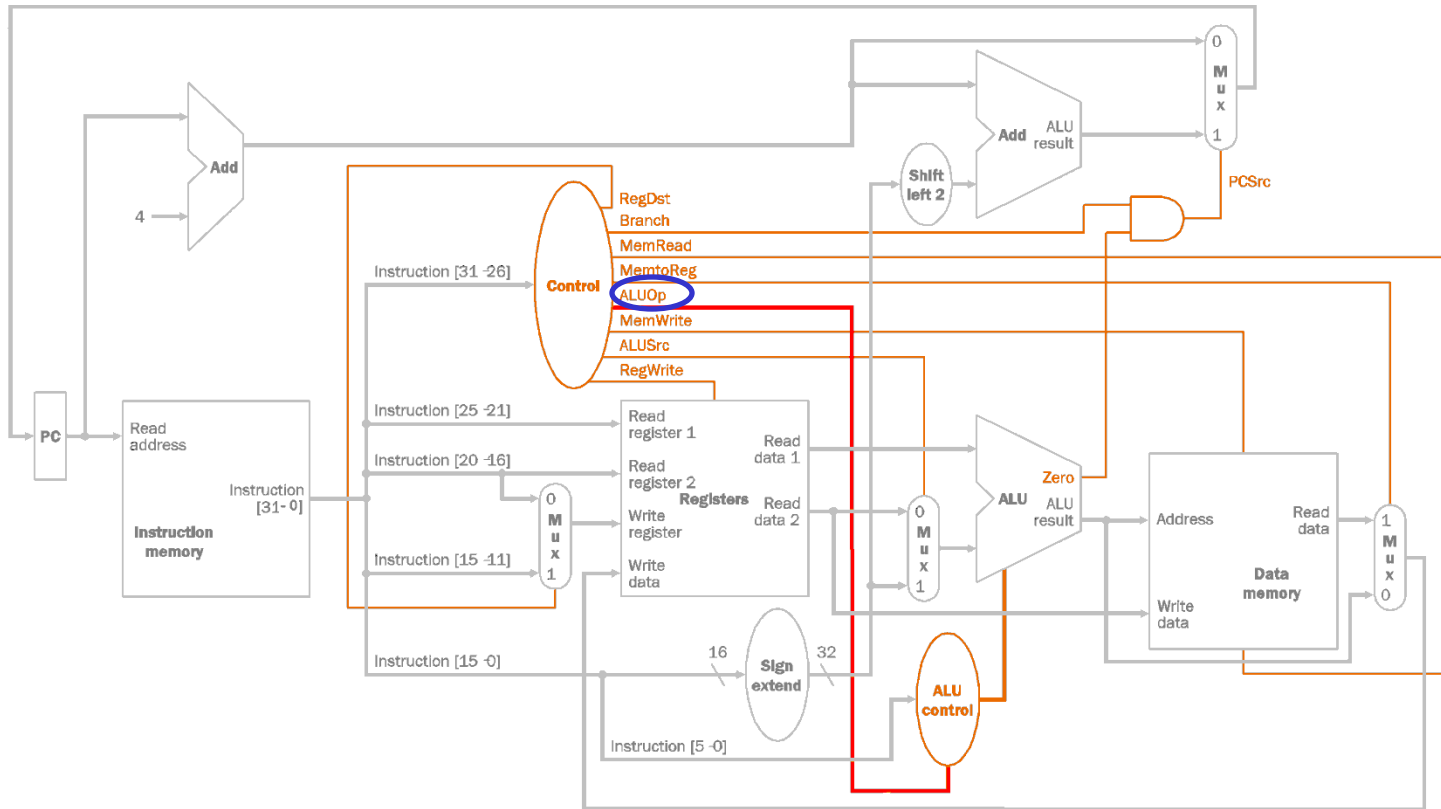
Review of the Control signals

Signal name	Effect when deasserted	Effect when asserted
MemWrite	None	Enable write to the memory. Overwrite the memory contents designated by the address with the value on the write data input
ALUSrc	The Second ALU operand comes from the second register file output (read data port 2)	The second ALU operand is the sign-extended 16-bit data (bits 15-0)
PCSrc	The next PC picks up from the output of the adder that computes PC+4	The next PC picks up the output of from the adder that computes the branch target
RegWrite	None	Enable data write to the register specified by the register destination number



