Smith College

Computer Science

CSC231—Assembly

Week #6 — Spring 2017

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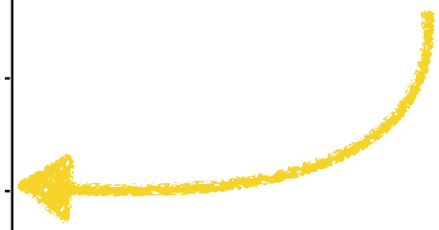
Logical Instructions

AND, OR, NOT, XOR

a	b	a and b
F	F	F
F	T	F
T	F	F
T	T	T

Truth Table



a	b	a and b
F	F	F
F	T	F
T	F	F
T	T	T

a	b	a and b
0	0	0
0	1	0
1	0	0
1	1	1

a	b	a and b
F	F	F
F	T	F
T	F	F
T	T	T

a	b	a and b
0	0	0
0	1	0
1	0	0
1	1	1

a	b	a or b
0	0	0
0	1	1
1	0	1
1	1	1

a	b	a and b
F	F	F
F	T	F
T	F	F
T	T	T

a	b	a and b
0	0	0
0	1	0
1	0	0
1	1	1

a	b	a or b
0	0	0
0	1	1
1	0	1
1	1	1

a	b	a xor b
0	0	0
0	1	1
1	0	1
1	1	0

a	b	a and b
F	F	F
F	T	F
T	F	F
T	T	T

a	b	a and b
0	0	0
0	1	0
1	0	0
1	1	1

a	b	a or b
0	0	0
0	1	1
1	0	1
1	1	1

a	b	a xor b
0	0	0
0	1	1
1	0	1
1	1	0

a	not a
0	1
1	0

```
    10010
and 11100
---------
```

```
    10010
 or 11100
---------
```

```
    10010
xor 11100
---------
```

```
not 11100
---------
```

Instruction	Feature
AND	Good for setting bits to 0
OR	Good for setting bits to 1
XOR	Good for flipping bits
NOT	Good for complementing all the bits

Image from http://www.staugustinechico.com/wp-content/uploads/2015/05/remember.jpg

and

and dest, src

```
and     op8,op8
and     op16,op16
and     op32,op32

op: mem, reg, imm
```

```
alpha db    0xf3
beta  dw    4
x     dd    6
```

```
and   byte[alpha],7
mov   ax,0x1234
and   ax,0xFF00

and   dword[x], 2
```

or

or dest, src

```
or      op8,op8
or      op16,op16
or      op32,op32

op: mem, reg, imm
```

```
alpha db    3
beta  dw    4
x     dw    0x0F06
```

```
or    byte[alpha],4
mov   ax,0x1234
or    ax,0xFF00

or    word[x], 15
```

xor

xor dest, src

```
xor      op8,op8
xor      op16,op16
xor      op32,op32

op: mem, reg, imm
```

```
alpha db     3
beta  dw     4
x     dd     0xF06
```

```
xor     byte[alpha],0x0F
mov     ax,0x1234
xor     ax,0xFF00

xor     dword[x], 15
```

not

not oprnd

```
not     op8
not     op16
not     op32

op: mem, reg
```

```
alpha db    3
beta  dw    4
x     dd    0xF06
```

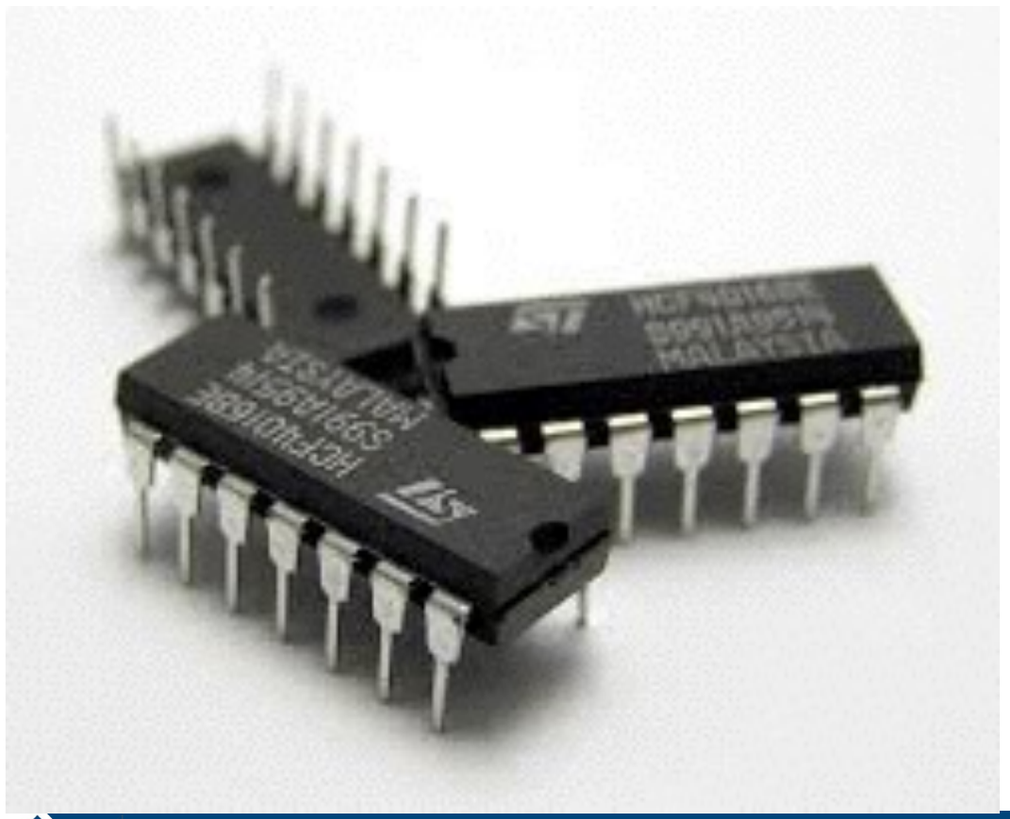
```
not     byte[alpha]
mov     ax,0x1234
not     ax

not     dword[x]
```

Exercise

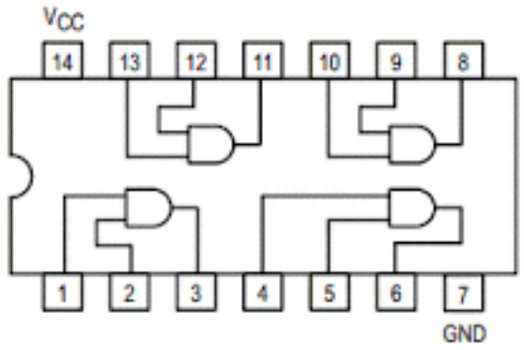
```
x       dd      0
most    dd      0
least   dd      0
        call    _getInput     ; eax <- user int
        mov     dword[x], eax
```

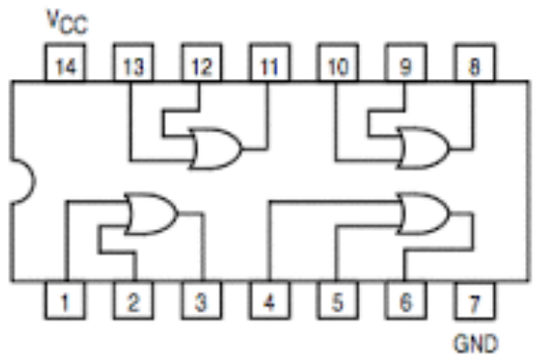
```
; set most to contain all 0s except most
; significant bit of x.  Set least to
; contain all 1s except least significant
; bit of x
```

