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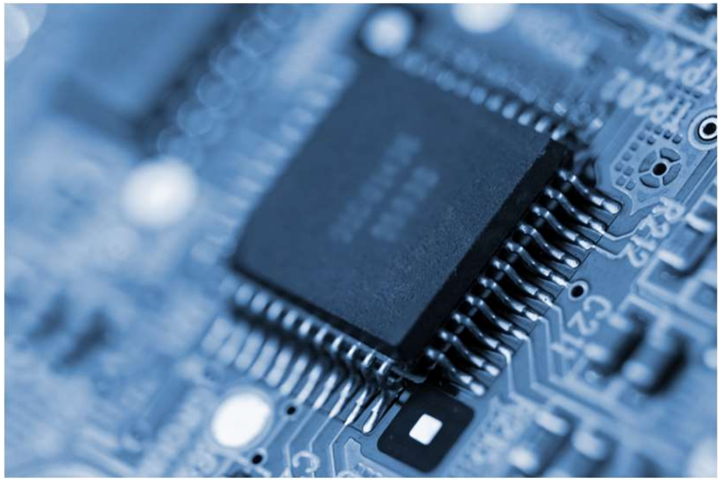
Computer Processors

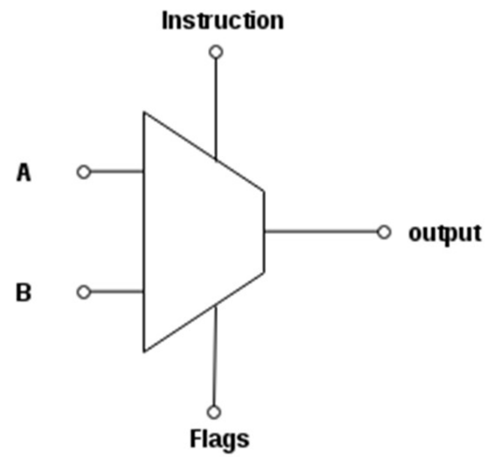
Arithmetic Logic Unit



Lecture 9

Arithmetic Logic Unit

- The Arithmetic Logic Unit (ALU) is the centerpiece of any modern day computer
- The ALU implements a set of logic commands
- The ALU allows for the selection of which command should be output



Arithmetic Logic Unit

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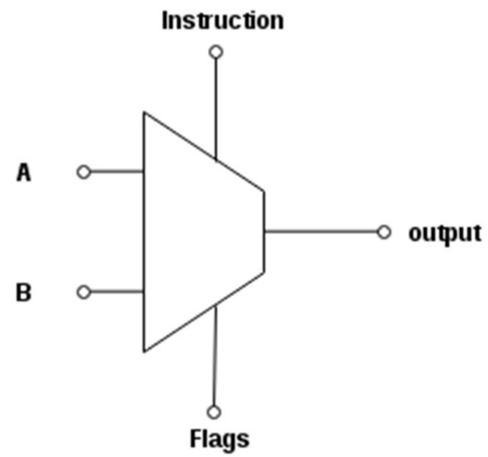
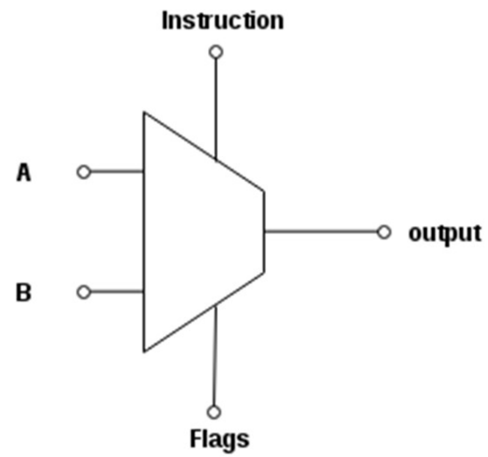
- ALU's implement a fixed set of functions
- Each function can take at most two multi-bit arguments
- The ALU outputs the result of the boolean function and a set of flags



Arithmetic Logic Unit

- The instruction is a set of control bits which select which function the ALU should output
  - And
  - Adder
  - Pre/post processing on inputs/outputs



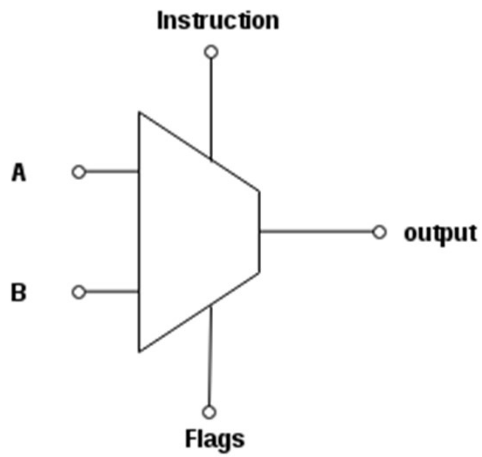
Arithmetic Logic Unit

Our specific ALU accepts

- Two 16-bit wide arguments
- A 6-bit wide instruction (control bits)

And outputs

- A 16-bit wide output
- A bit to indicate if the output is 0
- A bit to indicate if the output is less that 0



