Pass Structure of Assembler

Subject : Systems Programming

Assembly Language

- Assembly language is low level/middle level language.
- An assembly language is machine dependent.
- It differs from computer to computer.
- Writing programs in assembly language is very

easy as compared to machine(binary) language.

Assembly language programming Terms:

- **Location Counter: (LC) points to the next** instruction.

Literals: constant values

A literal is **a character string whose value is given by the characters themselves**

Symbols: name of variables and labels

Procedures: methods/ functions

Assembly language Statements:

- **Assembly language Statements:**
- Imperative Statements:
- Declarative/Declaration Statements:
- Assembler Directive:

ASSEMBLY LANGUAGE STATEMENTS

- IMPERATIVE STATEMENTS
- These are executable statements
- They instruct the assembler to do certain task
- These generate some actions to instruct the assembler to perform certain tasks.
- Add x,y
- sub a,b
- read a
- Print y
- Mover, x,Areg

- Imperative means mnemonics
- These are executable statements.
- Each imperative statement indicates an action
- to be taken during execution of the program.
- E.g. MOVER BREG, X
- STOP
- READ X
- ADD AREG, Z

- **Declarative Statements**
- Declaration statements are for reserving
- memory for variables.
- We can specify the initial value of a
- variable.
- It has two types:
- DS // Declare Storage
- DC // Declare Constant

- DECLRATIVE STATEMENTS
- For reserving memory for the variable.
- One word of memory is reserverd using DS statement.
- DS- declare storage
- DC-declare constant
- A DS 1
- A DC ‘5’
- Or single statement B DC ’5’

- **DS(Declare Storage):**
- Syntax:
- [Label] DS <Constant specifying size>
- E.g.X DS 1
- **DC (Declare Constant):**
- Syntax:
- [Label] DC <constant specifying value>
- E.g Y DC ‘5’

- For variable A is reserved one word of memory
- Using DC we can initialize the variable with value 5
- We can do both steps by single statement using B DC ‘5’
- By default one word of memory is reserved for the variable B and then it is assigned or initialized with value 5.

- Assembler directives
- Directs the assembler to do certain action
- START < constant >
- Starts the program and gives the starting address of the program as a constant.
- END

PROGRAM TERMINATES AFTER THE END STATEMENT

- **Assembler Directive**
- Assembler directive instruct the assembler to perform certain actions during assembly of a program.
- Some assembler directive are:
- START <address constant>
- END

Sample Assembly Code

1. START 100 It is an AD statement because it has Assembler directive START

2. MOVER AREG, X It is an IS because it starts with mnemonic.
3. MOVER BREG, Y
4. ADD AREG, Y
5. MOVEM AREG, X

6. X DC '10' It is an DS/ DL statement because it has DC
7. Y DS 1 It is an DS/ DL statement because it has DS
8. END

Identify the types of

State.No	IS	DS	AD
1			
2			
3			
4			
5			
6			
7			
8			

ADVANCED ASSEMBLER DIRCTIVES

- Modified unique statements to perform some special functions
- It directs the assembler to perform some specific action.
- ORIGIN
- LTORG
- EQU

```
          Start 200
           MOVE BREG='5'        200
LOOP   MOVE AREG N             201
           ADD  BREG =  '2'        202
           ORIGIN LOOP+5
NEXT    BC ANY, LOOP             206
            LTORG                207
           ORIGIN NEXT+3
           N DC 5                209
           END                   210
```

- First check where is origin statement
- Right hand side of origin is constant and operand
- ORIGIN statement tells us that what should be the address of next immediate instruction
- In a given program it will evaluate the this address using statement loop+5
- Loop label is at the address 201and after adding 5 to it we get address 206 which is the address should be assigned to label NEXT of the next instruction.So the address of instruction immediate after ORIGIN is given the address 206.

LTORG

- In the above program the literal occurs 2 times
- The literals are represented by ‘’ for example in the program the literals are ‘5’ and ‘2’
- Literals are stored in literal table
- But the address are not assigned to them
- Address are assigned only when LTORG instruction occurs in the program
- When this instruction runs

Only then the address are assigned to the literal.

index	literal	address	
0	='4'	207	
1	='2'	208	

Advanced Assembler Directives

Equate:

The EQU directive is used to equate a name with an expression, symbolic address,

or number. Whenever this name is used as a symbol, it is replaced.

We might do something, such as the following, which makes the symbol R12 to be equal to 12, and replaced by that value when the assembler is run.

E.G. R12 EQU 12

Advanced Assembler Directives

LTORG :

The LTORG directive instructs the assembler to assemble the current literal pool immediately.

The Literal Pool contains a collection of anonymous constant definitions, which are generated by the assembler.

The LTORG directive defines the start of a literal pool.

Syntax :

LTORG

- First check where is origin statement
- Right hand side of origin is constant and operand
- ORIGIN statement tells us that what should be the address of next immediate instruction
- In a given program it will evaluate the this address using statement loop+5
- Loop label is at the address 201and after adding 5 to it we get address 206 which is the address should be assigned to label NEXT of the next instruction.so the address of instruction immediate after ORIGIN is given the address 206.