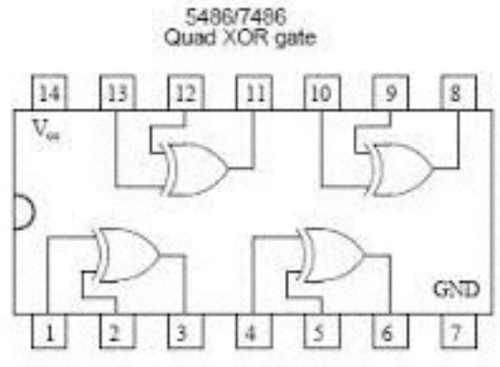
Logic Design

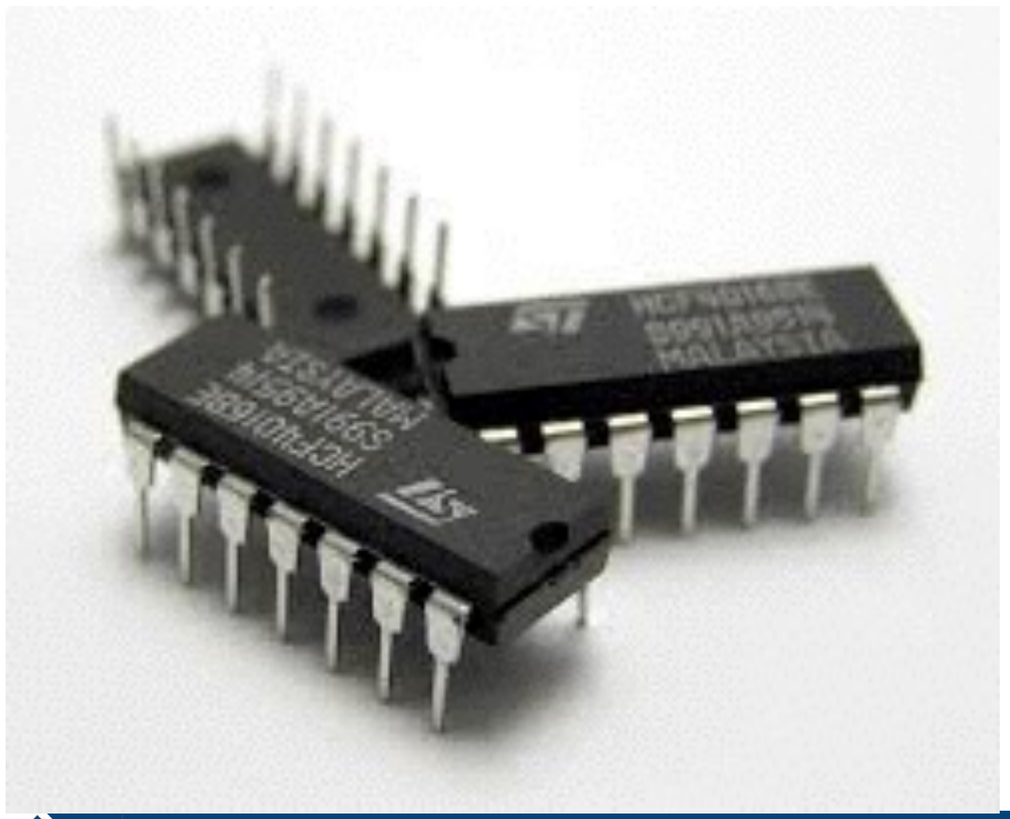


Logic Design









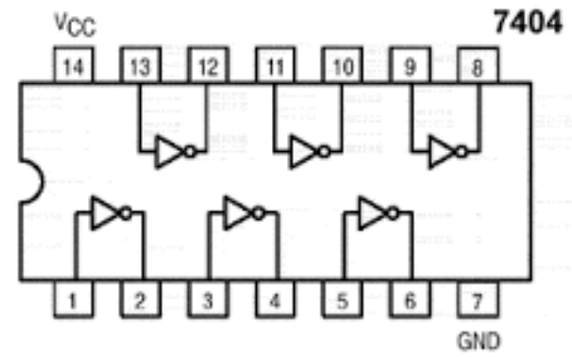
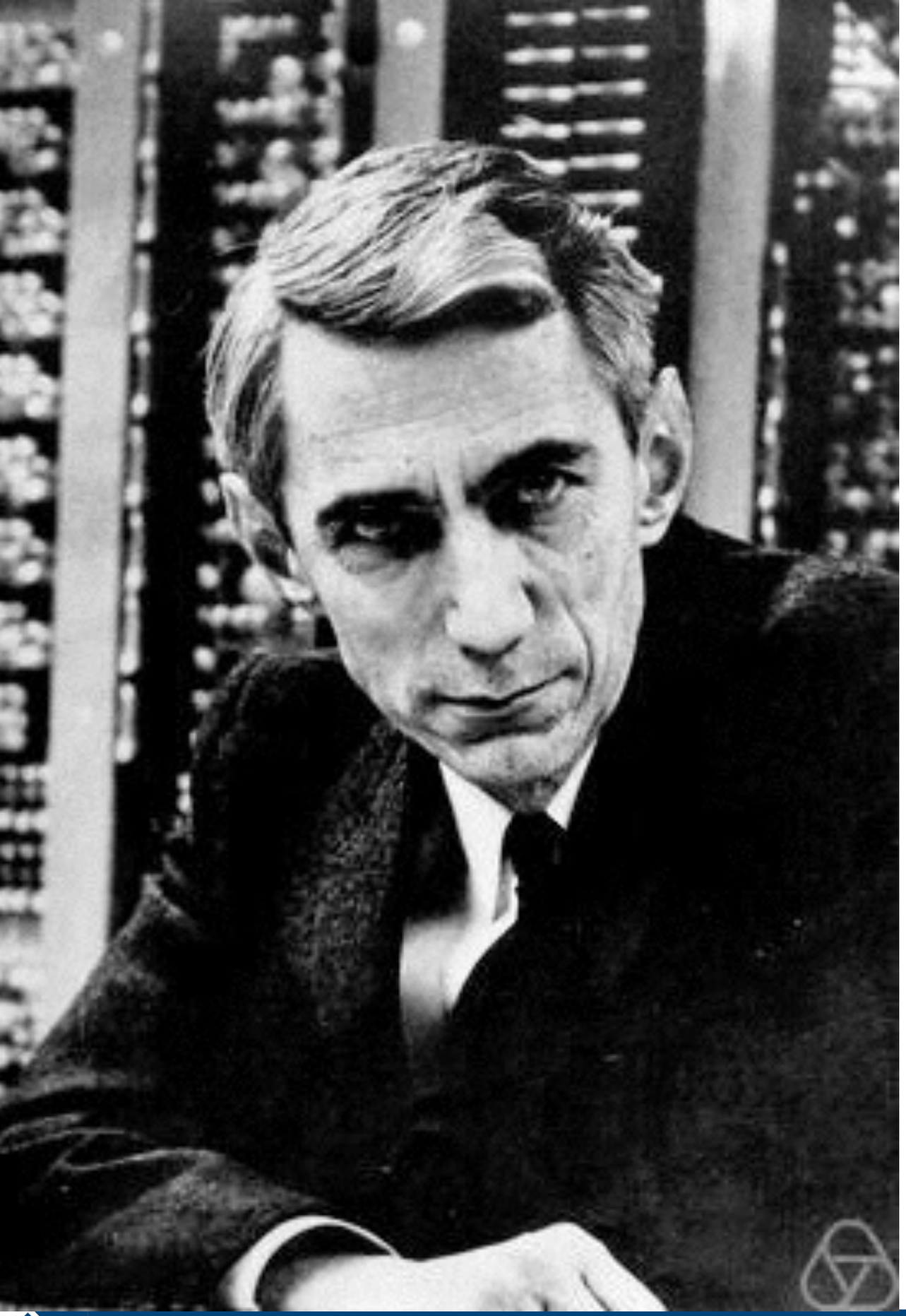