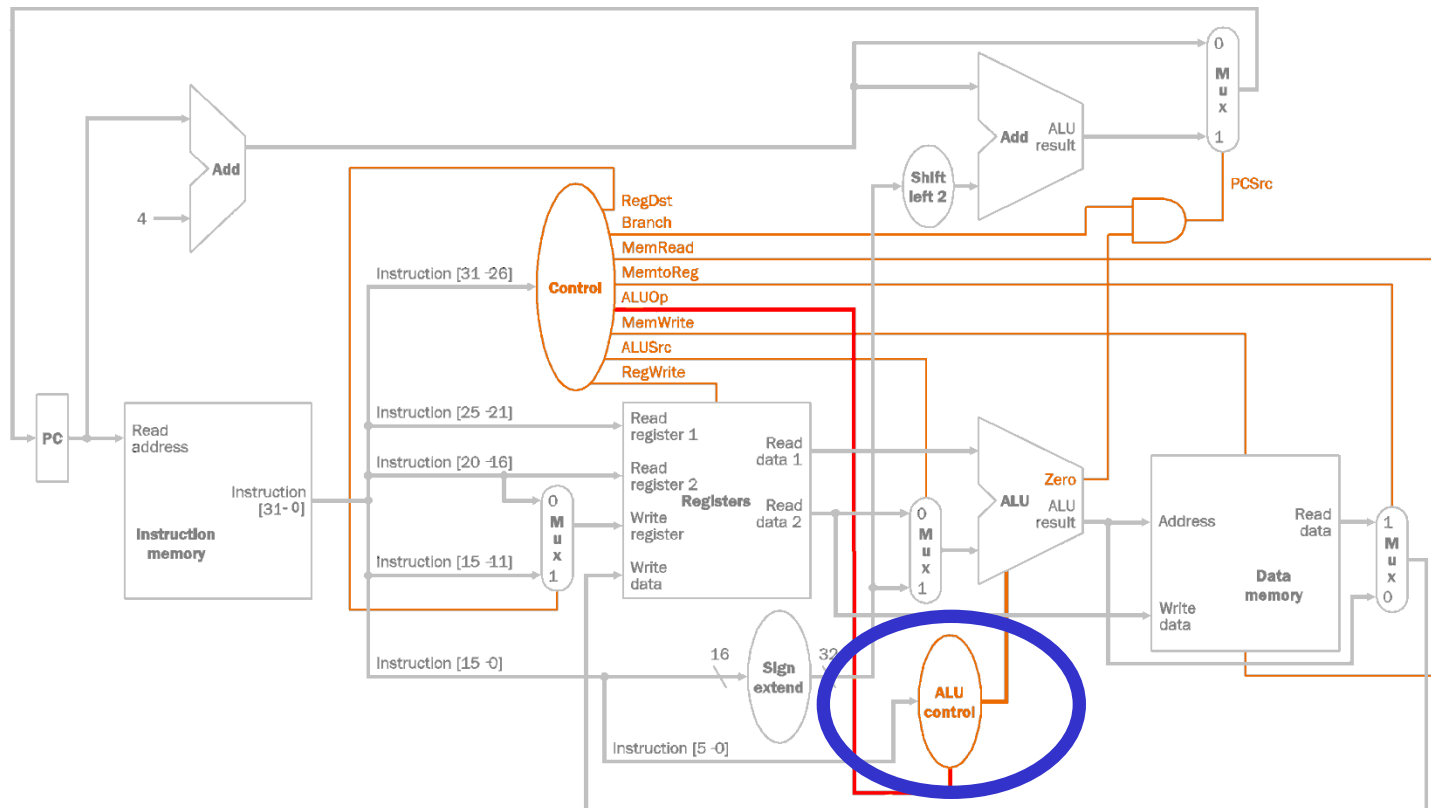
Review of the Control signals

ALUOp signal (2-bit)	Effect
00	ADD operation at the ALU for Load/Store instructions
01	SUB operation at the ALU for BEQ
10	ALU operation determined by the funct field (bits 5-0)



Review of the Control signals

ALU control signal (4-bit)	Effect
0000	The ALU will perform the AND operation
0001	The ALU will perform the OR operation
0010	The ALU will perform the ADD operation
0110	The ALU will perform the SUB operation
0111	The ALU will perform the Set on Less Than (SLT) operation
1100	The ALU will perform the NOR operation



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Exercises

❑ Execution of the R-type instruction "AND"

Description	Bitwise AND operation on the values of the registers Rs and Rt. Store the result in Rd.
Operation	$\$Rd = \$Rs \& \$Rt$; $PC = PC + 4$
Syntax	AND $\$Rd, \$Rs, \$Rt$
Encoding	000000 sssss ttttt ddddd 00000 100100 OpCode Rs Rt Rd Shift function

❑ Example: AND \$t0, \$t1, \$t2

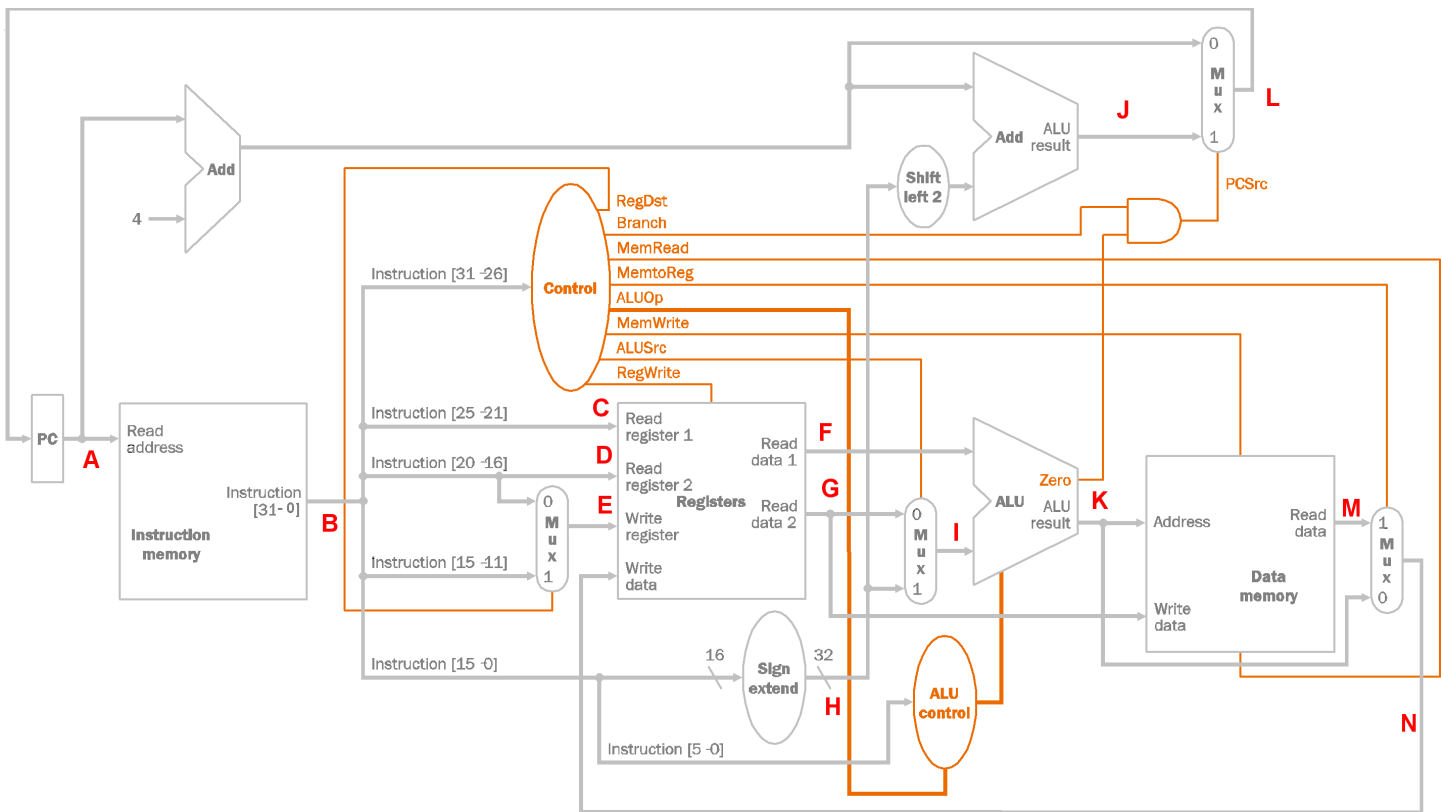
❑ Encoding 000000 01001 01010 01000 00000 100100

□ Step 1 (fetch):

A= address of the instruction

B= 000000 01001 01010 01000 00000 100100

Control signals not yet generated



Execution of "AND \$t0, \$t1, \$t2"

Step 2 (decode):

