UNIT-II

Macro and Macro processor

- Macro:-
  - Macro instructions are single line abbreviations for group of instructions.
- Using a macro, programmer can define a single “instruction” to represent block of code.

MACRO --------- Start of definition

INCR --------- Macro name

A 1,DATA

A 2,DATA ------Sequence of instructions to be

A 3,DATA abbreviated

MEND --------- End of definition

Macro Expansion

- Replacement of macro call by corresponding sequence of instructions is called as macro expansion

Source	Expanded source
Macro	:
Incr	:
A 1, data	:
A 2, data	:
A 3, data	:
MEND	:
:	A 1, Data
:	A 2, Data
INCR	A 3, Data
:	:
:	:
INCR	:
:	A 1, Data
:	A 2, Data
data DC F’5’	A 3, Data
:	data DC F ‘5’
:	
END	

Features of macro facility

Macro instructions arguments

```
:
:
A 1,data1
A 2,data1
A 3,data1
:
:
A 1,data2
A 2,data2
A 3,data2
:
Data1 DC F’5’
Data2 DC F’6’
```

Source	Expanded Source
MACRO	:
INCR &arg (Macro name with	:
A 1,&arg one argument)	:
A 2,&arg	:
A 3,&arg	:
MEND	A 1,data1
:	A 2,data1
:	A 3,data1
INCR data1 (use of data1 as	:
: operand)	A 1,data2
:	A 2,data2
INCR data 2 (use of data1 as	A 3,data2
: operand)	:
data1 DC F’5’	:
data2 DC F’6’	data1 DC F’5’
:	data2 DC F’6’
END	

Example: more than one arguments.

```
A 1,data1
A 2,data2
A 3,data3
:
A 1,data3
A 2,data2
A 3,data1
:
data1 DC F’5’
data2 DC F’6’
```

Source	Expanded source
MACRO	:
& lab1 INCR & arg 1, & arg 2, & arg 3	:
& lab 1 A 1, &arg1	:
A 2, &arg2	:
A 3, &arg3	:
MEND	:
:	:
:	:
:	LOOP 1 A 1, data 1
LOOP1 INCR data1, data2, data3	A 2, data 2
:	A 3, data 3
:	:
:	:
LOOP2 INCR data3, data2, data1	LOOP 2 A 1, data3
:	A 2, data2
:	A 3, data1
data1 DC F ‘5’	:
data2 DC F ‘6’	data1 DC F ‘5’
data3 DC F ‘7’	data2 DC F ‘6’
	data3 DC F ‘7’

Two ways of specifying arguments to a macro call

- **A) Positional argument**

Argument are matched with dummy arguments according to order in which they appear.

- INCR A,B,C
- ‘A’ replaces first dummy argument
- ‘B’ replaces second dummy argument
- ‘C’ replaces third dummy argument

- **B) keyword arguments**
- This allows reference to dummy arguments by name as well as by position.
- e.g.
- INCR &arg1 = A,&arg3 = C, &arg2 =’B’
- e.g.
- INCR &arg1 = &arg2 = A, &arg2 =’C’

Conditional macro expansion

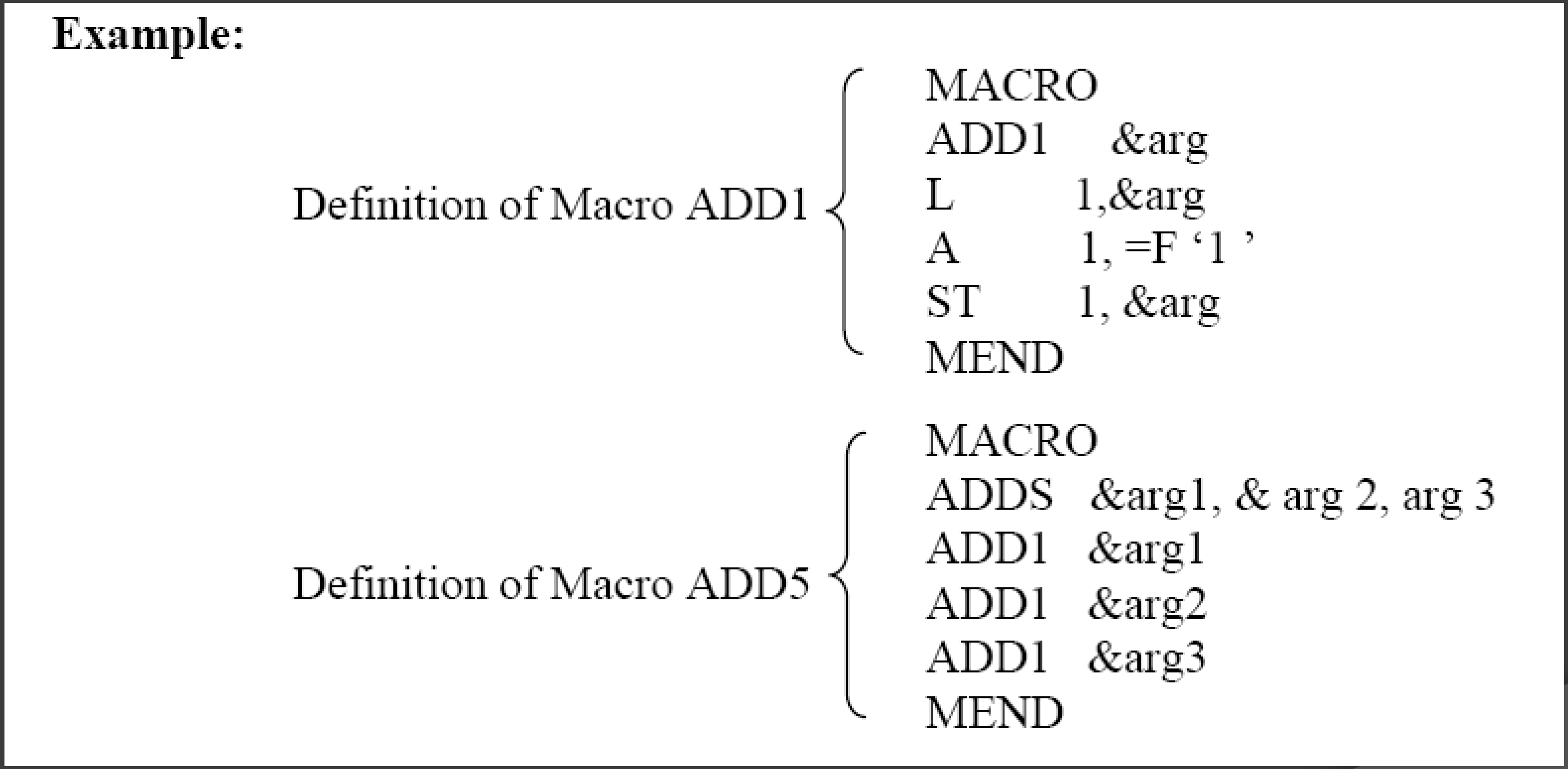
- This allows conditional selection of machine instructions that appear in expansion of macro call.
- The macro processor pseudo op-codes AIF and AGO help to do conditional macro expansion.
- AIF is conditional branch pseudo op, it performs arithmetic test and branch only if condition is true.
- AGO is unconditional pseudo op or it is like go to statement.
- Both statements specify a label appearing in some other instruction within macro definition.
- These are macro processor directives and they do not appear in expanded source code

Source Program	Expanded Program
:	
MACRO	
& arg0 INCR & count, & arg1, & arg 2, & arg3	
& arg0 A 1, &arg1	
AIF (& Count EQ.1). FINAL	
A 2,& arg2	LOOP1 A 1, data1
AIF (&count EQ 2). FINAL	A 2, data2
A 3, &arg3	A 3, data3
.FINAL MEND	:
:	:
LOOP1 INCR 3, data1, data2, data3	LOOP2 A 1, data3
:	A 2, data2
:	:
LOOP2 INCR 2, data3, data2	:
:	LOOP3 A 1, data1
LOOP3 INCR 1, data1	:
:	data1 DC ‘5’
data1 DC ‘5’	data2 DC ‘6’
data2 DC ‘6’	data3 DC ‘7’
data3 DC ‘7’	:

Macro-calls within macro

- Macros are abbreviations of instruction sequence. Such abbreviations are also present within other macro definition.