Image from http://www.willegal.net/appleii/images/motherboard.jpg

Apple II Motherboard

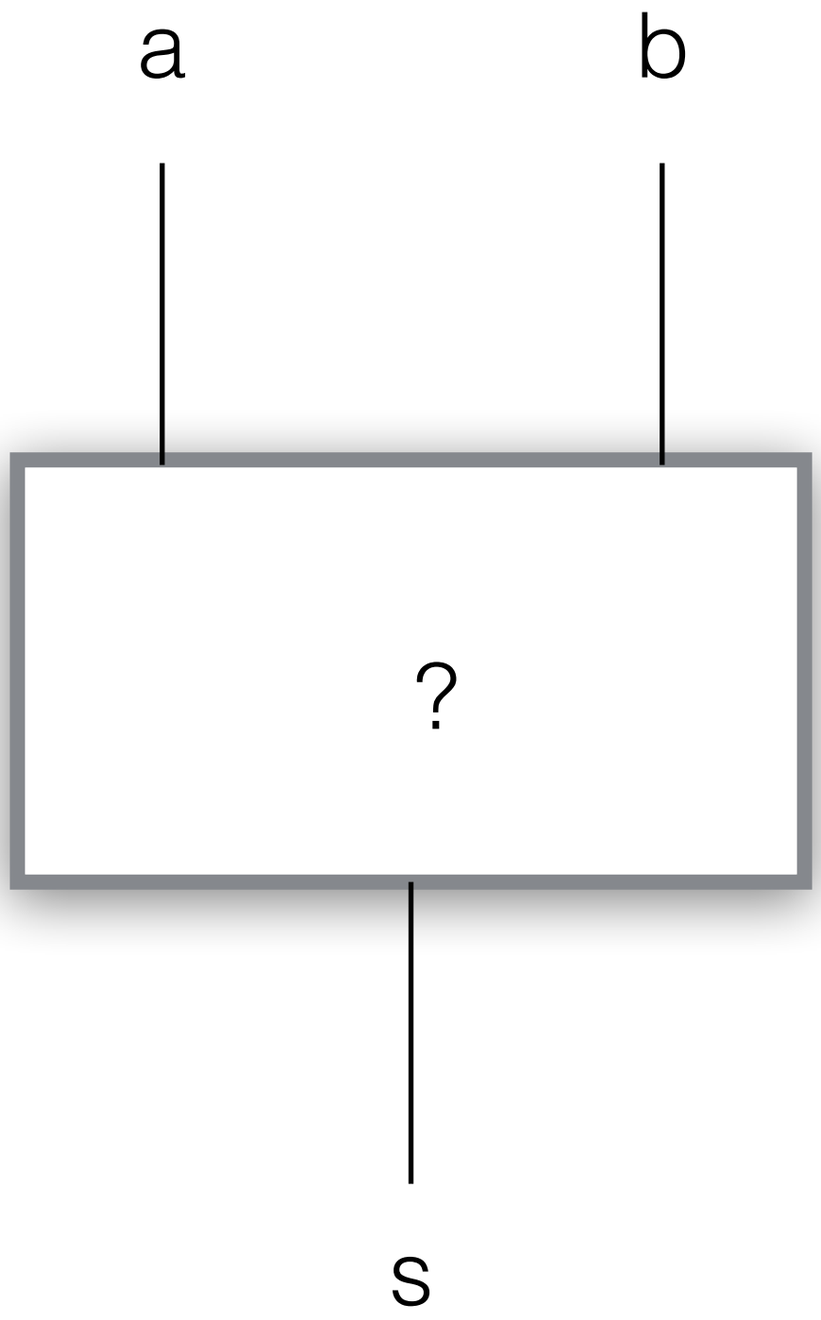


A Bit of History

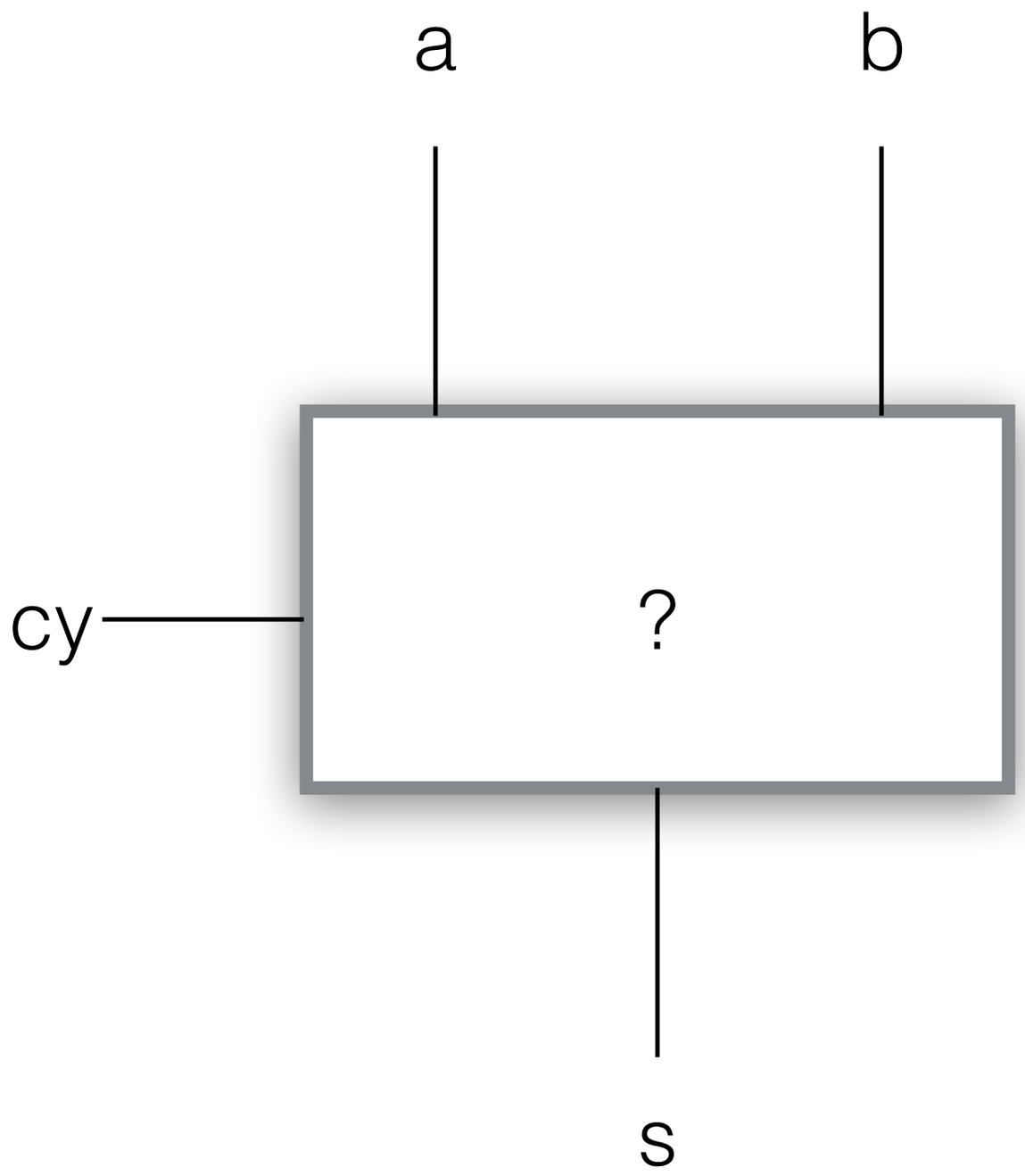
- Claude Shannon
- 21 years old
- 1937
- MIT Master's Thesis
- All arithmetic operations on binary numbers can be performed using boolean logic operators

