TUTORIAL

Emulador ***Emu8086*** do

Microprocessador 8086

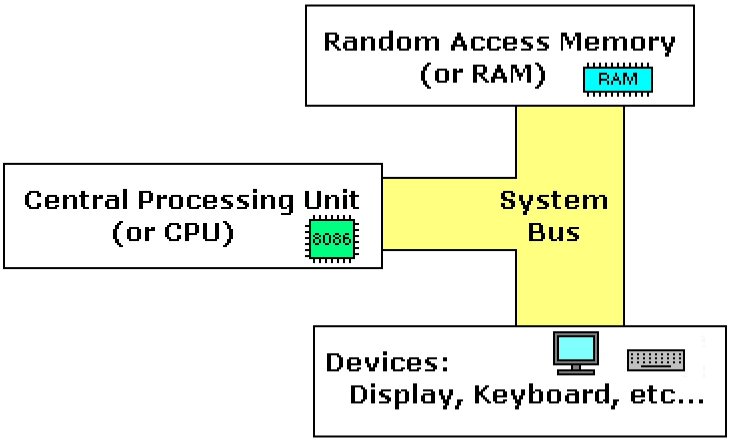
8086 Assembler Tutorial for Beginners (Part 1)

This tutorial is intended for those who are not familiar with assembler at all, or have a very distant idea about it. Of course if you have knowledge of some other programming language (Basic, C/C++, Pascal...) that may help you a lot. But even if you are familiar with assembler, it is still a good idea to look through this document in order to study *Emu8086* syntax.

It is assumed that you have some knowledge about number representation (HEX/BIN), if not it is highly recommended to study **Numbering Systems Tutorial** before you proceed.

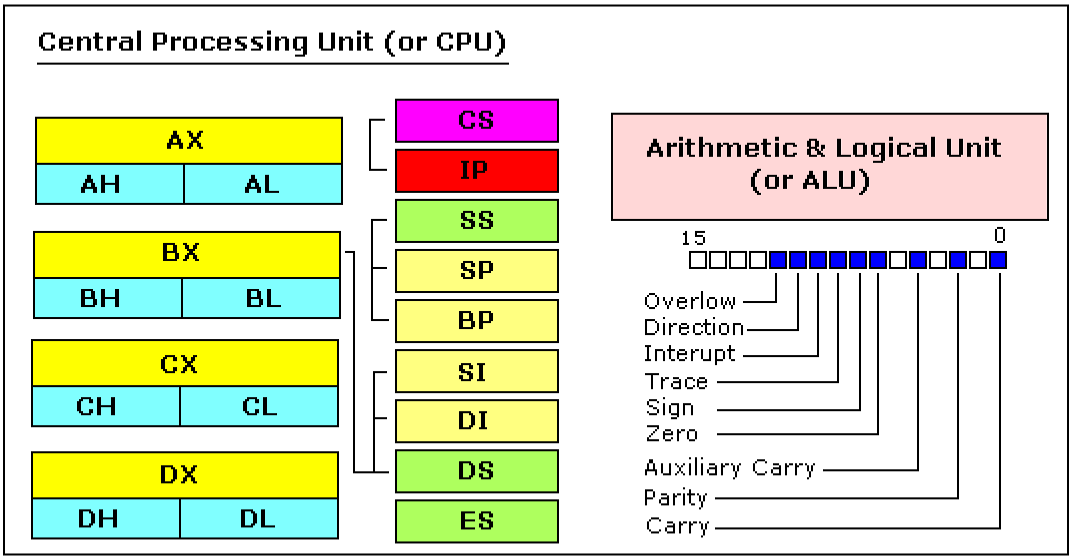
What is an assembly language?

Assembly language is a low level programming language. You need to get some knowledge about computer structure in order to understand anything. The simple computer model as I see it:



The **system bus** (shown in yellow) connects the various components of a computer.
The **CPU** is the heart of the computer, most of computations occur inside the **CPU**.
RAM is a place to where the programs are loaded in order to be executed.

Inside the CPU



GENERAL PURPOSE REGISTERS

8086 CPU has 8 general purpose registers, each register has its own name:

- **AX** - the accumulator register (divided into **AH / AL**).
- **BX** - the base address register (divided into **BH / BL**).
- **CX** - the count register (divided into **CH / CL**).
- **DX** - the data register (divided into **DH / DL**).
- **SI** - source index register.
- **DI** - destination index register.
- **BP** - base pointer.
- **SP** - stack pointer.

Despite the name of a register, it's the programmer who determines the usage for each general purpose register. The main purpose of a register is to keep a number (variable). The size of the above registers is 16 bit, it's something like: **0011000000111001b** (in binary form), or **12345** in decimal (human) form.

4 general purpose registers (AX, BX, CX, DX) are made of two separate 8 bit registers, for example if AX= **0011000000111001b**, then AH=**00110000b** and AL=**00111001b**. Therefore, when you modify any of the 8 bit registers 16 bit register is also updated, and vice-versa. The same is for other 3 registers, "H" is for high and "L" is for low part.

Because registers are located inside the CPU, they are much faster than memory. Accessing a memory location requires the use of a system bus, so it takes much longer. Accessing data in a register usually takes no time. Therefore, you should try to keep variables in the registers. Register sets are very small and most registers have special purposes which limit their use as variables, but they are still an excellent place to store temporary data of calculations.

SEGMENT REGISTERS

- **CS** - points at the segment containing the current program.
- **DS** - generally points at segment where variables are defined.
- **ES** - extra segment register, it's up to a coder to define its usage.
- **SS** - points at the segment containing the stack.

Although it is possible to store any data in the segment registers, this is never a good idea. The segment registers have a very special purpose - pointing at accessible blocks of memory.

Segment registers work together with general purpose register to access any memory value. For example if we would like to access memory at the physical address **12345h** (hexadecimal), we should set the **DS = 1230h** and **SI = 0045h**. This is good, since this way we can access much more memory than with a single register that is limited to 16 bit values.
CPU makes a calculation of physical address by multiplying the segment register by 10h and adding general purpose register to it (1230h * 10h + 45h = 12345h):

```
 12300
+ 0045
 -----
 12345
```

The address formed with 2 registers is called an **effective address**.
By default **BX, SI** and **DI** registers work with **DS** segment register;
BP and **SP** work with **SS** segment register.
Other general purpose registers cannot form an effective address!
Also, although **BX** can form an effective address, **BH** and **BL** cannot!

SPECIAL PURPOSE REGISTERS

- **IP** - the instruction pointer.
- **Flags Register** - determines the current state of the processor.

IP register always works together with **CS** segment register and it points to currently executing instruction.
Flags Register is modified automatically by CPU after mathematical operations, this allows to determine the type of the result, and to determine conditions to transfer control to other parts of the program.
Generally you cannot access these registers directly.

8086 Assembler Tutorial for Beginners (Part 2)

Memory Access

To access memory we can use these four registers: **BX, SI, DI, BP**.
Combining these registers inside **[ ]** symbols, we can get different memory locations. These combinations are supported (addressing modes):

[BX + SI] [BX + DI] [BP + SI] [BP + DI]	[SI] [DI] d16 (variable offset only) [BX]	[BX + SI] + d8 [BX + DI] + d8 [BP + SI] + d8 [BP + DI] + d8
[SI] + d8 [DI] + d8 [BP] + d8 [BX] + d8	[BX + SI] + d16 [BX + DI] + d16 [BP + SI] + d16 [BP + DI] + d16	[SI] + d16 [DI] + d16 [BP] + d16 [BX] + d16

d8 - stays for 8 bit displacement.

d16 - stays for 16 bit displacement.

Displacement can be a immediate value or offset of a variable, or even both. It's up to compiler to calculate a single immediate value.

Displacement can be inside or outside of **[ ]** symbols, compiler generates the same machine code for both ways.

Displacement is a **signed** value, so it can be both positive or negative.

Generally the compiler takes care about difference between **d8** and **d16**, and generates the required machine code.

For example, let's assume that **DS = 100**, **BX = 30**, **SI = 70**.
The following addressing mode: **[BX + SI] + 25**
is calculated by processor to this physical address: **100 * 16 + 30 + 70 + 25 = 1725**.

By default **DS** segment register is used for all modes except those with **BP** register, for these **SS** segment register is used.

There is an easy way to remember all those possible combinations using this chart:

BX	SI	+ disp
BP	DI	

You can form all valid combinations by taking only one item from each column or skipping the column by not taking anything from it. As you see **BX** and **BP** never go together. **SI** and **DI** also don't go together. Here is an example of a valid addressing mode: **[BX+5]**.

The value in segment register (CS, DS, SS, ES) is called a "**segment**",
and the value in purpose register (BX, SI, DI, BP) is called an "**offset**".
When DS contains value **1234h** and SI contains the value **7890h** it can be also recorded as **1234:7890**. The physical address will be 1234h * 10h + 7890h = 19BD0h.

In order to say the compiler about data type,
these prefixes should be used:

BYTE PTR - for byte.
WORD PTR - for word (two bytes).

For example:
BYTE PTR [BX]   ; byte access.
    or
WORD PTR [BX]   ; word access.
Emu8086 supports shorter prefixes as well:

b. - for **BYTE PTR**
w. - for **WORD PTR**

sometimes compiler can calculate the data type automatically, but you may not and should not rely on that when one of the operands is an immediate value.

MOV instruction

- Copies the **second operand** (source) to the **first operand** (destination).
- The source operand can be an immediate value, general-purpose register or memory location.
- The destination register can be a general-purpose register, or memory location.
- Both operands must be the same size, which can be a byte or a word.

These types of operands are supported:

```
MOV REG, memory
MOV memory, REG
MOV REG, REG
MOV memory, immediate
MOV REG, immediate
```

For segment registers only these types of **MOV** are supported:

```
MOV SREG, memory
MOV memory, SREG
MOV REG, SREG
MOV SREG, REG
```

```
MOV SREG, REG
```

SREG: DS, ES, SS, and only as second operand: CS.

REG: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.

memory: [BX], [BX+SI+7], variable, etc...

The **MOV** instruction cannot be used to set the value of the **CS** and **IP** registers.

Here is a short program that demonstrates the use of **MOV** instruction:

```
#MAKE_COM#      ; instruct compiler to make COM file.
ORG 100h        ; directive required for a COM program.
MOV AX, 0B800h  ; set AX to hexadecimal value of B800h.
MOV DS, AX      ; copy value of AX to DS.
MOV CL, 'A'     ; set CL to ASCII code of 'A', it is 41h.
MOV CH, 01011111b ; set CH to binary value.
MOV BX, 15Eh    ; set BX to 15Eh.
MOV [BX], CX    ; copy contents of CX to memory at B800:015E
RET             ; returns to operating system.
```

You can **copy & paste** the above program to *Emu8086* code editor, and press [**Compile and Emulate**] button (or press **F5** key on your keyboard).

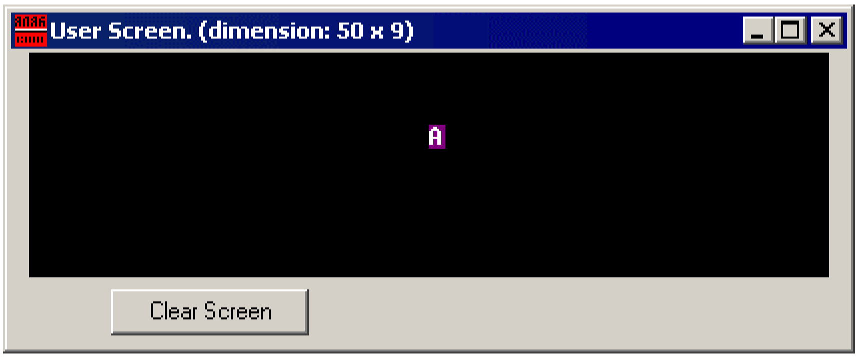
The Emulator window should open with this program loaded, click [**Single Step**] button and watch the register values.

How to do **copy & paste**:

1. Select the above text using mouse, click before the text and drag it down until everything is selected.
2. Press **Ctrl + C** combination to copy.
3. Go to *Emu8086* source editor and press **Ctrl + V** combination to paste.

As you may guess, "**;**" is used for comments, anything after "**;**" symbol is ignored by compiler.

You should see something like that when program finishes:



Actually the above program writes directly to video memory, so you may see that **MOV** is a very powerful instruction.

8086 Assembler Tutorial for Beginners (Part 3)

Variables

Variable is a memory location. For a programmer it is much easier to have some value be kept in a variable named "**var1**" then at the address 5A73:235B, especially when you have 10 or more variables.

Our compiler supports two types of variables: **BYTE** and **WORD**.

Syntax for a variable declaration:

name **DB** *value*

name **DW** *value*

DB - stays for Define Byte.
DW - stays for Define Word.

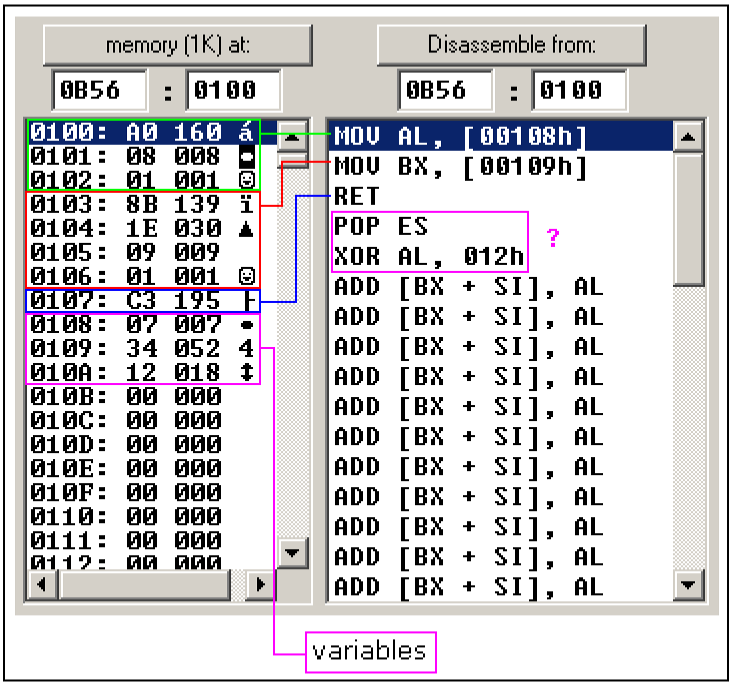
name - can be any letter or digit combination, though it should start with a letter. It's possible to declare unnamed variables by not specifying the name (this variable will have an address but no name).

value - can be any numeric value in any supported numbering system (hexadecimal, binary, or decimal), or "**?**" symbol for variables that are not initialized.