Macro-calls within macro



Example:

Definition of Macro ADD1

```
MACRO
ADD1    &arg
L       1,&arg
A       1, =F ‘1 ’
ST      1, &arg
MEND
```

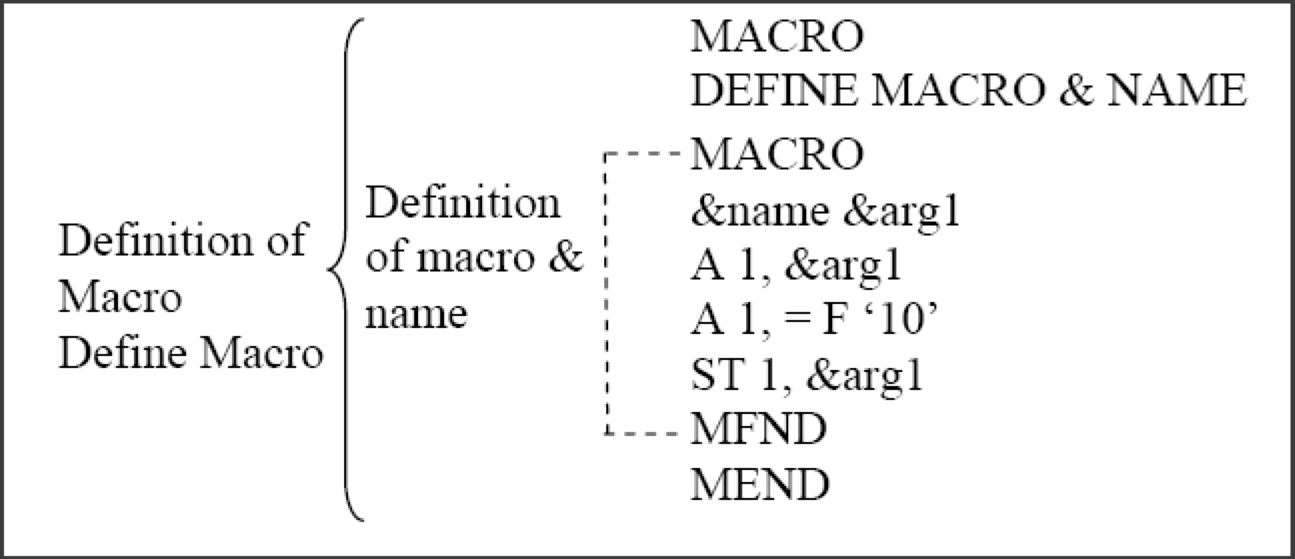
Definition of Macro ADD5

```
MACRO
ADDS   &arg1, & arg 2, arg 3
ADD1   &arg1
ADD1   &arg2
ADD1   &arg3
MEND
```

Source Code	Expanded code (level 1)	Expanded code (level 2)
:		
:		
MACRO		
ADD 1, &arg		
L 1, &arg		
A 1, = F ‘10’		
ST 1, &arg		
MEND		
MACRO		
ADDS &arg1, &arg2, arg3		
ADD1 &arg1		
ADD1 &arg2		
ADD1 &arg3		
MEND	Expansion of ADDS	
:	:	
:	:	
ADDS data1, data2, data3	ADD1 data 1	
:	ADD1 data 2	
:	ADD1 data 3	
data 1 DC F‘5’	:	
data 2 DC F‘6’	:	
data 3 DC F‘7’	:	
END	:	
	data DC F ‘5’	
	data DC F ‘6’	
	data DC F ‘7’	
	END	

Source Code	Expanded code (level 1)	Expanded code (level 2)
: : MACRO ADD 1, &arg L 1, &arg A 1, = F ‘10’ ST 1, &arg MEND MACRO ADDS &arg1, &arg2, arg3 ADD1 &arg1 ADD1 &arg2 ADD1 &arg3 MEND : : ADDS data1, data2, data3 : : data 1 DC F‘5’ data 2 DC F‘6’ data 3 DC F‘7’ END	Expansion of ADDS : : ADD1 data 1 ADD1 data 2 ADD1 data 3 : : : : data DC F ‘5’ data DC F ‘6’ data DC F ‘7’ END	Expansion of ADD1 L 1, data 1 A 1, = F ‘10’ ST 1, data 1 L 1, data 2 A 1, = F ‘10’ ST 1, data 2 L 1, data 3 A 1, = F ‘10’ ST 1, data 3 data1 DC F‘5’ data2 DC F‘6’ data3 DC F‘7’ END

Macro-instructions defining macros



Definition of Macro Define Macro

Definition of macro & name

```
MACRO
DEFINE MACRO & NAME
MACRO
&name &arg1
A 1, &arg1
A 1, = F ‘10’
ST 1, &arg1
MFND
MEND
```

Macro-instructions defining macros

- Macro-definition, which itself is a sequence of instruction, can be abbreviated by using macro.
- It is important to note that inner macro is not defined until the outer macro is called.
- The user might call the above macro with the statement-
- DEFINE-MACRO ADD1
- When this call is executed then the macro ADD1 will be defined. So after the above call user can call the ADD1 macro in following way-
- ADD1 data1
- The macro processor will generate the sequence

```
L    1, data1
A   1,=F’0’
ST 1,data1.
```

Implementation

- There are **four basic task** that a macro-processor must perform
  - **Recognize macro definition**

    A macro instruction processor must recognize macro definition identified by MACRO & MEND pseudo – operations.
  - **Save the Definition**

    The processor must store the macro – definitions which will be needed at the time of expansion of calls.
  - **Recognize the Macro call**

    The processor must recognize macro calls that appear as operation mnemonics.
  - **Expand calls & substitute arguments**

    The macro call is replaced by the macro definition. The dummy arguments are replaced by the actual data .

Two pass Macro Processor

- General Design Steps
- **Step 1: Specification of Problem:-**
- **Step 2 Specification of databases:-**
- **Step 3 Specification of database formats**
- **Step 4 : Algorithm**

Specify the problem

- In Pass-I the macro definitions are searched and stored in the macro definition table and the entry is made in macro name table
- In Pass-II the macro calls are identified and the arguments are placed in the appropriate place and the macro calls are replaced by macro definitions.