https://en.wikipedia.org/wiki/Claude_Shannon

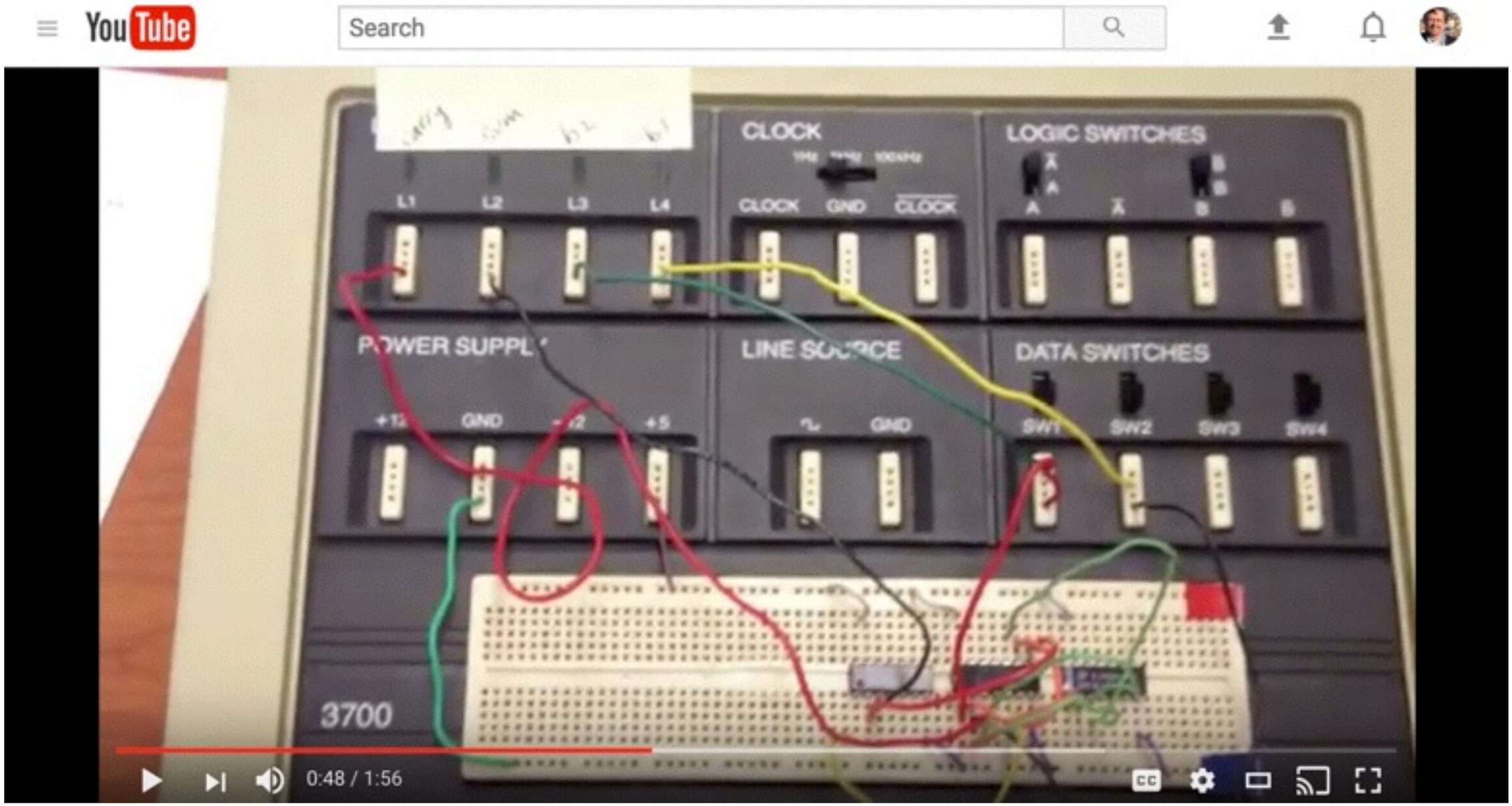
Designing a 2-bit Adder with Logic


a
b
?
S

$$\begin{array}{r} 0 \\ +\ 0 \\ \hline = \quad . \end{array} \qquad \begin{array}{r} 0 \\ +\ 1 \\ \hline = \quad . \end{array} \qquad \begin{array}{r} 1 \\ +\ 0 \\ \hline = \quad . \end{array} \qquad \begin{array}{r} 1 \\ +\ 1 \\ \hline = \quad . \end{array}$$



