Machine Language

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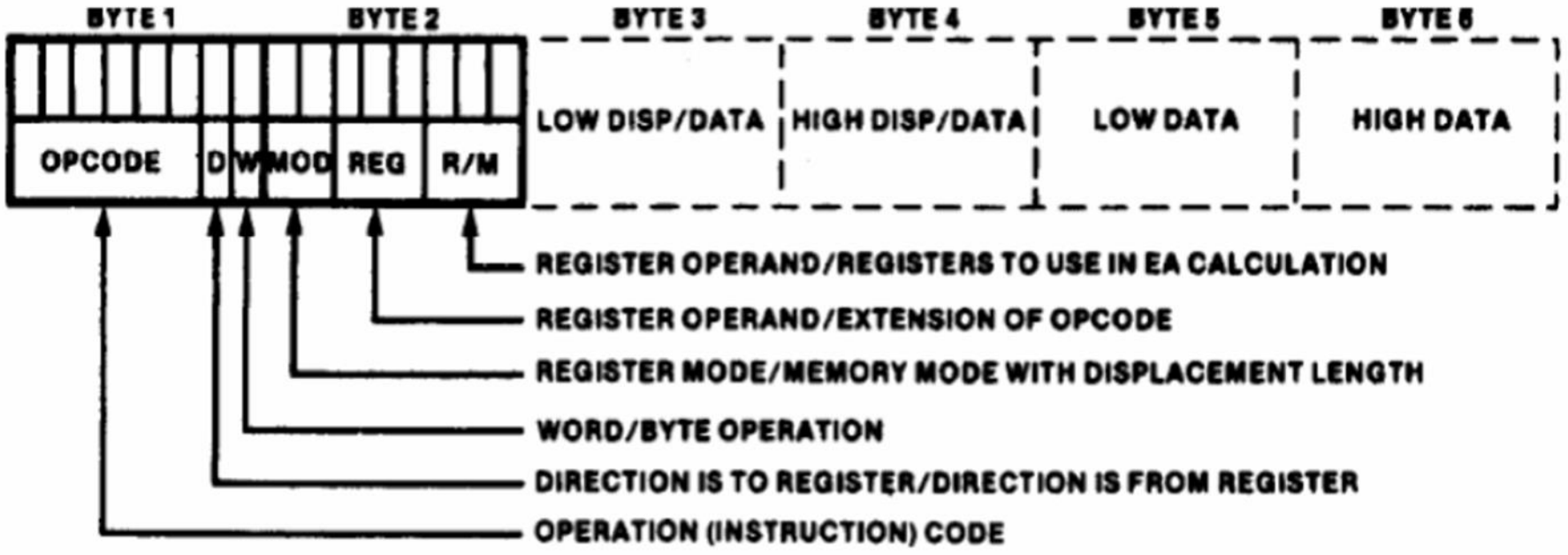
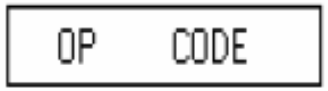
Instruction Format

byte	7	6	5	4	3	2	1	0	
1	opcode						d	w	Opcode byte
2	mod		reg			r/m			Addressing mode byte
3	[optional]								low disp, addr, or data
4	[optional]								high disp, addr, or data
5	[optional]								low data
6	[optional]								high data

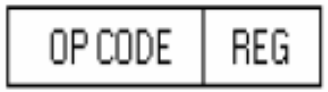
8086-General Instruction Format



One byte instruction - implied operand(s)



One byte instruction - register mode



REG - Register
MOD - Mode
R/M - Register or memory
DISP - Displacement
DATA - Immediate data

Register to register

Register to/from memory with no displacement

Register to/from memory with displacement

(If 16-bit displacement is used)

Immediate operand to register

(If 16-bit data are used)

Immediate operand to memory with 16-bit displacement

(If 16-bit data are used)

CODE	EXPLANATION
00	Memory Mode, no displacement follows*
01	Memory Mode, 8-bit displacement follows
10	Memory Mode, 16-bit displacement follows
11	Register Mode (no displacement)

*Except when R/M = 110, then 16-bit displacement follows

(a)

