PROGRAMMING THE BASIC COMPUTER

Introduction

Machine Language

Assembly Language

Assembler

Program Loops

Programming Arithmetic and Logic Operations

Subroutines

Input-Output Programming

INTRODUCTION

Those concerned with computer architecture should have a knowledge of both hardware and software because the two branches influence each other.

Instruction Set of the *Basic Computer*

Symbol	*Hexa code*	*Description*
AND	0 or 8	AND M to AC
ADD	1 or 9	Add M to AC, carry to E
LDA	2 or A	Load AC from M
STA	3 or B	Store AC in M
BUN	4 or C	Branch unconditionally to m
BSA	5 or D	Save return address in m and branch to m+1
ISZ	6 or E	Increment M and skip if zero
CLA	7800	Clear AC
CLE	7400	Clear E
CMA	7200	Complement AC
CME	7100	Complement E
CIR	7080	Circulate right E and AC
CIL	7040	Circulate left E and AC
INC	7020	Increment AC, carry to E
SPA	7010	Skip if AC is positive
SNA	7008	Skip if AC is negative
SZA	7004	Skip if AC is zero
SZE	7002	Skip if E is zero
HLT	7001	Halt computer
INP	F800	Input information and clear flag
OUT	F400	Output information and clear flag
SKI	F200	Skip if input flag is on
SKO	F100	Skip if output flag is on
ION	F080	Turn interrupt on
IOF	F040	Turn interrupt off

m: effective address
M: memory word (operand) found at m

MACHINE LANGUAGE

- Program

  A list of instructions or statements for directing the computer to perform a required data processing task

- Various types of programming languages
  - Hierarchy of programming languages

    - Machine-language
      - Binary code
      - Octal or hexadecimal code

    - Assembly-language (Assembler)
      - Symbolic code

    - High-level language (Compiler)

COMPARISON OF PROGRAMMING LANGUAGES

- Binary Program to Add Two Numbers

Location	Instruction Code
0	0010 0000 0000 0100
1	0001 0000 0000 0101
10	0011 0000 0000 0110
11	0111 0000 0000 0001
100	0000 0000 0101 0011
101	1111 1111 1110 1001
110	0000 0000 0000 0000

- Hexa program

Location	Instruction
000	2004
001	1005
002	3006
003	7001
004	0053
005	FFE9
006	0000

- Program with Symbolic OP-Code

Location	Instruction		Comments
000	LDA	004	Load 1st operand into AC
001	ADD	005	Add 2nd operand to AC
002	STA	006	Store sum in location 006
003	HLT		Halt computer
004	0053		1st operand
005	FFE9		2nd operand (negative)
006	0000		Store sum here

- Assembly-Language Program

```
      ORG   0     /Origin of program is location 0
      LDA   A     /Load  operand from location A
      ADD   B     /Add  operand from location B
      STA   C     /Store sum in location C
      HLT         /Halt computer
A,    DEC   83    /Decimal operand
B,    DEC   -23   /Decimal operand
C,    DEC   0     /Sum stored in location C
      END         /End of symbolic program
```

- Fortran Program

```
INTEGER  A, B, C
DATA  A,83 / B,-23
C = A + B
END
```

ASSEMBLY LANGUAGE

Syntax of the BC assembly language

Each line is arranged in three columns called fields

Label field

- May be empty or may specify a symbolic address consists of up to 3 characters
- Terminated by a comma

Instruction field

- Specifies a **machine or a pseudo** instruction
- May specify one of
  * Memory reference instr. (MRI)
    MRI consists of two or three symbols separated by spaces.
    ADD OPR (direct address MRI)
    ADD PTR I (indirect address MRI)
  * Register reference or input-output instr.
    Non-MRI does not have an address part
  * Pseudo instr. with or without an operand
    Symbolic address used in the instruction field must be defined somewhere as a label

Comment field

- May be empty or may include a comment

PSEUDO-INSTRUCTIONS

ORG N
Hexadecimal number N is the memory loc.
for the instruction or operand listed in the following line