Specification of databases:-

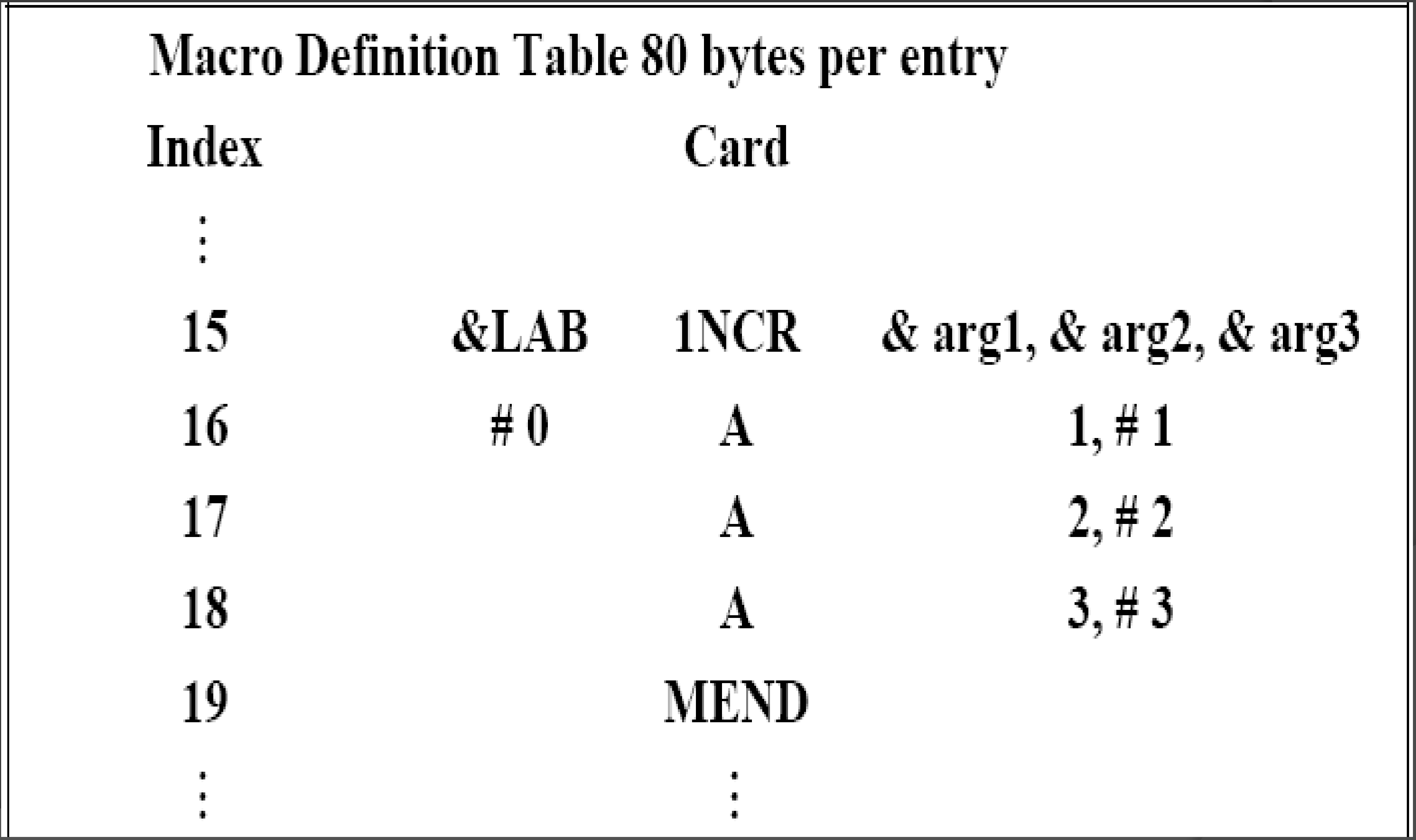
Pass 1:-

- The input macro source program.
- The output macro source program to be used by Pass2.
- Macro-Definition Table (MDT), to store the body of macro def^{ns}.
- Macro-Definition Table Counter (MDTC), to mark next available entry MDT.
- Macro- Name Table (MNT), used to store names of macros.
- Macro Name Table counter (MNTC), used to indicate the next available entry in MNT.
- Argument List Array (ALA), used to substitute index markers for dummy arguments before storing a macro-def^{ns}.

Specification of databases:-

- **Pass 2:-**
- The copy of the input from Pass1.
- The output expanded source to be given to assembler.
- MDT, created by Pass1.
- MNT, created by Pass1.
- Macro-Definition Table Pointer (MDTP), used to indicate the next line of text to be used during macro-expansion.
- Argument List Array (ALA), used to substitute macro-call arguments for the index markers in the stored macro-def^{ns}

Specification of database format:-

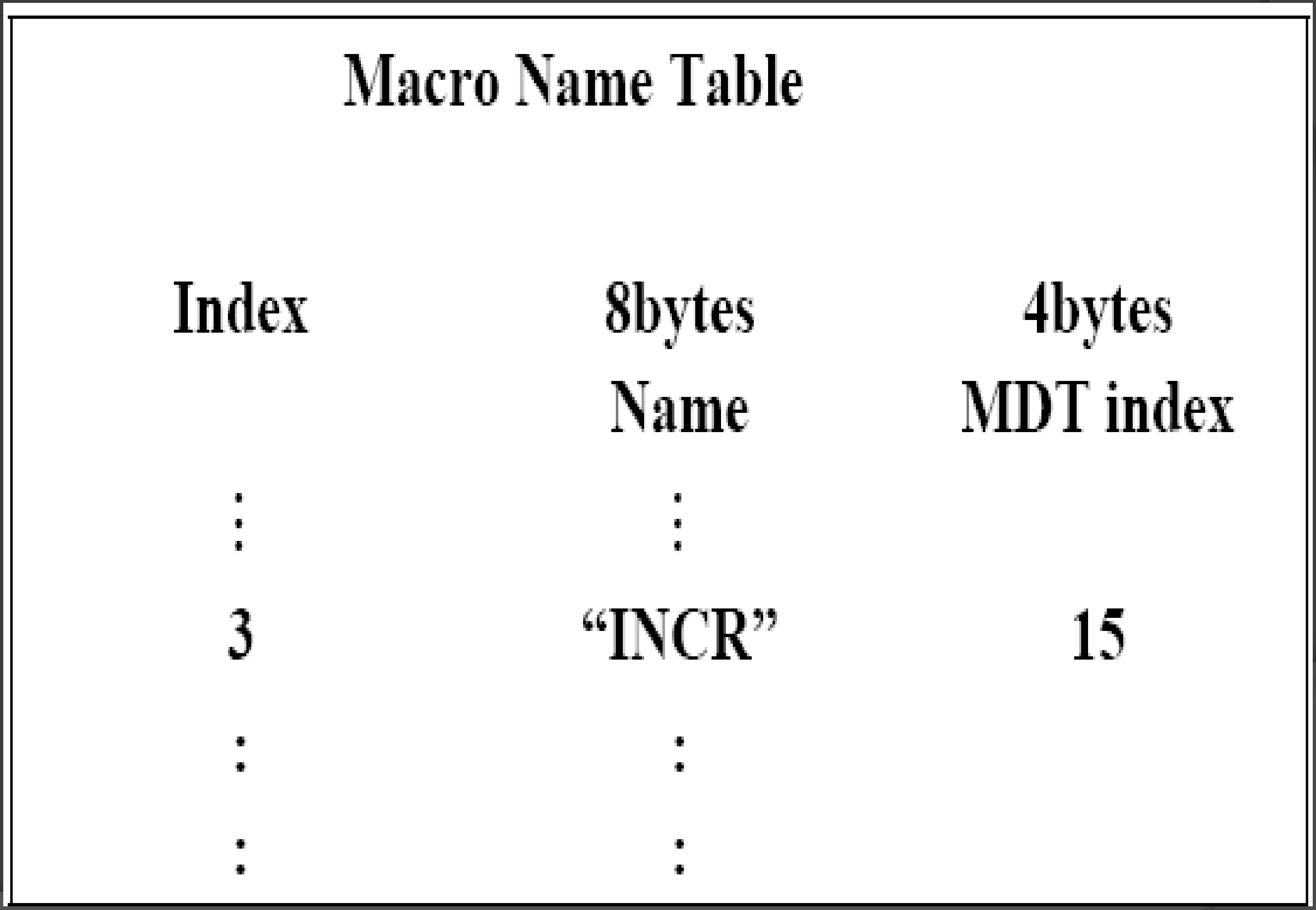


Macro Definition Table 80 bytes per entry

Index		Card	
⋮			
15	&LAB	1NCR	& arg1, & arg2, & arg3
16	# 0	A	1, # 1
17		A	2, # 2
18		A	3, # 3
19		MEND	
⋮		⋮	

- MDT is a table of text lines.
- Every line of each macro definition except the MACRO line, is stored in the MDT (MACRO line is useless during macro-expansion)
- MEND is kept to indicate the end of the dep^{ns}.
- The macro-name line is retained to facilitate keyword argument replacement.

Macro Names Table (MNT):



Macro Name Table

Index	8bytes Name	4bytes MDT index
⋮	⋮	
3	“INCR”	15
:	:	
:	:	