As you probably know from *part 2* of this tutorial, **MOV** instruction is used to copy values from source to destination.
Let's see another example with **MOV** instruction:

```
#MAKE_COM#
ORG 100h

MOV AL, var1
MOV BX, var2

RET    ; stops the program.

VAR1 DB 7
var2 DW 1234h
```

Copy the above code to *Emu8086* source editor, and press **F5** key to compile and load it in the emulator. You should get something like:



As you see this looks a lot like our example, except that variables are replaced with actual memory locations. When compiler makes machine code, it automatically replaces all variable names with their **offsets**. By default segment is loaded in **DS** register (when **COM** files is loaded the value of **DS** register is set to the same value as **CS** register - code segment).

In memory list first row is an **offset**, second row is a **hexadecimal value**, third row is **decimal value**, and last row is an **ASCII** character value.

Compiler is not case sensitive, so "**VAR1**" and "**var1**" refer to the same variable.

The offset of **VAR1** is **0108h**, and full address is **0B56:0108**.

The offset of **var2** is **0109h**, and full address is **0B56:0109**, this variable is a **WORD** so it occupies **2 BYTES**. It is assumed that low byte is stored at lower address, so **34h** is located before **12h**.

You can see that there are some other instructions after the **RET** instruction, this happens because disassembler has no idea about where the data starts, it just processes the values in memory and it understands them as valid 8086 instructions (we will learn them later). You can even write the same program using **DB** directive only:

```
#MAKE_COM#
ORG 100h

DB 0A0h
DB 08h
DB 01h

DB 8Bh
DB 1Eh
DB 09h
DB 01h

DB 0C3h

DB 7

DB 34h
DB 12h
```

Copy the above code to *Emu8086* source editor, and press **F5** key to compile and load it in the emulator. You should get the same disassembled code, and the same functionality!

As you may guess, the compiler just converts the program source to the set of bytes, this set is called **machine code**, processor understands the **machine code** and executes it.

ORG 100h is a compiler directive (it tells compiler how to handle the source code). This directive is very important when you work with variables. It tells compiler that the executable file will be loaded at the **offset** of 100h (256 bytes), so compiler should calculate the correct address for all variables when it replaces the variable names with their **offsets**. Directives are never converted to any real **machine code**.
Why executable file is loaded at **offset** of **100h**? Operating system keeps some data about the program in the first 256 bytes of the **CS** (code segment), such as command line parameters and etc.
Though this is true for **COM** files only, **EXE** files are loaded at offset of **0000**, and generally use special segment for variables. Maybe we'll talk more about **EXE** files later.

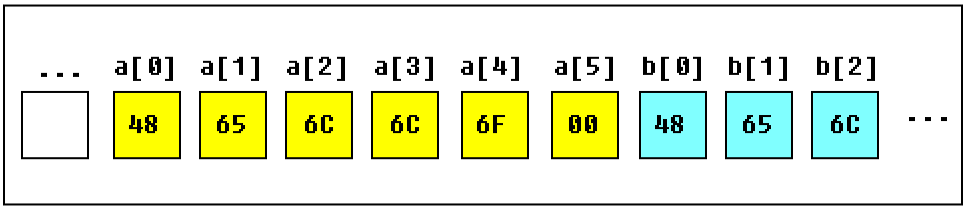
Arrays

Arrays can be seen as chains of variables. A text string is an example of a byte array, each character is presented as an ASCII code value (0..255).

Here are some array definition examples:

a DB 48h, 65h, 6Ch, 6Ch, 6Fh, 00h
b DB 'Hello', 0

b is an exact copy of the *a* array, when compiler sees a string inside quotes it automatically converts it to set of bytes. This chart shows a part of the memory where these arrays are declared:



You can access the value of any element in array using square brackets, for example:
MOV AL, a[3]

You can also use any of the memory index registers **BX, SI, DI, BP**, for example:
MOV SI, 3
MOV AL, a[SI]

If you need to declare a large array you can use **DUP** operator.
The syntax for **DUP**:

<u>number</u> DUP (<u>value(s)</u>)
<u>number</u> - number of duplicate to make (any constant value).
<u>value</u> - expression that DUP will duplicate.

for example:
c DB 5 DUP(9)
is an alternative way of declaring:
c DB 9, 9, 9, 9, 9

one more example:
d DB 5 DUP(1, 2)
is an alternative way of declaring:
d DB 1, 2, 1, 2, 1, 2, 1, 2, 1, 2

Of course, you can use **DW** instead of **DB** if it's required to keep values larger then 255, or smaller then -128. **DW** cannot be used to declare strings!

The expansion of **DUP** operand should not be over 1020 characters! (the expansion of last example is 13 chars), if you need to declare huge array divide declaration it in two lines (you will get a single huge array in the memory).

Getting the Address of a Variable

There is **LEA** (Load Effective Address) instruction and alternative **OFFSET** operator. Both **OFFSET** and **LEA** can be used to get the offset address of the variable.
LEA is more powerful because it also allows you to get the address of an indexed variables. Getting the address of the variable can be very useful in some situations, for example when you need to pass parameters to a procedure.

Reminder:
In order to tell the compiler about data type,
these prefixes should be used:

BYTE PTR - for byte.
WORD PTR - for word (two bytes).

For example:
BYTE PTR [BX]   ; byte access.
    or
WORD PTR [BX]   ; word access.
Emu8086 supports shorter prefixes as well:

b. - for **BYTE PTR**
w. - for **WORD PTR**

sometimes compiler can calculate the data type automatically, but you may not and should not rely on that when one of the operands is an immediate value.

Here is first example:

```
ORG 100h

MOV    AL, VAR1              ; check value of VAR1 by moving it to AL.
LEA    BX, VAR1              ; get address of VAR1 in BX.
```

Here is another example, that uses **OFFSET** instead of **LEA**:

```
ORG 100h
```

```
RET

VAR1   DB  22h

END
```

Both examples have the same functionality.

These lines:
LEA BX, VAR1
MOV BX, OFFSET VAR1
are even compiled into the same machine code: MOV BX, num
num is a 16 bit value of the variable offset.

Please note that only these registers can be used inside square brackets (as memory pointers): **BX, SI, DI, BP**!
(see previous part of the tutorial).

Constants

Constants are just like variables, but they exist only until your program is compiled (assembled). After definition of a constant its value cannot be changed. To define constants **EQU** directive is used:

name EQU < any expression >

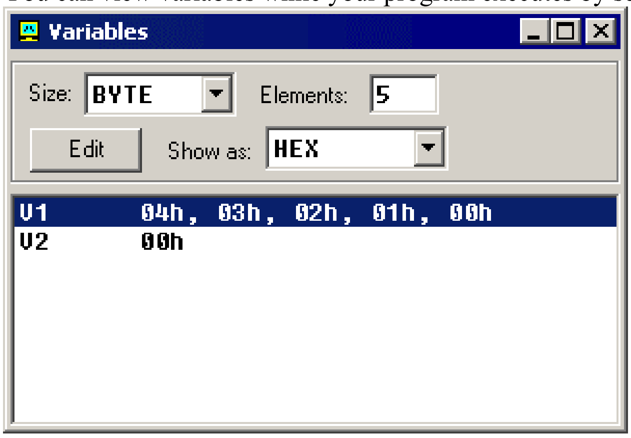
For example:

```
k EQU 5

MOV AX, k
```

The above example is functionally identical to code:

```
MOV AX, 5
```

You can view variables while your program executes by selecting "**Variables**" from the "**View**" menu of emulator.



To view arrays you should click on a variable and set **Elements** property to array size. In assembly language there are not strict data types, so any variable can be presented as an array.

Variable can be viewed in any numbering system:

- **HEX** - hexadecimal (base 16).
- **BIN** - binary (base 2).
- **OCT** - octal (base 8).
- **SIGNED** - signed decimal (base 10).
- **UNSIGNED** - unsigned decimal (base 10).
- **CHAR** - ASCII char code (there are 256 symbols, some symbols are invisible).

You can edit a variable's value when your program is running, simply double click it, or select it and click **Edit** button.

It is possible to enter numbers in any system, hexadecimal numbers should have "**h**" suffix, binary "**b**" suffix, octal "**o**" suffix, decimal numbers require no suffix. String can be entered this way:
'hello world', 0
(this string is zero terminated).

Arrays may be entered this way:
1, 2, 3, 4, 5
(the array can be array of bytes or words, it depends whether **BYTE** or **WORD** is selected for edited variable).

Expressions are automatically converted, for example:
when this expression is entered:
5 + 2
it will be converted to **7** etc...

8086 Assembler Tutorial for Beginners (Part 4)

Interrupts

Interrupts can be seen as a number of functions. These functions make the programming much easier, instead of writing a code to print a character you can simply call the interrupt and it will do everything for you. There are also interrupt functions that work with disk drive and other hardware. We call such functions **software interrupts**.

Interrupts are also triggered by different hardware, these are called **hardware interrupts**. Currently we are interested in **software interrupts** only.

To make a **software interrupt** there is an **INT** instruction, it has very simple syntax:

INT value

Where **value** can be a number between 0 to 255 (or 0 to 0FFh),
generally we will use hexadecimal numbers.
You may think that there are only 256 functions, but that is not correct. Each interrupt may have sub-functions.
To specify a sub-function **AH** register should be set before calling interrupt.
Each interrupt may have up to 256 sub-functions (so we get 256 * 256 = 65536 functions). In general **AH** register is used, but sometimes other registers maybe in use. Generally other registers are used to pass parameters and data to sub-function.

The following example uses **INT 10h** sub-function **0Eh** to type a "Hello!" message. This functions displays a character on the screen, advancing the cursor and scrolling the screen as necessary.

```
#MAKE_COM#        ; instruct compiler to make COM file.
ORG    100h

; The sub-function that we are using
; does not modify the AH register on
; return, so we may set it only once.

MOV    AH, 0Eh    ; select sub-function.

; INT 10h / 0Eh sub-function
; receives an ASCII code of the
; character that will be printed
; in AL register.

MOV    AL, 'H'    ; ASCII code: 72
INT    10h        ; print it!

MOV    AL, 'e'    ; ASCII code: 101
INT    10h        ; print it!

MOV    AL, 'l'    ; ASCII code: 108
INT    10h        ; print it!

MOV    AL, 'l'    ; ASCII code: 108
INT    10h        ; print it!

MOV    AL, 'o'    ; ASCII code: 111
INT    10h        ; print it!

MOV    AL, '!'    ; ASCII code: 33
INT    10h        ; print it!

RET               ; returns to operating system.
```

Copy & paste the above program to *Emu8086* source code editor, and press [**Compile and Emulate**] button. Run it!

See **list of supported interrupts** for more information about interrupts.

8086 Assembler Tutorial for Beginners (Part 5)

Library of common functions - emu8086.inc

To make programming easier there are some common functions that can be included in your program. To make your program use functions defined in other file you should use the **INCLUDE** directive followed by a file name. Compiler automatically searches for the file in the same folder where the source file is located, and if it cannot find the file there - it searches in **Inc** folder.

Currently you may not be able to fully understand the contents of the **emu8086.inc** (located in **Inc** folder), but it's OK, since you only need to understand what it can do.

To use any of the functions in **emu8086.inc** you should have the following line in the beginning of your source file:

include 'emu8086.inc'

---

emu8086.inc defines the following **macros**:

- **PUTC char** - macro with 1 parameter, prints out an ASCII char at current cursor position.

- **GOTOXY col, row** - macro with 2 parameters, sets cursor position.

- **PRINT string** - macro with 1 parameter, prints out a string.

- **PRINTN string** - macro with 1 parameter, prints out a string. The same as PRINT but automatically adds "carriage return" at the end of the string.

- **CURSOROFF** - turns off the text cursor.

- **CURSORON** - turns on the text cursor.

To use any of the above macros simply type its name somewhere in your code, and if required parameters, for example:

```
include emu8086.inc

ORG    100h

PRINT 'Hello World!'

GOTOXY 10, 5

PUTC 65          ; 65 - is an ASCII code for 'A'
PUTC 'B'

RET              ; return to operating system.
END              ; directive to stop the compiler.
```

When compiler process your source code it searches the **emu8086.inc** file for declarations of the macros and replaces the macro names with real code. Generally macros are relatively small parts of code, frequent use of a macro may make your executable too big (procedures are better for size optimization).

---

emu8086.inc also defines the following **procedures**:

- **PRINT_STRING** - procedure to print a null terminated string at current cursor position, receives address of string in **DS:SI** register. To use it declare: **DEFINE_PRINT_STRING** before **END** directive.

- **PTHIS** - procedure to print a null terminated string at current cursor position (just as PRINT_STRING), but receives address of string from Stack. The ZERO TERMINATED string should be defined just after the CALL instruction. For example:

  ```
  CALL PTHIS
  db 'Hello World!', 0
  ```

  To use it declare: **DEFINE_PTHIS** before **END** directive.

- **GET_STRING** - procedure to get a null terminated string from a user, the received string is written to buffer at **DS:DI**, buffer size should be in **DX**. Procedure stops the input when 'Enter' is pressed. To use it declare: **DEFINE_GET_STRING** before **END** directive.

- **CLEAR_SCREEN** - procedure to clear the screen, (done by scrolling entire screen window), and set cursor position to top of it. To use it declare: **DEFINE_CLEAR_SCREEN** before **END** directive.

- **SCAN_NUM** - procedure that gets the multi-digit SIGNED number from the keyboard, and stores the result in **CX** register. To use it declare: **DEFINE_SCAN_NUM** before **END** directive.

- **PRINT_NUM** - procedure that prints a signed number in **AX** register. To use it declare: **DEFINE_PRINT_NUM** and **DEFINE_PRINT_NUM_UNS** before **END** directive.

- **PRINT_NUM_UNS** - procedure that prints out an unsigned number in **AX** register. To use it declare: **DEFINE_PRINT_NUM_UNS** before **END** directive.