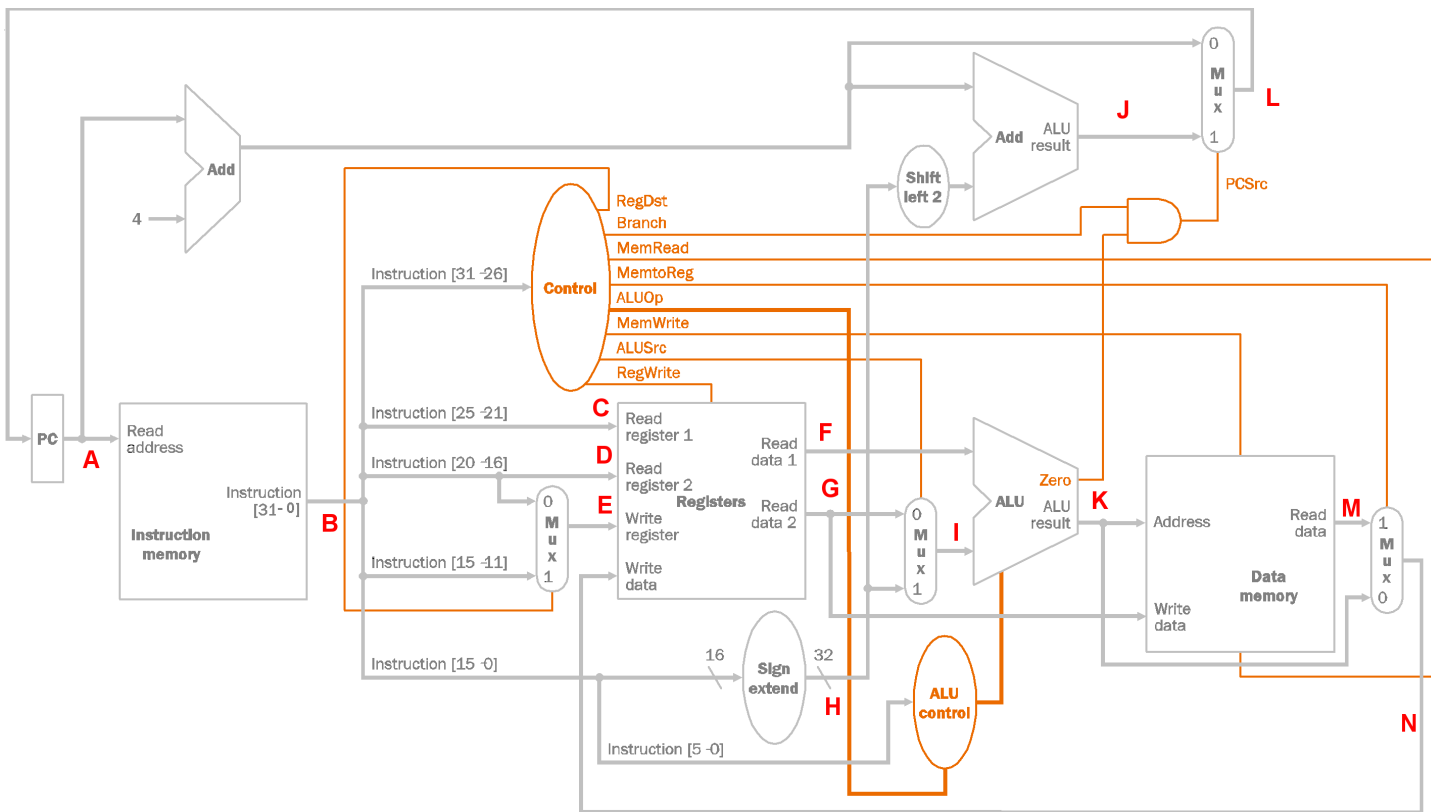
C = 01001, D = 01010, E = 01000

F = value of Rs

G = value of Rt, H = 0000 0000 0000 0000 01000 00000 100100

Instruction fetched:

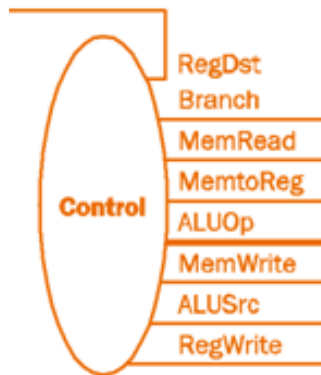
000000	01001	01010	01000	00000	100100
OpCode	Rs	Rt	Rd	Shift	function



□ Step 2 (control signals)

Instruction fetched:

000000 01001 01010 01000 00000 100100
 OpCode Rs Rt Rd Shift function



Control signal	Value
RegDst	1 (R-type instruction)
Branch	0 (not a branch instruction i.e. BEQ)
MemRead	0 (not the LW instruction)
MemtoReg	0 (not the LW instruction)
ALUOp	10 (R-type instruction)
MemWrite	0 (not the SW instruction)
ALUSrc	0 (R-type instruction)
RegWrite	1 (R-type instruction needs to write back)

Inputs		Outputs
Func (bits 5:0)	ALUOp	ALU Control
100 100	10	0000 (AND operation)

❑ Step 3 (execution):

