Smith College
Computer Science

CSC231 - Assembly

Week #5

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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***

Conversion

Super Useful!

Decimal to Binary Conversion

Review
Shifting

101001 =

$$101001 = 1x2^5 + 0x2^4 + 1x2^3 + 0x2^2 + 0x2^1 + 1x2^0$$

$$101001 = 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41d$$

$$101001 = 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41d$$

$$\frac{101001}{2} = \frac{1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0}{2}$$

$$101001 = 1\text{x}2^5 + 0\text{x}2^4 + 1\text{x}2^3 + 0\text{x}2^2 + 0\text{x}2^1 + 1\text{x}2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41\text{d}$$

$$\frac{101001}{2} = \frac{1\text{x}2^5 + 0\text{x}2^4 + 1\text{x}2^3 + 0\text{x}2^2 + 0\text{x}2^1 + 1\text{x}2^0}{2}$$

$$= \frac{1\text{x}2^5}{2} + \frac{0\text{x}2^4}{2} + \frac{1\text{x}2^3}{2} + \frac{0\text{x}2^2}{2} + \frac{0\text{x}2^1}{2} + \frac{1\text{x}2^0}{2}$$

$$101001 = 1\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41d$$

$$\frac{101001}{2} = \frac{1\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0}{2}$$

$$= \frac{1\times2^5}{2} + \frac{0\times2^4}{2} + \frac{1\times2^3}{2} + \frac{0\times2^2}{2} + \frac{0\times2^1}{2} + \frac{1\times2^0}{2}$$
$$= 1\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$$

$$101001 = 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41d$$

$$\frac{101001}{2} = \frac{1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0}{2}$$

$$= \frac{1 \times 2^5}{2} + \frac{0 \times 2^4}{2} + \frac{1 \times 2^3}{2} + \frac{0 \times 2^2}{2} + \frac{0 \times 2^1}{2} + \frac{1 \times 2^0}{2}$$
$$= 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$$

$$= 10100$$

$$101001 = 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 32 + 0 + 8 + 0 + 0 + 1$$
$$= 41d$$

$$\frac{101001}{2} = \frac{1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0}{2}$$

$$= \frac{1 \times 2^5}{2} + \frac{0 \times 2^4}{2} + \frac{1 \times 2^3}{2} + \frac{0 \times 2^2}{2} + \frac{0 \times 2^1}{2} + \frac{1 \times 2^0}{2}$$
$$= 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$$

$$= 10100$$
$$= 16 + 0 + 4 + 0 + 0$$
$$= 20d$$

Dividing by the base extracts the least significant digit

Python Program

```
# prompts user for an integer
# decomposes the integer into binary

x = int( input( "> " ) )
binary = ""

while True:
    if x==0:
       break

    remainder = x % 2
    quotient  = x // 2

    if remainder == 0:
        binary = "0" + binary
    else:
        binary = "1" + binary

    print( "%5d = %5d * 2 + %d    quotient=%5d remainder=%d binary=%16s"
           % (x, quotient, remainder, quotient, remainder, binary ) )

    x = quotient
```