LTORG

- In the above program the literal occurs 2 times
- The literals are represented by ‘’ for example in the program the literals are ‘5’ and ‘2’
- Literals are stored in literal table
- But the address are not assigned to them
- Address are assigned only when LTORG instruction occurs in the program
- When this instruction runs

Only then the address are assigned to the literal.

index	literal	address	
0	='4'	207	
1	='2'	208	

- In the above literal table address are not assigned to ‘2’ and ‘4’
- When the LTORG instruction occurs then only the literals are assigned the address
- The address of the literal ‘4’ is assigned the address value which is the address of LTORG instruction i.e 207
- Next literal ‘4’ is assigned the address 208 which is the next immediate address after LTORG instruction.

LTORG

- If the LTORG instruction does not occur in the program then literals are not assigned any address till the end of the program.
- After the program ends then only literals are assigned the addresses which are the next address where program ends.

EQU

- < LABEL> EQU < ADDRESS>
- X EQU Y
- Label X is associated with address Y
- EQU is used to give the label or symbol which is on left side of EQU assign or associate the address given on right hand side of Y.

How LC Operates?

Sr. NO		LC
1	START 100	
2	MOVER AREG, X	100
3	MOVER BREG, Y	101
4	ADD AREG, BREG	102
5	MOVEM AREG, X	103
6	X DC '10'	104
7	Y DC '15'	105
8	END	

Identify symbol, literals, AD, DS, IS , Symbol, Literal Label

- START 100
- MOVER BREG, ='2'
- LOOP MOVER AREG, N
- ADD BREG, ='1'
- ORIGIN LOOP+5
- LTORG
- ORIGIN NEXT +2
- LAST STOP
- N DC '5'
- END

Solution (From Previous Example)

Sr. No	AD	DS	IS	Symbol	Literal	Label
1	AD					
2			IS		=2	
3			IS	N		LOOP
4			IS		=1	
5	AD					
6	AD					
7	AD					
8			IS			LAST
9		DS				
10	AD					

ASSEMBLER

- **Assembler**
- • An Assembler is a translator which
- translates assembly language code into
- machine language with help of data
- structure.
- • It has two types
- • Pass 1 Assembler.
- • Pass 2 Assembler.

ASSEMBLER

- **General design procedure of assembler**
- • Statement of Problem
- • Data Structure
- • Format of databases
- • Algorithms
- • Look for modularity.

ASSEMBLER

- **Data Structure Used**
- • Data Structure used are as follows:
- • Symbol table
- • Literal Table
- • Mnemonic Opcode Table
- • Pool Table

Format of Databases

- Symbol Table:

Name of Symbol	address

- Literal Table:

Literal	address

- MOT:

Mnemonic	Machine Opcode	Class	Length

- Pool Table:

Literal Number

Pass 1 Assembler

- **Pass 1 Assembler**
- **• Pass 1 assembler separate the labels ,**
- mnemonic opcode table, and operand
- fields.
- • Determine storage requirement for every
- assembly language statement and update
- the location counter.
- • Build the symbol table. Symbol table is used
- to store each label and each variable and its
- corresponding address.

How pass 1 assembler works?

- **How pass 1 assembler works?**
- • Pass I uses following data structures.
- • 1. Machine opcode table.(MOT)
- • 2. Symbol Table(ST)
- • 3. Literal Table(LT)
- • 4. Pool Table(PT)
- • Contents of MOT are fixed for an assembler.

- · Pass 2 Assembler: Generate the machine code

Observe Following Program

```
START 200
MOVER AREG, ='5'
MOVEM AREG, X
L1 MOVER BREG, ='2'
ORIGIN L1+3
LTORG
NEXT ADD AREG, ='1'
SUB BREG, ='2'
BC LT, BACK
LTORG
BACK EQU L1
ORIGIN NEXT+5
MULT CREG, ='4'
STOP
X DS 1
END
```

Apply LC

```
START 200
            MOVER AREG, ='5'        200
            MOVEM AREG, X           201
      L1    MOVER BREG, ='2'        202
            ORIGIN L1+3
            LTORG
                        ='5'        205
                        ='2'        206

  NEXT      ADD AREG, ='1'          207
            SUB BREG, ='2'          208
            BC LT, BACK             209
            LTORG
                              ='1'  210
                              ='2'  211

BACK        EQU     L1
            ORIGIN NEXT+5
            MULT CREG, ='4'         212
            STOP                    213
            X DS 1                  214
            END
                  ='4'              215
```

Construct Symbol table

index	Symbol Name	Address
0	X	214
1	L1	202
2	NEXT	207
3	BACK	202

Construct Literal Table

index	Literal	Address
0	5	205
1	2	206
2	1	210
3	2	211
4	4	215

Pool Table.

- Pool table contains starting literal(index) of each pool.

Literal number
0
2
4

NOW CONSTRUCT INTERMEDIATE CODE/MACHINE CODE

- For constructing intermediate code we need MOT.