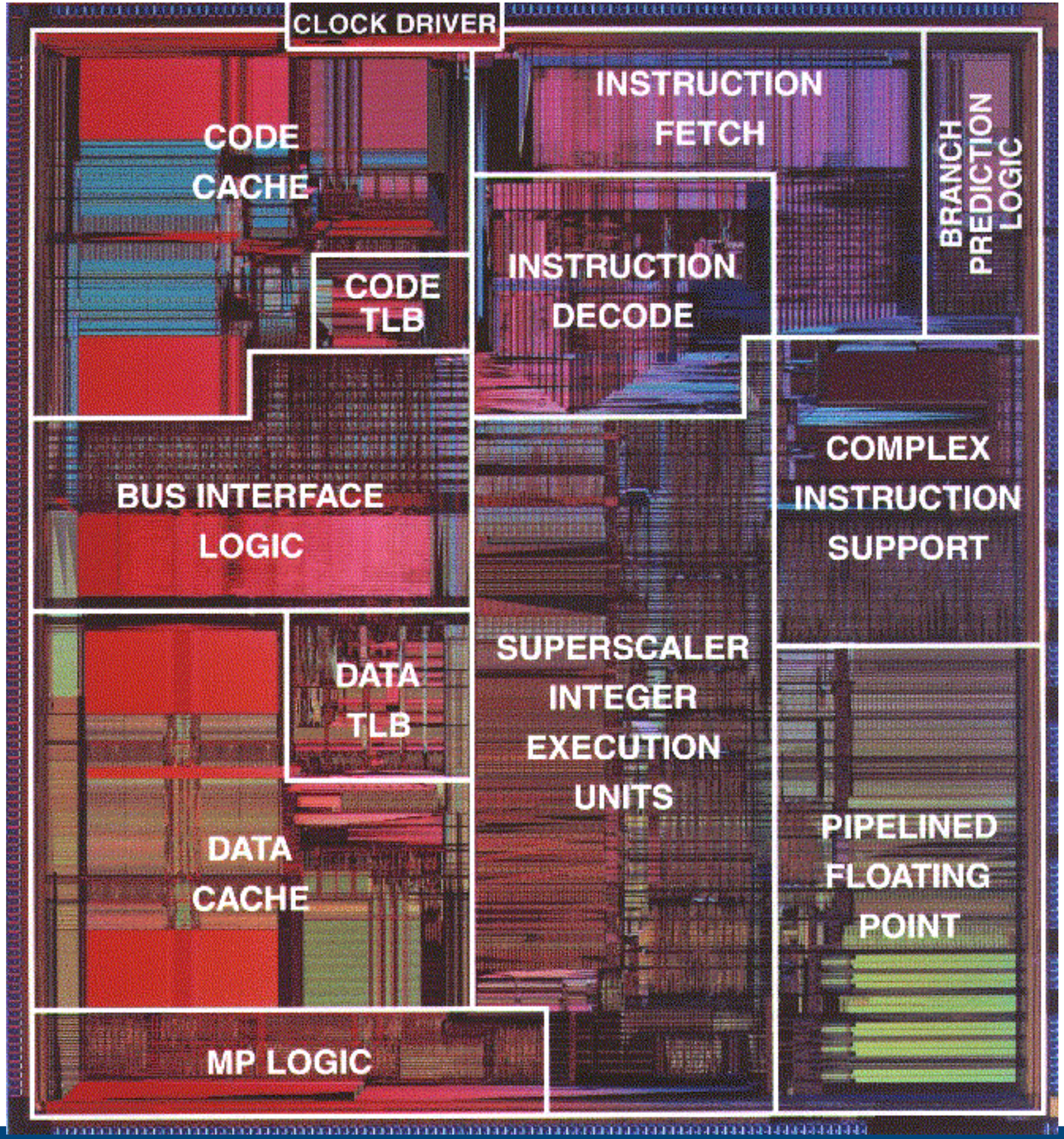
2 inputs
and 2 outputs



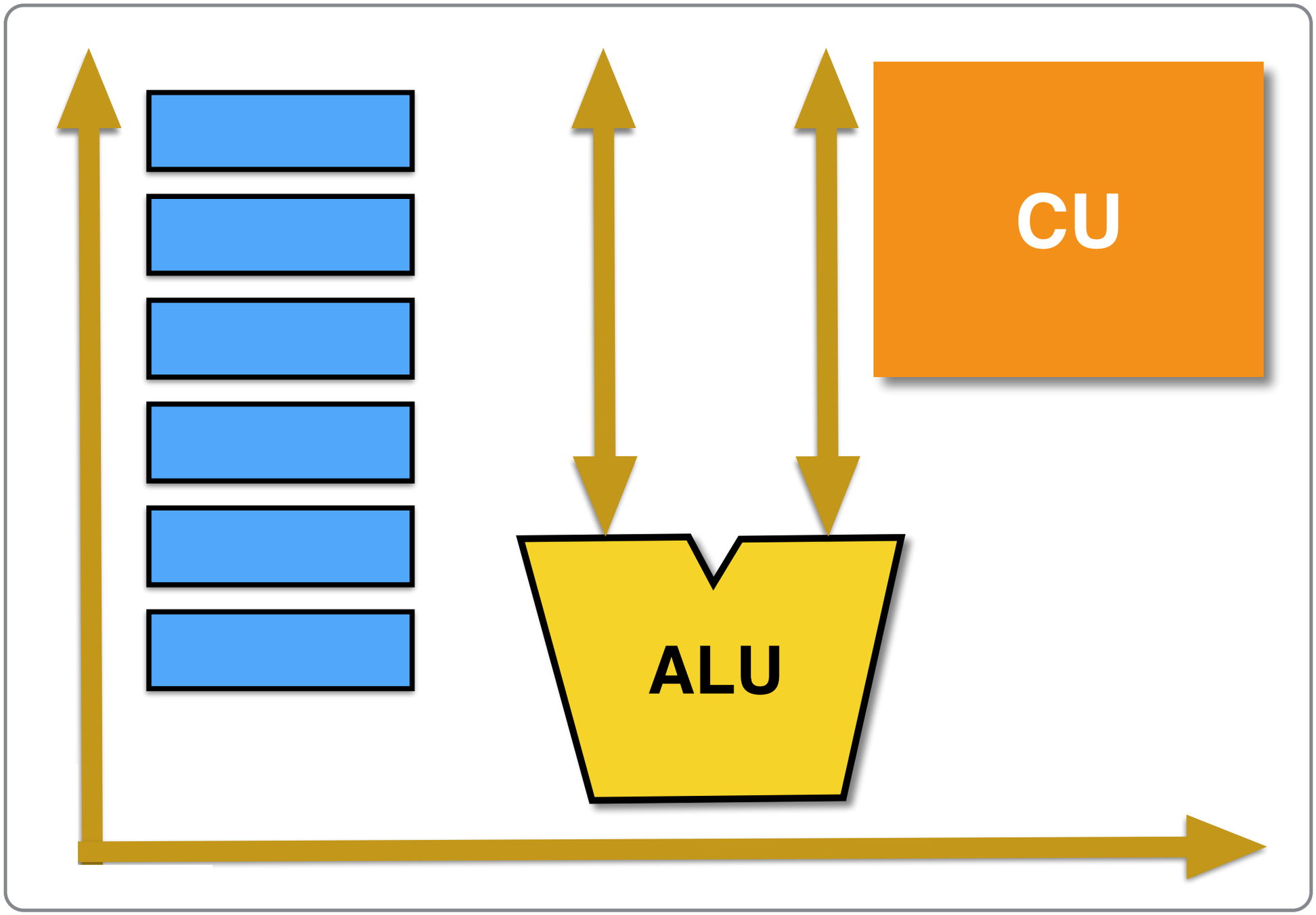
https://www.youtube.com/watch?v=xTQDIiSWK_k