To use any of the above procedures you should first declare the function in the bottom of your file (but before **END**!!), and then use **CALL** instruction followed by a procedure name. For example:

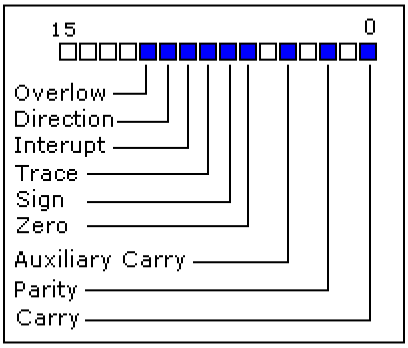
```
include 'emu8086.inc'

ORG    100h

LEA    SI, msg1       ; ask for the number
CALL   print_string   ;
CALL   scan_num       ; get number in CX.

MOV    AX, CX         ; copy the number to AX.

; print the following string:
CALL   pthis
DB  13, 10, 'You have entered: ', 0

CALL   print_num      ; print number in AX.

RET                   ; return to operating system.

msg1   DB  'Enter the number: ', 0

DEFINE_SCAN_NUM
DEFINE_PRINT_STRING
DEFINE_PRINT_NUM
DEFINE_PRINT_NUM_UNS  ; required for print_num.
DEFINE_PTHIS

END                   ; directive to stop the compiler.
```

First compiler processes the declarations (these are just regular the macros that are expanded to procedures). When compiler gets to **CALL** instruction it replaces the procedure name with the address of the code where the procedure is declared. When **CALL** instruction is executed control is transferred to procedure. This is quite useful, since even if you call the same procedure 100 times in your code you will still have relatively small executable size. Seems complicated, isn't it? That's ok, with the time you will learn more, currently it's required that you understand the basic principle.

8086 Assembler Tutorial for Beginners (Part 6)

Arithmetic and Logic Instructions

Most Arithmetic and Logic Instructions affect the processor status register (or **Flags**)



As you may see there are 16 bits in this register, each bit is called a **flag** and can take a value of **1** or **0**.

- **Carry Flag (CF)** - this flag is set to **1** when there is an **unsigned overflow**. For example when you add bytes **255 + 1** (result is not in range 0...255). When there is no overflow this flag is set to **0**.

- **Zero Flag (ZF)** - set to **1** when result is **zero**. For none zero result this flag is set to **0**.

- **Sign Flag (SF)** - set to **1** when result is **negative**. When result is **positive** it is set to **0**. Actually this flag take the value of the most significant bit.

- **Overflow Flag (OF)** - set to **1** when there is a **signed overflow**. For example, when you add bytes **100 + 50** (result is not in range -128...127).

- **Parity Flag (PF)** - this flag is set to **1** when there is even number of one bits in result, and to **0** when there is odd number of one bits. Even if result is a word only 8 low bits are analyzed!

- **Auxiliary Flag (AF)** - set to **1** when there is an **unsigned overflow** for low nibble (4 bits).

- **Interrupt enable Flag (IF)** - when this flag is set to **1** CPU reacts to interrupts from external devices.

- **Direction Flag (DF)** - this flag is used by some instructions to process data chains, when this flag is set to **0** - the processing is done forward, when this flag is set to **1** the processing is done backward.

There are 3 groups of instructions.

First group: **ADD**, **SUB**,**CMP**, **AND**, **TEST**, **OR**, **XOR**

These types of operands are supported:

```
REG, memory
memory, REG
REG, REG
memory, immediate
REG, immediate
```

REG: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.

memory: [BX], [BX+SI+7], variable, etc...

immediate: 5, -24, 3Fh, 10001101b, etc...

After operation between operands, result is always stored in first operand. **CMP** and **TEST** instructions affect flags only and do not store a result (these instruction are used to make decisions during program execution).

These instructions affect these flags only:

CF, **ZF**, **SF**, **OF**, **PF**, **AF**.

- **ADD** - add second operand to first.
- **SUB** - Subtract second operand to first.
- **CMP** - Subtract second operand from first **for flags only**.
- **AND** - Logical AND between all bits of two operands. These rules apply:

  1 AND 1 = 1
  1 AND 0 = 0
  0 AND 1 = 0
  0 AND 0 = 0

  As you see we get **1** only when both bits are **1**.

- **TEST** - The same as **AND** but **for flags only**.
- **OR** - Logical OR between all bits of two operands. These rules apply:

  1 OR 1 = 1
  1 OR 0 = 1
  0 OR 1 = 1
  0 OR 0 = 0

  As you see we get **1** every time when at least one of the bits is **1**.

- **XOR** - Logical XOR (exclusive OR) between all bits of two operands. These rules apply:

  1 XOR 1 = 0
  1 XOR 0 = 1
  0 XOR 1 = 1
  0 XOR 0 = 0

  As you see we get **1** every time when bits are different from each other.

Second group: **MUL**, **IMUL**, **DIV**, **IDIV**

These types of operands are supported:

REG
memory

REG: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.

memory: [BX], [BX+SI+7], variable, etc...

MUL and **IMUL** instructions affect these flags only:
CF, **OF**
When result is over operand size these flags are set to **1**, when result fits in operand size these flags are set to **0**.

For **DIV** and **IDIV** flags are undefined.

- **MUL** - Unsigned multiply:

when operand is a **byte**:
AX = AL * operand.

when operand is a **word**:
(DX AX) = AX * operand.

- **IMUL** - Signed multiply:

when operand is a **byte**:
AX = AL * operand.

when operand is a **word**:
(DX AX) = AX * operand.

- **DIV** - Unsigned divide:

when operand is a **byte**:
AL = AX / operand
AH = remainder (modulus). .

when operand is a **word**:
AX = (DX AX) / operand
DX = remainder (modulus). .

- **IDIV** - Signed divide:

when operand is a **byte**:
AL = AX / operand
AH = remainder (modulus). .

when operand is a **word**:
AX = (DX AX) / operand
DX = remainder (modulus). .

Third group: **INC**, **DEC**, **NOT**, **NEG**

These types of operands are supported:

REG
memory

REG: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.

memory: [BX], [BX+SI+7], variable, etc...

INC, **DEC** instructions affect these flags only:
ZF, **SF**, **OF**, **PF**, **AF**.

NOT instruction does not affect any flags!

NEG instruction affects these flags only:
CF, **ZF**, **SF**, **OF**, **PF**, **AF**.

- **NOT** - Reverse each bit of operand.

- **NEG** - Make operand negative (two's complement). Actually it reverses each bit of operand and then adds 1 to it. For example 5 will become -5, and -2 will become 2.

8086 Assembler Tutorial for Beginners (Part 7)

Program Flow Control

Controlling the program flow is a very important thing, this is where your program can make decisions according to certain conditions.

- **Unconditional Jumps**

  The basic instruction that transfers control to another point in the program is **JMP**.

  The basic syntax of **JMP** instruction:

  ```
  JMP label
  ```

  To declare a *label* in your program, just type its name and add "**:**" to the end, label can be any character combination but it cannot start with a number, for example here are 3 legal label definitions:

  ```
  label1:
  label2:
  a:
  ```

  Label can be declared on a separate line or before any other instruction, for example:

  ```
  x1:
  MOV AX, 1

  x2: MOV AX, 2
  ```

  Here is an example of **JMP** instruction:

  ```
  ORG    100h

  MOV    AX, 5          ; set AX to 5.
  MOV    BX, 2          ; set BX to 2.

  JMP    calc           ; go to 'calc'.

  back:  JMP stop       ; go to 'stop'.

  calc:
  ADD    AX, BX         ; add BX to AX.
  JMP    back           ; go 'back'.

  stop:

  RET                   ; return to operating system.
  END                   ; directive to stop the compiler.
  ```

  Of course there is an easier way to calculate the some of two numbers, but it's still a good example of **JMP** instruction.

As you can see from this example **JMP** is able to transfer control both forward and backward. It can jump anywhere in current code segment (65,535 bytes).

- **Short Conditional Jumps**

Unlike **JMP** instruction that does an unconditional jump, there are instructions that do a conditional jumps (jump only when some conditions are in act). These instructions are divided in three groups, first group just test single flag, second compares numbers as signed, and third compares numbers as unsigned.

Jump instructions that test single flag

Instruction	Description	Condition	Opposite
JZ , JE	Jump if Zero (Equal).	ZF = 1	JNZ, JNE
JC , JB, JNAE	Jump if Carry (Below, Not Above Equal).	CF = 1	JNC, JNB, JAE
JS	Jump if Sign.	SF = 1	JNS
JO	Jump if Overflow.	OF = 1	JNO
JPE, JP	Jump if Parity Even.	PF = 1	JPO
JNZ , JNE	Jump if Not Zero (Not Equal).	ZF = 0	JZ, JE
JNC , JNB, JAE	Jump if Not Carry (Not Below, Above Equal).	CF = 0	JC, JB, JNAE
JNS	Jump if Not Sign.	SF = 0	JS
JNO	Jump if Not Overflow.	OF = 0	JO
JPO, JNP	Jump if Parity Odd (No Parity).	PF = 0	JPE, JP

- As you can see there are some instructions that do that same thing, that's correct, they even are assembled into the same machine code, so it's good to remember that when you compile **JE** instruction - you will get it disassembled as: **JZ**.
Different names are used to make programs easier to understand and code.

Jump instructions for signed numbers

	Jump if Not Less or Equal (not <=).	and SF = OF	
JL , JNGE	Jump if Less (<). Jump if Not Greater or Equal (not >=).	SF <> OF	JNL, JGE
JGE , JNL	Jump if Greater or Equal (>=). Jump if Not Less (not <).	SF = OF	JNGE, JL
JLE , JNG	Jump if Less or Equal (<=). Jump if Not Greater (not >).	ZF = 1 or SF <> OF	JNLE, JG

•

<> - sign means not equal.

Jump instructions for unsigned numbers

Instruction	Description	Condition	Opposite Instruction
JE , JZ	Jump if Equal (=). Jump if Zero.	ZF = 1	JNE, JNZ
JNE , JNZ	Jump if Not Equal (<>). Jump if Not Zero.	ZF = 0	JE, JZ
JA , JNBE	Jump if Above (>). Jump if Not Below or Equal (not <=).	CF = 0 and ZF = 0	JNA, JBE
JB , JNAE, JC	Jump if Below (<). Jump if Not Above or Equal (not >=). Jump if Carry.	CF = 1	JNB, JAE, JNC
JAE , JNB, JNC	Jump if Above or Equal (>=). Jump if Not Below (not <). Jump if Not Carry.	CF = 0	JNAE, JB
JBE , JNA	Jump if Below or Equal (<=). Jump if Not Above (not >).	CF = 1 or ZF = 1	JNBE, JA

Generally, when it is required to compare numeric values **CMP** instruction is used (it does the same as **SUB** (subtract) instruction, but does not keep the result, just affects the flags).

The logic is very simple, for example:
it's required to compare 5 and 2,
5 - 2 = 3
the result is not zero (Zero Flag is set to 0).

Another example:
it's required to compare 7 and 7,
7 - 7 = 0
the result is zero! (Zero Flag is set to 1 and **JZ** or **JE** will do the jump).

Here is an example of **CMP** instruction and conditional jump:

```
include emu8086.inc
ORG    100h

MOV    AL, 25     ; set AL to 25.
MOV    BL, 10     ; set BL to 10.

CMP    AL, BL     ; compare AL - BL.

JE     equal      ; jump if AL = BL (ZF = 1).

PUTC   'N'        ; if it gets here, then AL <> BL,
JMP    stop       ; so print 'N', and jump to stop.

equal:            ; if gets here,
PUTC   'Y'        ; then AL = BL, so print 'Y'.

stop:
```

- Try the above example with different numbers for **AL** and **BL**, open flags by clicking on [**FLAGS**] button, use [**Single Step**] and see what happens, don't forget to recompile and reload after every change (use **F5** shortcut).

- All conditional jumps have one big limitation, unlike **JMP** instruction they can only jump **127** bytes forward and **128** bytes backward (note that most instructions are assembled into 3 or more bytes).

  We can easily avoid this limitation using a cute trick:

  - Get a opposite conditional jump instruction from the table above, make it jump to *label_x*.
  - Use **JMP** instruction to jump to desired location.
  - Define *label_x:* just after the **JMP** instruction.

  label_x: - can be any valid label name.

  Here is an example:

```
not_equal:

; let's assume that here we
; have a code that is assembled
; to more then 127 bytes...


PUTC   'N'      ; if it gets here, then AL <> BL,
JMP    stop     ; so print 'N', and jump to stop.

equal:          ; if gets here,
PUTC   'Y'      ; then AL = BL, so print 'Y'.

stop:

RET             ; gets here no matter what.

END
```

Another, yet rarely used method is providing an immediate value instead of a label. When immediate value starts with a '$' character relative jump is performed, otherwise compiler calculates instruction that jumps directly to given offset. For example:

```
ORG    100h

; unconditional jump forward:
; skip over next 2 bytes,
JMP $2
a DB 3    ; 1 byte.
b DB 4    ; 1 byte.

; JCC jump back 7 bytes:
; (JMP takes 2 bytes itself)
MOV BL,9
DEC BL      ; 2 bytes.
CMP BL, 0   ; 3 bytes.
JNE $-7

RET
END
```

8086 Assembler Tutorial for Beginners (Part 8)

Procedures

Procedure is a part of code that can be called from your program in order to make some specific task. Procedures make program more structural and easier to understand. Generally procedure returns to the same point from where it was called.

The syntax for procedure declaration:

<u>name</u> PROC

```
    ; here goes the code
    ; of the procedure ...

RET
name ENDP
```

name - is the procedure name, the same name should be in the top and the bottom, this is used to check correct closing of procedures.

Probably, you already know that **RET** instruction is used to return to operating system. The same instruction is used to return from procedure (actually operating system sees your program as a special procedure).

PROC and **ENDP** are compiler directives, so they are not assembled into any real machine code. Compiler just remembers the address of procedure.

CALL instruction is used to call a procedure.

Here is an example:

```
ORG    100h

CALL   m1
MOV    AX, 2
RET                 ; return to operating system.

m1     PROC
MOV    BX, 5
RET                 ; return to caller.
m1     ENDP

END
```

The above example calls procedure **m1**, does **MOV BX, 5**, and returns to the next instruction after **CALL**: **MOV AX, 2**.