Enhanced Machine opcode Table

Table 1.10.1 : An enhanced machine opcode table (MOT)

	Mnemonic opcode	Class	Opcode	Length
0	STOP	IS	00	1
1	ADD	IS	01	1
2	SUB	IS	02	1
3	MULT	IS	03	1
4	MOVER	IS	04	1
5	MOVEM	IS	05	1
6	COMP	IS	06	1
7	BC	IS	07	1
8	DIV	IS	08	1
9	READ	IS	09	1
10	PRINT	IS	10	1
11	START	AD	01	–
12	END	AD	02	–
13	ORIGIN	AD	03	–
14	EQU	AD	04	–
15	LTORG	AD	05	–
16	DS	DL	01	–
17	DC	DL	02	1
18	AREG	RG	01	–
19	BREG	RG	02	–
20	CREG	RG	03	–
21	EQ	CC	01	–

Mnemonic opcode	Class	Opcode	Length
LT	CC	02	–
GT	CC	03	–
LE	CC	04	–
GE	CC	05	–
NE	CC	06	–
ANY	CC	07	–

Design of two pass assembler

- Tasks performed by the passes of a two pass assembler are as follows:
- **Pass 1:**

1.Separate the symbol, mnemonic opcode, and operand fields.

2. Build the symbol table.

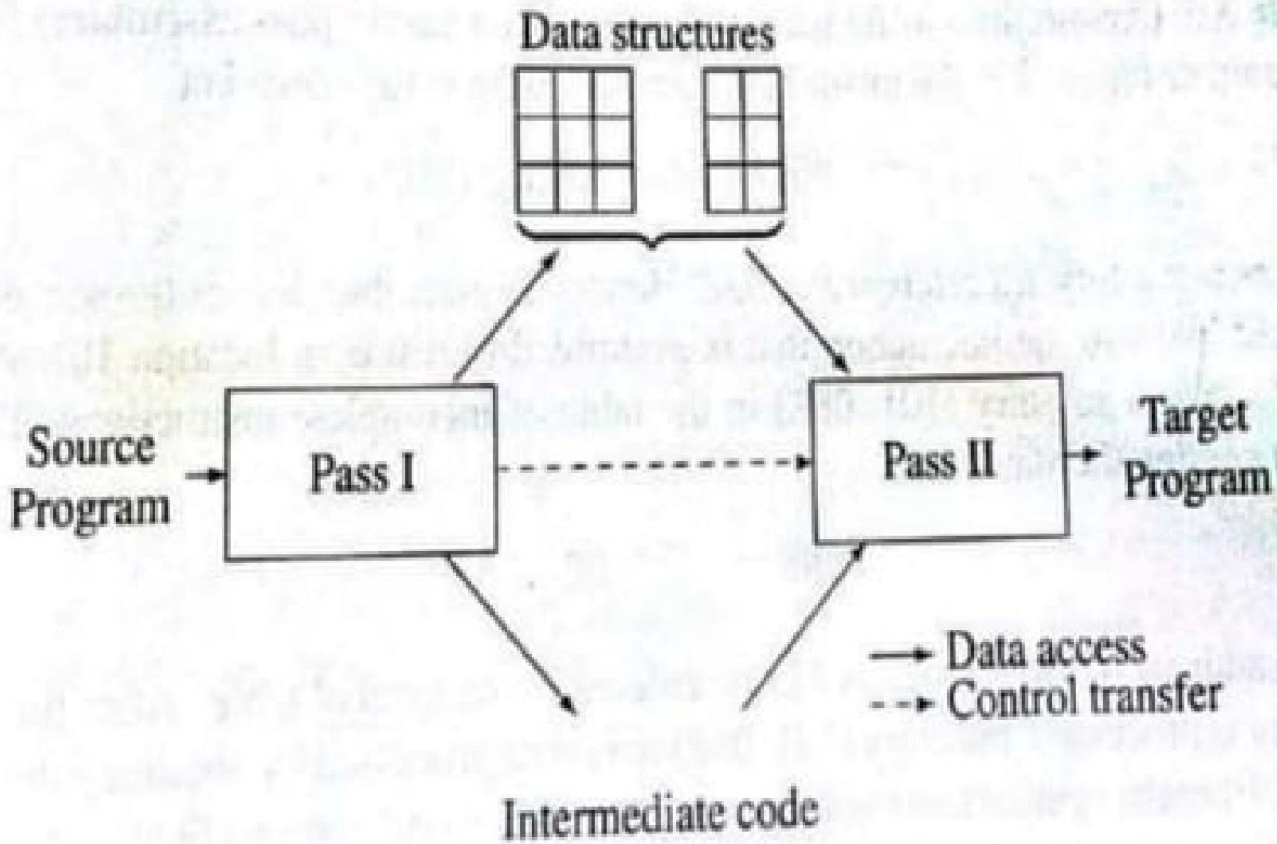
3. Perform LC processing.