Arithmetic Logic Unit

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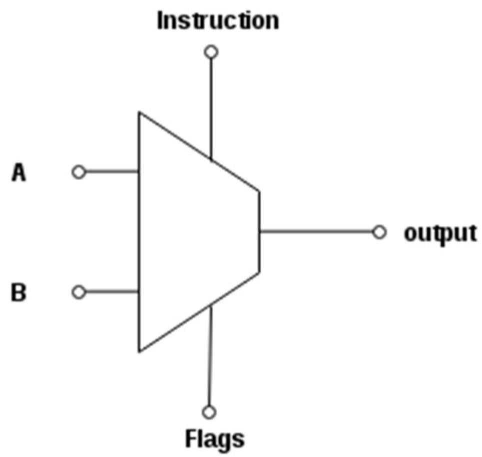
- With a 6-bit wide instruction gives the ALU

  a possible 2^6 (=64) instructions

- We are only interested in 18 of them



Control bits

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- The ALU has the choice between two basic functions logical **And** and **Addition**
- All operations are multi-bit operations
- All of the required components were covered in **Lecture 4 - Common Logic Configurations**

Bit	Description
za	Zero input **A**
na	Negate input **A**
zb	Zero input **B**
nb	Negate input **B**
f	Select between & and +
no	Negate output

Control bits

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- Each of the 18 configurations of the control bits does something of interest
- Let us consider the control bits set to 001110
  - The ALU is instructed to compute a-1
  - Input **A** is neither zero'ed nor negated
  - Input **B** is zeroed and then negated (2's complement -1_{10})
  - f-bit set to **Addition**

za	na	zb	nb	f	no	output
1	0	1	0	1	0	0
1	1	1	1	1	1	1
1	1	1	0	1	0	-1
0	0	1	1	0	0	a
1	1	0	0	0	0	b
0	0	1	1	0	1	$\neg a$
1	1	0	0	0	1	$\neg b$
0	0	1	1	1	1	$-a$
1	1	0	0	1	1	$-b$
0	1	1	1	1	1	$a+1$
1	1	0	1	1	1	$b+1$
0	0	1	1	1	0	$a-1$
1	1	0	0	1	0	$b-1$
0	0	0	0	1	0	$a+b$
0	1	0	0	1	1	$a-b$
0	0	0	1	1	1	$b-a$
0	0	0	0	0	0	$a\&b$
0	1	0	1	0	1	$a\|b$

	za	na	zb	nb	f	no	output
	0	0	1	1	1	0	a-1
a							
b							

	za	na	zb	nb	f	no	output
	0	0	1	1	1	1	-a
a							
b							

<table>
<tr><td></td><td>za</td><td>na</td><td>zb</td><td>nb</td><td>f</td><td>no</td><td>output</td></tr>
<tr><td></td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>a-1</td></tr>
<tr><td>a</td><td>a</td><td>a</td><td>a</td><td>a</td><td rowspan="2">a-1</td><td rowspan="2">a-1</td><td rowspan="2">a-1</td></tr>
<tr><td>b</td><td>b</td><td>b</td><td>0</td><td>-1
(11111111)</td></tr>
</table>

<table>
<tr><td></td><td>za</td><td>na</td><td>zb</td><td>nb</td><td>f</td><td>no</td><td>output</td></tr>
<tr><td></td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>-a</td></tr>
<tr><td>a</td><td>a</td><td>a</td><td>a</td><td>a</td><td rowspan="2">a-1</td><td rowspan="2">!(a-1)</td><td rowspan="2">-a</td></tr>
<tr><td>b</td><td>b</td><td>b</td><td>0</td><td>-1</td></tr>
</table>

Control bits

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You should verify that the rest do what is claimed in the table

What do the other 46 control bit configurations do?

za	na	zb	nb	f	no	output
1	0	1	0	1	0	0
1	1	1	1	1	1	1
1	1	1	0	1	0	-1
0	0	1	1	0	0	a
1	1	0	0	0	0	b
0	0	1	1	0	1	$\neg a$
1	1	0	0	0	1	$\neg b$
0	0	1	1	1	1	$-a$
1	1	0	0	1	1	$-b$
0	1	1	1	1	1	$a+1$
1	1	0	1	1	1	$b+1$
0	0	1	1	1	0	$a-1$
1	1	0	0	1	0	$b-1$
0	0	0	0	1	0	$a+b$
0	1	0	0	1	1	$a-b$
0	0	0	1	1	1	$b-a$
0	0	0	0	0	0	$a\&b$
0	1	0	1	0	1	$a\|b$

Implementation

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Notice that the ALU is composed of

- A logic circuit that can negate or zero an input (times 2)
- Logic circuits for **Addition** and **And.**
- A logic circuit to select between them
- A logic circuit to negate the output
- A logic circuit to handle flags

Only the last one has not been implemented already

ALU

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- The ALU we implement is quite basic
- No multiplication/division
- No floating point numbers
- No exponentiation (required for some encryptions)
- Modern ALU’s support many more operations

ALU most similar to a microprocessor or 1970’s ALU’s

Summary

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- Introduced the ALU
- Discussed the implementation
- Compared it to current architectures

Interested in logic design? [Digital Logic Design]