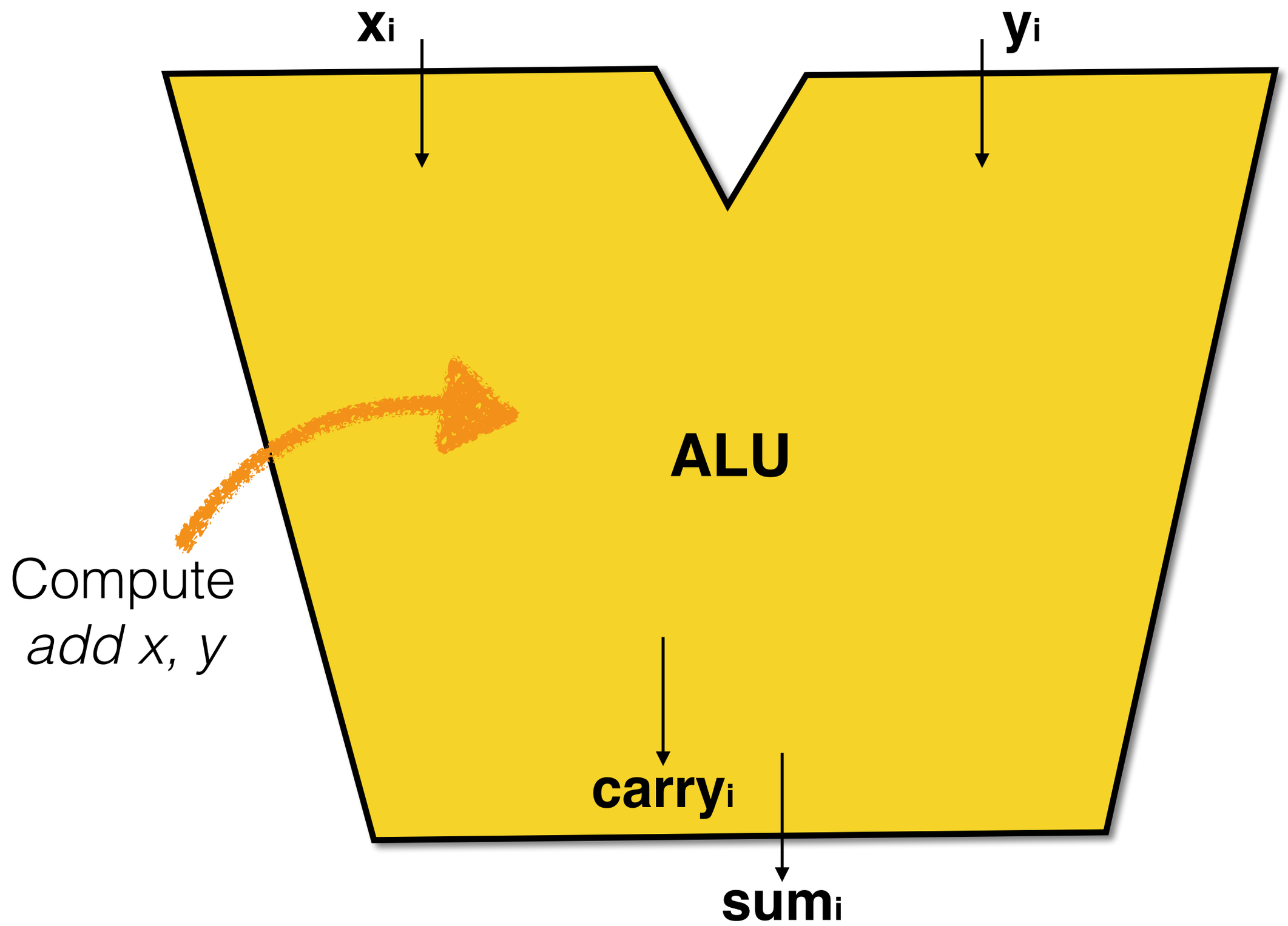
We stopped here last time…

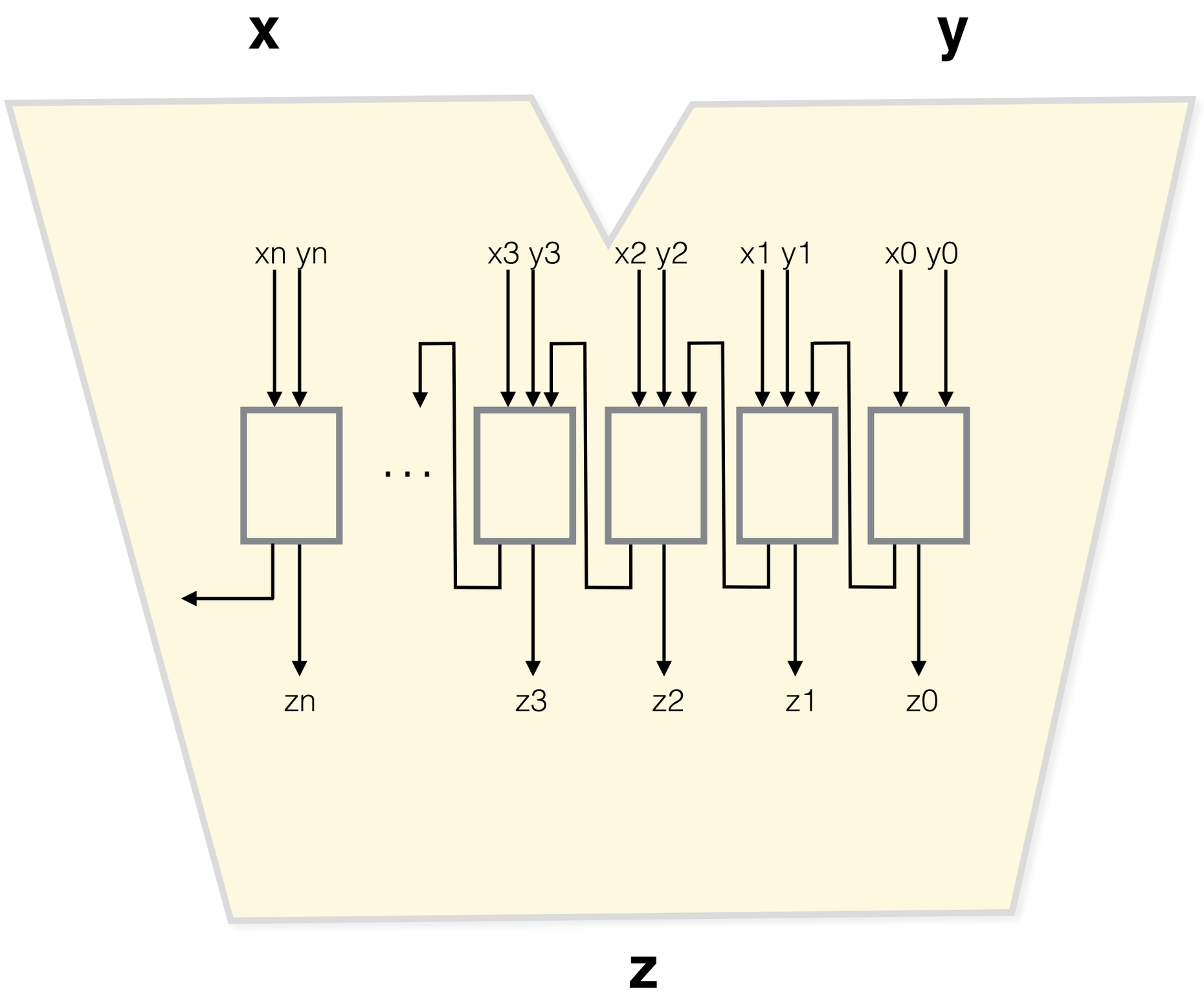
NEGATIVE NUMBERS

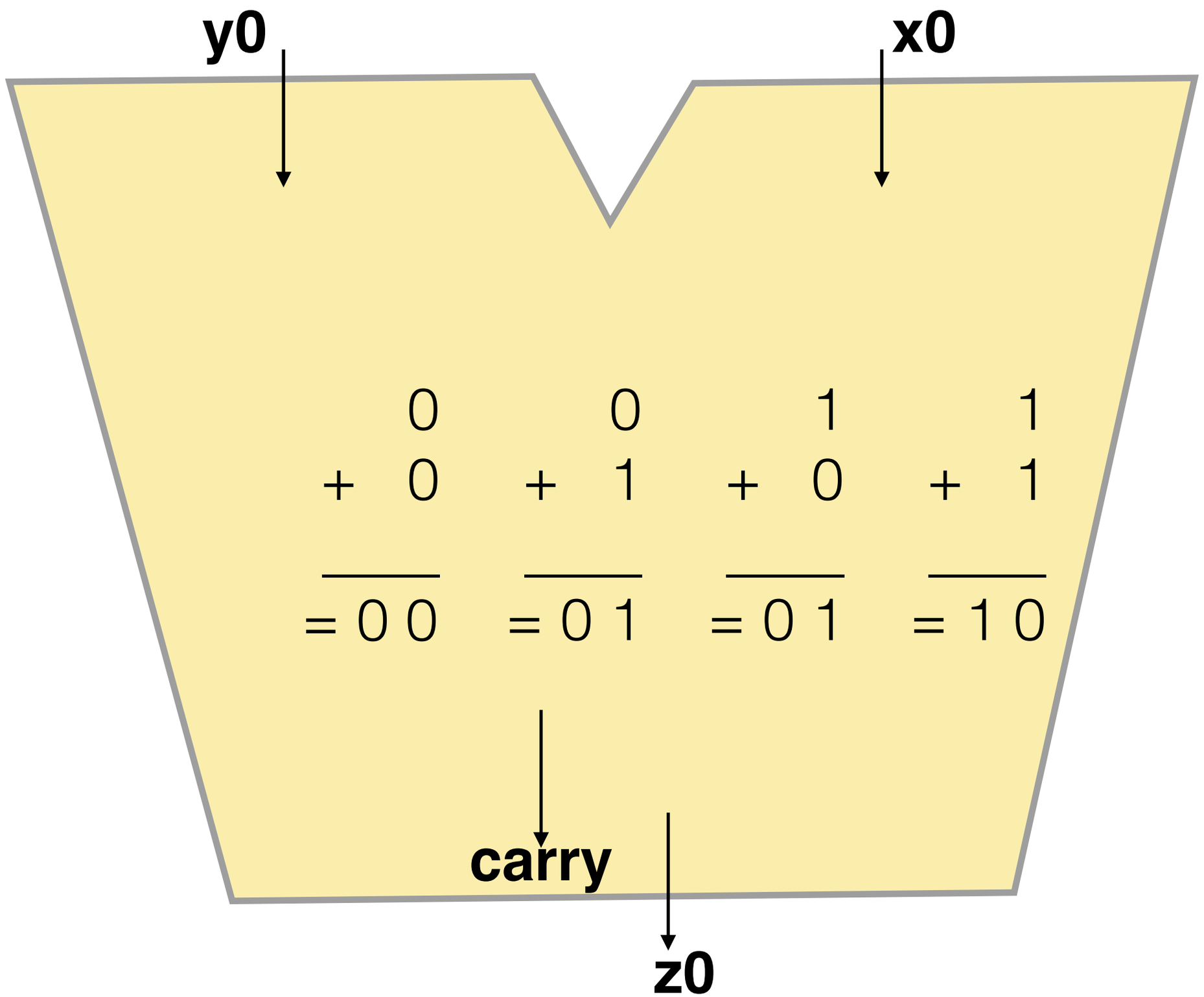

CLOCK DRIVER
CODE CACHE
INSTRUCTION FETCH
BRANCH PREDICTION LOGIC
CODE TLB
INSTRUCTION DECODE
BUS INTERFACE LOGIC
COMPLEX INSTRUCTION SUPPORT
DATA TLB
SUPERSCALER INTEGER EXECUTION UNITS
DATA CACHE
PIPELINED FLOATING POINT
MP LOGIC