4. Construct intermediate representation(or IC).

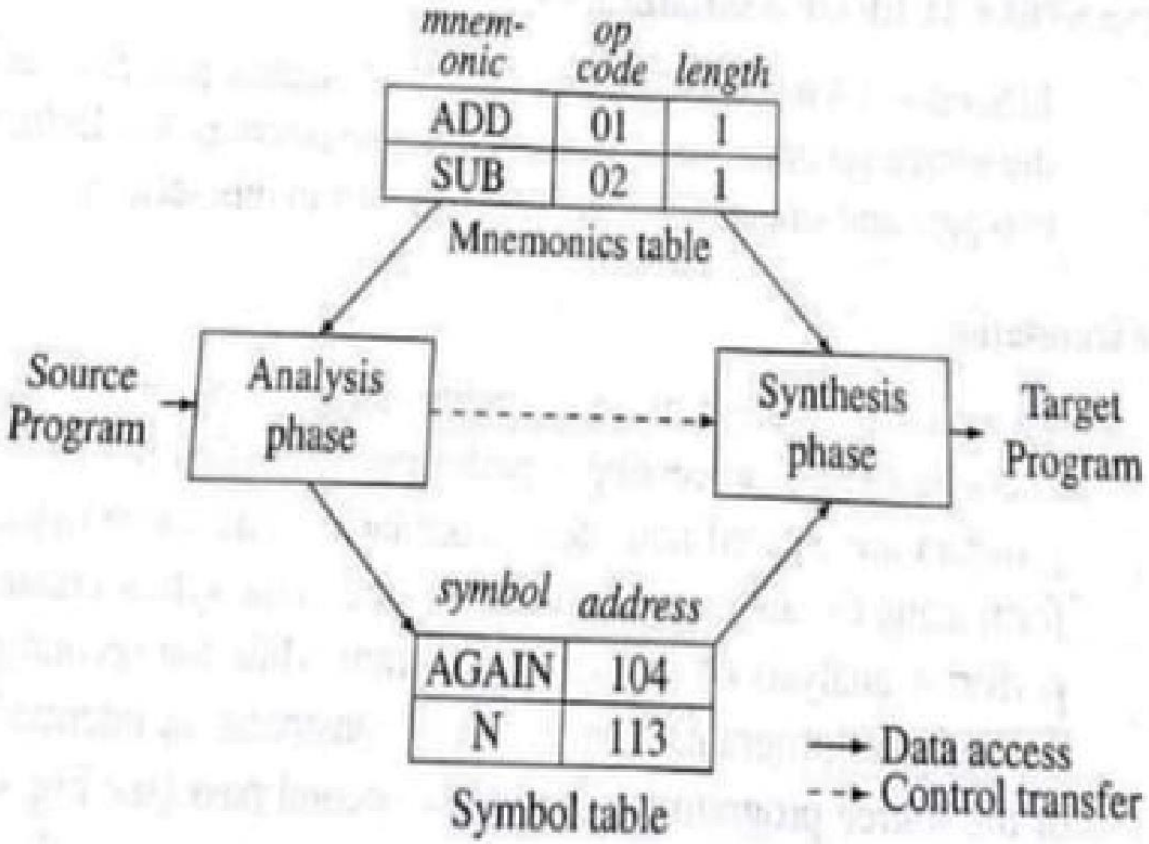
- **Pass 2:**

1. Synthesize the target program.

Two Pass Assembler



Analysis Phase Vs. Synthesis Phase



Comparison between Pass 1 and Pass2

Sr. No	Pass 1	Pass 2
01	It requires only one scan to generate machine code	It requires two scan to generate machine code.
02	It has forward reference problem.	It don't have forward reference problem.
03	It performs analysis of source program and synthesis of the intermediate code.	It process the IC to synthesize the target program.
04	It is faster than pass 2.	It is slow as compared to pass 1.

ASSEMBLER

- An assembly language program can be translated into machine language.
- It involves following steps:
- 1. Find addresses of variable.
- 2. Replace symbolic addresses by numeric addresses.
- 3. Replace symbolic opcodes by machine operation codes.
- 4. Reserve storage for data.

Step 1

- We can find out addresses of variable using LC.
- First identify all variables in your program.
- **START 100**
- **MOVER AREG, X**
- **MOVER BREG, Y**
- **ADD AREG, X**
- **MOVEM AREG, X**
- **X DC '10'**
- **Y DC '15'**
- **END**

Step 1

Sr. NO		LC
1	START 100	
2	MOVER AREG, X	100
3	MOVER BREG, Y	101
4	ADD AREG, X	102
5	MOVEM AREG, X	103
6	X DC '10'	104
7	Y DC '15'	105
8	END	

Sr. No	Name of Variable(Symbol)	Address
1	X	104
2	Y	105

Step2: Replace all symbolic address with numeric address.

- START 100
- MOVER AREG, 104
- MOVER BREG, 105
- ADD AREG, 104
- MOVEM AREG, 104
- X DC '10'
- Y DC '15'
- END

Memory is reserved but no code is generated.

Step3: Replace symbolic opcodes by machine operation codes.