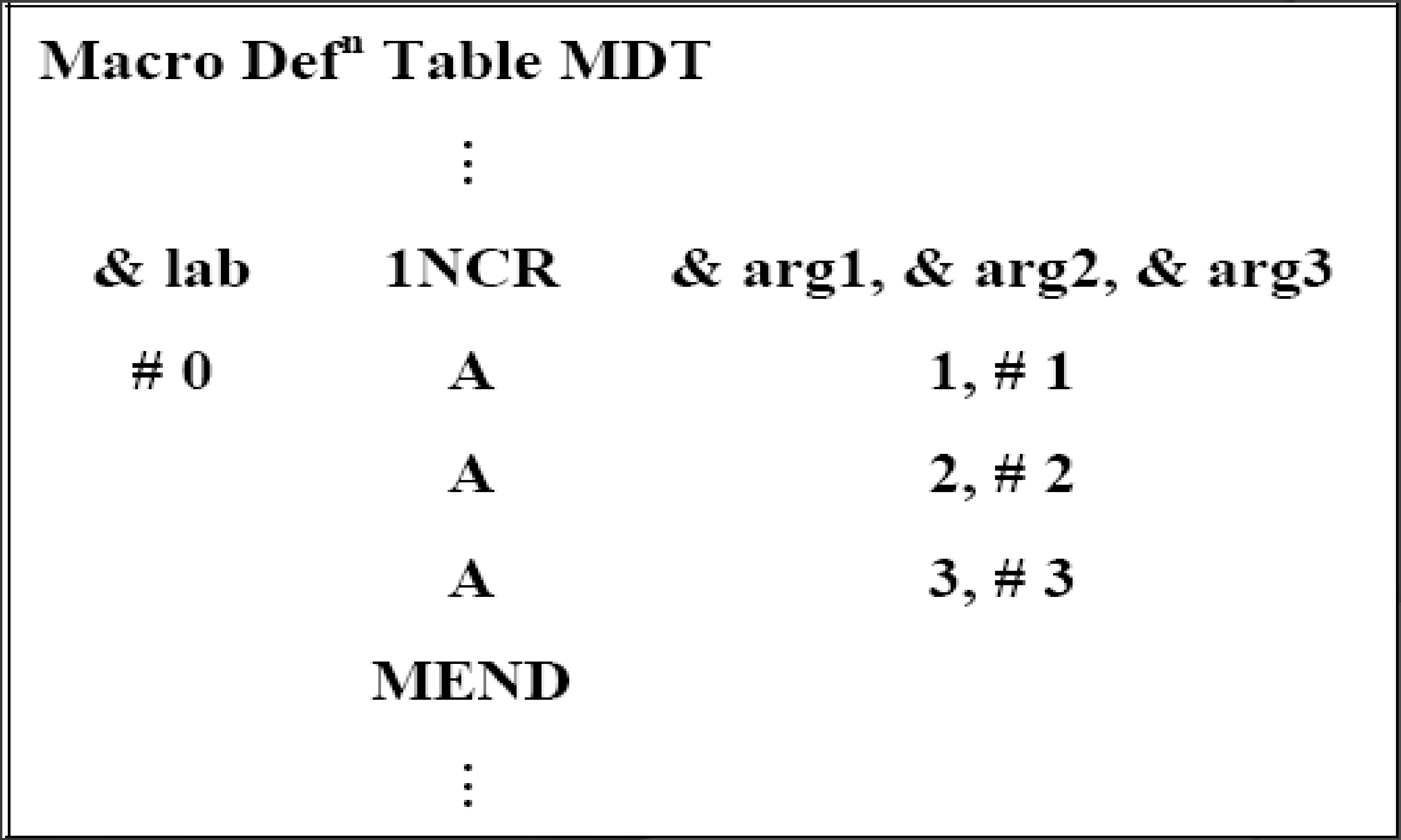
- Each MNT entry consists of
  - A character string (the macro name) &
  - A pointer (index) to the entry in MDT that corresponds to the beginning of the macro-definition.(MDT index)

Argument List Array (ALA):

- ALA is used during both Pass1 & Pas2 but for some what reverse functions.
- During Pass1, in order to simplify later argument replacement during macro expansion, dummy arguments are replaced with positional indicators when def^{n} is stored.

  Ex. # 1, # 2, # 3 etc.
- The ith dummy argument on the macro-name is represented in the body by #i.
- These symbols are used in conjunction with ALA prepared before expansion of a macro-call.
- Symbolic dummy argument are retained on macro-name to enable the macro processor to handle argument replacement byname rather by position.

During pass-I

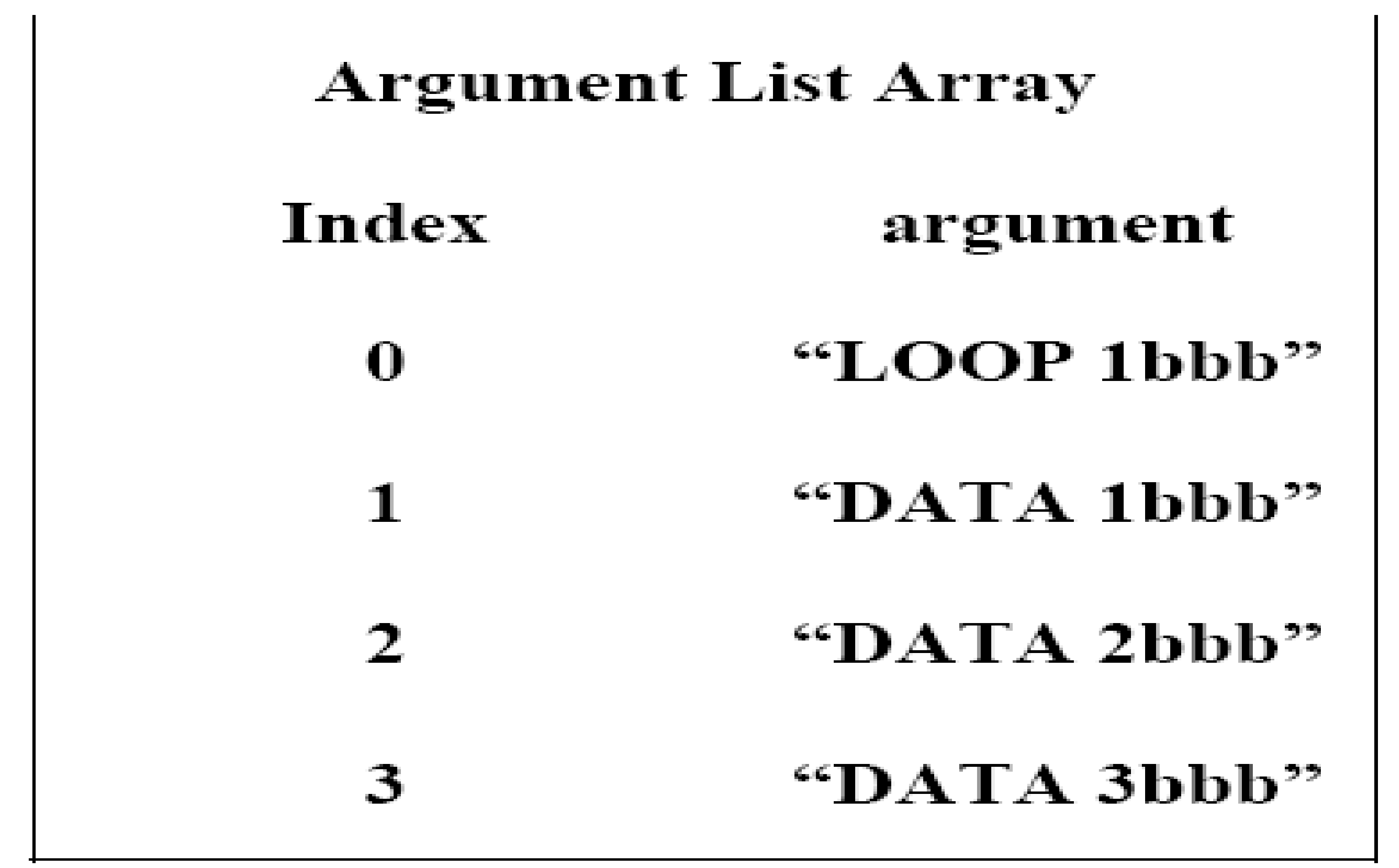


Macro Def^{n} Table MDT

	⋮	
& lab	1NCR	& arg1, & arg2, & arg3
# 0	A	1, # 1
	A	2, # 2
	A	3, # 3
	MEND	
	⋮	

During Pass-II

- During Pass2 it is necessary to substitute macro call arguments for the index markers stored in the macro.
- Thus upon encountering the call expander would prepare a ALA as shown below:
- LOOP 1NCR DATA1, DATA2, DATA3,}
- → Call in main prog.
- → ALA is prepare of after this call is encountered.