Processor




x_i
y_i
ALU
Compute
add x, y
$carry_i$
sum_i


x
y
xn yn
x3 y3
x2 y2
x1 y1
x0 y0
zn
z3
z2
z1
z0
z

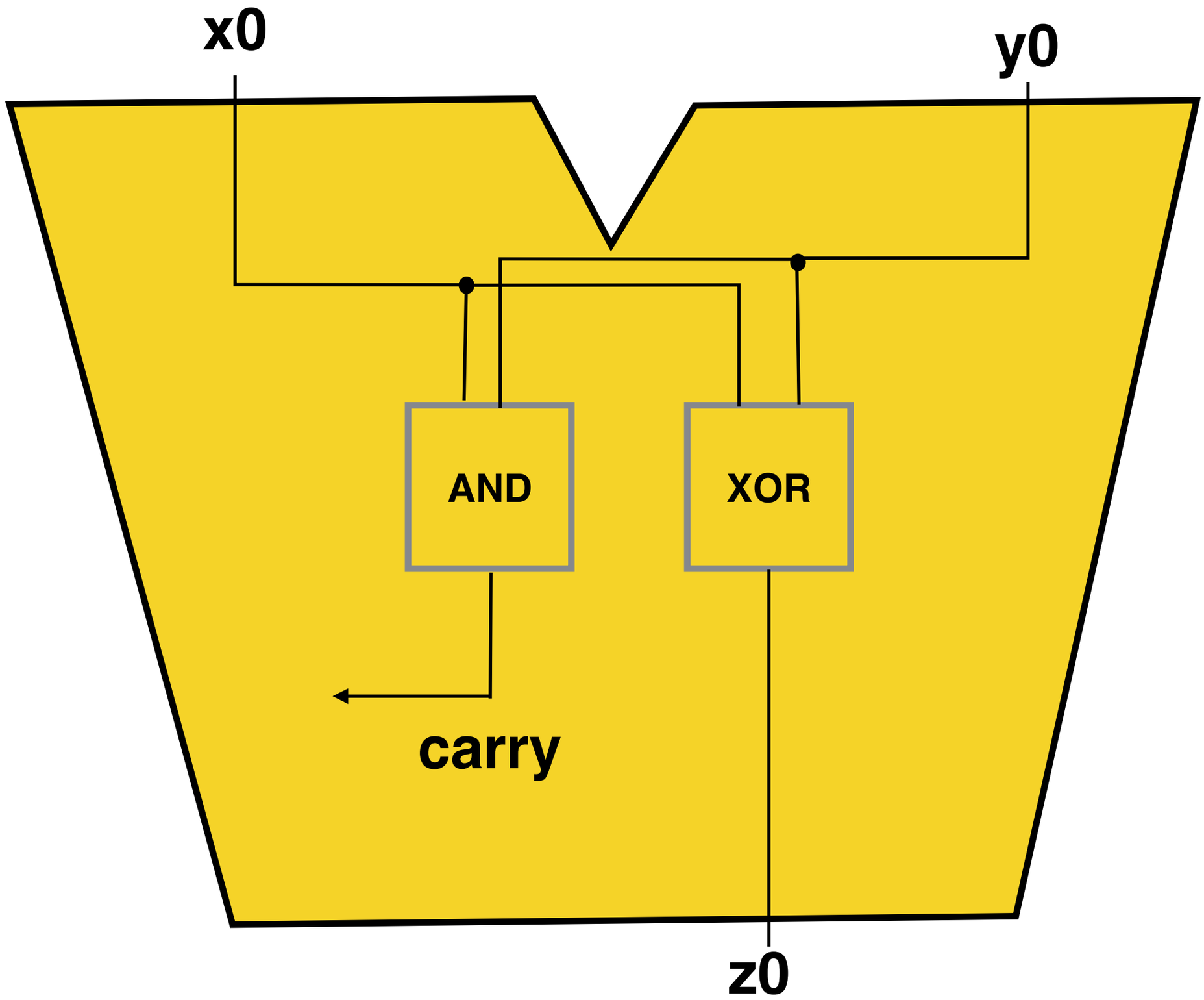

y0
x0
0 0 1 1
+ 0 + 1 + 0 + 1
= 0 0 = 0 1 = 0 1 = 1 0
carry
z0

x0	y0	Carry	z0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

x0	y0	Carry	z0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Carry = x0 **and** y0

z0 = x0 **xor** y0


x0
y0
AND
XOR
carry
z0

Moral of the Story:
Addition is performed
by logic operations
using *natural* binary numbers…

(*unsigned arithmetic*)

How can we represent signed binary numbers when all we have are **bits** (0/1)?

Whichever system we use should work with the binary adder in the ALU…

4-bit Nybble

Binary	Hex	Unsigned Decimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

4-bit Nybble

Sign Bit

Binary	Hex	Unsigned Decimal
0 000	0	0
0 001	1	1
0 010	2	2
0 011	3	3
0 100	4	4
0 101	5	5
0 110	6	6
0 111	7	7
1 000	8	8
1 001	9	9
1 010	A	10
1 011	B	11
1 100	C	12
1 101	D	13
1 110	E	14
1 111	F	15

4-bit Nybble

Binary	Hex	Unsigned Decimal
0 000	0	0
0 001	1	1
0 010	2	2
0 011	3	3
0 100	4	4
0 101	5	5
0 110	6	6
0 111	7	7
1 000	8	8
1 001	9	9
1 010	A	10
1 011	B	11
1 100	C	12
1 101	D	13
1 110	E	14
1 111	F	15

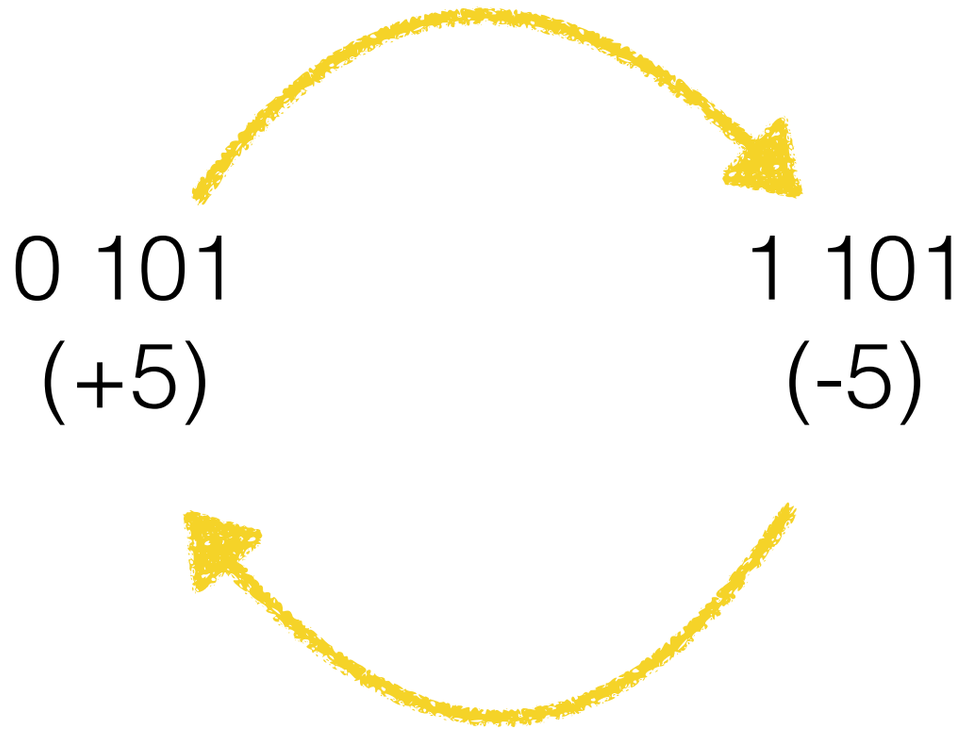
Positive Numbers

Negative Numbers

Signed Magnitude

Number *System*

Signed Magnitude Rule: To find the opposite of a number, just flip its MSB



and vice versa…

4-bit Nybble

Binary	Hex	Unsigned Decimal	**Signed Magnitude**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-0**
1 001	9	9	**-1**
1 010	A	10	**-2**
1 011	B	11	**-3**
1 100	C	12	**-4**
1 101	D	13	**-5**
1 110	E	14	**-6**
1 111	F	15	**-7**

Does this System work With the ALU Adder?

Binary	Hex	Unsigned Decimal	**Signed Magnitud**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-0**
1 001	9	9	**-1**
1 010	A	10	**-2**
1 011	B	11	**-3**
1 100	C	12	**-4**
1 101	D	13	**-5**
1 110	E	14	**-6**
1 111	F	15	**-7**

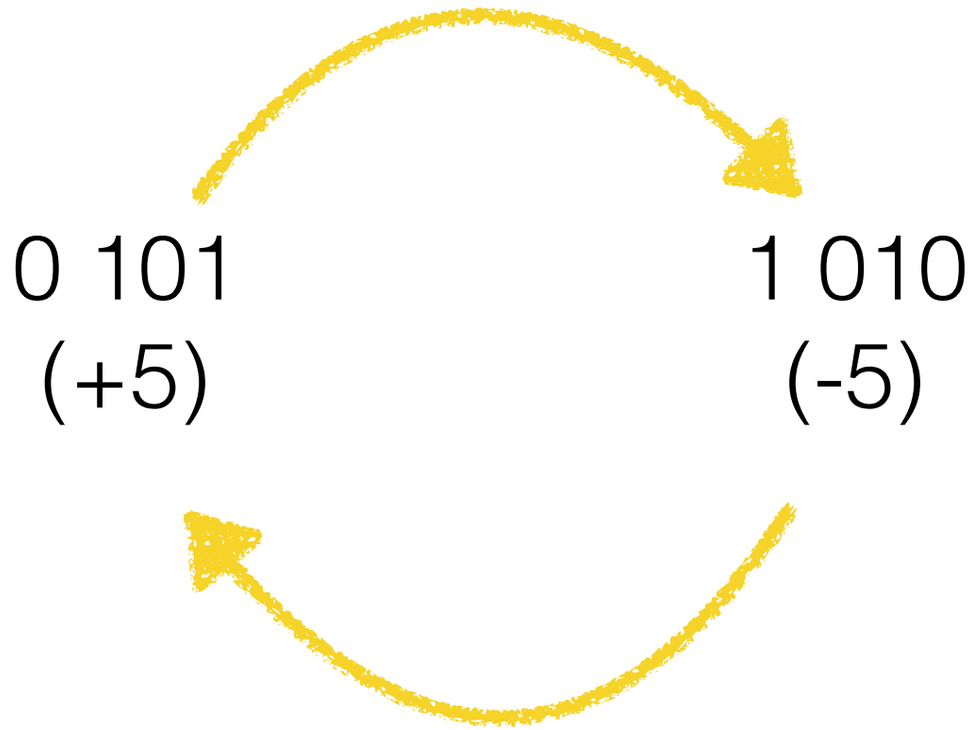
```
   3
+ -3
-----
=  0
```

```
   4
+ -1
-----
=  3
```

1's Complement

Number ***System***

1's Complement Rule: To find the opposite of a number, just flip all its bits



and vice versa…

4-bit Nybble

Binary	Hex	Unsigned Decimal	**1's Complement**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-7**
1 001	9	9	**-6**
1 010	A	10	**-5**
1 011	B	11	**-4**
1 100	C	12	**-3**
1 101	D	13	**-2**
1 110	E	14	**-1**
1 111	F	15	**-0**

Does this System work With the ALU Adder?