LC	Assembly Instruction	Machine Code
101	MOVER AREG, 104	04 01 104
102	MOVER BREG, 105	04 02 105
103	ADD AREG, 104	01 01 104
104	MOVEM AREG, 104	05 01 104
105		
106		
107		

Question For u

```
          START 101
          READ N
          MOVER BREG, ONE
          MOVEM BREG,
AGAIN     TERM  MULT BREG,
          TERM  MOVER CREG,
          TERM  ADD CREG,
          ONE  MOVEM CREG,
          TERM  COMP CREG,
          N
          BC LE, AGAIN
          MOVEM BREG, RESULT
          PRINT RESULT
          STOP
          N DS 1
          RESULT DS 1
          ONE DC '1'
          TERM DS 1
```

Question For U

```
START 102
READ X
READ Y
MOVER AREG, X
ADD AREG, Y
MOVEM AREG, RESULT
PRINT RESULT
STOP
X DS 1
Y DS 1
RESULT DS 1
END
```

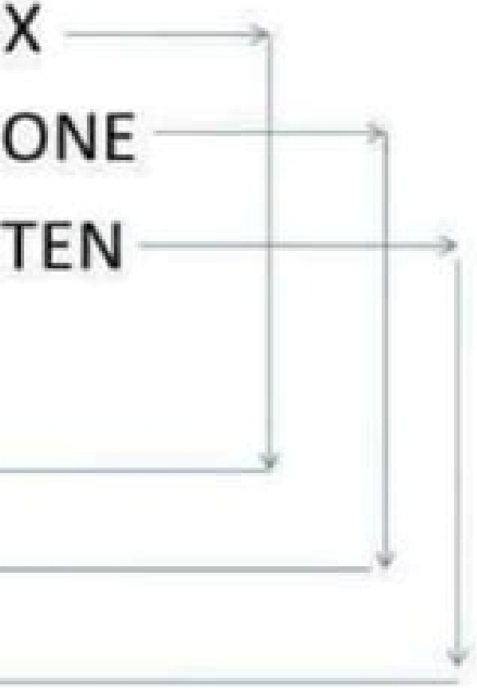
Forward Reference Problem

- Using a variable before its definition is called as forward reference problem.
- E.g.
- START 100
- MOVEM AREG, X
- MOVER BREG, Y
- ADD AREG, Y
- X DC '4'
- Y DC '5'
- END

- In example variable X, Y are making forward reference.
- So, We can solve it by using back patching.

Consider another example

```
        START   100
        MOVER   AREG, X
L1      ADD     BREG, ONE
        ADD     CREG, TEN
        STOP
X       DC      '5'
ONE     DC      '1'
TEN     DC      '10'
        END
```



Apply LC

	START	100	
	MOVER	AREG, X	100
L1	ADD	BREG, ONE	101
	ADD	CREG, TEN	102
	STOP		103
X	DC	'5'	104
ONE	DC	'1'	105
TEN	DC	'10'	106
	END		

Try to convert into machine code

```
        START   100
        MOVER   AREG, X
L1      ADD     BREG, ONE
        ADD     CREG, TEN
        STOP
X       DC      '5'
ONE     DC      '1'
TEN     DC      '10'
        END
```

100	04	1 ___
101	01	2 ___
102	06	3 ___
103	00	0 000
104		
105		
106		

Backpatching

- The operand field of instruction containing a forward reference is left blank initially.
- Step 1: Construct TII(Table of incomplete instruction)

Instruction Address	Symbol Making a forward reference
100	X
101	ONE
102	TEN

- **Step 2 :** After encountering END statement symbol table would contain the address of all symbols defined in the source program.

SYMBOL NAME	ADDRESS
X	104
ONE	105
TEN	106

- Now we can generate machine code…

04	1	104
01	2	105
01	03	106
00	0	000

Single Pass Assembler

- Forward reference: reference to a label that is defined later in the program.


```
START   200
ADD     AREG    A
..      ..
A       DS      2
..      ..
END
```

- Table of Incomplete Instruction

Instruction Address	Symbol
200	A
..	..

Single Pass Assembler

- Forward reference: reference to a label that is defined later in the program.

Symbol	Address
A	

```
START   200
ADD     AREG    A
..      ..
A       DS      2
..      ..
END
```

- Table of Incomplete Instruction

Instruction Address	Symbol
200	A
..	..

Single Pass Assembler

- Forward reference: reference to a label that is defined later in the program.

```
STAR    200
T
ADD     AREG    A
..      ..
A       DS      2
..      ..
END
```

Target Code

```
200     01  01  -
…       ..  ..  ..
202
```

- Table of Incomplete Instruction

Instruction Address	Symbol
200	A
..	..

Symbol	Address
A	202
..	..

