

Computer Structure and Language

Hamid Sarbazi-Azad
Department of Computer Engineering
Sharif University of Technology (SUT)
Tehran, Iran



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Computer Structure & Language -- Lecture #6: IBM360 Machine

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IBM System 360/370:

- IBM360 was introduced in 1964 (IBM370 in 1970); a CISC machine that could perform about 35 KIPS (compatible to USSR's Ryad).
- IBM370 has 13 instructions more than IBM360.
- In 1989, IBM360/370 machines accounted for more than half of the estimated \$260B value of large computer systems worldwide.



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Machine Structure:

Memory size:

2²⁴ bytes

Addressable unit:

8 bits (byte)

Word length:

32 bits, Big Endian, Aligned.

ISA types:

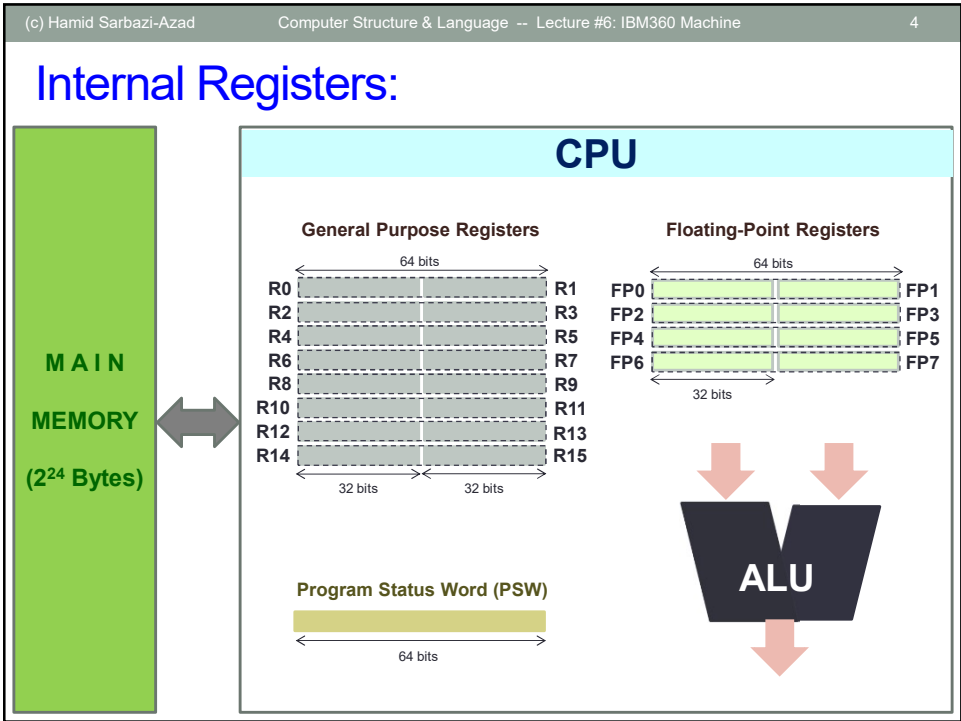
Register-Register,
Register-Memory,
Memory-Memory.

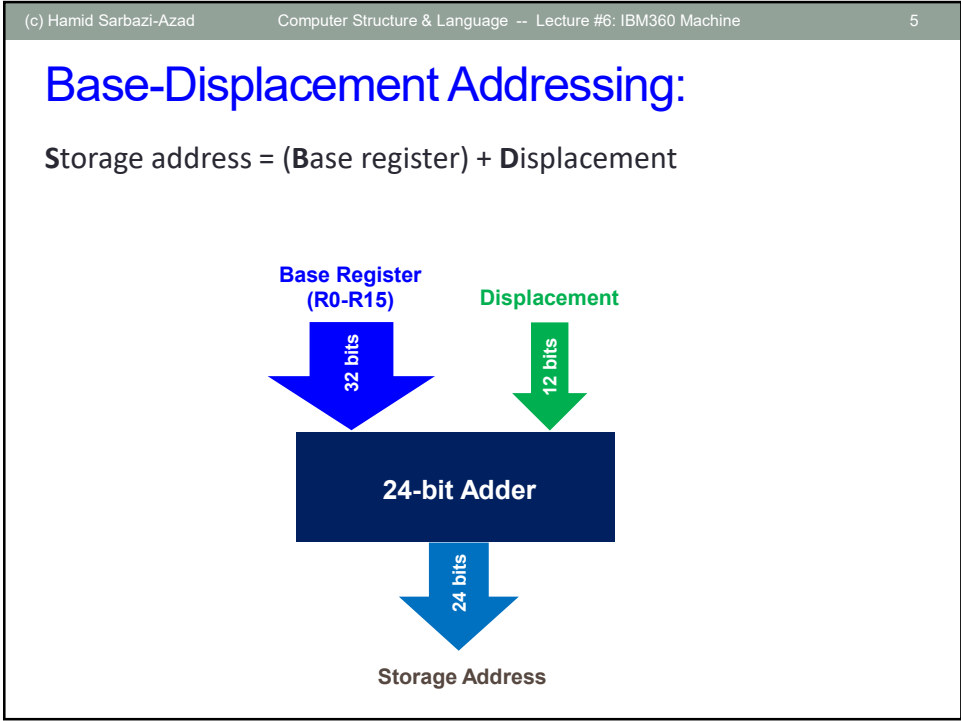
Addressing modes:

Segmented,
Indexed,
Register (direct/indirect),
Implied, and Immediate.