Argument List Array

Index	argument
0	“LOOP 1bbb”
1	“DATA 1bbb”
2	“DATA 2bbb”
3	“DATA 3bbb”

Algorithm

- Pass1 of macro processor makes a line-by-line scan over its input.
- Set MDTC = 1 as well as MNTC = 1.
- Read next line from input program.
- If it is a MACRO pseudo-op, the entire macro definition except this (MACRO) line is stored in MDT.
- The name is entered into Macro Name Table along with a **pointer to the first location of MDT entry of the definition**.
- When the END pseudo-op is encountered all the macro-def^{ns} have been processed, so control is transferred to pass2

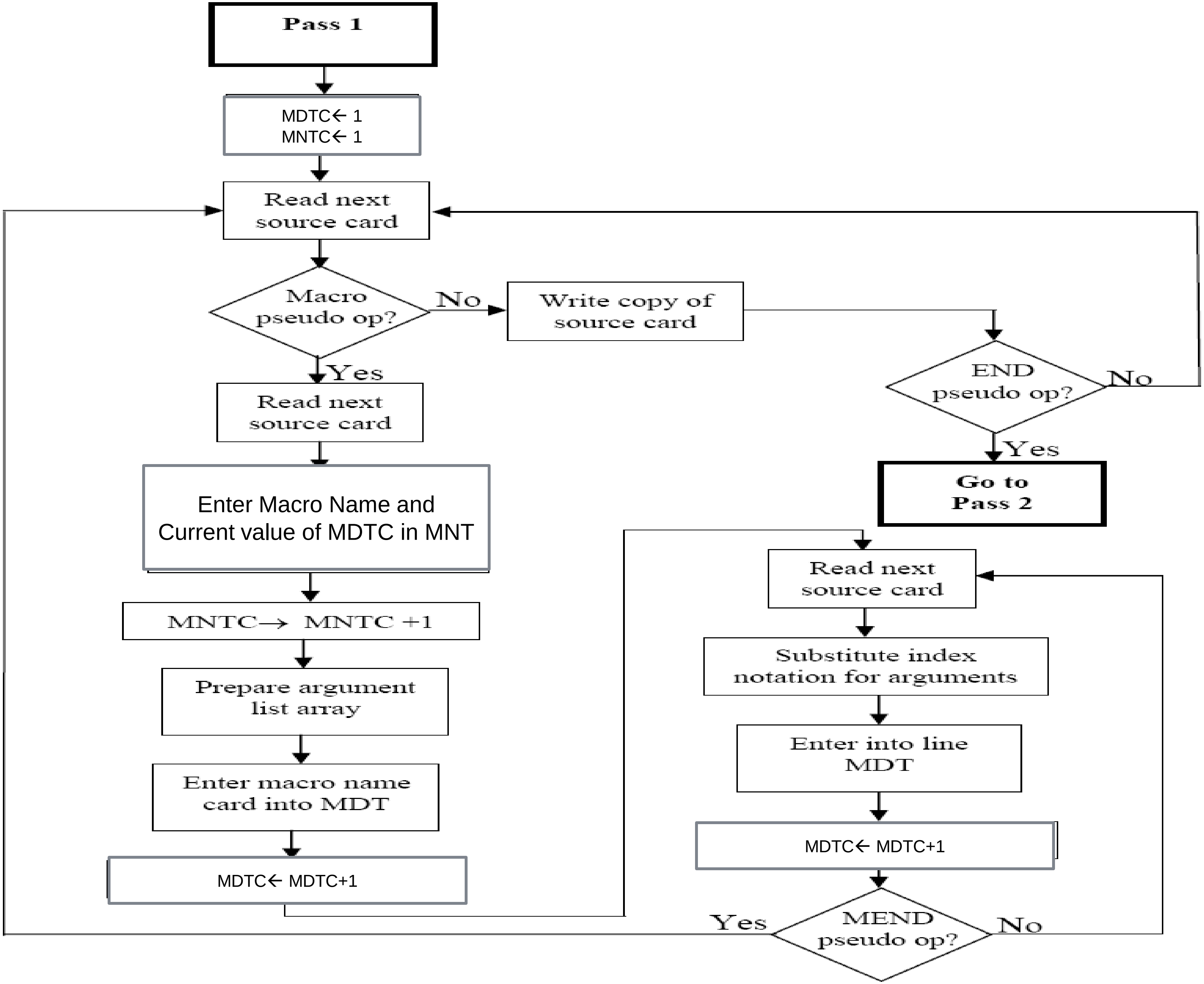


Fig.2.1 pass 1 Processing Macro definitions

Algorithm for Pass – 2

- This algorithm reads one line of i/p prog. at a time.
- for each Line it checks if op-code of that line matches any of the MNT entry.
- When match is found (i.e. when call is pointer called MDTF to corresponding macro def^{ns} stored in MDT.
- The initial value of MDTP is obtained from MDT index field of MNT entry.
- The macro expander prepares the ALA consisting of a table of dummy argument indices & corresponding arguments to the call.
- Reading proceeds from the MDT, as each successive line is read, The values form the argument list one substituted for dummy arguments indices in the macro def^{n}.
- Reading MEND line in MDT terminates expansion of macro & scanning continues from the input file.
- When END pseudo-op encountered , the expanded source program is given to the assembler

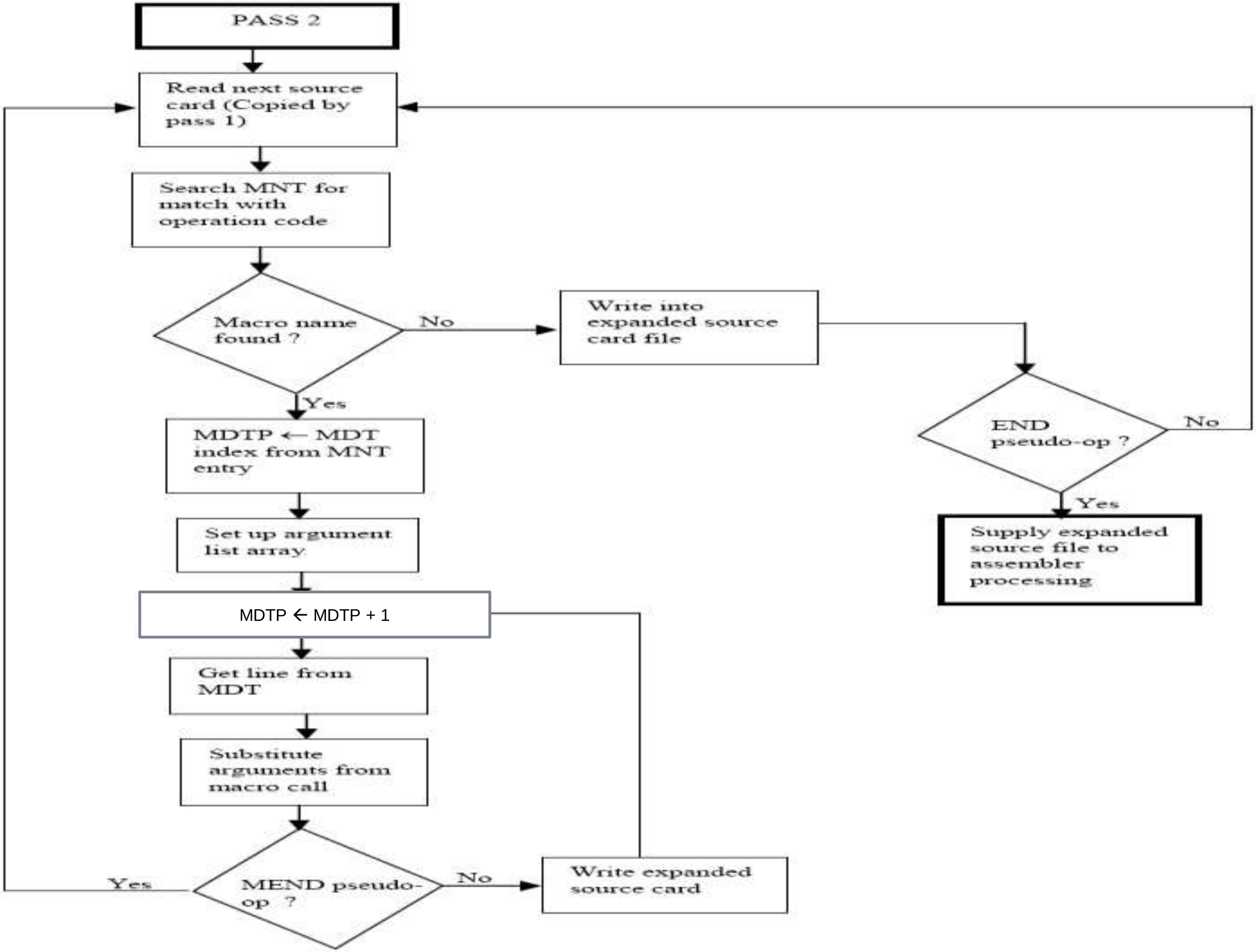

PASS 2
Read next source card (Copied by pass 1)
Search MNT for match with operation code
Macro name found ?
No
Write into expanded source card file
END pseudo-op ?
No
Yes
Supply expanded source file to assembler processing
Yes
MDTP ← MDT index from MNT entry
Set up argument list array
MDTP ← MDTP + 1
Get line from MDT
Substitute arguments from macro call
MEND pseudo-op ?
Yes
No
Write expanded source card