Target Code

```
200   01    01    202
..    ..    ..    ..
202
```

Single pass Assembler Examples

SOURCE PROGRAM			
	START	101	
	READ	N	
	MOVER	BREG,	ONE
	MOVEM	BREG,	TERM
AGAIN	MULT	BREG,	TERM
	MOVER	CREG,	TERM
	ADD	CREG,	ONE
	MOVEM	CREG,	TERM
	COMP	CREG,	TERM
	BC	LE,	AGAIN
	MOVEM	BREG,	RESULT
	PRINT	RESULT	
	STOP		
N	DS	1	
RESULT	DS	1	
ONE	DC	'1'	
TERM	DS	1	
	END		

TARGET CODE			
101	09	-	
102	04	02	-
103	05	02	-
104	03	02	-
105	04	03	-
106	01	03	-
107	05	03	-
108	06	03	-
109	07	02	104
110	05	02	-
111	10	-	
112	00		
113			
114			
115			
116			

TII

INSTRUCTION Address	SYMBOL
101	N
102	ONE
103	TERM
104	TERM
105	TERM
106	ONE
107	TERM
108	TERM
110	RESULT
111	RESULT

Symbol Table

SYMBOL	ADDRESS
N	113
ONE	115
TERM	116
RESULT	114

Single pass Assembler Examples

SOURCE PROGRAM			
	START	101	
	READ	N	
	MOVER	BREG,	ONE
	MOVEM	BREG,	TERM
AGAIN	MULT	BREG,	TERM
	MOVER	CREG,	TERM
	ADD	CREG,	ONE
	MOVEM	CREG,	TERM
	COMP	CREG,	TERM
	BC	LE,	AGAIN
	MOVEM	BREG,	RESULT
	PRINT	RESULT	
	STOP		
N	DS	1	
RESULT	DS	1	
ONE	DC	'1'	
TERM	DS	1	
	END		

TARGET CODE			
101	09	113	
102	04	02	115
103	05	02	116
104	03	02	116
105	04	03	116
106	01	03	115
107	05	03	116
108	06	03	116
109	07	02	104
110	05	02	114
111	10	114	
112	00		
113			
114			
115			
116			

TII	
INSTRUCTION Address	SYMBOL
101	N
102	ONE
103	TERM
104	TERM
105	TERM
106	ONE
107	TERM
108	TERM
110	RESULT
111	RESULT

Symbol Table	
SYMBOL	ADDRESS
N	113
ONE	115
TERM	116
AGAIN	104
RESULT	114

1.3 Design of Two Pass Assembler

- PASS I
  - Separate the symbol, mnemonic opcode,and operand fields.
  - Build the symbol table
  - Perform LC processing
  - Construct intermediate code
- PASS II
  - Synthesize the target code

Three Main Data Structures

- Operation Code Table (OPTAB)
- Location Counter (LOCCTR)
- Symbol Table (SYMTAB)

OPTAB operation code table

- Content
  - The mapping between mnemonic and machine code. Also include the instruction format, available addressing modes, and length information.
- Characteristic
  - Static table. The content will never change.
- Implementation

  Array or hash table. Because the content will never change, we can optimize its search speed.
- In pass 1, OPTAB is used to look up and validate mnemonics in the source program.
- In pass 2, OPTAB is used to translate mnemonics to machine instructions.

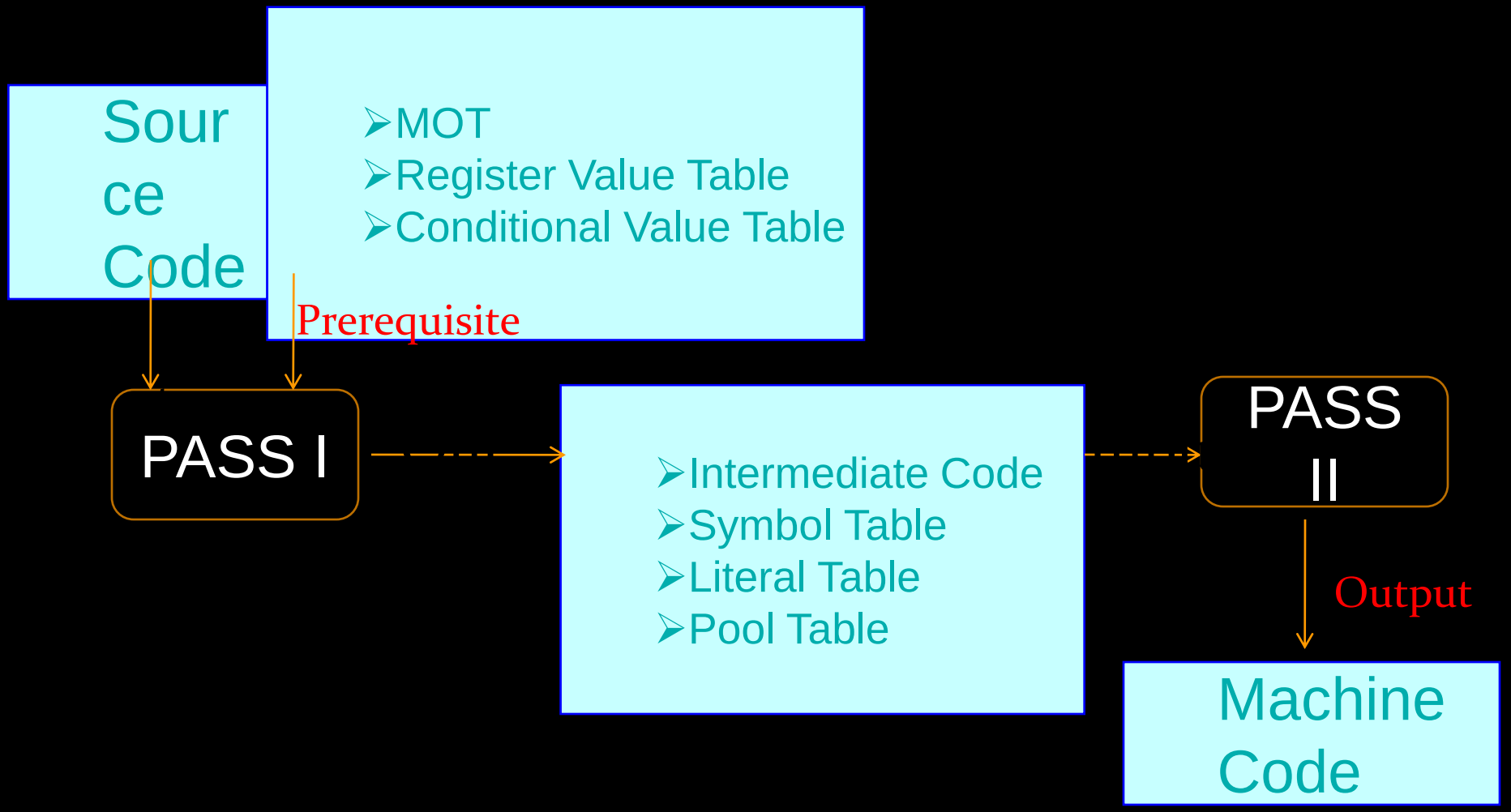
Location Counter (LOCCTR)