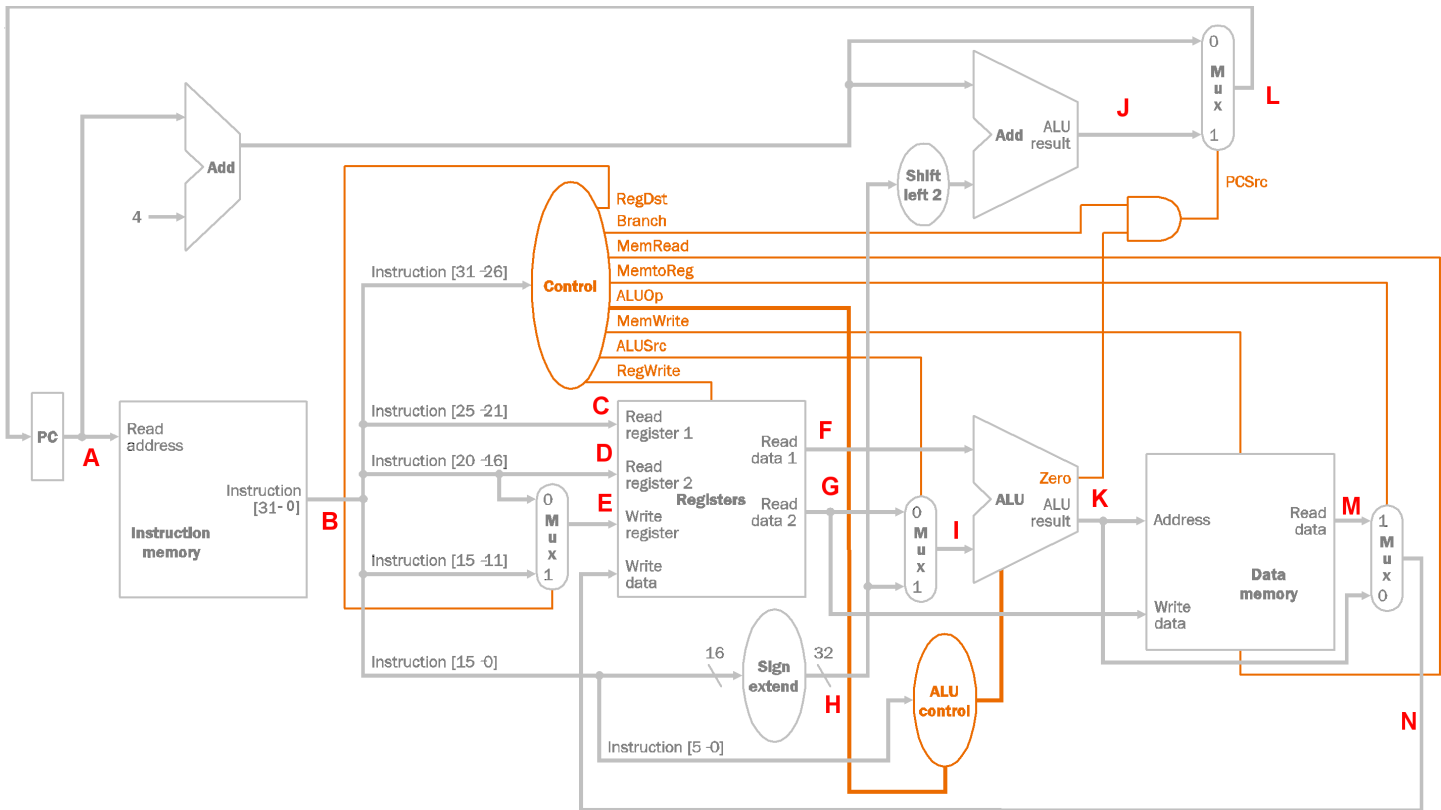
ALUSrc = 0, therefore I = value of Rt

J = 0000 0000 0000 0001 0000 0000 1001 0000 + PC + 4

ALU Control = 0000, therefore K = (value of Rs) bitwise_AND (value of Rt),

Branch = 0 => **PCSrc = 0**, therefore L = PC + 4

Instruction fetched:
 000000 01001 01010 01000 00000 100100

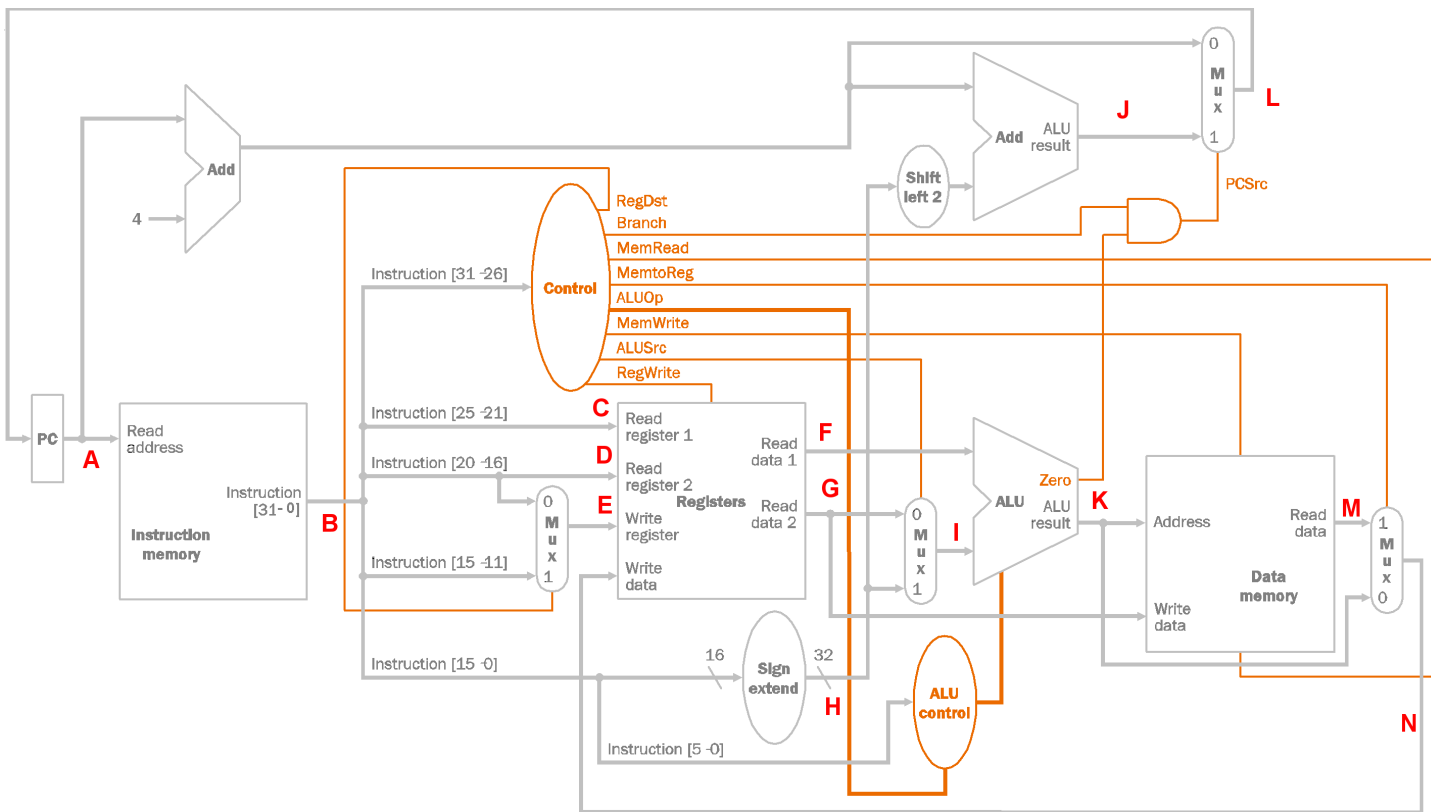


- Step 4 (memory)

Instruction fetched:

000000 01001 01010 01000 00000 100100

MemRead=0, therefore M = Empty (can't read)



- Step 5 (write back):

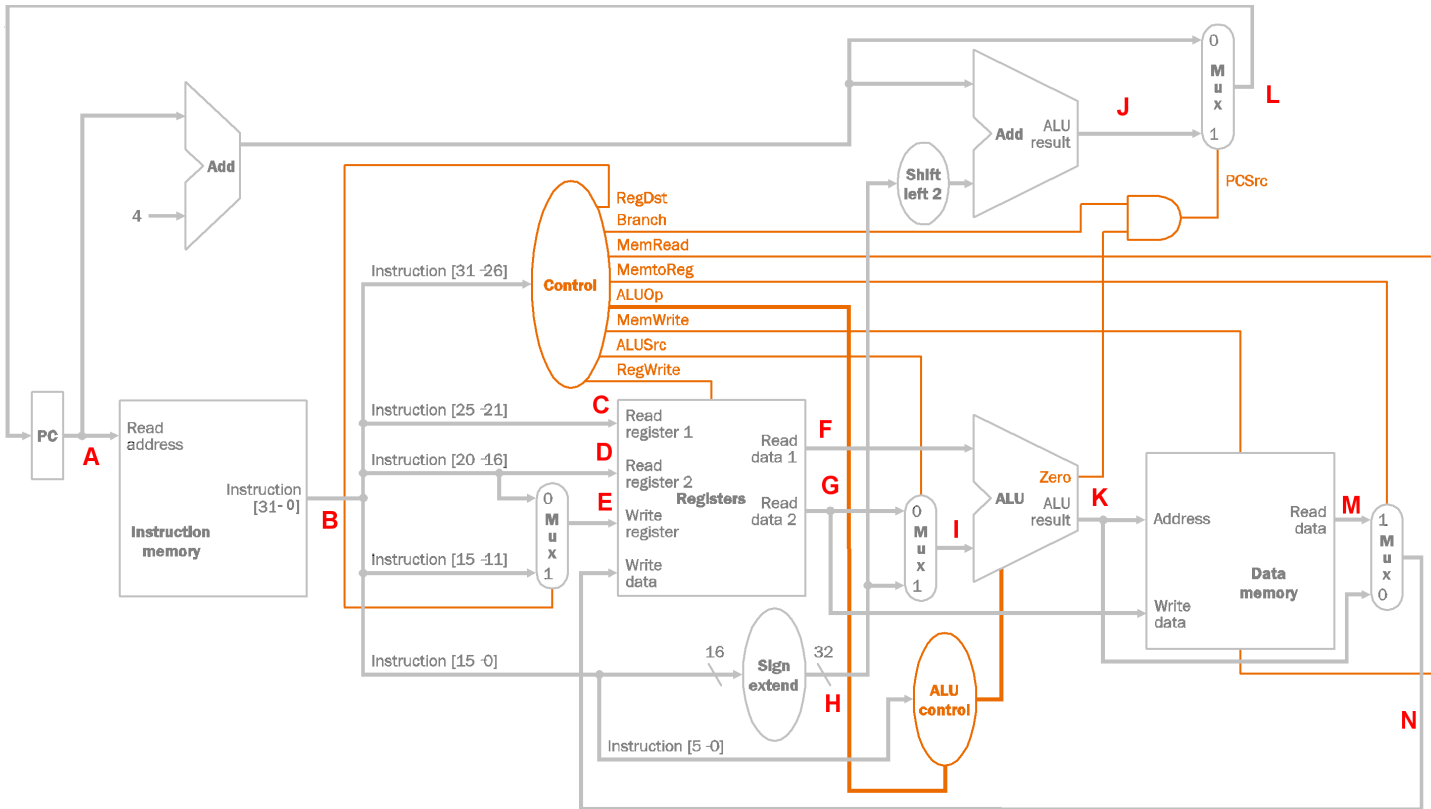
Instruction fetched:

000000 01001 01010 01000 00000 100100

MemtoReg=0, therefore N= Results of the ALU

= (value of Rs) bitwise_AND (value of Rt)

RegWrite=1, RegDst=1, therefore N is written back to register 01000 (\$t0)



Question 1: Repeat the execution of the I-type instruction "SW \$t0, 8(\$t1)" by filling the values for A-N and also the control signals.

❑ Execution of the I-type instruction "SW"

Description	Memory reference operation on the values of the registers Rs and the memory location pointed by Rt + offset. Store the result in memory pointed by Rt + offset.
Operation	$\$Rt + \text{offset} = \Rs ; $PC = PC + 4$
Syntax	SW \$Rs, offset(\$Rt)
Encoding	101011 sssss ttttt 0000000000001000 OpCode Rs Rt Immediate

❑ Example: SW \$t0, 8(\$t1)