Fig. 2.2 Pass 2 Processing Macro calls and expansion

MACROS	PROCEDURE
1 The corresponding machine code is written every time a macro is called in a program.	1 The Corresponding m/c code is written only once in memory
2 Program takes up more memory space.	2 Program takes up comparatively less memory space.
3 No transfer of program counter.	3 Transferring of program counter is required.
4 No overhead of using stack for transferring control.	4 Overhead of using stack for transferring control.
5 Execution is fast	5 Execution is comparatively slow.
6 Assembly time is more.	6 Assembly time is comparatively less.
7 More advantageous to the programs when repeated group of instruction is too short.	7 More advantageous to the programs when repeated group of instructions is quite large.

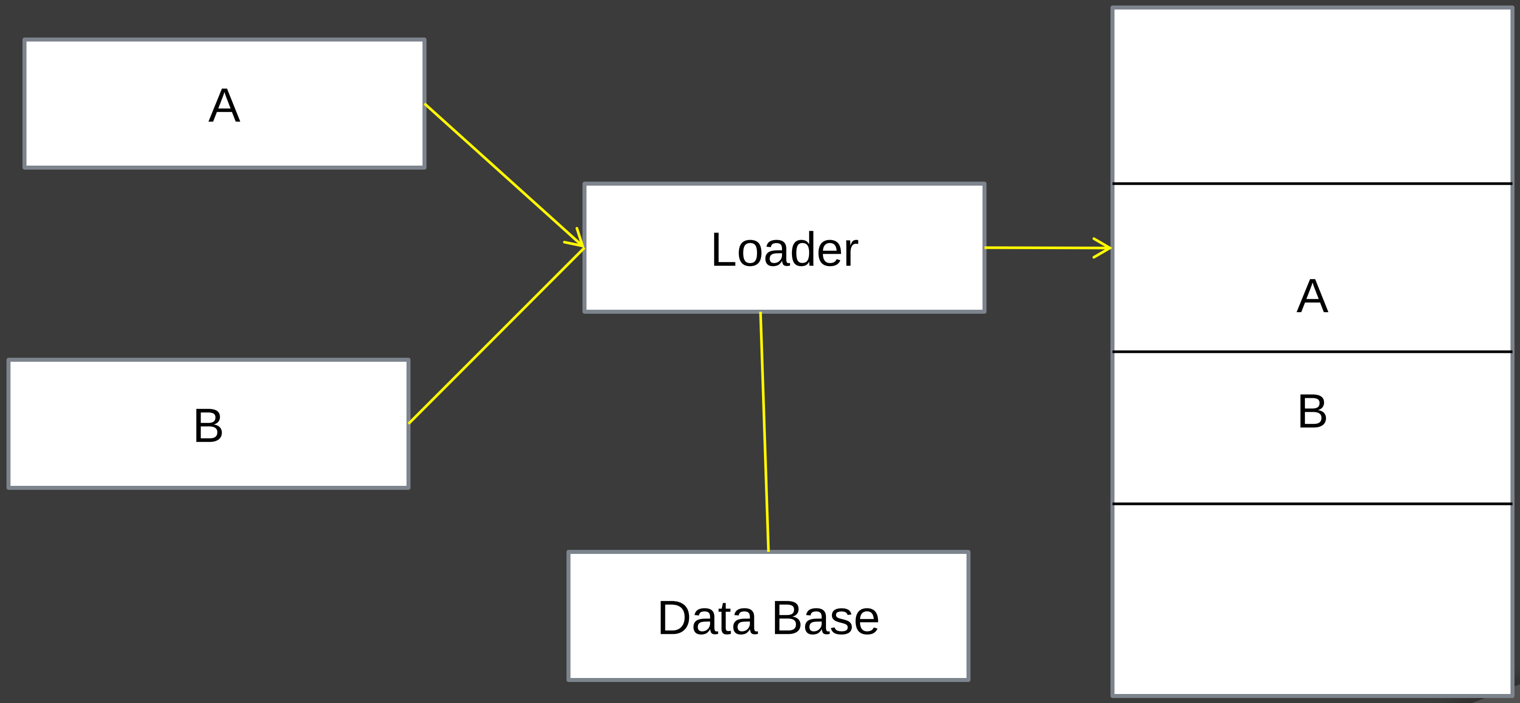
Loaders

- Loader is a program which accepts the object program decks and prepares these programs for execution by the computer and initiates the execution

The loader must perform the following functions

1. Allocate space in memory for the program(Allocation)
2. Resolve symbolic references between object decks(Linking)
3. Adjust all address dependent locations, such as address constants, to corresponds to the allocated space (Relocation)
4. Physically place the machine instruction and data in memory(Loading)

Loader

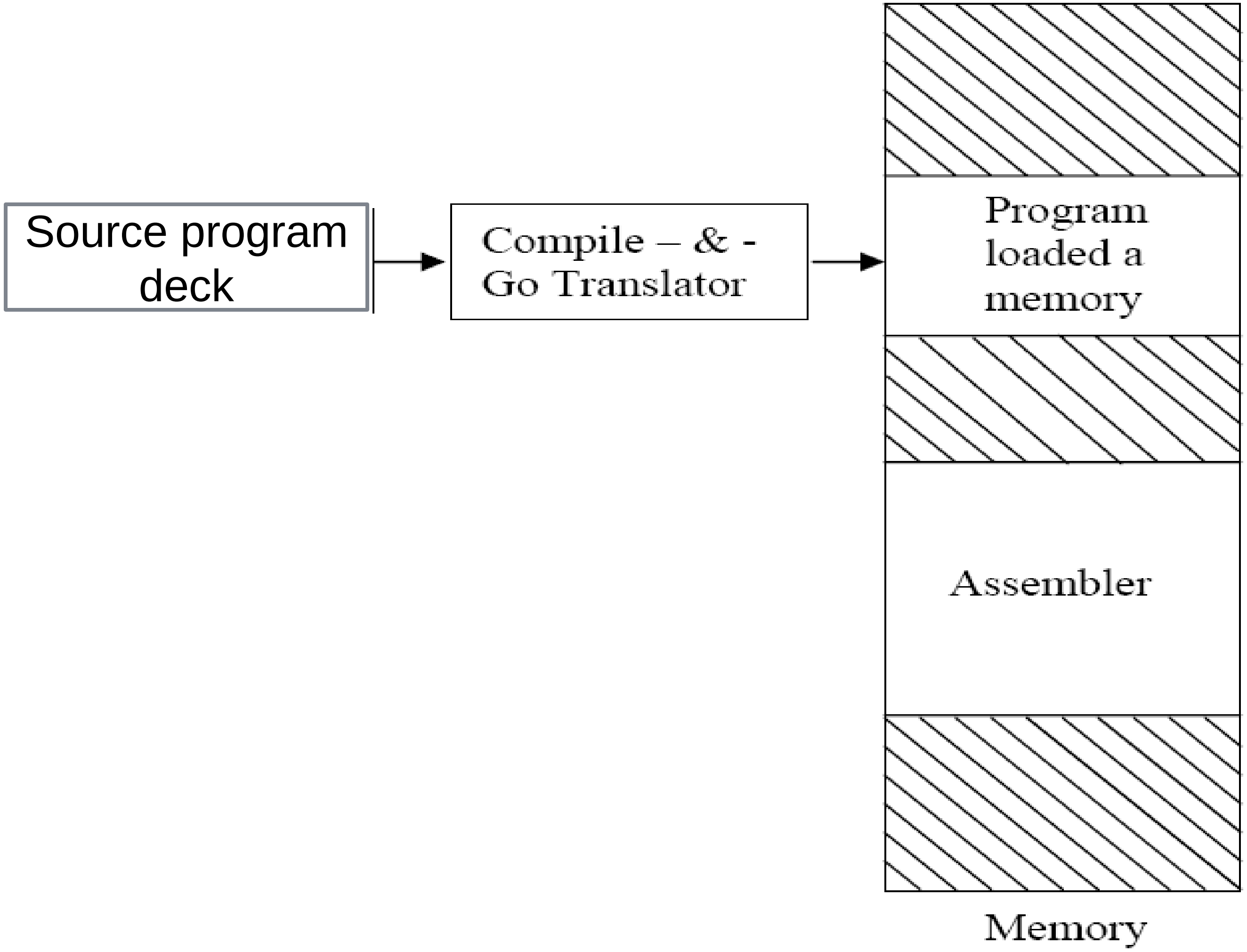


Program Loaded in memory ready for Execution

Loader Schemes

- Compile-and-Go loader
- General Loader Scheme
- Absolute Loading scheme
- Subroutine Linkages
- Relocating Loaders
- Direct Linking Loaders