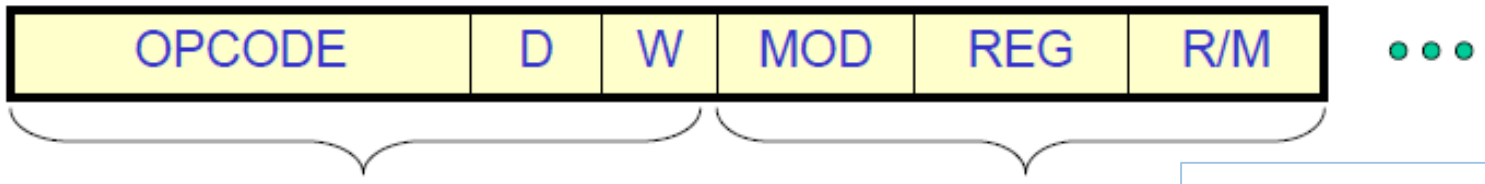
Segment Override	
00	ES
01	CS
10	SS
11	DS

REG field is used to identify the register for the first operand

REG	W = 0	W = 1
000	AL	AX
001	CL	CX
010	DL	DX
011	BL	BX
100	AH	SP
101	CH	BP
110	DH	SI
111	BH	DI

MOD = 11			EFFECTIVE ADDRESS CALCULATION			
R/M	W = 0	W = 1	R/M	MOD = 00	MOD = 01	MOD = 10
000	AL	AX	000	(BX) + (SI)	(BX) + (SI) + D8	(BX) + (SI) + D16
001	CL	CX	001	(BX) + (DI)	(BX) + (DI) + D8	(BX) + (DI) + D16
010	DL	DX	010	(BP) + (SI)	(BP) + (SI) + D8	(BP) + (SI) + D16
011	BL	BX	011	(BP) + (DI)	(BP) + (DI) + D8	(BP) + (DI) + D16
100	AH	SP	100	(SI)	(SI) + D8	(SI) + D16
101	CH	BP	101	(DI)	(DI) + D8	(DI) + D16
110	DH	SI	110	DIRECT ADDRESS	(BP) + D8	(BP) + D16
111	BH	DI	111	(BX)	(BX) + D8	(BX) + D16

Converting Assembly Language Instructions to Machine Code



(1 bit) Direction. 1 = Register is Destination, 0 = Register is source.

An instruction can be coded with 1 to 6 bytes

Byte 1 contains three kinds of information:

- Opcode field (6 bits) specifies the operation such as add, subtract, or move
- Register Direction Bit (D bit)
  - Tells the register operand in REG field in byte 2 is source or destination operand
    - 1:Data flow to the REG field from R/M
    - 0: Data flow from the REG field to the R/M
- Data Size Bit (W bit)
  - Specifies whether the operation will be performed on 8-bit or 16-bit data
    - 0: 8 bits
    - 1: 16 bits

Byte 2 has two fields:

- Mode field (MOD) – 2 bits
- Register field (REG) - 3 bits
- Register/memory field (R/M field) – 2 bits

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MOD = 11			EFFECTIVE ADDRESS CALCULATION			
R/M	W = 0	W = 1	R/M	MOD = 00	MOD = 01	MOD = 10
000	AL	AX	000	(BX) + (SI)	(BX) + (SI) + D8	(BX) + (SI) + D16
001	CL	CX	001	(BX) + (DI)	(BX) + (DI) + D8	(BX) + (DI) + D16
010	DL	DX	010	(BP) + (SI)	(BP) + (SI) + D8	(BP) + (SI) + D16
011	BL	BX	011	(BP) + (DI)	(BP) + (DI) + D8	(BP) + (DI) + D16
100	AH	SP	100	(SI)	(SI) + D8	(SI) + D16
101	CH	BP	101	(DI)	(DI) + D8	(DI) + D16
110	DH	SI	110	DIRECT ADDRESS	(BP) + D8	(BP) + D16
111	BH	DI	111	(BX)	(BX) + D8	(BX) + D16

Examples

- MOV BL,AL
- Opcode for MOV = 100010
- We'll encode AL so
  - D = 0 (AL source operand)
- W bit = 0 (8-bits)
- MOD = 11 (register mode)
- REG = 000 (code for AL)
- R/M = 011