Binary	Hex	Unsigned Decimal	**1's Complement**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-7**
1 001	9	9	**-6**
1 010	A	10	**-5**
1 011	B	11	**-4**
1 100	C	12	**-3**
1 101	D	13	**-2**
1 110	E	14	**-1**
1 111	F	15	**-0**

```
    3
+  -3
-----
=   0
```

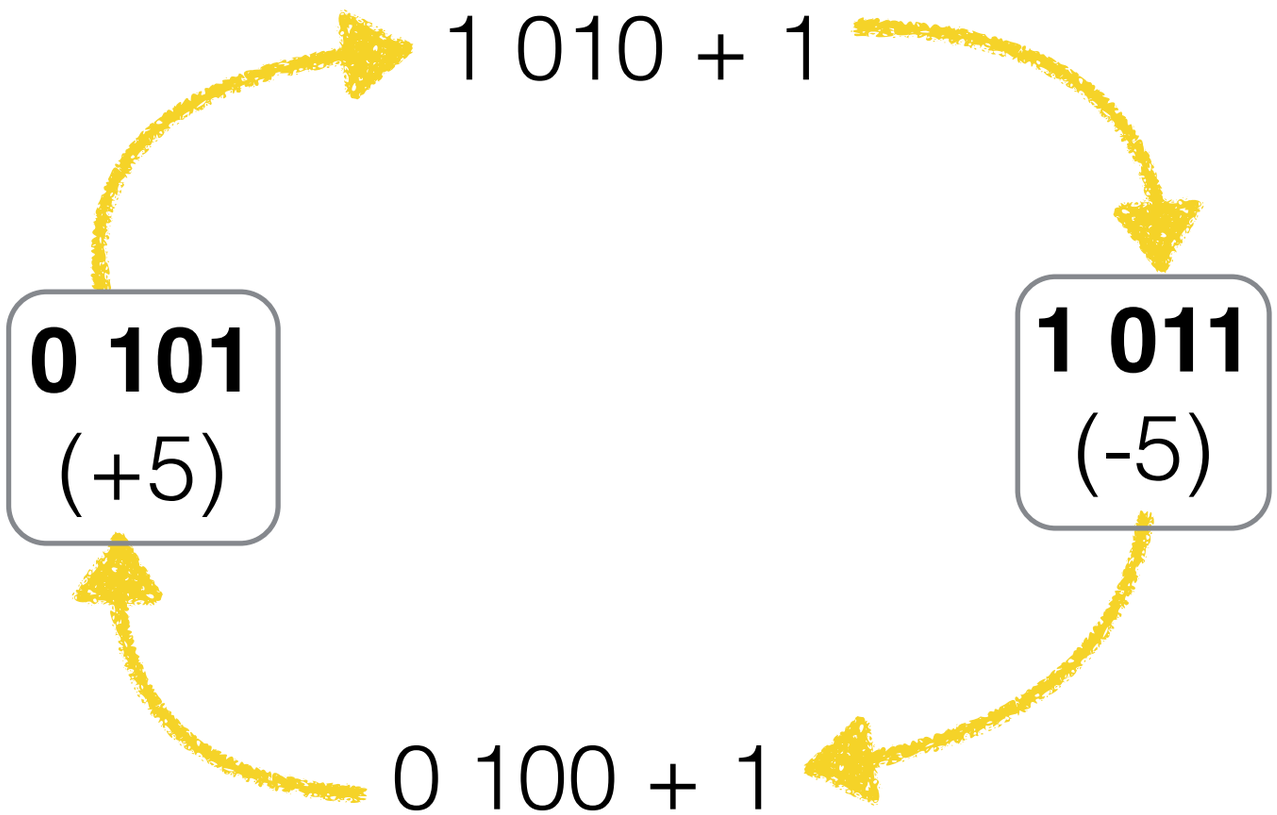
```
    4
+  -1
-----
=   3
```

```
    5
+  -3
-----
=   2
```

2's Complement

Number ***System***

2's Complement Rule: To find the opposite of a number, just flip all its bits, and add 1



and vice versa…

4-bit Nybble

Binary	Hex	Unsigned Decimal	**2's Complement**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-8**
1 001	9	9	**-7**
1 010	A	10	**-6**
1 011	B	11	**-5**
1 100	C	12	**-4**
1 101	D	13	**-3**
1 110	E	14	**-2**
1 111	F	15	**-1**

Does this System work With the ALU Adder?

Binary	Hex	Unsigned Decimal	**2's Complement**
0 000	0	0	**+0**
0 001	1	1	**+1**
0 010	2	2	**+2**
0 011	3	3	**+3**
0 100	4	4	**+4**
0 101	5	5	**+5**
0 110	6	6	**+6**
0 111	7	7	**+7**
1 000	8	8	**-8**
1 001	9	9	**-7**
1 010	A	10	**-6**
1 011	B	11	**-5**
1 100	C	12	**-4**
1 101	D	13	**-3**
1 110	E	14	**-3**
1 111	F	15	**-1**

```
   3
+ -3
-----
=  0
```

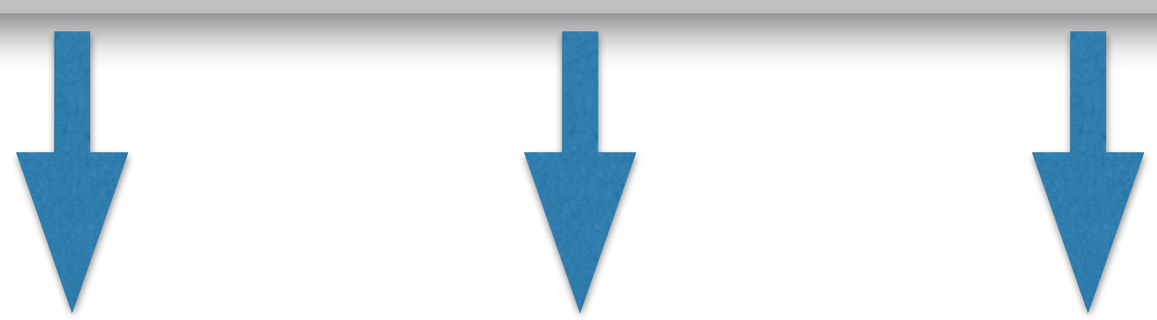
```
   4
+ -1
-----
=  3
```

```
   5
+ -3
-----
=  2
```

Interesting Property

- What is the binary representation of **-1** as a byte?
- What is the binary representation of **-1** as a word?
- What is the binary representation of **-1** as a dword?

```java
int x = 0x7fffffff - 5;

for ( int i=0; i<10; i++ )
   System.out.println( x++ );
```



getcopy Loop0x7fffffff.java

What did you just learn about Java **ints?**

neg

neg oprnd

```
neg      op8
neg      op16
neg      op32

op: mem, reg
```

```
alpha db     1
beta  dw     4
x     dd     0xF06

      neg    byte[alpha]
      mov    ax,1234
      neg    ax

      neg    dword[x]
```

To get the 2's complement of an int

Range of 2's Comp't. ints

Binary	Hex	Unsigned Decimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

Type	Minimum	Maximum	# Bytes
byte	0	255	1
unsigned short	0	65535	2
signed short	-32768	32767	2
unsigned int	0	4,294,967,295	4
signed int	-2,147,483,648	2,147,483,647	4
signed long	-9,223,372,036,854,775,808	9,223,372,036,854,775,807	8

Exercises

http://www.science.smith.edu/dftwiki/index.php/CSC231_Exercises_on_Signed_Numbers