END
Denotes the end of symbolic program

DEC N
Signed decimal number N to be converted to the binary

HEX N
Hexadecimal number N to be converted to the binary

Example: Assembly language program to subtract two numbers

```
        ORG  100      / Origin of program is location 100
        LDA  SUB      / Load subtrahend to AC
        CMA           / Complement AC
        INC           / Increment AC
        ADD  MIN      / Add minuend to AC
        STA  DIF      / Store difference
        HLT           / Halt computer
MIN,    DEC  83       / Minuend
SUB,    DEC  -23      / Subtrahend
DIF,    HEX  0        / Difference stored here
        END           / End of symbolic program
```

TRANSLATION TO BINARY

Hexadecimal Code		Symbolic Program	
Location	Content		
			ORG 100
100	2107		LDA SUB
101	7200		CMA
102	7020		INC
103	1106		ADD MIN
104	3108		STA DIF
105	7001		HLT
106	0053	MIN,	DEC 83
107	FFE9	SUB,	DEC -23
108	0000	DIF,	HEX 0
			END

ASSEMBLER - FIRST PASS -

Assembler

Source Program - Symbolic Assembly Language Program

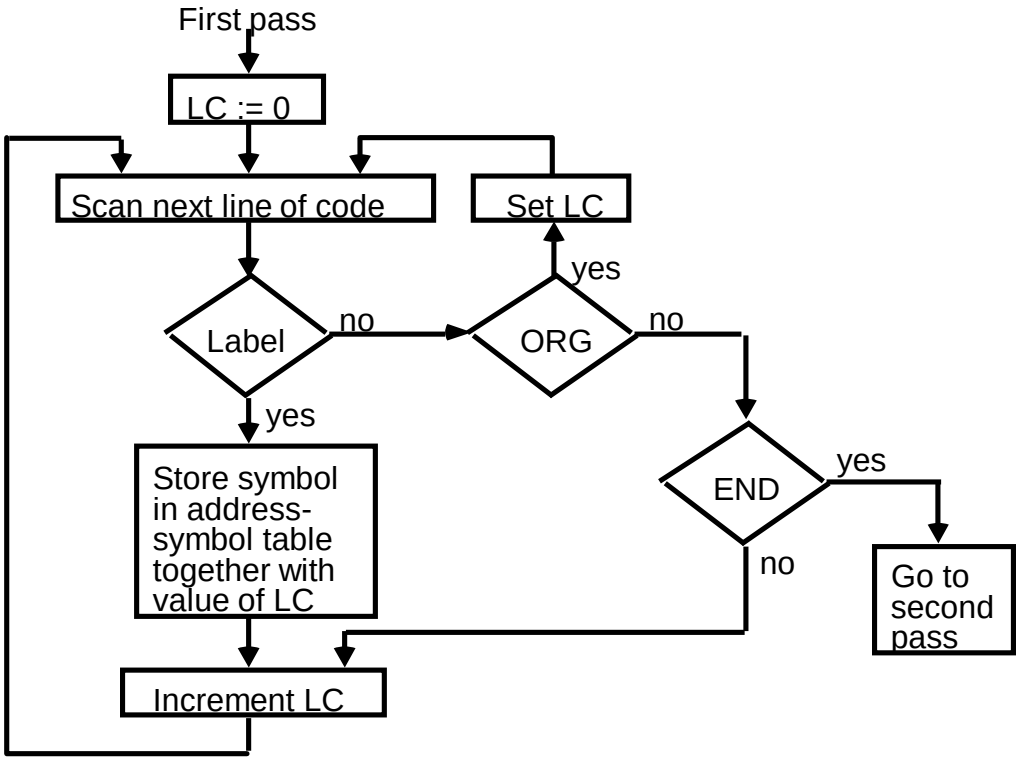
Object Program - Binary Machine Language Program

Two pass assembler

1st pass: generates a table that correlates all user defined (address) symbols with their binary equivalent value