- This variable can help in the assignment of addresses.
- It is initialized to the beginning address specified in the START statement.
- After each source statement is processed, the length of the assembled instruction and data area to be generated is added to LOCCTR.
- Thus, when we reach a label in the source program, the current value of LOCCTR gives the address to be associated with that label.

Symbol Table (SYMTAB)

- Content
  - Include the label name and value (address) for each label in the source program.
  - Include type and length information (e.g., int64)
  - With flag to indicate errors (e.g., a symbol defined in two places)
- Characteristic
  - Dynamictable (I.e., symbols may be inserted, deleted, or searched in the table)
- Implementation
  - Hash table can be used to speed up search
  - Because variable names may be very similar (e.g., LOOP1, LOOP2), the selected hash function must perform well with such non-random keys.

Required Data Structures for Two Pass Assembler



Intermediate Code Forms

- Variant I
- Variant II : Symbols, registers and conditional code

SOURCE PROGRAM			
	START	200	
	READ	A	
LOOP	MOVER	AREG,	A
	:		
	:		
	SUB	AREG,	='1'

VARIANT –I		
(AD,01)	(C,200)	
(IS,09)	(S,01)	
(IS,04)	1	(S,01)
:		
:		
(IS,02)	1	(L,01)

VARIANT -II		
(AD,01)	(C,200)	
(IS,09)	A	
(IS,04)	AREG,	A
:		
:		
(IS,02)	AREG,	(L,01)

Assembler Pass I

SOURCE PROGRAM

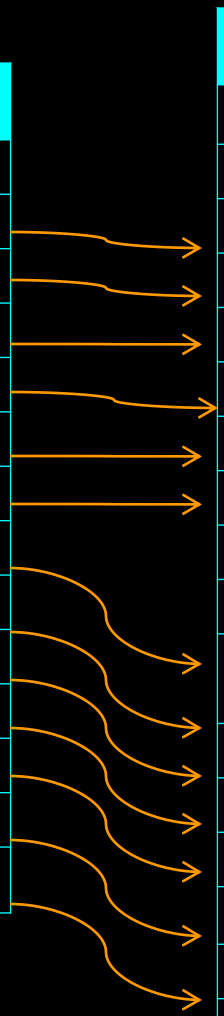
	START	200	
	MOVER	AREG,	='5'
	MOVEM	AREG,	A
LOOP	MOVER	AREG,	A
	MOVER	CREG,	B
	ADD	CREG,	='1'
	LTORG		
NEXT1	SUB	AREG,	'=1'
	ORIGIN	LOOP+1	
	MULT	CREG,	B
A	DS	2	
BACK	EQU	LOOP	
B	DC	1	
	END		

INTERMEDIATE CODE

	(AD,01)		(C,200)
200	(IS,04)	1	(L,01)
201	(IS,05)	1	(S,01)
202	(IS,04)	1	(S,01)
203	(IS,04)	3	(S,03)
204	(IS,01)	3	(L,02)
	(AD,05)		
205			005
206			001
207	(IS,02)	1	(L,03)
	(AD,03)	(S,02)+(C,1)	
203	(IS,03)	3	(S,03)
204	(DL,02)	(C,02)	
	(AD,04)	(S,02)	
206	(DL,02)	(C,02)	
	(AD,02)		
207			001

Assembler Pass I

SOURCE PROGRAM			
	START	200	
	MOVER	AREG,	='5'
	MOVEM	ADD,	A
LOOP	MOVER	AREG,	A
	MOVER	CREG,	B
	ADD	CREG,	='1'
	LTORG		
NEXT1	SUB	AREG,	'=1'
	ORIGIN	LOOP+1	
	MULT	CREG,	B
A	DS	1	
BACK	EQU	LOOP	
B	DS	1	
	END		