There are several ways to pass parameters to procedure, the easiest way to pass parameters is by using registers, here is another example of a procedure that receives two parameters in **AL** and **BL** registers, multiplies these parameters and returns the result in **AX** register:

```
ORG    100h

MOV    AL, 1
MOV    BL, 2

CALL   m2
CALL   m2
CALL   m2
```

```
ORG    100h

MOV    AL, 1
MOV    BL, 2

CALL   m2
CALL   m2
CALL   m2
CALL   m2

RET                 ; return to operating system.

m2     PROC
MUL    BL           ; AX = AL * BL.
RET                 ; return to caller.
m2     ENDP

END
```

In the above example value of **AL** register is update every time the procedure is called, **BL** register stays unchanged, so this algorithm calculates **2** in power of **4**,
so final result in **AX** register is **16** (or 10h).

Here goes another example,
that uses a procedure to print a *Hello World!* message:

```
ORG    100h

LEA    SI, msg       ; load address of msg to SI.
```

```
msg    DB  'Hello World!', 0   ; null terminated string.

END
```

"**b.**" - prefix before [SI] means that we need to compare bytes, not words. When you need to compare words add "**w.**" prefix instead. When one of the compared operands is a register it's not required because compiler knows the size of each register.

8086 Assembler Tutorial for Beginners (Part 9)

The Stack

Stack is an area of memory for keeping temporary data. Stack is used by **CALL** instruction to keep return address for procedure, **RET** instruction gets this value from the stack and returns to that offset. Quite the same thing happens when **INT** instruction calls an interrupt, it stores in stack flag register, code segment and offset. **IRET** instruction is used to return from interrupt call.

We can also use the stack to keep any other data,
there are two instructions that work with the stack:

PUSH - stores 16 bit value in the stack.

POP - gets 16 bit value from the stack.

Syntax for **PUSH** instruction:

```
PUSH REG
PUSH SREG
PUSH memory
PUSH immediate
```

REG: AX, BX, CX, DX, DI, SI, BP, SP.

SREG: DS, ES, SS, CS.

memory: [BX], [BX+SI+7], 16 bit variable, etc...

immediate: 5, -24, 3Fh, 10001101b, etc...

Syntax for **POP** instruction:

```
POP REG
POP SREG
POP memory
```

REG: AX, BX, CX, DX, DI, SI, BP, SP.

SREG: DS, ES, SS, (except CS).

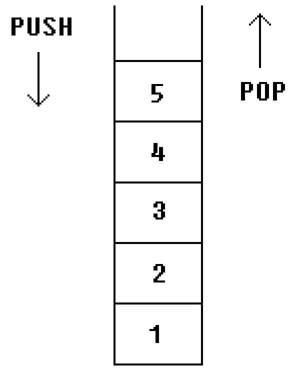
memory: [BX], [BX+SI+7], 16 bit variable, etc...

Notes:

- **PUSH** and **POP** work with 16 bit values only!

- Note: **PUSH immediate** works only on 80186 CPU and later!

The stack uses **LIFO** (Last In First Out) algorithm, this means that if we push these values one by one into the stack: **1, 2, 3, 4, 5** the first value that we will get on pop will be **5**, then **4**, **3**, **2**, and only then **1**.



It is very important to do equal number of **PUSH**s and **POP**s, otherwise the stack maybe corrupted and it will be impossible to return to operating system. As you already know we use **RET** instruction to return to operating system, so when program starts there is a return address in stack (generally it's 0000h).

PUSH and **POP** instruction are especially useful because we don't have too much registers to operate with, so here is a trick:

- Store original value of the register in stack (using **PUSH**).

- Use the register for any purpose.

- Restore the original value of the register from stack (using **POP**).

Here is an example:

```
ORG    100h

MOV    AX, 1234h
PUSH   AX          ; store value of AX in stack.
MOV    AX, 5678h   ; modify the AX value.
POP    AX          ; restore the original value of AX.
```

Another use of the stack is for exchanging the values,
here is an example:

```
ORG    100h
```

```
PUSH   AX        ; store value of AX in stack.
PUSH   BX        ; store value of BX in stack.
POP    AX        ; set AX to original value of BX.
POP    BX        ; set BX to original value of AX.
RET

END
```

The exchange happens because stack uses **LIFO** (Last In First Out) algorithm, so when we push **1212h** and then **3434h**, on pop we will first get **3434h** and only after it **1212h**.

The stack memory area is set by **SS** (Stack Segment) register, and **SP** (Stack Pointer) register. Generally operating system sets values of these registers on program start.

"**PUSH *source***" instruction does the following:

- Subtract **2** from **SP** register.
- Write the value of ***source*** to the address **SS:SP**.

"**POP *destination***" instruction does the following:

- Write the value at the address **SS:SP** to ***destination***.
- Add **2** to **SP** register.

The current address pointed by **SS:SP** is called **the top of the stack**.

For **COM** files stack segment is generally the code segment, and stack pointer is set to value of **0FFFEh**. At the address **SS:0FFFEh** stored a return address for **RET** instruction that is executed in the end of the program.

You can visually see the stack operation by clicking on [**Stack**] button on emulator window. The top of the stack is marked with "<" sign.

8086 Assembler Tutorial for Beginners (Part 10)

Macros

Macros are just like procedures, but not really. Macros look like procedures, but they exist only until your code is compiled, after compilation all macros are replaced with real instructions. If you declared a macro and never used it in your code, compiler will simply ignore it. **emu8086.inc** is a good example of how macros can be used, this file contains several macros to make coding easier for you.

```
Macro definition:

name    MACRO  [parameters,...]

         <instructions>

ENDM
```

```
MyMacro    MACRO  p1, p2, p3

    MOV AX, p1
    MOV BX, p2
    MOV CX, p3

ENDM

ORG 100h

MyMacro 1, 2, 3

MyMacro 4, 5, DX

RET
```

The above code is expanded into:

```
MOV AX, 00001h
MOV BX, 00002h
MOV CX, 00003h
MOV AX, 00004h
MOV BX, 00005h
MOV CX, DX
```

Some important facts about **macros** and **procedures**:

- To mark the end of the procedure, you should type the name of the procedure before the **ENDP** directive.

Macros are expanded directly in code, therefore if there are labels inside the macro definition you may get "Duplicate declaration" error when macro is used for twice or more. To avoid such problem, use **LOCAL** directive followed by names of variables, labels or procedure names. For example:

```
MyMacro2    MACRO
            LOCAL label1, label2

            CMP  AX, 2
            JE label1
            CMP  AX, 3
            JE label2
            label1:
                        INC  AX
            label2:
                        ADD  AX, 2
ENDM

ORG 100h

MyMacro2
MyMacro2

RET
```

If you plan to use your macros in several programs, it may be a good idea to place all macros in a separate file. Place that file in **Inc** folder and use **INCLUDE *file-name*** directive to use macros. See **Library of common functions - emu8086.inc** for an example of such file.

8086 Assembler Tutorial for Beginners (Part 11)

Making your own Operating System

Usually, when a computer starts it will try to load the first 512-byte sector (that's Cylinder **0**, Head **0**, Sector **1**) from any diskette in your **A:** drive to memory location 0000h:7C00h and give it control. If this fails, the BIOS tries to use the MBR of the first hard drive instead.

This tutorial covers booting up from a floppy drive, the same principles are used to boot from a hard drive. But using a floppy drive has several advantages:

- You can keep your existing operating system intact (Windows, DOS...).
- It is easy to modify the boot record of a floppy disk.

Example of a simple floppy disk boot program:

```
; directive to create BOOT file:
```

```
#MAKE_BOOT#

; Boot record is loaded at 0000:7C00,
; so inform compiler to make required
; corrections:
ORG 7C00h

; load message address into SI register:
LEA SI, msg

; teletype function id:
MOV AH, 0Eh

print:   MOV AL, [SI]
         CMP AL, 0
         JZ done
         INT 10h   ; print using teletype.
         INC SI
         JMP print

; wait for 'any key':
done:      MOV AH, 0
           INT 16h

; store magic value at 0040h:0072h:
;   0000h - cold boot.
;   1234h - warm boot.
MOV     AX, 0040h
MOV     DS, AX
MOV     w.[0072h], 0000h ; cold boot.

JMP         0FFFFh:0000h            ; reboot!


new_line EQU 13, 10

msg DB  'Hello This is My First Boot Program!'
    DB  new_line, 'Press any key to reboot', 0
```

Copy the above example to **Emu8086** source editor and press [**Compile and Emulate**] button. The Emulator automatically loads ".boot" file to 0000h:7C00h.

You can run it just like a regular program, or you can use the **Virtual Drive** menu to **Write 512 bytes at 7C00h to** the **Boot Sector** of a virtual floppy drive (FLOPPY_0 file in Emulator's folder).
After writing your program to the Virtual Floppy Drive, you can select **Boot from Floppy** from **Virtual Drive** menu.

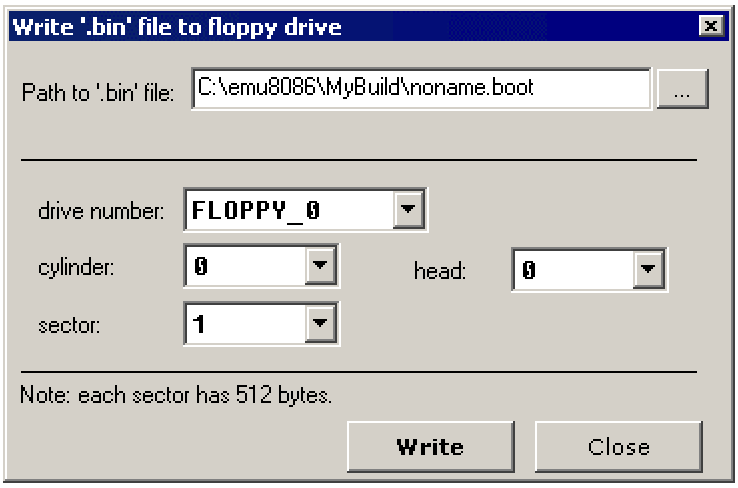
If you are curious, you may write the virtual floppy (**FLOPPY_0**) or "**.boot**" file to a real floppy disk and boot your computer from it, I recommend using "RawWrite for Windows" from:
http://uranus.it.swin.edu.au/~jn/linux/rawwrite.htm
(recent builds now work under all versions of Windows!)

Note: however, that this **.boot** file is ***not*** an MS-DOS compatible boot sector (it will not allow you to read or write data on this diskette until you format it again), so don't bother writing only this sector to a diskette with data on it. As a matter of fact, if you use any 'raw-write' programs, such at the one listed above, they will erase all of the data anyway. So make sure the diskette you use doesn't contain any important data.

"**.boot**" files are limited to 512 bytes (sector size). If your new Operating System is going to grow over this size, you will need to use a boot program to load data from other sectors. A good example of a tiny Operating System can be found in "Samples" folder as:
micro-os_loader.asm
micro-os_kernel.asm

To create extensions for your Operating System (over 512 bytes), you can use "**.bin**" files (select "**BIN Template**" from "**File**" -> "**New**" menu).

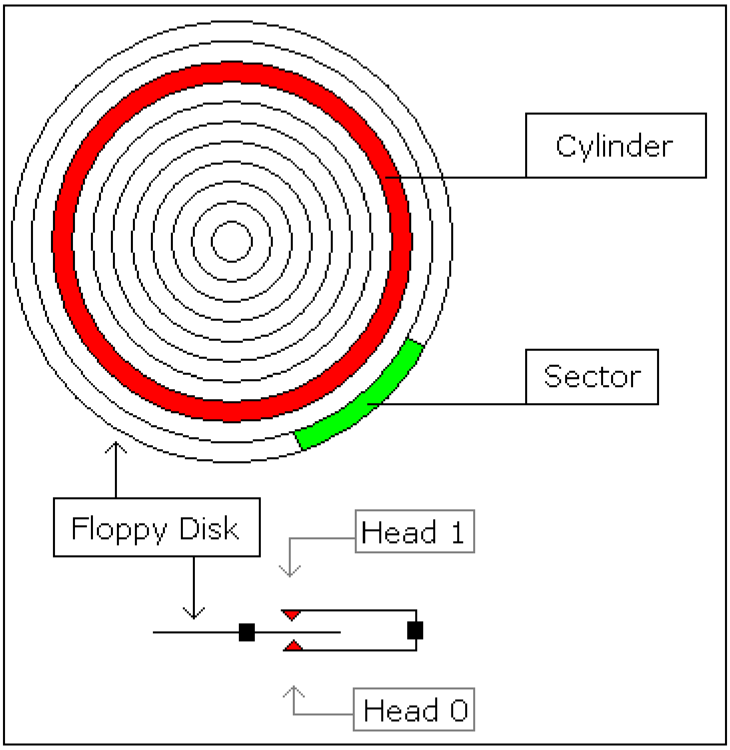
To write "**.bin**" file to virtual floppy, select **"Write .bin file to floppy..."** from **"Virtual Drive"** menu of emulator:



You can also use this to write "**.boot**" files.

> Sector at:
>
> Cylinder: 0
> Head:0
> Sector: 1
>
> is the boot sector!

Idealized floppy drive and diskette structure:



For a **1440 kb** diskette:

- Floppy disk has 2 sides, and there are 2 heads; one for each side (**0..1**), the drive heads move above the surface of the disk on each side.
- Each side has 80 cylinders (numbered **0..79**).
- Each cylinder has 18 sectors (**1..18**).
- Each sector has **512** bytes.
- Total size of floppy disk is: 2 x 80 x 18 x 512 = 1,474,560 bytes.

To read sectors from floppy drive use **INT 13h / AH = 02h**.

8086 Assembler Tutorial for Beginners (Part 12)

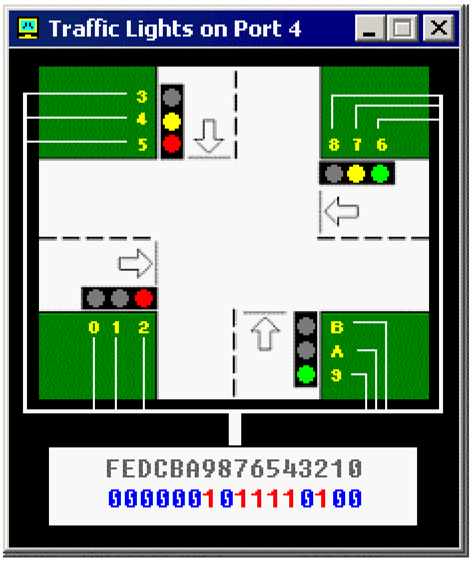
Controlling External Devices

There are 3 devices attached to the emulator: Traffic Lights, Stepper-Motor and Robot. You can view devices using "**Virtual Devices**" menu of the emulator.