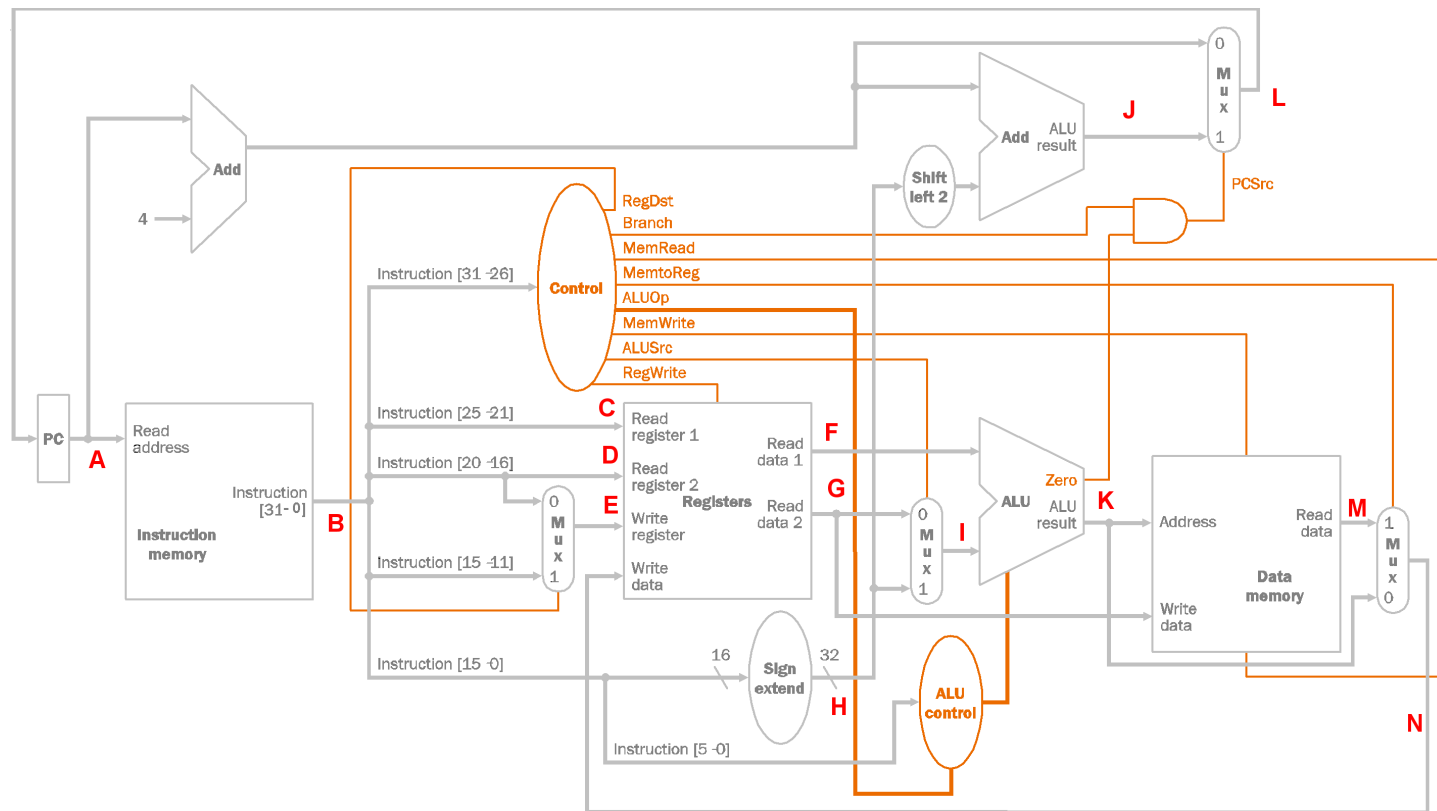
❑ Encoding 101011 01000 01001 0000000000001000

❑ Step 1 (fetch):

A= address of the instruction

B= 101011 01000 01001 0000000000001000

Control signals not yet generated

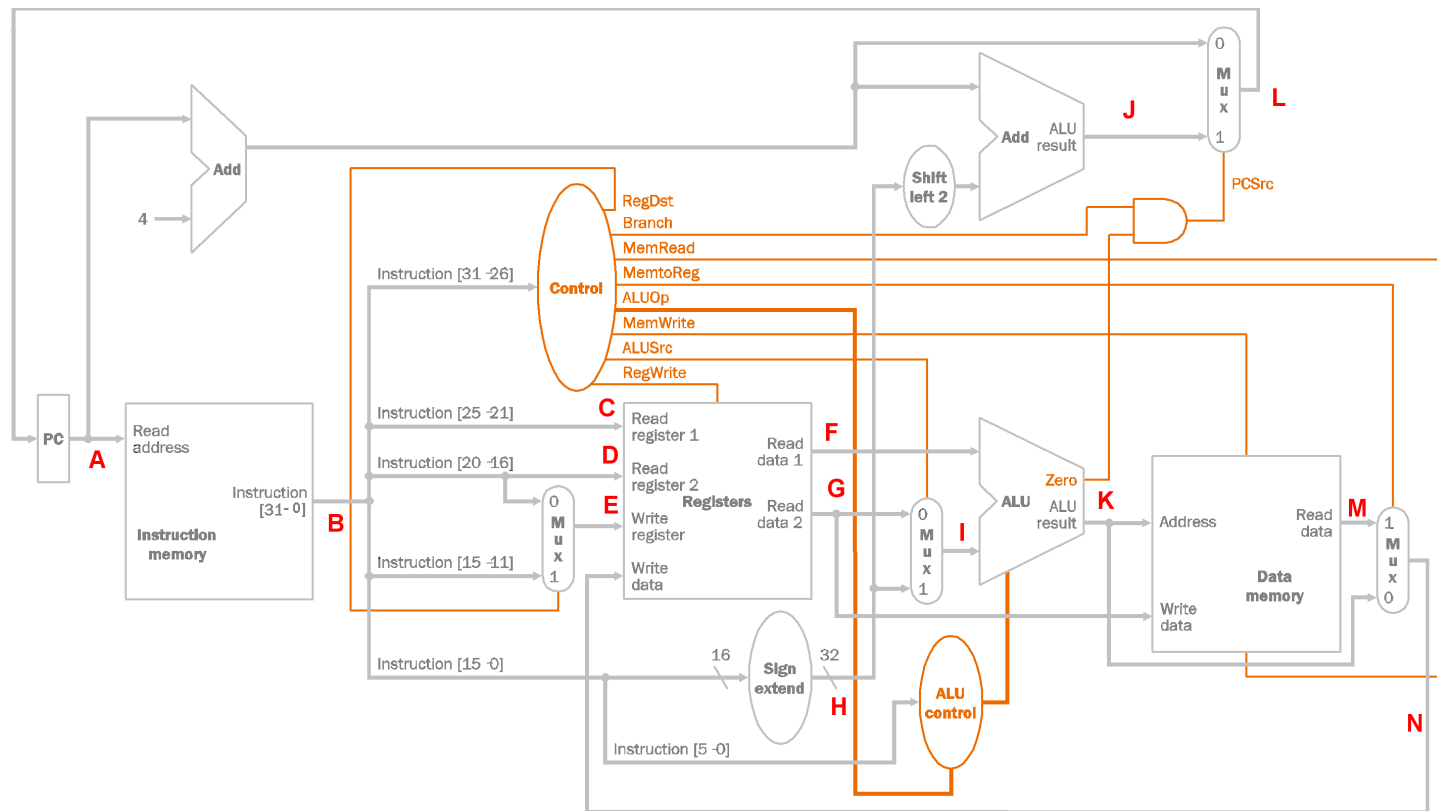


❑ Step 2 (decode):

C = 01000, D = 01001, E = None
 F = value of Rt

❑ G = value of Rs, H= 0000 0000 0000 0000 0000000000001000

Instruction fetched:
 101011 01000 01001 0000000000001000
 OpCode Rs Rt Immediate

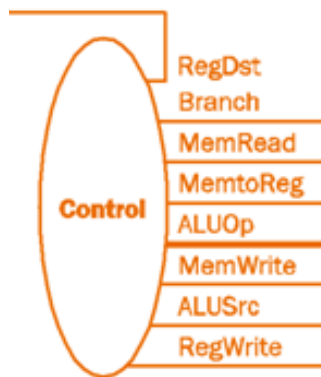


❑ Step 2 (control signals)