Compile-and-Go Loader



Source program deck

Compile – & - Go Translator

Program loaded a memory

Assembler

Memory

Fig.2.7 Compile - & - Go Loader

- In this scheme assembler run in one part of memory and place object instructions & data, as they are assembled, directly into their assigned memory location.
- When assembly is completed, assembler causes a transfer to the starting instruction of the program

- **Advantages:-**
- It is relatively easy to implement. Assembler simply places code into core and loader transfer control to starting instruction of newly assembled program.
-
- **Disadvantages:-**
- i) A portion of memory is always occupied by assembler. That portion is unavailable to any other object program.
- ii) User’s program have to be reassemble every time it is run.
- iii) If source program contains sub routine written in different languages, then different assemblers have to be stored in memory (i.e. again wastage of memory).

General Loading Scheme

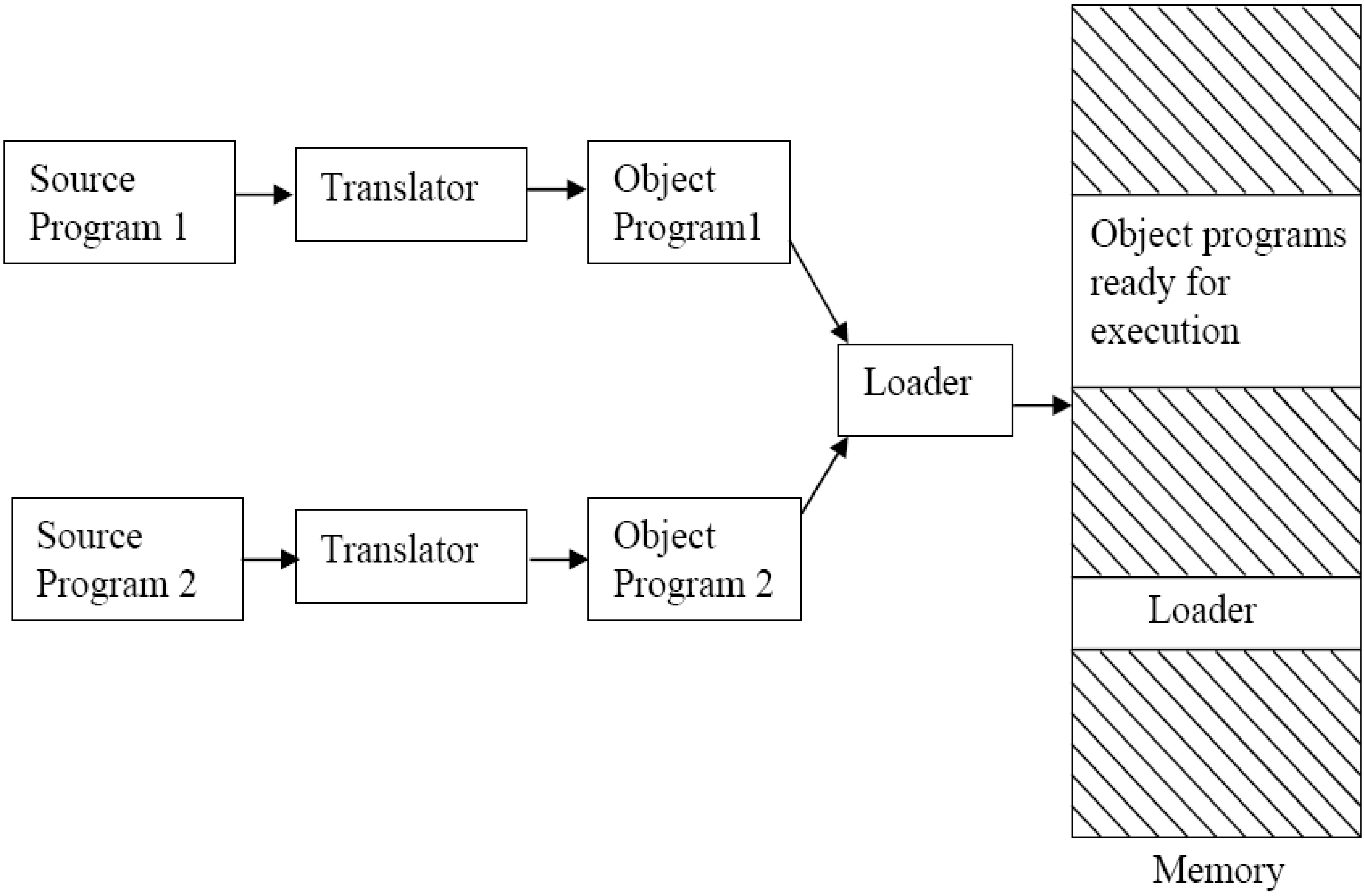


Fig.2.8 General Loader

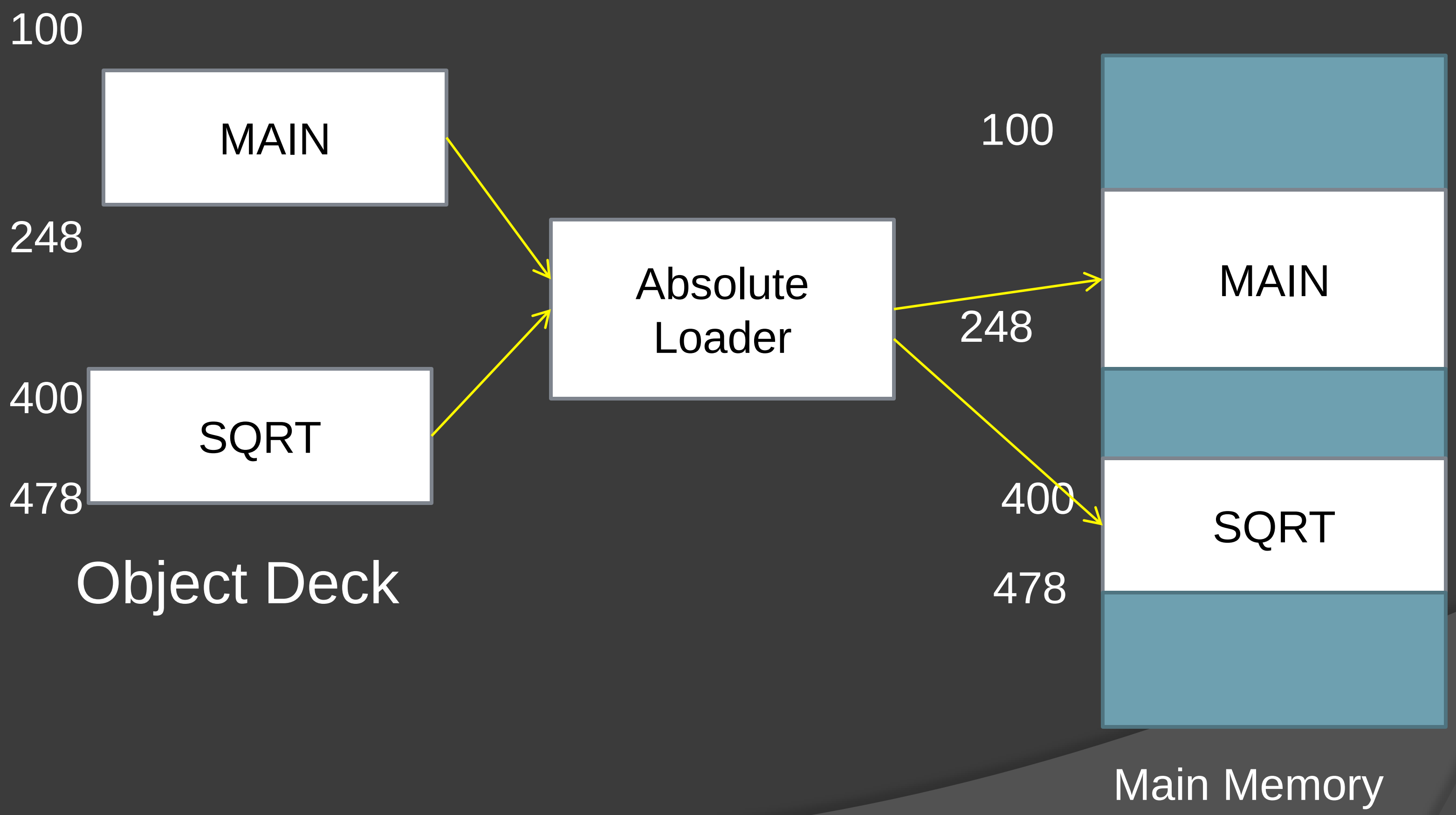
General Loader Scheme

- In this scheme the output of assembler is saved and loaded whenever code is to be executed.
- Assembled program could be loaded, in the same area into memory where assembler was stored (because now assembling is completed assembler is removed from main memory).
- Function of loader is to accept instruction, data and other information in object format and put it into memory in executable format.

- **Advantages:-**
  - No need to put assembler in main memory all the time it can be removed after assembly is completed. Assembled program is stored in secondary storage in object form
  - Loader is required to put object code in memory in executable format, which is smaller in size.
  - Every time when we run program one do not have to assembler it every time.
  - Even if subroutine are in different languages, their object code & linkage conventions will be in one language.
- **Disadvantage:-**

  Addition of a new program ‘Loader’ into system.

Absolute Loader



Absolute Loaders:-

- The simplest type of loader scheme which fits to the general model is called as absolute loader.
- Assembler produces object code, which is stored on secondary storage (instead of directly loaded into main memory like in compile -&-go).
- Loader in turn accepts this object code, places it into core at prescribed place by assembler for execution.

Advantages:-

- This scheme makes more memory available to the user, an assembler is not in memory at load time.
- Simple to implement.

Disadvantages:-

- Programmer must specify to the assembler, the address of memory location where program is to be loaded.
- When program contains more than one subroutines, then programmer must remember the address of each and have to user it explicitly in other subroutines to perform subroutine linkages.
- Programmer must be careful not to assign same or overlapping locations to two subroutines.

Thus in absolute loader scheme four loader functions are performed by

- Allocation - by programmer
- Linking - by programmer
- Relocation - by assembler
- Loading - by loader

Subroutine linkage

- The problem is:: A MAIN program A wishes to transfer to sub-program B. However the assembler does not know this symbol and declare it as an undefined symbol (error) unless a special mechanism has been provided.
- This mechanism has been implemented with a direct-linking or a relocating loader.