Python Program

```
fiveNumbers35 — pi@raspberrypiREG: ~ — ssh — 88×20
pi@raspberrypiREG: ~          pi@raspberrypiREG: ~          Python
231b@aurora ~/handout $ ./decimal2binary.py
> 12345
12345 =  6172 * 2 + 1   (quotient= 6172 remainder=   1) -- binary=                1
 6172 =  3086 * 2 + 0   (quotient= 3086 remainder=   0) -- binary=               01
 3086 =  1543 * 2 + 0   (quotient= 1543 remainder=   0) -- binary=              001
 1543 =   771 * 2 + 1   (quotient=  771 remainder=   1) -- binary=             1001
  771 =   385 * 2 + 1   (quotient=  385 remainder=   1) -- binary=            11001
  385 =   192 * 2 + 1   (quotient=  192 remainder=   1) -- binary=           111001
  192 =    96 * 2 + 0   (quotient=   96 remainder=   0) -- binary=          0111001
   96 =    48 * 2 + 0   (quotient=   48 remainder=   0) -- binary=         00111001
   48 =    24 * 2 + 0   (quotient=   24 remainder=   0) -- binary=        000111001
   24 =    12 * 2 + 0   (quotient=   12 remainder=   0) -- binary=       0000111001
   12 =     6 * 2 + 0   (quotient=    6 remainder=   0) -- binary=      00000111001
    6 =     3 * 2 + 0   (quotient=    3 remainder=   0) -- binary=     000000111001
    3 =     1 * 2 + 1   (quotient=    1 remainder=   1) -- binary=    1000000111001
    1 =     0 * 2 + 1   (quotient=    0 remainder=   1) -- binary=   11000000111001
231b@aurora ~/handout $
```

```
# prompts user for an int
# decomposes the integer

x = int( input( "> " ) )
binary = ""

while True:
    if x==0:
        break

    remainder = x % 2
    quotient  = x // 2

    if remainder == 0:
        binary = "0" + binary
    else:
        binary = "1" + binary

    print( "%5d = %5d * 2 + %d    quotient=%5d remainder=%d binary=%16s"
           % (x, quotient, remainder, quotient, remainder, binary ) )

    x = quotient
```

Binary to Decimal

$$
\begin{aligned}
101001 &= 1\text{x}2^5 + 0\text{x}2^4 + 1\text{x}2^3 + 0\text{x}2^2 + 0\text{x}2^1 + 1\text{x}2^0 \\
&= 32 + 0 + 8 + 0 + 0 + 1 \\
&= 41\text{d}
\end{aligned}
$$

Binary to Hex

1010010 =

1010010 = 01010010

1010010 = 01010010

= 0101 0010

^

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

1010010 = 01010010
= 0101 0010
^

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

1010010 = 01010010
= 0101 0010
= 5 2

Hex to Binary

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

5A1F =

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

5A1F = 0101 1010 0001 1111

Hex to Decimal

1A2F =

$$1A2F = 1 \times 16^3 + A \times 16^2 + 2 \times 16^1 + F \times 16^0$$

$$=$$

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

$$
\begin{aligned}
1A2F &= 1 \times 16^3 + A \times 16^2 + 2 \times 16^1 + F \times 16^0 \\
&= 1 \times 4096 + 10 \times 256 + 2 \times 16 + 15 \times 1 \\
&=
\end{aligned}
$$

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

$$
\begin{aligned}
1A2F &= 1 \times 16^3 + A \times 16^2 + 2 \times 16^1 + F \times 16^0 \\
&= 1 \times 4096 + 10 \times 256 + 2 \times 16 + 15 \times 1 \\
&= 4096 + 2560 + 32 + 15 \\
&=
\end{aligned}
$$

0000	**0**
0001	**1**
0010	**2**
0011	**3**
0100	**4**
0101	**5**
0110	**6**
0111	**7**
1000	**8**
1001	**9**
1010	**A**
1011	**B**
1100	**C**
1101	**D**
1110	**E**
1111	**F**

$$\begin{aligned} 1A2F &= 1 \times 16^3 + A \times 16^2 + 2 \times 16^1 + F \times 16^0 \\ &= 1 \times 4096 + 10 \times 256 + 2 \times 16 + 15 \times 1 \\ &= 4096 + 2560 + 32 + 15 \\ &= 6703 \end{aligned}$$

Decimal to Hex

Do:

Decimal —> Binary

Binary—> Hex

Exercises

http://www.science.smith.edu/dftwiki/index.php/CSC231_Review_of_hexadecimal_number_system

Convert these **hexadecimal** numbers to **binary**, and to **decimal**.

```
1111

1234

AAAA

F001

FFFF
```

Convert these **decimal** numbers to **binary**, and **hexadecimal**

65

127

What comes after these **hexadecimal** numbers, logically?