D=0 when Data moving from a register

OPCODE	D	W	MOD	REG	R/M
100010	0	0	11	000	011

MOV BL,AL => 10001000 11000011 = 88 C3h

ADD AX,[SI] => 00000011 00000100 = 03 04 h

ADD [BX][DI] + 1234h, AX => 00000001 10000001 __ __ h

=> 01 81 34 12 h

In some cases, S, V and Z are used before w

The S, V, Z fields of the opcode in specific instructions

Field	Value	Function
S	0	No sign extension
	1	Sign extend 8-bit immediate data to 16 bits if W=1
V	0	Shift/rotate count is one
	1	Shift/rotate count is specified in CL register
Z	0	Repeat/loop while zero flag is clear
	1	Repeat/loop while zero flag is set

• SR (2-bit segment register identifier field)—used in instructions to specify a segment register

The segment register identifiers

Register	SR
ES	00
CS	01
SS	10
DS	11

Example 1 : MOV CH, BL

This instruction transfers 8 bit content of BL

Into CH

The 6 bit Opcode for this instruction is 100010_2 D bit indicates whether the register specified by the REG field of byte 2 is a source or destination operand.

D=0 indicates BL is a source operand.

W=0 byte operation

In byte 2, since the second operand is a register MOD field is 11_2.

The R/M field = 101 (CH)

Register (REG) field = 011 (BL)

Hence the machine code for MOV CH, BL is

10001000 11 011 101

Byte 1 Byte2

= 88DD16

Example 2 : SUB Bx, (DI)

This instruction subtracts the 16 bit content of memory location addressed by DI and DS from Bx. The 6 bit Opcode for SUB is 001010_2.

D=1 so that REG field of byte 2 is the destination operand. W=1 indicates 16 bit operation.

MOD = 00

REG = 011

R/M = 101

The machine code is

0010	1011	0001	1101
2	B	1	D

$2B1D_{16}$

Example 3 : Code for MOV 1234 (BP), DX

Here we have specify DX using REG field, the D bit must be 0, indicating the DX is the source register. The REG field must be 010 to indicate DX register. The W bit must be 1 to indicate it is a word operation. 1234 [BP] is specified using MOD value of 10 and R/M value of 110 and a displacement of 1234H. The 4 byte code for this instruction would be 89 96 34 12H.

Opcode	D	W	MOD	REG	R/M	LB displacement	HB displacement
100010	0	1	10	010	110	34H	12H

Example 4 : Code for MOV DS : 2345 [BP], DX

Here we have to specify DX using REG field. The D bit must be o, indicating that Dx is the source register. The REG field must be 010 to indicate DX register. The w bit must be 1 to indicate it is a word operation. 2345 [BP] is specified with MOD=10 and R/M = 110 and displacement = 2345 H.

Whenever BP is used to generate the Effective Address (EA), the default segment would be SS. In this example, we want the segment register to be DS, we have to provide the segment override prefix byte (SOP byte) to start with. The SOP byte is 001 SR 110, where SR value is provided as per table shown below.

SR	Segment register
00	ES
01	CS
10	SS
11	DS

To specify DS register, the SOP byte would be 001 11 110 = 3E H. Thus the 5 byte code for this instruction would be 3E 89 96 45 23 H.

SOP	Opcode	D	W	MOD	REG	R/M	LB disp.	HD disp.
3EH	1000 10	0	1	10	010	110	45	23

Suppose we want to code MOV SS : 2345 (BP), DX. This generates only a 4 byte code, without SOP byte, as SS is already the default segment register in this case.

Example 5 :

Give the instruction template and generate code for the instruction ADD OFABE [BX], [DI], DX (code for ADD instruction is 000000)

ADD OFABE [BX] [DI], DX

Here we have to specify DX using REG field. The bit D is 0, indicating that DX is the source register. The REG field must be 010 to indicate DX register. The w must be 1 to indicate it is a word operation. FABE (BX + DI) is specified using MOD value of 10 and R/M value of 001 (from the summary table). The 4 byte code for this instruction would be

Opcode	D	W	MOD	REG	R/M	16 bit disp.		=01 91 BE FAH
000000	0	1	10	010	001	BEH	FAH	

Example 6 :

Give the instruction template and generate the code for the instruction MOV AX, [BX]

(Code for MOV instruction is 100010)

AX destination register with D=1 and code for AX is 000 [BX] is specified using 00 Mode and R/M value 111

It is a word operation

Opcode	D	W	Mod	REG	R/M	=8B 07H
100010	1	1	00	000	111	