For technical information see **I/O ports** section of Emu8086 reference.

In general, it is possible to use any x86 family CPU to control all kind of devices, the difference maybe in base I/O port number, this can be altered using some tricky electronic equipment. Usually the "**.bin**" file is written into the Read Only Memory (ROM) chip, the system reads program from that chip, loads it in RAM module and runs the program. This principle is used for many modern devices such as micro-wave ovens and etc...

Traffic Lights

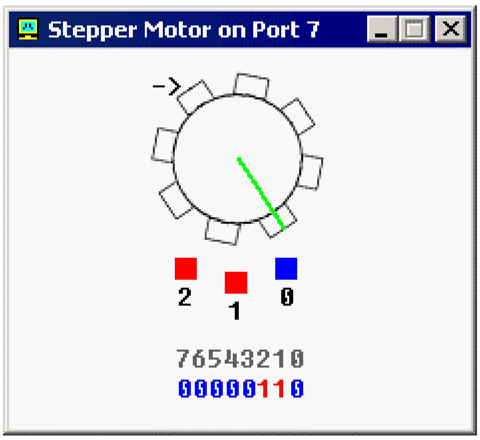


Usually to control the traffic lights an array (table) of values is used. In certain periods of time the value is read from the array and sent to a port. For example:

```
; directive to create BIN file:
#MAKE_BIN#
#CS=500#
#DS=500#
#SS=500#
#SP=FFFF#
#IP=0#

; skip the data table:
JMP start

table DW 100001100001b
      DW 110011110011b
      DW 001100001100b
      DW 011110011110b

start:

MOV SI, 0

; set loop counter to number
; of elements in table:
MOV CX, 4

next_value:

; get value from table:
```

```
LOOP next_value

; start from over from
; the first value
JMP start

; ==========================
PAUSE PROC
; store registers:
PUSH CX
PUSH DX
PUSH AX

; set interval (1 million
; microseconds - 1 second):
MOV     CX, 0Fh
MOV     DX, 4240h
MOV     AH, 86h
INT     15h

; restore registers:
POP AX
POP DX
POP CX
RET
PAUSE ENDP
; ==========================
```

Stepper-Motor



The motor can be half stepped by turning on pair of magnets, followed by a single and so on.

The motor can be full stepped by turning on pair of magnets, followed by another pair of magnets and in the end followed by a single magnet and so on. The best way to make full step is to make two half steps.

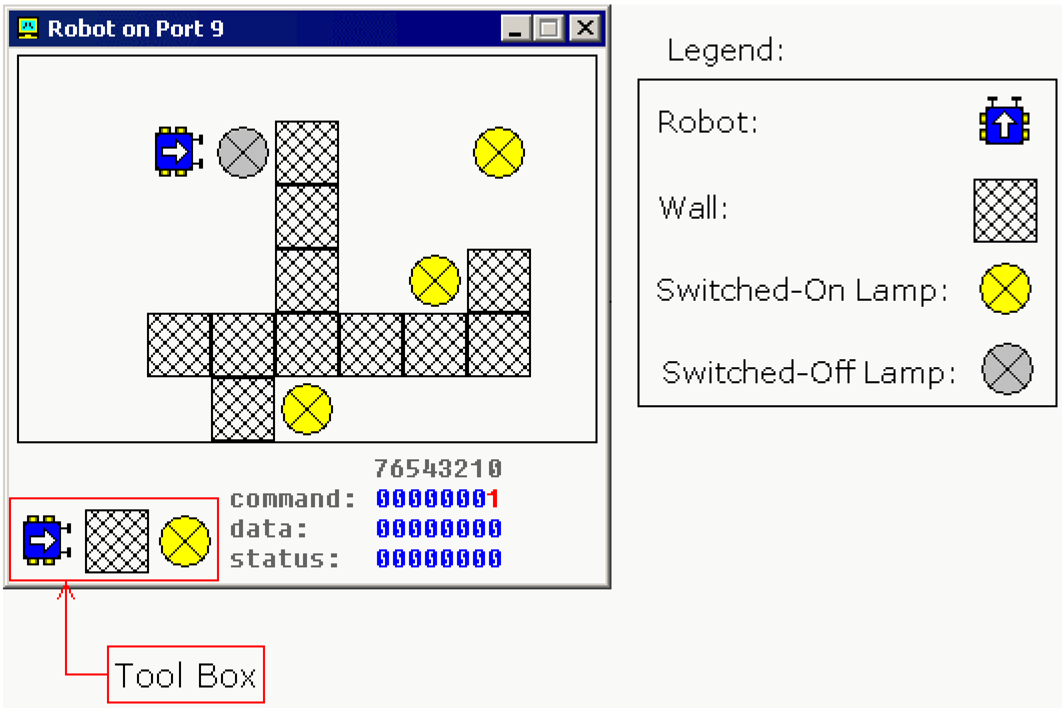
Half step is equal to **11.25** degrees.
Full step is equal to **22.5** degrees.

The motor can be turned both clock-wise and counter-clock-wise.

See **stepper_motor.asm** in Samples folder.

See also **I/O ports** section of Emu8086 reference.

Robot



Complete list of robot instruction set is given in **I/O ports** section of Emu8086 reference.

To control the robot a complex algorithm should be used to achieve maximum efficiency. The simplest, yet very inefficient, is random moving algorithm, see **robot.asm** in Samples folder.

It is also possible to use a data table (just like for Traffic Lights), this can be good if robot always works in the same surroundings.

Complete 8086 instruction set

Quick reference:

AAA	CMPSB	JAE	JNBE	JPO	MOV	RCR	SCASB
AAD	CMPSW	JB	JNC	JS	MOVSB	REP	SCASW
AAM	CWD	JBE	JNE	JZ	MOVSW	REPE	SHL
AAS	DAA	JC	JNG	LAHF	MUL	REPNE	SHR
ADC	DAS	JCXZ	JNGE	LDS	NEG	REPNZ	STC
ADD	DEC	JE	JNL	LEA	NOP	REPZ	STD
AND	DIV	JG	JNLE	LES	NOT	RET	STI

CALL	HLT	JGE	JNO	LODSB	OR	RETF	STOSB
CBW	IDIV	JL	JNP	LODSW	OUT	ROL	STOSW
CLC	IMUL	JLE	JNS	LOOP	POP	ROR	SUB
CLD	IN	JMP	JNZ	LOOPE	POPA	SAHF	TEST
CLI	INC	JNA	JO	LOOPNE	POPF	SAL	XCHG
CMC	INT	JNAE	JP	LOOPNZ	PUSH	SAR	XLATB
CMP	INTO	JNB	JPE	LOOPZ	PUSHA	SBB	XOR
	IRET				PUSHF		
	JA				RCL		

Operand types:

REG: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.

SREG: DS, ES, SS, and only as second operand: CS.

memory: [BX], [BX+SI+7], variable, etc...(see **Memory Access**).

immediate: 5, -24, 3Fh, 10001101b, etc...

Notes:

- When two operands are required for an instruction they are separated by comma. For example:

  REG, memory

- When there are two operands, both operands must have the same size (except shift and rotate instructions). For example:

  AL, DL
  DX, AX
  m1 DB ?
  AL, m1
  m2 DW ?
  AX, m2

- Some instructions allow several operand combinations. For example:

  memory, immediate
  REG, immediate

  memory, REG
  REG, SREG

- Some examples contain macros, so it is advisable to use **Shift + F8** hot key to *Step Over* (to make macro code execute at maximum speed set **step delay** to zero), otherwise emulator will step through each instruction of a macro. Here is an example that uses PRINTN macro:

```
#make_COM#
include 'emu8086.inc'
ORG 100h
MOV AL, 1
MOV BL, 2
PRINTN 'Hello World!'   ; macro.
MOV CL, 3
PRINTN 'Welcome!'       ; macro.
RET
```

These marks are used to show the state of the flags:

1 - instruction sets this flag to **1**.
0 - instruction sets this flag to **0**.
r - flag value depends on result of the instruction.
? - flag value is undefined (maybe **1** or **0**).

Some instructions generate exactly the same machine code, so disassembler may have a problem decoding to your original code. This is especially important for Conditional Jump instructions (see "Program Flow Control" in Tutorials for more information).

Instructions in alphabetical order:

<table>
<tr><td>Instruction</td><td>Operands</td><td>Description</td></tr>
<tr><td>AAA</td><td>No operands</td><td>ASCII Adjust after Addition.
Corrects result in AH and AL after addition when working with BCD values.

It works according to the following Algorithm:

if low nibble of AL > 9 or AF = 1 then:
AL = AL + 6
AH = AH + 1
AF = 1
CF = 1
else
AF = 0
CF = 0
in both cases:
clear the high nibble of AL.

Example:
MOV AX, 15 ; AH = 00, AL = 0Fh
AAA ; AH = 01, AL = 05
RET<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>?</td><td>?</td><td>?</td><td>?</td><td>r</td></tr></table></td></tr>
<tr><td>AAD</td><td>No operands</td><td>ASCII Adjust before Division. Prepares two BCD values for division.
Algorithm:
AL = (AH * 10) + AL
AH = 0
Example:
MOV AX, 0105h ; AH = 01, AL = 05
AAD ; AH = 00, AL = 0Fh (15)
RET<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>?</td><td>r</td><td>r</td><td>?</td><td>r</td><td>?</td></tr></table></td></tr>
<tr><td>AAM</td><td>No operands</td><td>ASCII Adjust after Multiplication.
Corrects the result of multiplication of two BCD values.

Algorithm:
AH = AL / 10
AL = remainder
Example:
MOV AL, 15 ; AL = 0Fh</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>AAM ; AH = 01, AL = 05
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>?</td><td>r</td><td>r</td><td>?</td><td>r</td><td>?</td></tr></table>
</td>
</tr>
<tr>
<td>AAS</td>
<td>No operands</td>
<td>ASCII Adjust after Subtraction.
Corrects result in AH and AL after subtraction when working with BCD values.

Algorithm:

if low nibble of AL > 9 or AF = 1 then:
AL = AL - 6
AH = AH - 1
AF = 1
CF = 1
else
AF = 0
CF = 0
in both cases:
clear the high nibble of AL.

Example:
MOV AX, 02FFh ; AH = 02, AL = 0FFh
AAS ; AH = 01, AL = 09
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>?</td><td>?</td><td>?</td><td>?</td><td>r</td></tr></table>
</td>
</tr>
<tr>
<td>ADC</td>
<td>REG, memory
memory, REG
REG, REG
memory, immediate
REG, immediate</td>
<td>Add with Carry.
Algorithm:

operand1 = operand1 + operand2 + CF

Example:
STC ; set CF = 1
MOV AL, 5 ; AL = 5
ADC AL, 1 ; AL = 7
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
</td>
</tr>
<tr>
<td>ADD</td>
<td>REG, memory
memory, REG
REG, REG
memory, immediate
REG, immediate</td>
<td>Add.

Algorithm:

operand1 = operand1 + operand2

Example:
MOV AL, 5 ; AL = 5
ADD AL, -3 ; AL = 2
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
</td>
</tr>
<tr>
<td>AND</td>
<td>REG, memory
memory, REG</td>
<td>Logical AND between all bits of two operands. Result is stored in operand1.

These rules apply:</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>memory, immediate
REG, immediate</td>
<td>1 AND 0 = 0
0 AND 1 = 0
0 AND 0 = 0

Example:
MOV AL, 'a'   ; AL = 01100001b
AND AL, 11011111b ; AL = 01000001b ('A')
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td></tr><tr><td>0</td><td>r</td><td>r</td><td>0</td><td>r</td></tr></table>
</td>
</tr>
<tr>
<td>CALL</td>
<td>procedure name
label
4-byte address</td>
<td>Transfers control to procedure, return address is (IP) is pushed to stack. 4-byte address may be entered in this form: 1234h:5678h, first value is a segment second value is an offset (this is a far call, so CS is also pushed to stack).

Example:
#make_COM#
ORG 100h ; for COM file.

CALL p1
ADD AX, 1
RET   ; return to OS.

p1 PROC   ; procedure declaration.
    MOV AX, 1234h
    RET   ; return to caller.
p1 ENDP
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>CBW</td>
<td>No operands</td>
<td>Convert byte into word.
Algorithm:

if high bit of AL = 1 then:
AH = 255 (0FFh)
else
AH = 0
Example:
MOV AX, 0   ; AH = 0, AL = 0
MOV AL, -5 ; AX = 000FBh (251)
CBW   ; AX = 0FFFBh (-5)
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>CLC</td>
<td>No operands</td>
<td>Clear Carry flag.
Algorithm:

CF = 0
<table><tr><td>C</td></tr><tr><td>0</td></tr></table>
</td>
</tr>
<tr>
<td>CLD</td>
<td>No operands</td>
<td>Clear Direction flag. SI and DI will be incremented by chain instructions: CMPSB, CMPSW, LODSB, LODSW, MOVSB, MOVSW, STOSB, STOSW.
Algorithm:
DF = 0
<table><tr><td>D</td></tr></table>
</td>
</tr>
</table>

		0
CLI	No operands	Clear Interrupt enable flag. This disables hardware interrupts. Algorithm: IF = 0 I 0
CMC	No operands	Complement Carry flag. Inverts value of CF. Algorithm: if CF = 1 then CF = 0 if CF = 0 then CF = 1 C r

CMP	REG, memory
	memory, REG
	REG, REG
	memory, immediate
	REG, immediate
		Compare.
		Algorithm:
		operand1 - operand2
		
		result is not stored anywhere, flags are set (OF, SF, ZF, AF, PF, CF) according to result.
		