Instruction fetched:

101011 01000 01001 0000000000001000

OpCode Rs Rt Immediate



Control signal	Value
RegDst	X
Branch	0 (not a branch instruction i.e. BEQ)
MemRead	0 (not the LW instruction)
MemtoReg	X (not the LW instruction)
ALUOp	00 (I-type instruction)
MemWrite	1 (not the LW instruction)
ALUSrc	1 (I-type instruction)
RegWrite	0 (not R-type instruction that needs write back)

Inputs		Outputs
Func (bits 5:0)	ALUOp	ALU Control
XXX XXX	00	0010 (SW operation)

Instruction fetched:

101011 01000 01001 0000000000001000

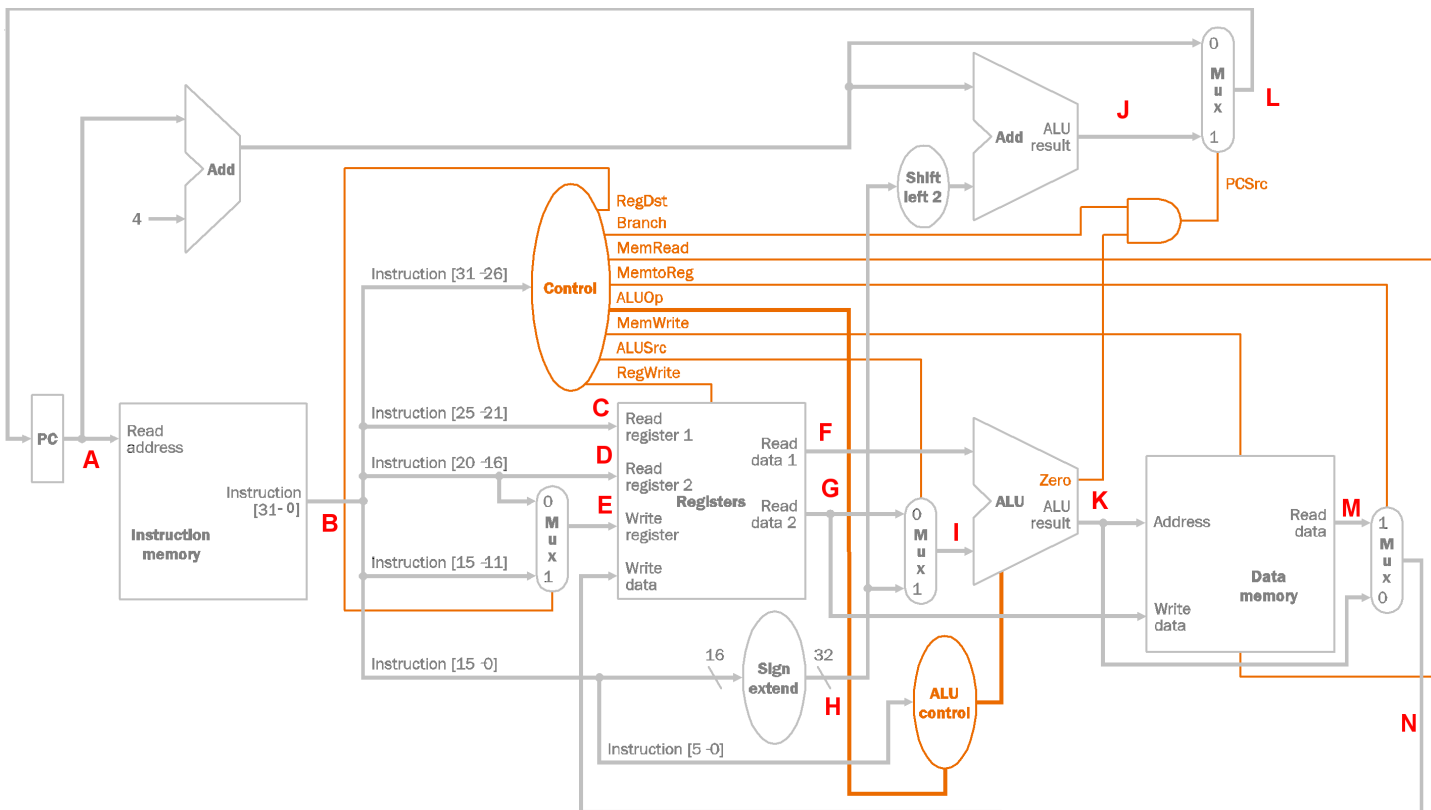
Step 3 (execution):