Data types:

Signed integer (2's complement),
Unsigned binary,
Character (byte),
Decimal,
Floating-point.





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Data Alignment in Main Memory:

	Main Memory (word wide view)	Main Memory (half-word-wide view)	Main Memory (byte-wide view)
210000h	11 11 00 AF	11 00	11
210004h	21 23 22 66	21 23	21
210008h	23 43 33 01	22 66	22
21000Ch	35 11 8C EF	23 43	23
210010h	77 0C 18 27	33 01	33
210014h	D6 33 D7 A2	35 11	35
210018h	21 32 23 33	8C EF	8C
21001Ch	35 8C 77 8D	77 0C	77
210020h	6D 07 32 FF	18 27	18
210024h	35 11 8C EF	D6 33	D6
210028h	23 43 33 01	D7 A2	D7
21002Ch			
210030h			
210034h			
210038h	WORD		
21003Ch			
210040h	HALF-WORD HALF-WORD	HALF-WORD	
210044h			
210048h	Byte Byte Byte Byte	Byte Byte	Byte

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Data Alignment in Main Memory (cont.):

Main Memory (double-word wide view)

210000h	11	11	11	00	AF	00	FF	A0
210008h	21	23	22	66	23	43	33	01
210010h	35	11	8C	EF	77	0C	18	78
210018h	D6	33	D7	A2	21	32	23	33
210020h	35	8C	77	8D	6D	07	32	FF
210028h	35	11	8C	EF	23	43	33	01
210030h	21	22	23	33	35	8C	77	81
210038h	8D	6D	71	66	23	43	33	01
210040h								
210048h								
210050h								
210058h								
210060h								
210068h								
210070h								
210078h								
210080h								

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Instruction Formats:

RR (Register-Register): 2 Bytes

OPCODE	r1	r2
0 0 x x x x x x	4 bits	4 bits

RX (Register-Indexed): 4 Bytes

OPCODE	r1	X2	B2	D2
0 1 x x x x x x	4 bits	4 bits	4 bits	12 bits

RS (Register-Storage): 4 Bytes

OPCODE	r1	r3	B2	D2
1 0 x x x x x x	4 bits	4 bits	4 bits	12 bits

SI (Storage-Immediate): 4 Bytes

OPCODE	I2	B1	D1
1 0 x x x x x x	8 bits	4 bits	12 bits

SS1 (Storage-Storage 1-Length): 6 Bytes

OPCODE	L-1	B1	D1	B2	D2
1 1 x x x x x x	8 bits	4 bits	12 bits	4 bits	12 bits

SS2 (Storage-Storage 2-Length): 6 Bytes

OPCODE	L1 - 1	L2 - 1	B1	D1	B2	D2
1 1 x x x x x x	4 bits	4 bits	4 bits	12 bits	4 bits	12 bits

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Instruction Formats:

RR (Register-Register)

OPCODE

r1

r2

0 0 x x x x x x

4 bits

4 bits

All mnemonics of this format have character R at the end.

Example 1:

Assembly instruction: SR 12,5

Operation: $R12 \leftarrow (R12) - (R5)$

Machine code: 1BC5

Example 2:

Assembly instruction: NR 6,10

Operation: $R6 \leftarrow (R6) \wedge (R10)$

Machine code: 146A

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Instruction Formats:

RX (Register-Indexed)

OPCODE

r1

X2

B2

D2

0 1 x x x x x x

4 bits

4 bits

4 bits

12 bits

Most machine instructions are coded in this format.

Example 1:

Assembly instruction: S 10,NUM

Operation: $R10 \leftarrow (R10) - (M_{NUM})$

Machine code: 5BA0C01A

NUM address = (R12) + 01Ah

Example 2:

Assembly instruction: L 15,N10

Operation: $R15 \leftarrow (M_{N10});$

Machine code: 58F0B11B

N10 address = (R11) + 11Bh

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Instruction Formats:

RS (Register-Storage)

OPCODE

r1

r3

B2

D2

1 0 x x x x x x

4 bits

4 bits

4 bits

12 bits

This format includes some 3-operand instructions.

Example 1:
Assembly instruction: SLL 5,3
Operation: $R5 \leftarrow (R5) \ll 3$
Machine code: 89500003

Example 2:
Assembly instruction: LM 2,5,A
Operation: $R2 \leftarrow (M_A); R3 \leftarrow (M_{A+4}); R4 \leftarrow (M_{A+8}); R5 \leftarrow (M_{A+12});$
Machine code: 9825C01B
A address = (R12) + 01Bh

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Instruction Formats:

SI (Storage-Immediate)

OPCODE

I2

B1

D1

1 0 x x x x x x

8 bits

4 bits

12 bits

Only byte immediate can be used in this format. We will see later how programmer can use other immediate data types.