aaAA

9999

19F

1ABF

FFEF

F00F

ABCDEF

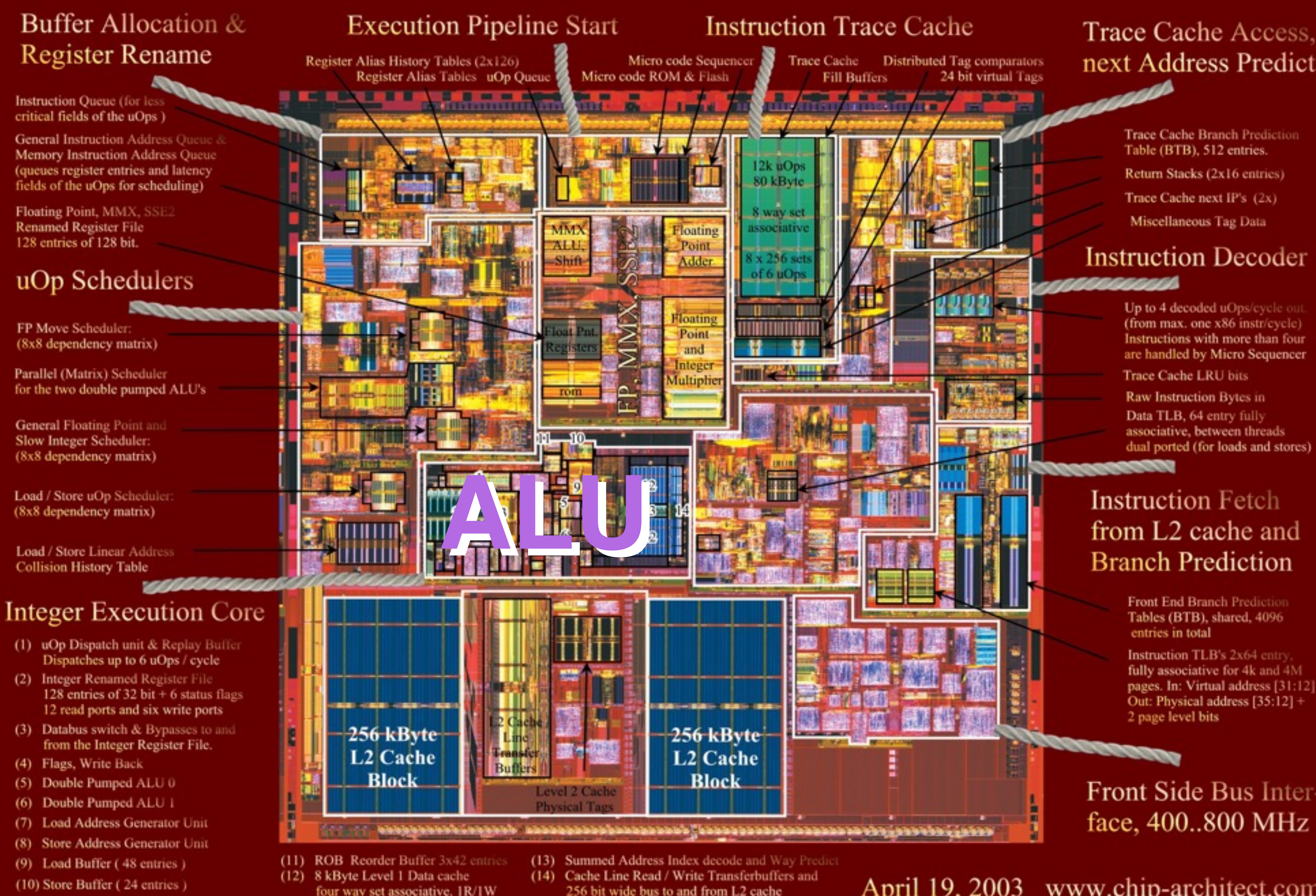
Perform the following additions in hex

```
  1000      1234      1234      FFFF
+ AAAA    +    F    + ABCD    + FFFF
```

We stopped here last time…

More Arithmetic Instructions

Intel Pentium 4 Northwood



Right now,
we are dealing only
with **UNSIGNED** integers!

inc

inc operand

```
inc     reg8
inc     reg16
inc     reg32
inc     mem8
inc     mem16
inc     mem32
```