		Example:
		MOV AL, 5
		MOV BL, 5
		CMP AL, BL ; AL = 5, ZF = 1 (so equal!)
		RET
		C Z S O P A
		r r r r r r

CMPSB	No operands	Compare bytes: ES:[DI] from DS:[SI].
		Algorithm:
		• DS:[SI] - ES:[DI]
		• set flags according to result: OF, SF, ZF, AF, PF, CF
		• if DF = 0 then
		  ○ SI = SI + 1
		  ○ DI = DI + 1
		else
		  ○ SI = SI - 1
		  ○ DI = DI - 1
		Example:
		see **cmpsb.asm** in Samples.
		C Z S O P A
		r r r r r r

CMPSW	No operands	Compare words: ES:[DI] from DS:[SI].
		Algorithm:
		• DS:[SI] - ES:[DI]
		• set flags according to result: OF, SF, ZF, AF, PF, CF
		• if DF = 0 then
		  ○ SI = SI + 2
		  ○ DI = DI + 2
		else
		  ○ SI = SI - 2
		  ○ DI = DI - 2

		Example: see **cmpsw.asm** in Samples. C | Z | S | O | P | A r | r | r | r | r | r

CWD	No operands	Convert Word to Double word.
		Algorithm:
		
		if high bit of AX = 1 then:
		• DX = 65535 (0FFFFh)
		else
		• DX = 0
		Example:
		MOV DX, 0 ; DX = 0
		MOV AX, 0 ; AX = 0
		MOV AX, -5 ; DX AX = 00000h:0FFFBh
		CWD ; DX AX = 0FFFFh:0FFFBh
		RET
		C | Z | S | O | P | A
		unchanged

DAA	No operands	Decimal adjust After Addition.
		Corrects the result of addition of two packed BCD values.
		Algorithm:
		
		if low nibble of AL > 9 or AF = 1 then:
		• AL = AL + 6
		• AF = 1
		if AL > 9Fh or CF = 1 then:
		• AL = AL + 60h
		• CF = 1
		
		Example:
		MOV AL, 0Fh ; AL = 0Fh (15)
		DAA ; AL = 15h
		RET
		C | Z | S | O | P | A
		r | r | r | r | r | r

DAS	No operands	Decimal adjust After Subtraction.
		Corrects the result of subtraction of two packed BCD values.
		Algorithm:
		if low nibble of AL > 9 or AF = 1 then:
		• AL = AL - 6
		• AF = 1
		if AL > 9Fh or CF = 1 then:
		• AL = AL - 60h
		• CF = 1
		
		Example:
		MOV AL, 0FFh ; AL = 0FFh (-1)
		DAS ; AL = 99h, CF = 1
		RET
		C | Z | S | O | P | A
		r | r | r | r | r | r

DEC	REG memory	Decrement. Algorithm:

<table>
<tr>
<td></td>
<td></td>
<td>Example:
MOV AL, 255 ; AL = 0FFh (255 or -1)
DEC AL ; AL = 0FEh (254 or -2)
RET
<table><tr><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
CF - unchanged!</td>
</tr>
<tr>
<td>DIV</td>
<td>REG
memory</td>
<td>Unsigned divide.
Algorithm:
when operand is a byte:
AL = AX / operand
AH = remainder (modulus)
when operand is a word:
AX = (DX AX) / operand
DX = remainder (modulus)
Example:
MOV AX, 203 ; AX = 00CBh
MOV BL, 4
DIV BL ; AL = 50 (32h), AH = 3
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr></table></td>
</tr>
<tr>
<td>HLT</td>
<td>No operands</td>
<td>Halt the System.

Example:
MOV AX, 5
HLT
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>IDIV</td>
<td>REG
memory</td>
<td>Signed divide.
Algorithm:
when operand is a byte:
AL = AX / operand
AH = remainder (modulus)
when operand is a word:
AX = (DX AX) / operand
DX = remainder (modulus)
Example:
MOV AX, -203 ; AX = 0FF35h
MOV BL, 4
IDIV BL ; AL = -50 (0CEh), AH = -3 (0FDh)
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr></table></td>
</tr>
<tr>
<td>IMUL</td>
<td>REG
memory</td>
<td>Signed multiply.
Algorithm:
when operand is a byte:
AX = AL * operand.
when operand is a word:
(DX AX) = AX * operand.
Example:
MOV AL, -2
MOV BL, -4
IMUL BL ; AX = 8
RET</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td><table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>?</td><td>?</td><td>r</td><td>?</td><td>?</td></tr></table>CF=OF=0 when result fits into operand of IMUL.</td></tr>
<tr><td>IN</td><td>AL, im.byte
AL, DX
AX, im.byte
AX, DX</td><td>Input from port into AL or AX.
Second operand is a port number. If required to access port number over 255 - DX register should be used.
Example:
IN AX, 4 ; get status of traffic lights.
IN AL, 7 ; get status of stepper-motor.<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td></tr>
<tr><td>INC</td><td>REG
memory</td><td>Increment.
Algorithm:

operand = operand + 1

Example:
MOV AL, 4
INC AL ; AL = 5
RET<table><tr><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>CF - unchanged!</td></tr>
<tr><td>INT</td><td>immediate byte</td><td>Interrupt numbered by immediate byte (0..255).
Algorithm:
Push to stack:
flags register
CS
IP
IF = 0
Transfer control to interrupt procedure
Example:
MOV AH, 0Eh ; teletype.
MOV AL, 'A'
INT 10h ; BIOS interrupt.
RET<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td><td>I</td></tr><tr><td colspan="6">unchanged</td><td>0</td></tr></table></td></tr>
<tr><td>INTO</td><td>No operands</td><td>Interrupt 4 if Overflow flag is 1.

Algorithm:

if OF = 1 then INT 4

Example:
; -5 - 127 = -132 (not in -128..127)
; the result of SUB is wrong (124),
; so OF = 1 is set:
MOV AL, -5
SUB AL, 127 ; AL = 7Ch (124)
INTO ; process error.
RET</td></tr>
<tr><td>IRET</td><td>No operands</td><td></td></tr>
</table>

		Algorithm: Pop from stack: ○ IP ○ CS ○ flags register C Z S O P A popped

JA	label	Short Jump if first operand is Above second operand (as set by CMP instruction). Unsigned.
		Algorithm:
		if (CF = 0) and (ZF = 0) then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 250
		CMP AL, 5
		JA label1
		PRINT 'AL is not above 5'
		JMP exit
		label1:
		PRINT 'AL is above 5'
		exit:
		RET
		C Z S O P A
		unchanged

JAE	label	Short Jump if first operand is Above or Equal to second operand (as set by CMP instruction). Unsigned.
		Algorithm:
		if CF = 0 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 5
		CMP AL, 5
		JAE label1
		PRINT 'AL is not above or equal to 5'
		JMP exit
		label1:
		PRINT 'AL is above or equal to 5'
		exit:
		RET
		C Z S O P A
		unchanged

JB	label	Short Jump if first operand is Below second operand (as set by CMP instruction). Unsigned.
		
		Algorithm:
		if CF = 1 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 1
		CMP AL, 5
		JB label1
		PRINT 'AL is not below 5'
		JMP exit
		label1:
		PRINT 'AL is below 5'

		exit: RET C Z S O P A unchanged

JBE	label	Short Jump if first operand is Below or Equal to second operand (as set by CMP instruction). Unsigned.
		Algorithm:
		if CF = 1 or ZF = 1 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 5
		CMP AL, 5
		JBE label1
		PRINT 'AL is not below or equal to 5'
		JMP exit
		label1:
		PRINT 'AL is below or equal to 5'
		exit:
		RET
		C Z S O P A
		unchanged

JC	label	Short Jump if Carry flag is set to 1.
		Algorithm:
		if CF = 1 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 255
		ADD AL, 1
		JC label1
		PRINT 'no carry.'
		JMP exit
		label1:
		PRINT 'has carry.'
		exit:
		RET
		C Z S O P A
		unchanged

JCXZ	label	Short Jump if CX register is 0. Algorithm: if CX = 0 then jump Example: include 'emu8086.inc' #make_COM# ORG 100h MOV CX, 0 JCXZ label1 PRINT 'CX is not zero.' JMP exit label1: PRINT 'CX is zero.' exit: RET C Z S O P A unchanged

<table>
<tr>
<td>JE</td>
<td>label</td>
<td>Short Jump if first operand is Equal to second operand (as set by CMP instruction). Signed/Unsigned.
Algorithm:
        if ZF = 1 then jump
Example:
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 5
  CMP AL, 5
  JE label1
  PRINT 'AL is not equal to 5.'
  JMP exit
label1:
  PRINT 'AL is equal to 5.'
exit:
  RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JG</td>
<td>label</td>
<td>Short Jump if first operand is Greater then second operand (as set by CMP instruction). Signed.
Algorithm:
        if (ZF = 0) and (SF = OF) then jump
Example:
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 5
  CMP AL, -5
  JG label1
  PRINT 'AL is not greater -5.'
  JMP exit
label1:
  PRINT 'AL is greater -5.'
exit:
  RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JGE</td>
<td>label</td>
<td>Short Jump if first operand is Greater or Equal to second operand (as set by CMP instruction). Signed.
Algorithm:
        if SF = OF then jump
Example:
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 2
  CMP AL, -5
  JGE label1
  PRINT 'AL < -5'
  JMP exit
label1:
  PRINT 'AL >= -5'
exit:
  RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JL</td>
<td>label</td>
<td>Short Jump if first operand is Less then second operand (as set by CMP instruction). Signed.
Algorithm:</td>
</tr>
</table>

		if SF <> OF then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, -2
		CMP AL, 5
		JL label1
		PRINT 'AL >= 5.'
		JMP exit
		label1:
		PRINT 'AL < 5.'
		exit:
		RET
		C Z S O P A
		unchanged

JLE	label	Short Jump if first operand is Less or Equal to second operand (as set by CMP instruction). Signed.
		Algorithm:
		if SF <> OF or ZF = 1 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, -2
		CMP AL, 5
		JLE label1
		PRINT 'AL > 5.'
		JMP exit
		label1:
		PRINT 'AL <= 5.'
		exit:
		RET
		C Z S O P A
		unchanged

JMP	label
	4-byte address
		Unconditional Jump. Transfers control to another part of the program. *4-byte address* may be entered in this form: 1234h:5678h, first value is a segment second value is an offset.
		Algorithm:
		always jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 5
		JMP label1 ; jump over 2 lines!
		PRINT 'Not Jumped!'
		MOV AL, 0
		label1:
		PRINT 'Got Here!'
		RET
		C Z S O P A
		unchanged

JNA	label	Short Jump if first operand is Not Above second operand (as set by CMP instruction). Unsigned. Algorithm: if CF = 1 or ZF = 1 then jump Example: include 'emu8086.inc' #make_COM#

<table>
<tr><td></td><td></td><td>
<pre>
  ORG 100h
  MOV AL, 2
  CMP AL, 5
  JNA label1
  PRINT 'AL is above 5.'
  JMP exit
label1:
  PRINT 'AL is not above 5.'
exit:
  RET
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td></tr>
<tr><td>JNAE</td><td>label</td><td>
Short Jump if first operand is Not Above and Not Equal to second operand (as set by CMP instruction). Unsigned.
Algorithm:
if CF = 1 then jump
Example:
<pre>
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 2
  CMP AL, 5
  JNAE label1
  PRINT 'AL >= 5.'
  JMP exit
label1:
  PRINT 'AL < 5.'
exit:
  RET
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td></tr>
<tr><td>JNB</td><td>label</td><td>
Short Jump if first operand is Not Below second operand (as set by CMP instruction). Unsigned.
Algorithm:
if CF = 0 then jump
Example:
<pre>
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 7
  CMP AL, 5
  JNB label1
  PRINT 'AL < 5.'
  JMP exit
label1:
  PRINT 'AL >= 5.'
exit:
  RET
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td></tr>
<tr><td>JNBE</td><td>label</td><td>
Short Jump if first operand is Not Below and Not Equal to second operand (as set by CMP instruction). Unsigned.
Algorithm:
if (CF = 0) and (ZF = 0) then jump
Example:
<pre>
  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AL, 7
</pre>
</td></tr>
</table>

		CMP AL, 5 JNBE label1 PRINT 'AL <= 5.' JMP exit label1: PRINT 'AL > 5.' exit: RET C Z S O P A unchanged

JNC	label	Short Jump if Carry flag is set to 0.
		Algorithm:
		if CF = 0 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		ADD AL, 3
		JNC label1
		PRINT 'has carry.'
		JMP exit
		label1:
		PRINT 'no carry.'
		exit:
		RET
		C Z S O P A
		unchanged

JNE	label	Short Jump if first operand is Not Equal to second operand (as set by CMP instruction). Signed/Unsigned.
		Algorithm:
		if ZF = 0 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		CMP AL, 3
		JNE label1
		PRINT 'AL = 3.'
		JMP exit
		label1:
		PRINT 'Al <> 3.'
		exit:
		RET
		C Z S O P A
		unchanged

JNG	label	Short Jump if first operand is Not Greater then second operand (as set by CMP instruction). Signed.
		Algorithm:
		if (ZF = 1) and (SF <> OF) then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		CMP AL, 3
		JNG label1
		PRINT 'AL > 3.'

		JMP exit label1: PRINT 'Al <= 3.' exit: RET C Z S O P A unchanged

JNGE	label	Short Jump if first operand is Not Greater and Not Equal to second operand (as set by CMP instruction). Signed.
		Algorithm:
		if SF <> OF then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		CMP AL, 3
		JNGE label1
		PRINT 'AL >= 3.'
		JMP exit
		label1:
		PRINT 'Al < 3.'
		exit:
		RET
		C Z S O P A
		unchanged

JNL	label	Short Jump if first operand is Not Less then second operand (as set by CMP instruction). Signed.
		Algorithm:
		if SF = OF then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		CMP AL, -3
		JNL label1
		PRINT 'AL < -3.'
		JMP exit
		label1:
		PRINT 'Al >= -3.'
		exit:
		RET
		C Z S O P A
		unchanged

JNLE	label	Short Jump if first operand is Not Less and Not Equal to second operand (as set by CMP instruction). Signed.
		
		Algorithm:
		if (SF = OF) and (ZF = 0) then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 2
		CMP AL, -3
		JNLE label1
		PRINT 'AL <= -3.'
		JMP exit

<table>
<tr><td></td><td></td><td>label1:
PRINT 'Al > -3.'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td></tr>
<tr><td>JNO</td><td>label</td><td>Short Jump if Not Overflow.