Example 1:
Assembly instruction: MVI T1,X'5F'
Operation: $M_{T1} \leftarrow 5F$
Machine code: 925FC0BA
T1 address = (R12) + 0BAh

Example 2:
Assembly instruction: OI 100(3),C'.'
Operation: $M_{(R3)+100} \leftarrow (M_{(R3)+100}) \vee 5C;$
Machine code: 965C3064
EBCDIC(' ') = 5Ch

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Instruction Formats:

SS1 (Storage-Storage 1-Length)

OPCODE

L-1

B1

D1

B2

D2

1 1 x x x x x x

8 bits

4 bits

12 bits

4 bits

12 bits

Example 1:

Assembly instruction: MVC DST(100),SRC

Operation: Move 100 bytes from M_{SRC} to M_{DST}.

Machine code: D263C00AC110

DST address = (R12) + 0Ah

SRC address = (R12) + 110h

Example 2:

Assembly instruction: OC AREA(10),10(4)

Operation: Or 10 bytes in M_{AREA} with 10 byte from M_{10+(R4)}

Machine code: D609911B400A

AREA address = (R9)+11Bh

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Instruction Formats:

SS2 (Storage-Storage 2-Length)

OPCODE

L1 - 1

L2 - 1

B1

D1

B2

D2

1 1 x x x x x x

4 bits

4 bits

4 bits

12 bits

4 bits

12 bits

Example:

Assembly instruction: AP NUM1(6),NUM2(5)

Operation: Add decimal number of 5 bytes at M_{NUM2} to a decimal number of 6 bytes in M_{NUM1}.

Machine code: FA54C10ACF10

NUM1 address = (R12) + 10Ah

NUM2 address = (R12) + F10h

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Program Structure:

PROG-NAME

START

Initial Address

→ Default Initial Address is 0

.

.

START-LABEL

...

.

.

Some directives/instructions to define Base register and initialize it

.

.

Instructions

.

.

Some instructions to return the control to OS

.

.

Some directives to define variables

.

.

END

START-LABEL

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Notations:

- General format of an assembly instruction is:

Label

Mnemonic

Opr1,Opr2,Opr3

Inline Comment can come after last operand

Note that:

- Labels should start at first column.

- Full-line comment starts with * at the first column

- Mnemonic come at column 2+.

- Label, Mnemonic, Operands and then Inline comment are separated by 1+ blanks.

Example:

LOOP AR 5,6 Add the content of R6 into R5

* "LOOP" is a label, "AR" is mnemonic, "5,6" show operands, and "Add the content of R6 to R5"

* is an inline comment

L 6,ADAD1

* No label is used, "L" is mnemonic, "6,ADA1" show operands, no comment is used

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Notations:

You can use:

- Numbers in the assembly program in (default) decimal, Octal, Binary and Hexadecimal bases using O, B, and X prefixes.

Example: B'000001010111" == O'0127" == X'057' == 87

- **DS** (define storage) directive to define a variable (allocate space for it)

Example: ARRAY DS 20F

- **DC** (define constant) directive to define a variable and initialize it

Example: NUM1 DC F'-5'

- **EQU** (Equate) directive to define a constant.

Example: R5 EQU 5 then use as: AR R5,R5 == AR 5,5

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Examples of Variable Definition:

.....

* We define some WORD variables.

* Lets assume Location Counter = 0000FEh, here.

VAR1 DS 3F

VAR2 DC F'1'

VAR3 DC F'1',F'-2',2F'100'

.....

Symbol Table

Symbol	Address
VAR1	000100h
VAR2	00010Ch
VAR3	000110h

Main Memory

0000FCh	--	--	--
000100h	--	--	--
000104h	--	--	--
000108h	--	--	--
00010Ch	00	00	00 01
000110h	00	00	00 01
000114h	FF	FF	FF FE
000118h	00	00	00 64
00011Ch	00	00	00 64
000120h			

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Sample Program:

STOCK START 256
BEGIN BALR 11,0
 USING *,11
 L 3,OLDOH
 A 3,RECPT
 S 3,ISSUE
 ST 3,NEWOH
 EOJ
OLDOH DC F'9'
RECPT DC F'4'
ISSUE DC F'6'
NEWOH DS F

LOC	OBJECT CODE	ADDR1	ADDR2	STMT	SOURCE	STATEMENT
000100				1	STOCK	START 256
000100	05B0			2	BEGIN	BALR 11,0
000102				3		USING *,11
000102	5830 B012		00114	4		L 3,OLDOH
000106	5A30 B016		00118	5		A 3,RECPT
00010A	5830 B01A		0011C	6		S 3,ISSUE
00010E	5030 B01E		00120	7		ST 3,NEWOH
				8		EOJ
000114	00000009			9	OLDOH	DC F'9'
000118	00000004			12	RECPT	DC F'4'
00011C	00000006			13	ISSUE	DC F'6'
000120				14	NEWOH	DS F
000100				15	END	BEGIN

The listing of the program

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