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

      inc   al
      inc   cx
      inc   ebx

      inc   word[beta]   ;beta <- 5
      inc   dword[x]     ;x <- 1
```

dec

dec operand

```
dec     reg8
dec     reg16
dec     reg32
dec     mem8
dec     mem16
dec     mem32
```

```
alpha db    3
beta  dw    4
x     dd    6

      dec   al            ;al <- al-1
      dec   cx
      dec   ebx

      dec   word[beta]    ;beta <- 3
      dec   dword[x]      ;x <- 5
```

mul

mul operand

```
mul     reg8
mul     reg16
mul     reg32
mul     mem8
mul     mem16
mul     mem32
```

Observation

```
   1001
x  1110
```

mul

```
mul     reg8
mul     reg16
mul     reg32
mul     mem8
mul     mem16
mul     mem32
```

mul operand

edx:eax <— $operand_{32}$ * eax
dx:ax <— $operand_{16}$ * ax
ax <— $operand_{8}$ * al

```
alpha db    3
beta  dw    4
x     dd    6

      mul   byte[alpha]   ;ax <- al*alpha
      mul   ebx           ;edx:eax <-
                          ;     ebx*eax
```

This has tremendously important **consequences**!

```
public class JavaLimits {

        public static void main(String[] args) {
                // ----------------------------------------------
                // a multiplication of ints
                int x = 0x30000001;
                int y = 0x30000001;

                System.out.println( "x = " + x );
                System.out.println( "y = " + y );

                int z = x * y;

                System.out.println( "z = " + z );
                System.out.println();

        }
}
```

```
public class JavaLimits {

        public static void main(String[] args) {
                // ----------------------------------------------
                // a multiplication of ints
                int x = 0x30000001;
                int y = 0x30000001;

                System.out.println( "x = " + x );
                System.out.println( "y = " + y );

                int z = x * y;

                System.out.println( "z = " + z );
                System.out.println();

        }
}
```

```
x = 805306369
y = 805306369
z = 1610612737
```

How big is a 32-bit **int**?

Ranges (Unsigned Integers)

8 bits	0 - 255
16 bits	0 - 65,535
32 bits	0 - 4,294,967,295

div

```
div     reg8
div     reg16
div     reg32
div     mem8
div     mem16
div     mem32
```

div operand

R : Q	
edx:eax	<— edx:eax/ $operand_{32}$
dx:ax	<— dx:ax / $operand_{16}$
ah:al	<— ax / $operand_{8}$

```
alpha db    3
beta  dw    4
x     dd    6
;compute beta/alpha
      mov   ax, word[beta]
      div   byte[alpha]
;quotient in al
;remainder in ah
```

Exercise

Compute x = 2*alpha +3*beta + x - 1

```
alpha db     3
beta  dw     4
x     dd     6
```

Logical Instructions

AND, OR, NOT, XOR

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

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

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

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

and

and dest, src

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

op: mem, reg, imm
```

```
alpha db    3
beta  dw    4
x     dd    6

      and   byte[alpha],4
      mov   ax,0x1234
      and   ax,0xFF00

      and   dword[x], 1
```

or

or dest, src

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

op: mem, reg, imm
```

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

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

      or    dword[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],4
      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]
```

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

NEGATIVE NUMBERS

0100 1100

Signed Magnitude

0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111

Signed Magnitude

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

Signed Magnitude

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

```
    0 010
+   0 011
---------
```

```
    0 110
+   1 011
---------
```

1's Complement

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

1's Complement

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

```
    0 010
  + 0 011
  -------
```

```
    0 110
  + 1 011
  -------
```

```
    0 110
  + 1 111
  -------
```

2's Complement

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

2's Complement

```
0 000
0 001
0 010
0 011
0 100
0 101
0 110
0 111
1 000
1 001
1 010
1 011
1 100
1 101
1 110
1 111
```

```
    0 010
+   0 011
---------

    0 110
+   1 011
---------

    0 110
+   1 111
---------
```

Range of 2's Complement Number Systems