Algorithm:
if OF = 0 then jump
Example:
; -5 - 2 = -7 (inside -128..127)
; the result of SUB is correct,
; so OF = 0:

include 'emu8086.inc'
#make_COM#
ORG 100h
MOV AL, -5
SUB AL, 2 ; AL = 0F9h (-7)
JNO label1
PRINT 'overflow!'
JMP exit
label1:
PRINT 'no overflow.'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td></tr>
<tr><td>JNP</td><td>label</td><td>Short Jump if No Parity (odd). Only 8 low bits of result are checked. Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions.

Algorithm:
if PF = 0 then jump
Example:
include 'emu8086.inc'
#make_COM#
ORG 100h
MOV AL, 00000111b ; AL = 7
OR AL, 0 ; just set flags.
JNP label1
PRINT 'parity even.'
JMP exit
label1:
PRINT 'parity odd.'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td></tr>
<tr><td>JNS</td><td>label</td><td>Short Jump if Not Signed (if positive). Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions.
Algorithm:
if SF = 0 then jump
Example:
include 'emu8086.inc'
#make_COM#
ORG 100h
MOV AL, 00000111b ; AL = 7
OR AL, 0 ; just set flags.</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>JNS label1
PRINT 'signed.'
JMP exit
label1:
PRINT 'not signed.'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JNZ</td>
<td>label</td>
<td>Short Jump if Not Zero (not equal). Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions.
Algorithm:
if ZF = 0 then jump
Example:
include 'emu8086.inc'
#make_COM#
ORG 100h
MOV AL, 00000111b ; AL = 7
OR AL, 0 ; just set flags.
JNZ label1
PRINT 'zero.'
JMP exit
label1:
PRINT 'not zero.'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JO</td>
<td>label</td>
<td>Short Jump if Overflow.
Algorithm:
if OF = 1 then jump
Example:
; -5 - 127 = -132 (not in -128..127)
; the result of SUB is wrong (124),
; so OF = 1 is set:

include 'emu8086.inc'
#make_COM#
org 100h
MOV AL, -5
SUB AL, 127 ; AL = 7Ch (124)
JO label1
PRINT 'no overflow.'
JMP exit
label1:
PRINT 'overflow!'
exit:
RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table></td>
</tr>
<tr>
<td>JP</td>
<td>label</td>
<td>Short Jump if Parity (even). Only 8 low bits of result are checked. Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions.
Algorithm:
if PF = 1 then jump
Example:
include 'emu8086.inc'
#make_COM#
ORG 100h
MOV AL, 00000101b ; AL = 5</td>
</tr>
</table>

		OR AL, 0 ; just set flags. JP label1 PRINT 'parity odd.' JMP exit label1: PRINT 'parity even.' exit: RET C Z S O P A unchanged
JPE	label	Short Jump if Parity Even. Only 8 low bits of result are checked. Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions. Algorithm: if PF = 1 then jump Example: include 'emu8086.inc' #make_COM# ORG 100h MOV AL, 00000101b ; AL = 5 OR AL, 0 ; just set flags. JPE label1 PRINT 'parity odd.' JMP exit label1: PRINT 'parity even.' exit: RET C Z S O P A unchanged
JPO	label	Short Jump if Parity Odd. Only 8 low bits of result are checked. Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions. Algorithm: if PF = 0 then jump Example: include 'emu8086.inc' #make_COM# ORG 100h MOV AL, 00000111b ; AL = 7 OR AL, 0 ; just set flags. JPO label1 PRINT 'parity even.' JMP exit label1: PRINT 'parity odd.' exit: RET C Z S O P A unchanged
JS	label	Short Jump if Signed (if negative). Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions. Algorithm: if SF = 1 then jump Example: include 'emu8086.inc' #make_COM# ORG 100h MOV AL, 10000000b ; AL = -128 OR AL, 0 ; just set flags. JS label1

		PRINT 'not signed.' JMP exit label1: PRINT 'signed.' exit: RET C Z S O P A unchanged

JZ	label	Short Jump if Zero (equal). Set by CMP, SUB, ADD, TEST, AND, OR, XOR instructions.
		Algorithm:
		if ZF = 1 then jump
		Example:
		include 'emu8086.inc'
		#make_COM#
		ORG 100h
		MOV AL, 5
		CMP AL, 5
		JZ label1
		PRINT 'AL is not equal to 5.'
		JMP exit
		label1:
		PRINT 'AL is equal to 5.'
		exit:
		RET
		C Z S O P A
		unchanged

LAHF	No operands	Load AH from 8 low bits of Flags register. Algorithm: AH = flags register AH bit: 7 6 5 4 3 2 1 0 [SF] [ZF] [0] [AF] [0] [PF] [1] [CF] bits 1, 3, 5 are reserved. C Z S O P A unchanged
LDS	REG, memory	Load memory double word into word register and DS. Algorithm: • REG = first word • DS = second word Example: #make_COM# ORG 100h LDS AX, m RET m DW 1234h DW 5678h END AX is set to 1234h, DS is set to 5678h. C Z S O P A unchanged

LEA	REG, memory	Load Effective Address. Algorithm: • REG = address of memory (offset) Generally this instruction is replaced by MOV when assembling when possible. Example: #make_COM# ORG 100h LEA AX, m RET m DW 1234h END AX is set to: 0104h. LEA instruction takes 3 bytes, RET takes 1 byte, we start at 100h, so the address of 'm' is 104h. C Z S O P A unchanged
LES	REG, memory	Load memory double word into word register and ES. Algorithm: • REG = first word • ES = second word Example: #make_COM# ORG 100h LES AX, m RET m DW 1234h DW 5678h END AX is set to 1234h, ES is set to 5678h. C Z S O P A unchanged

LODSB	No operands	Load byte at DS:[SI] into AL. Update SI.
		Algorithm:
		• AL = DS:[SI]
		• if DF = 0 then
		  ○ SI = SI + 1
		  else
		  ○ SI = SI - 1
		Example:
		#make_COM#
		ORG 100h
		
		LEA SI, a1
		MOV CX, 5
		MOV AH, 0Eh
		
		m: LODSB
		INT 10h

		LOOP m RET a1 DB 'H', 'e', 'l', 'l', 'o' C Z S O P A unchanged

LODSW	No operands	Load word at DS:[SI] into AX. Update SI.
		Algorithm:
		• AX = DS:[SI]
		• if DF = 0 then
		  ○ SI = SI + 2
		  else
		  ○ SI = SI - 2
		Example:
		#make_COM#
		ORG 100h
		
		LEA SI, a1
		MOV CX, 5
		
		REP LODSW ; finally there will be 555h in AX.
		
		RET
		
		a1 dw 111h, 222h, 333h, 444h, 555h
		C Z S O P A
		unchanged

LOOP	label	Decrease CX, jump to label if CX not zero.
		Algorithm:
		• CX = CX - 1
		• if CX <> 0 then
		  ○ jump
		  else
		  ○ no jump, continue
		Example:
		  include 'emu8086.inc'
		  #make_COM#
		  ORG 100h
		  MOV CX, 5
		label1:
		  PRINTN 'loop!'
		  LOOP label1
		  RET
		C Z S O P A
		unchanged

LOOPE	label	Decrease CX, jump to label if CX not zero and Equal (ZF = 1).
		
		Algorithm:
		• CX = CX - 1
		• if (CX <> 0) and (ZF = 1) then
		  ○ jump
		  else
		  ○ no jump, continue
		Example:
		; Loop until result fits into AL alone,
		; or 5 times. The result will be over 255
		; on third loop (100+100+100),
		; so loop will exit.

<table>
<tr>
<td></td>
<td></td>
<td>
<pre>
   include 'emu8086.inc'
   #make_COM#
   ORG 100h
   MOV AX, 0
   MOV CX, 5
label1:
   PUTC '*'
   ADD AX, 100
   CMP AH, 0
   LOOPE label1
   RET
</pre>
<table>
<tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr>
<tr><td colspan="6">unchanged</td></tr>
</table>
</td>
</tr>
<tr>
<td>LOOPNE</td>
<td>label</td>
<td>
Decrease CX, jump to label if CX not zero and Not Equal (ZF = 0).
Algorithm:

CX = CX - 1
if (CX <> 0) and (ZF = 0) then
jump
else
no jump, continue

Example:
<pre>
; Loop until '7' is found,
; or 5 times.

   include 'emu8086.inc'
   #make_COM#
   ORG 100h
   MOV SI, 0
   MOV CX, 5
label1:
   PUTC '*'
   MOV AL, v1[SI]
   INC SI   ; next byte (SI=SI+1).
   CMP AL, 7
   LOOPNE label1
   RET
   v1 db 9, 8, 7, 6, 5
</pre>
<table>
<tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr>
<tr><td colspan="6">unchanged</td></tr>
</table>
</td>
</tr>
<tr>
<td>LOOPNZ</td>
<td>label</td>
<td>
Decrease CX, jump to label if CX not zero and ZF = 0.
Algorithm:

CX = CX - 1
if (CX <> 0) and (ZF = 0) then
jump
else
no jump, continue

Example:
<pre>
; Loop until '7' is found,
; or 5 times.

   include 'emu8086.inc'
   #make_COM#
   ORG 100h
   MOV SI, 0
   MOV CX, 5
label1:
   PUTC '*'
   MOV AL, v1[SI]
   INC SI   ; next byte (SI=SI+1).
   CMP AL, 7
   LOOPNZ label1
   RET
</pre>
</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>
v1 db 9, 8, 7, 6, 5
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>LOOPZ</td>
<td>label</td>
<td>
Decrease CX, jump to label if CX not zero and ZF = 1.
Algorithm:

CX = CX - 1
if (CX <> 0) and (ZF = 1) then
jump
else
no jump, continue

Example:
; Loop until result fits into AL alone,
; or 5 times. The result will be over 255
; on third loop (100+100+100),
; so loop will exit.

  include 'emu8086.inc'
  #make_COM#
  ORG 100h
  MOV AX, 0
  MOV CX, 5
label1:
  PUTC '*'
  ADD AX, 100
  CMP AH, 0
  LOOPZ label1
  RET
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>MOV</td>
<td>
REG, memory
memory, REG
REG, REG
memory, immediate
REG, immediate

SREG, memory
memory, SREG
REG, SREG
SREG, REG
</td>
<td>
Copy operand2 to operand1.

The MOV instruction <u>cannot</u>:

set the value of the CS and IP registers.
copy value of one segment register to another segment register (should copy to general register first).
copy immediate value to segment register (should copy to general register first).

Algorithm:
    operand1 = operand2
Example:
#make_COM#
ORG 100h
MOV AX, 0B800h ; set AX = B800h (VGA memory).
MOV DS, AX ; copy value of AX to DS.
MOV CL, 'A' ; CL = 41h (ASCII code).
MOV CH, 01011111b ; CL = color attribute.
MOV BX, 15Eh ; BX = position on screen.
MOV [BX], CX ; w.[0B800h:015Eh] = CX.
RET ; returns to operating system.
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>MOVSB</td>
<td>No operands</td>
<td>
Copy byte at DS:[SI] to ES:[DI]. Update SI and DI.
Algorithm:

ES:[DI] = DS:[SI]
if DF = 0 then
SI = SI + 1
DI = DI + 1
else

</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td>
SI = SI - 1
DI = DI - 1
Example:
<pre>
#make_COM#
ORG 100h

LEA SI, a1
LEA DI, a2
MOV CX, 5
REP MOVSB

RET

a1 DB 1,2,3,4,5
a2 DB 5 DUP(0)
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td></tr>
<tr><td>MOVSW</td><td>No operands</td><td>
Copy word at DS:[SI] to ES:[DI]. Update SI and DI.
Algorithm:
ES:[DI] = DS:[SI]
if DF = 0 then
SI = SI + 2
DI = DI + 2
else
SI = SI - 2
DI = DI - 2
Example:
<pre>
#make_COM#
ORG 100h

LEA SI, a1
LEA DI, a2
MOV CX, 5
REP MOVSW

RET

a1 DW 1,2,3,4,5
a2 DW 5 DUP(0)
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td></tr>
<tr><td>MUL</td><td>REG
memory</td><td>
Unsigned multiply.
Algorithm:
when operand is a byte:
AX = AL * operand.
when operand is a word:
(DX AX) = AX * operand.
Example:
<pre>
MOV AL, 200   ; AL = 0C8h
MOV BL, 4
MUL BL   ; AX = 0320h (800)
RET
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>?</td><td>?</td><td>r</td><td>?</td><td>?</td></tr></table>
CF=OF=0 when high section of the result is zero.
</td></tr>
<tr><td>NEG</td><td>REG
memory</td><td>
Negate. Makes operand negative (two's complement).
Algorithm:
Invert all bits of the operand
Add 1 to inverted operand
</td></tr>
</table>

		Example: MOV AL, 5 ; AL = 05h NEG AL ; AL = 0FBh (-5) NEG AL ; AL = 05h (5) RET C Z S O P A r r r r r r
NOP	No operands	No Operation. Algorithm: • Do nothing Example: ; do nothing, 3 times: NOP NOP NOP RET C Z S O P A unchanged
NOT	REG memory	Invert each bit of the operand. Algorithm: • if bit is 1 turn it to 0. • if bit is 0 turn it to 1. Example: MOV AL, 00011011b NOT AL ; AL = 11100100b RET C Z S O P A unchanged
OR	REG, memory memory, REG REG, REG memory, immediate REG, immediate	Logical OR between all bits of two operands. Result is stored in first operand. These rules apply: 1 OR 1 = 1 1 OR 0 = 1 0 OR 1 = 1 0 OR 0 = 0 Example: MOV AL, 'A' ; AL = 01000001b OR AL, 00100000b ; AL = 01100001b ('a') RET C Z S O P A 0 r r 0 r ?

OUT	im.byte, AL
	im.byte, AX
	DX, AL
	DX, AX
		Output from **AL** or **AX** to port.
		First operand is a port number. If required to access port number over 255 - **DX** register should be used.
		
		Example:
		MOV AX, 0FFFh ; Turn on all
		OUT 4, AX ; traffic lights.
		