2nd pass: binary translation

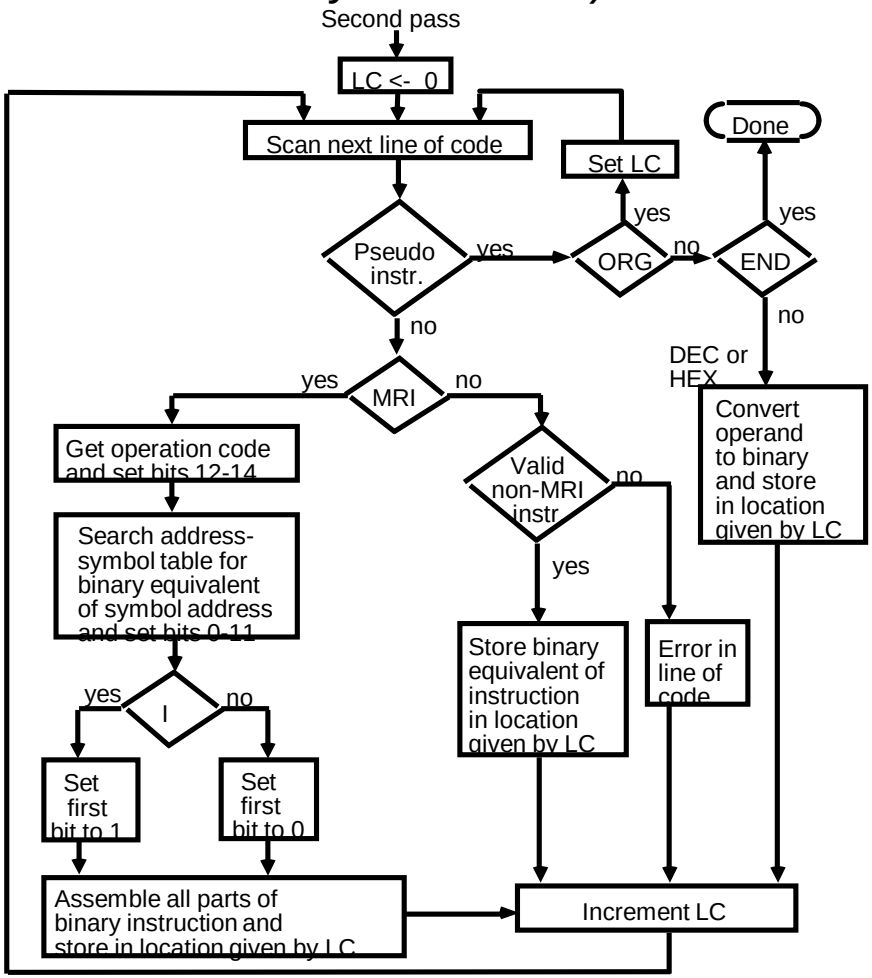
First pass



ASSEMBLER - SECOND PASS -

Second Pass

Machine instructions are translated by means of table-lookup procedures;
(1. Pseudo-Instruction Table, 2. MRI Table, 3. Non-MRI Table
4. Address Symbol Table)



PROGRAM LOOPS

Loop: A sequence of instructions that are executed many times, each with a different set of data

Fortran program to add 100 numbers:

```
      DIMENSION  A(100)
      INTEGER  SUM,  A
      SUM = 0
      DO  3  J = 1,  100
3     SUM = SUM + A(J)
```

Assembly-language program to add 100 numbers:

```
          ORG  100          / Origin of program is HEX 100
          LDA  ADS          / Load first address of operand
          STA  PTR          / Store in pointer
          LDA  NBR          / Load -100
          STA  CTR          / Store in counter
          CLA               / Clear AC
LOP,      ADD  PTR  I       / Add an operand to AC
          ISZ  PTR          / Increment pointer
          ISZ  CTR          / Increment counter
          BUN  LOP          / Repeat loop again
          STA  SUM          / Store sum
          HLT               / Halt
ADS,      HEX  150          / First address of operands
PTR,      HEX  0            / Reserved for a pointer
NBR,      DEC  -100         / Initial value for a counter
CTR,      HEX  0            / Reserved for a counter
SUM,      HEX  0            / Sum is stored here
          ORG  150          / Origin of operands is HEX 150
          DEC  75           / First operand
            .
            .
            .
          DEC  23           / Last operand
          END               / End of symbolic program
```