ALUSrc = 1, therefore I = value of immediate which is sign-extended as H

J = 0000 0000 0000 0000 0000 0000 0010 0000 + PC+4

ALU Control = 0010, therefore K = (value of Rt) plus (value of H),

Branch = 0 => **PCSrc=0**, therefore L = PC+4

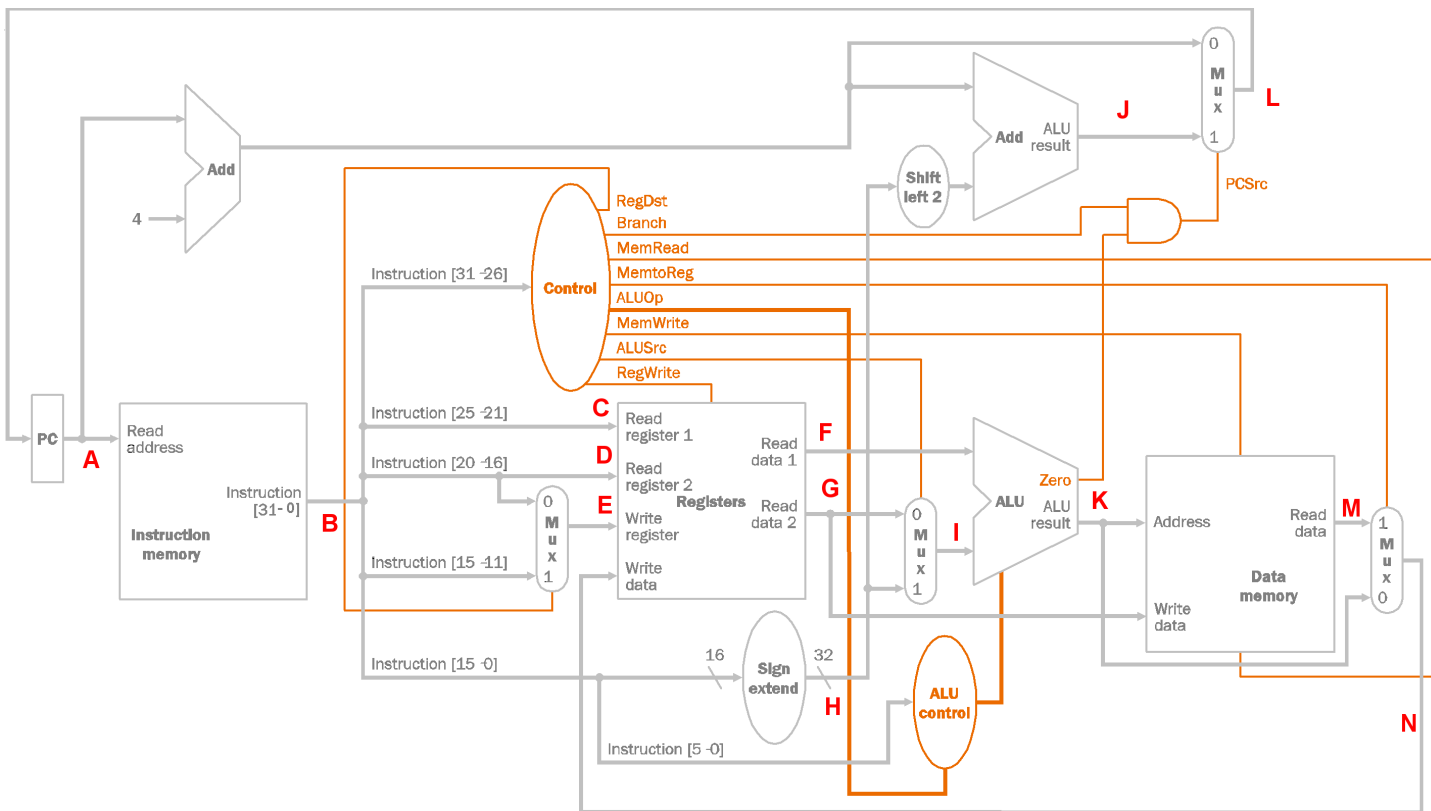


- Step 4 (memory)

Instruction fetched:
 101011 01000 01001 0000000000001000

MemRead=0, therefore **M** = Empty (can't read)

MemWrite=1, therefore write the value of **G** to memory location pointed by **K**



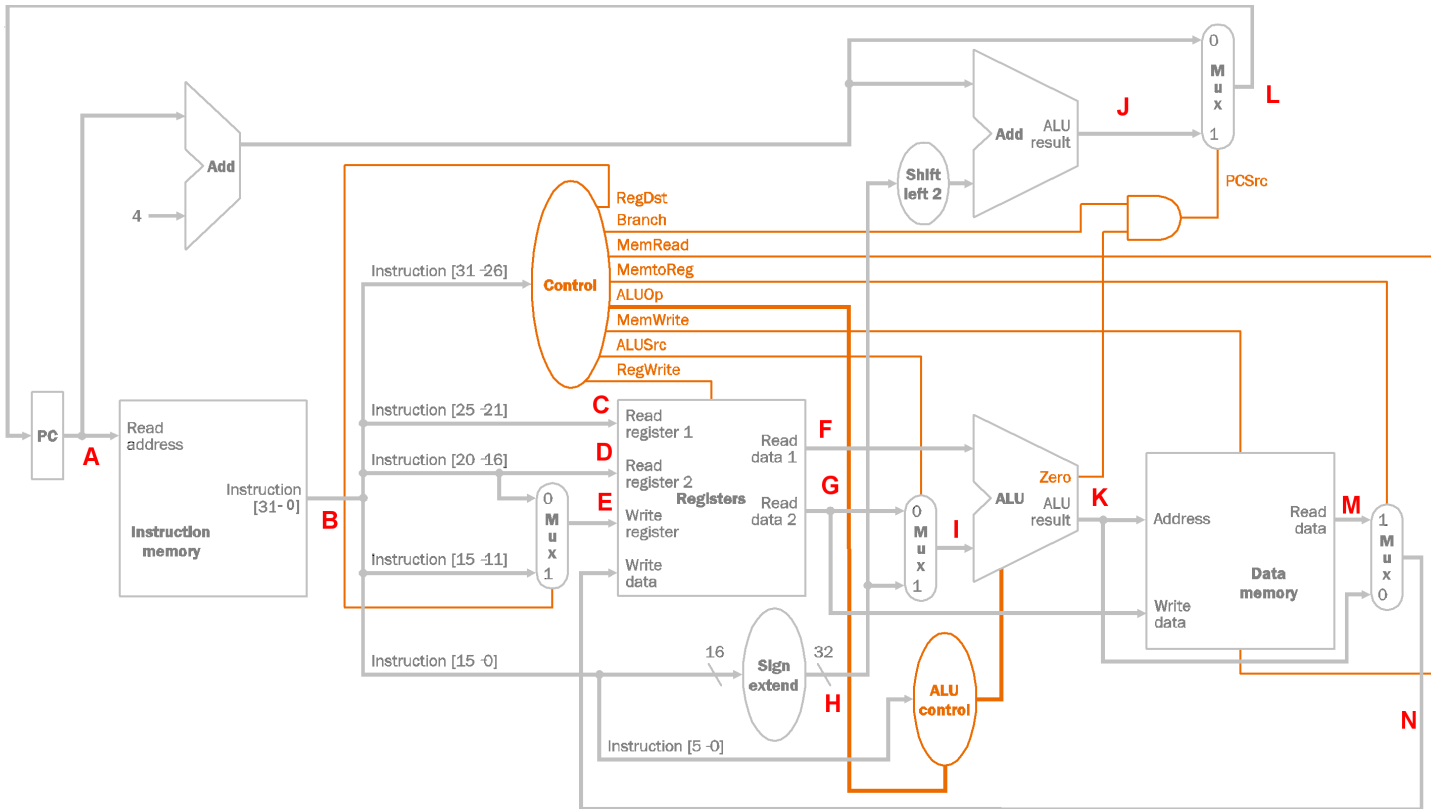
- Step 5 (write back):

Instruction fetched:

101011 01000 01001 0000000000001000

MemtoReg=X, therefore N= Not applicable

RegWrite=0, RegDst=X, therefore nothing is written back to register



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Sample execution of an instruction

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Exercises

Question 3: Repeat the execution of the following instruction by filling the values for A-N and also the control signals :

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OR $t0, $t1, $t2
```

Solution:

Similar to AND instruction but different with respect to the following:

Function bits: 100101

ALU Control input: 0001