		MOV AL, 100b ; Turn on the third
		OUT 7, AL ; magnet of the stepper-motor.
		C Z S O P A
		unchanged

POP	REG SREG memory	Get 16 bit value from the stack. Algorithm: • operand = SS:[SP] (top of the stack) • SP = SP + 2 Example: MOV AX, 1234h PUSH AX POP DX ; DX = 1234h RET C Z S O P A unchanged
POPA	No operands	Pop all general purpose registers DI, SI, BP, SP, BX, DX, CX, AX from the stack. SP value is ignored, it is Popped but not set to SP register). Note: this instruction works only on **80186** CPU and later! Algorithm: • POP DI • POP SI • POP BP • POP xx (SP value ignored) • POP BX • POP DX • POP CX • POP AX C Z S O P A unchanged
POPF	No operands	Get flags register from the stack. Algorithm: • flags = SS:[SP] (top of the stack) • SP = SP + 2 C Z S O P A popped
PUSH	REG SREG memory immediate	Store 16 bit value in the stack. Note: **PUSH immediate** works only on 80186 CPU and later! Algorithm: • SP = SP - 2 • SS:[SP] (top of the stack) = operand Example: MOV AX, 1234h PUSH AX POP DX ; DX = 1234h RET C Z S O P A unchanged
PUSHA	No operands	Push all general purpose registers AX, CX, DX, BX, SP, BP, SI, DI in the stack. Original value of SP register (before PUSHA) is used. Note: this instruction works only on **80186** CPU and later! Algorithm: • PUSH AX • PUSH CX

<table>
<tr>
<td></td>
<td></td>
<td>

PUSH DX
PUSH BX
PUSH SP
PUSH BP
PUSH SI
PUSH DI

<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>PUSHF</td>
<td>No operands</td>
<td>
Store flags register in the stack.

Algorithm:

SP = SP - 2
SS:[SP] (top of the stack) = flags

<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>RCL</td>
<td>memory, immediate
REG, immediate

memory, CL
REG, CL</td>
<td>
Rotate operand1 left through Carry Flag. The number of rotates is set by operand2.
When immediate is greater then 1, assembler generates several RCL xx, 1 instructions because 8086 has machine code only for this instruction (the same principle works for all other shift/rotate instructions).
Algorithm:
shift all bits left, the bit that goes off is set to CF and previous value of CF is inserted to the right-most position.

Example:
STC ; set carry (CF=1).
MOV AL, 1Ch ; AL = 00011100b
RCL AL, 1 ; AL = 00111001b, CF=0.
RET
<table><tr><td>C</td><td>O</td></tr><tr><td>r</td><td>r</td></tr></table>
OF=0 if first operand keeps original sign.
</td>
</tr>
<tr>
<td>RCR</td>
<td>memory, immediate
REG, immediate

memory, CL
REG, CL</td>
<td>
Rotate operand1 right through Carry Flag. The number of rotates is set by operand2.
Algorithm:
shift all bits right, the bit that goes off is set to CF and previous value of CF is inserted to the left-most position.

Example:
STC ; set carry (CF=1).
MOV AL, 1Ch ; AL = 00011100b
RCR AL, 1 ; AL = 10001110b, CF=0.
RET
<table><tr><td>C</td><td>O</td></tr><tr><td>r</td><td>r</td></tr></table>
OF=0 if first operand keeps original sign.
</td>
</tr>
<tr>
<td>REP</td>
<td>chain instruction</td>
<td>
Repeat following MOVSB, MOVSW, LODSB, LODSW, STOSB, STOSW instructions CX times.
Algorithm:
check_cx:

if CX <> 0 then

do following <u>chain instruction</u>
CX = CX - 1
go back to check_cx

else

exit from REP cycle

</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td>Z
r</td></tr>
<tr><td>REPE</td><td>chain instruction</td><td>Repeat following CMPSB, CMPSW, SCASB, SCASW instructions while ZF = 1 (result is Equal), maximum CX times.

Algorithm:
check_cx:
if CX <> 0 then
• do following chain instruction
• CX = CX - 1
• if ZF = 1 then:
  ○ go back to check_cx
  else
  ○ exit from REPE cycle
else
• exit from REPE cycle
Example:
see cmpsb.asm in Samples.
Z
r</td></tr>
<tr><td>REPNE</td><td>chain instruction</td><td>Repeat following CMPSB, CMPSW, SCASB, SCASW instructions while ZF = 0 (result is Not Equal), maximum CX times.
Algorithm:
check_cx:

if CX <> 0 then
• do following chain instruction
• CX = CX - 1
• if ZF = 0 then:
  ○ go back to check_cx
  else
  ○ exit from REPNE cycle
else
• exit from REPNE cycle
Z
r</td></tr>
<tr><td>REPNZ</td><td>chain instruction</td><td>Repeat following CMPSB, CMPSW, SCASB, SCASW instructions while ZF = 0 (result is Not Zero), maximum CX times.
Algorithm:
check_cx:
if CX <> 0 then
• do following chain instruction
• CX = CX - 1
• if ZF = 0 then:
  ○ go back to check_cx
  else
  ○ exit from REPNZ cycle
else
• exit from REPNZ cycle
Z
r</td></tr>
<tr><td>REPZ</td><td>chain instruction</td><td>Repeat following CMPSB, CMPSW, SCASB, SCASW instructions while ZF = 1 (result is Zero), maximum CX times.
Algorithm:</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>
if CX <> 0 then

do following chain instruction
CX = CX - 1
if ZF = 1 then:
go back to check_cx
else
exit from REPZ cycle

else
exit from REPZ cycle
<table><tr><td>Z</td></tr><tr><td>r</td></tr></table>
</td>
</tr>
<tr>
<td>RET</td>
<td>No operands
or even
immediate</td>
<td>
Return from near procedure.
Algorithm:

Pop from stack:
IP

if immediate operand is present: SP = SP + operand

Example:
<pre>
#make_COM#
ORG 100h ; for COM file.

CALL p1

ADD AX, 1

RET   ; return to OS.

p1 PROC   ; procedure declaration.
   MOV AX, 1234h
   RET   ; return to caller.
p1 ENDP
</pre>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>RETF</td>
<td>No operands
or even
immediate</td>
<td>
Return from Far procedure.
Algorithm:

Pop from stack:
IP
CS

if immediate operand is present: SP = SP + operand

<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
</td>
</tr>
<tr>
<td>ROL</td>
<td>memory,
immediate
REG,
immediate

memory, CL
REG, CL</td>
<td>
Rotate operand1 left. The number of rotates is set by operand2.
Algorithm:
shift all bits left, the bit that goes off is set to CF and the same bit is inserted to the right-most position.
Example:
<pre>
MOV AL, 1Ch   ; AL = 00011100b
ROL AL, 1   ; AL = 00111000b, CF=0.
RET
</pre>
<table><tr><td>C</td><td>O</td></tr><tr><td>r</td><td>r</td></tr></table>
OF=0 if first operand keeps original sign.
</td>
</tr>
<tr>
<td>ROR</td>
<td></td>
<td></td>
</tr>
</table>

	immediate REG, immediate memory, CL REG, CL	Algorithm: shift all bits right, the bit that goes off is set to CF and the same bit is inserted to the left-most position. Example: MOV AL, 1Ch ; AL = 00011100b ROR AL, 1 ; AL = 00001110b, CF=0. RET C O r r OF=0 if first operand keeps original sign.
SAHF	No operands	Store AH register into low 8 bits of Flags register. Algorithm: flags register = AH AH bit: 7 6 5 4 3 2 1 0 [SF] [ZF] [0] [AF] [0] [PF] [1] [CF] bits 1, 3, 5 are reserved. C Z S O P A r r r r r r
SAL	memory, immediate REG, immediate memory, CL REG, CL	Shift Arithmetic operand1 Left. The number of shifts is set by operand2. Algorithm: • Shift all bits left, the bit that goes off is set to CF. • Zero bit is inserted to the right-most position. Example: MOV AL, 0E0h ; AL = 11100000b SAL AL, 1 ; AL = 11000000b, CF=1. RET C O r r OF=0 if first operand keeps original sign.

SAR	memory, immediate
	REG, immediate
	
	memory, CL
	REG, CL
		Shift Arithmetic operand1 Right. The number of shifts is set by operand2.
		Algorithm:
		• Shift all bits right, the bit that goes off is set to CF.
		• The sign bit that is inserted to the left-most position has the same value as before shift.
		Example:
		MOV AL, 0E0h ; AL = 11100000b
		SAR AL, 1 ; AL = 11110000b, CF=0.
		
		MOV BL, 4Ch ; BL = 01001100b
		SAR BL, 1 ; BL = 00100110b, CF=0.
		
		RET
		C O
		r r
		OF=0 if first operand keeps original sign.

SBB	REG, memory memory, REG REG, REG memory, immediate REG, immediate	Subtract with Borrow. Algorithm: operand1 = operand1 - operand2 - CF Example: STC MOV AL, 5 SBB AL, 3 ; AL = 5 - 3 - 1 = 1 RET

<table>
<tr><td></td><td></td><td>
<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
</td></tr>
<tr><td>SCASB</td><td>No operands</td><td>
Compare bytes: AL from ES:[DI].
Algorithm:

ES:[DI] - AL
set flags according to result:
OF, SF, ZF, AF, PF, CF
if DF = 0 then
DI = DI + 1
else
DI = DI - 1

<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
</td></tr>
<tr><td>SCASW</td><td>No operands</td><td>
Compare words: AX from ES:[DI].
Algorithm:

ES:[DI] - AX
set flags according to result:
OF, SF, ZF, AF, PF, CF
if DF = 0 then
DI = DI + 2
else
DI = DI - 2

<table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr></table>
</td></tr>
<tr><td>SHL</td><td>memory, immediate
REG, immediate

memory, CL
REG, CL</td><td>
Shift operand1 Left. The number of shifts is set by operand2.
Algorithm:

Shift all bits left, the bit that goes off is set to CF.
Zero bit is inserted to the right-most position.

Example:
MOV AL, 11100000b
SHL AL, 1 ; AL = 11000000b, CF=1.

RET
<table><tr><td>C</td><td>O</td></tr><tr><td>r</td><td>r</td></tr></table>
OF=0 if first operand keeps original sign.
</td></tr>
<tr><td>SHR</td><td>memory, immediate
REG, immediate

memory, CL
REG, CL</td><td>
Shift operand1 Right. The number of shifts is set by operand2.
Algorithm:

Shift all bits right, the bit that goes off is set to CF.
Zero bit is inserted to the left-most position.

Example:
MOV AL, 00000111b
SHR AL, 1 ; AL = 00000011b, CF=1.

RET
<table><tr><td>C</td><td>O</td></tr><tr><td>r</td><td>r</td></tr></table>
OF=0 if first operand keeps original sign.
</td></tr>
<tr><td>STC</td><td>No operands</td><td>
Set Carry flag.
Algorithm:
CF = 1
</td></tr>
</table>

		C 1
STD	No operands	Set Direction flag. SI and DI will be decremented by chain instructions: CMPSB, CMPSW, LODSB, LODSW, MOVSB, MOVSW, STOSB, STOSW. Algorithm: DF = 1 D 1
STI	No operands	Set Interrupt enable flag. This enables hardware interrupts. Algorithm: IF = 1 I 1

STOSB	No operands	Store byte in AL into ES:[DI]. Update SI.
		Algorithm:
		• ES:[DI] = AL
		• if DF = 0 then
		  ○ DI = DI + 1
		  else
		  ○ DI = DI - 1
		Example:
		#make_COM#
		ORG 100h
		
		LEA DI, a1
		MOV AL, 12h
		MOV CX, 5
		
		REP STOSB
		
		RET
		
		a1 DB 5 dup(0)
		C Z S O P A
		unchanged

STOSW	No operands	Store word in AX into ES:[DI]. Update SI.
		Algorithm:
		• ES:[DI] = AX
		• if DF = 0 then
		  ○ DI = DI + 2
		  else
		  ○ DI = DI - 2
		Example:
		#make_COM#
		ORG 100h
		
		LEA DI, a1
		MOV AX, 1234h
		MOV CX, 5
		REP STOSW
		
		RET
		
		a1 DW 5 dup(0)

		C | Z | S | O | P | A unchanged

SUB	REG, memory
	memory, REG
	REG, REG
	memory, immediate
	REG, immediate
		Subtract.
		Algorithm:
		operand1 = operand1 - operand2
		
		Example:
		MOV AL, 5
		SUB AL, 1 ; AL = 4
		
		RET
		C | Z | S | O | P | A
		r | r | r | r | r | r

TEST	REG, memory memory, REG REG, REG memory, immediate REG, immediate	Logical AND between all bits of two operands for flags only. These flags are effected: **ZF, SF, PF.** Result is not stored anywhere. These rules apply: 1 AND 1 = 1 1 AND 0 = 0 0 AND 1 = 0 0 AND 0 = 0 Example: MOV AL, 00000101b TEST AL, 1 ; ZF = 0. TEST AL, 10b ; ZF = 1. RET C | Z | S | O | P 0 | r | r | 0 | r

XCHG	REG, memory
	memory, REG
	REG, REG
		Exchange values of two operands.
		Algorithm:
		operand1 < - > operand2
		
		Example:
		MOV AL, 5
		MOV AH, 2
		XCHG AL, AH ; AL = 2, AH = 5
		XCHG AL, AH ; AL = 5, AH = 2
		RET
		C | Z | S | O | P | A
		unchanged

XLATB	No operands	Translate byte from table. Copy value of memory byte at DS:[BX + unsigned AL] to AL register. Algorithm: AL = DS:[BX + unsigned AL] Example: #make_COM# ORG 100h LEA BX, dat MOV AL, 2 XLATB ; AL = 33h RET

		dat DB 11h, 22h, 33h, 44h, 55h <table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td colspan="6">unchanged</td></tr></table>
XOR	REG, memory memory, REG REG, REG memory, immediate REG, immediate	Logical XOR (Exclusive OR) between all bits of two operands. Result is stored in first operand. These rules apply: 1 XOR 1 = 0 1 XOR 0 = 1 0 XOR 1 = 1 0 XOR 0 = 0 Example: MOV AL, 00000111b XOR AL, 00000010b ; AL = 00000101b RET <table><tr><td>C</td><td>Z</td><td>S</td><td>O</td><td>P</td><td>A</td></tr><tr><td>0</td><td>r</td><td>r</td><td>0</td><td>r</td><td>?</td></tr></table>