INTERMEDIATE CODE			
	(AD,01)		(C,200)
200	(IS,04)	1	(L,01)
201	(IS,05)	1	(S,01)
202	(IS,04)	1	(S,01)
203	(IS,04)	3	(S,03)
204	(IS,01)	3	(L,02)
	(AD,05)		
205			005
206			001
207	(IS,02)	1	(L,03)
	(AD,03)	(S,02)+(C,1)	
203	(IS,03)	3	(S,03)
204	(DL,02)	(C,01)	
	(AD,04)	(S,02)	
205	(DL,02)	(C,01)	
	(AD,02)		
206			001

Assembler Pass I

INTERMEDIATE CODE

	(AD,01)		(C,200)
200	(IS,04)	1	(L,01)
201	(IS,05)	1	(S,01)
202	(IS,04)	1	(S,01)
203	(IS,04)	3	(S,03)
204	(IS,01)	3	(L,02)
	(AD,05)		
205			005
206			001
207	(IS,02)	1	(L,03)
	(AD,03)	(S,02)+(C,1)	
203	(IS,03)	3	(S,03)
204	(DL,02)	(C,02)	
	(AD,04)	(S,02)	
206	(DL,02)	(C,02)	
	(AD,02)		
207			001

SYMBOL TABLE

INDEX	SYMBOL	ADDRESS	LENGTH
01	A	204	2
02	LOOP	202	1
03	B	205	1
04	NEXT1	207	1
05	BACK	202	1

LITERAL TABLE

INDEX	LITERAL	ADDRESS
01	=‘5’	205
02	=‘1’	206
03	=‘1’	207

POOL TABLE

LIT_INDEX
#01
#03

Assembler Examples Convert Source code into Pass I & Pass II

	START	100	
	MOVER	AREG,	=‘5’
	ADD	CREG,	=‘1’
	A	DS	3
L1	MOVER	AREG,	B
	ADD	AREG,	C
	MOPVEM	AREG,	D
	LTORG		
	D	EQU	A+1
L2	PRINT	D	
	ORIGIN	A-1	
	SUB	AREG,	=‘1’
	MULT	CREG,	B
	C	DS	‘5’
	ORIGIN	L2+1	
	STOP		
	B	DC	’19’
	END		

EXAMPLE 2			
SIMPLE	START	100	
	BALR	15,	0
	USING	*,	15
LOOP	L	R1,	TWO
	A	R1,	FOUR
	ST	R1,	FOUR
	CLI	FOUR+3,	4
	BNE	LOOP	
	BR	14	
	R1	EQU	1
	TWO	DC	F’2’
	FOUR	DS	F
	END		

ASSUME:-BALR & BR are of two bytes….
L,A,ST,CLI,BNE are of four byte instructions…

Assembler Pass II

INTERMEDIATE CODE			
	(AD,01)		(C,200)
200	(IS,04)	1	(L,01)
201	(IS,05)	1	(S,01)
202	(IS,04)	1	(S,01)
203	(IS,04)	3	(S,03)
204	(IS,01)	3	(L,02)
	(AD,05)		
205			005
206			001
207	(IS,02)	1	(L,03)
	(AD,03)	(S,02)+(C,1)	
203	(IS,03)	3	(S,03)
204	(DL,02)	(C,02)	
	(AD,04)	(S,02)	
206	(DL,02)	(C,02)	
	(AD,02)		
207			001

TARGET CODE			
200	04	1	205
201	05	1	204
202	04	1	204
203	04	3	205
204	01	3	206
205			005
206			001
207	02	1	207
203	03	3	205
204			
206			
207			001

Assembler Examples

SOURCE PROGRAM			
	START	1000	
	READ	N	
	MOVER	B,	=‘1’
	MOVEM	B,	TERM
AGAIN	MULT	B,	TERM
	MOVER	C,	TERM
	ADD	C,	=‘1’
	MOVEM	C,	TERM
	COMP	C,	N
	BC	LE,	AGAIN
	MOVEM	B,	RESULT
	LTORG		
	PRINT	RESULT	
	STOP		
N	DS	1	
RESULT	DS	20	
TERM	DS	1	
	END		

INTERMEDIATE CODE			
	(AD,01)		(C,1000)
1000	(IS,09)		(S,01)
1001	(IS,04)	2	(L,01)
1002	(IS,05)	2	(S,02)
1003	(IS,03)	3	(S,02)
1004	(IS,05)	3	(S,02)
1005	(IS,01)	3	(L,01)
1006	(IS,05)	3	(S,02)
1007	(IS,06)	3	(S,01)
1008	(IS,07)	2	(S,03)
1009	(IS,05)	2	(S,04)
	()AD,05)		
1010			(L,01)
1011	(IS,10)		(S,04)
1012	(IS,00)		
1013	(DL,02)		(C,01)
1014	(DL,02)		(C,20)
1034	(DL,02)		(C,01)
	(AD,02)		