- The assembler pseudo-op EXTRN followed by a list of symbols indicates that these symbols are defined in another programs.
- Correspondingly if a symbol is defined in one program and referenced in others, we insert it into a symbol list following the pseudo-op ENTRY.
- The assembler will also inform the loader that these symbols may be referenced by other programs.

Subroutine linkage(Cont…1)

- Consider the following example::

```
MAIN   START
        EXTRN        SUBROUT
        -----------
        L            15, = A(SUBROUT)
        BALR         14,15 // reg 14 is return addr of caller.
        ---------
        END
```

The subroutine can be defined at other location as ::

```
SUBROUT  START
         USING        *,15
         -----------
         BR           14
         END
```

Relocating loaders

- To avoid possible reassembling of all subroutines when a single subroutine is changed, and to perform the task of allocation and linking for programmer, relocating loaders are developed.
- In this scheme, assembler assembles each procedure segment independently and passes on the text and information after relocation & inter segment references to the loader.

- Example:: BSS(Binary Symbolic Subroutines) loader used in IBM 7094, IBM 1130, etc.
- The o/p of a relocating assembler using a BSS scheme is the object program & information about all programs it references.
- It also provides the relocating information that needs to be changed if it is placed in an arbitrary place in core.
- BSS loader scheme is used on computers with a fixed length direct address instruction format.

5.RELOCATING LOADER(Cont…1)

SOURCE PROGRAM		REL. ADDR	RELOCATION	OBJECT CODE
MAIN	START			
EXTRN	SQRT	0	00	‘SQRT’
EXTRN	ERR	4	00	‘ERRb’
ST	14,SAVE	8	01	ST 14,36
L	1,=F ‘9’	12	01	L 1,40
BAL	14,SQRT	16	01	BAL 14,0
C	1, = F ‘3’	20	01	C 1,44
BNE	ERR	24	01	BC 7,4
L	14, SAVE	28	01	L 14,36
BR	14	32	0	BCR 15,14
SAVE	DS F	34	0	skipped for alignment
	END	36	00	temp. location
		40	00	
		44	00	

5.RELOCATING LOADER(Cont…2)

Absolute Address	Relative Address
400	0
404	4
408	8
412	12
416	16
420	20
424	24
428	28
432	32
436	36
440	40
444	44

```
BC  15,448
BC  15, 526
ST  14,436
L    1,440
BAL 14,400
C        1,444
BC        7,404
L         4,436
BCR   15,14
 (TEMP LOC)
          9
          3
```

LENGTH = 48 BYTES.

SQRT

ERR

LENGTH = 78 BYTES.

5.RELOCATING LOADER(Cont…3)

- **Drawbacks ::**

1) The transfer vector linkage is only useful for transfers & is not well situated for loading or storing external data(data located in another procedure segments).
2) The transfer vector increases the size of the object program in memory.

6. DIRECT-LINKING LOADER(cont…1)

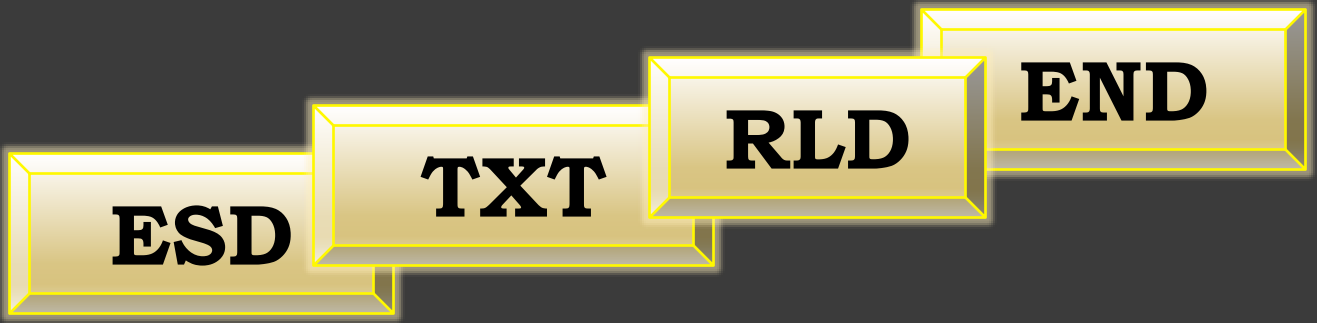


FIG: - OBJECT DESK FOR A DIRECT LINKING LOADER

- ESD – External Symbol dictionary.
- TXT – Text (contains actual assembled program).
- RLD - Relocation & Linkage Directory. – contains information about those locations in the program whose contents depends on the address at which the program is placed. These information are::
- Location of each constant that needs to be changed due to relocation.
- By what it has to be changed.
- The operation to be performed.

DIRECT-LINKING LOADER(cont…2)

- **ADVATAGES::**

1) It allows the programmer multiple procedure & data segments.
2) Complete freedom for the programmer to refer the data in other segments.
3) Provides flexibility in intersegment referencing & accessing ability.
4) Allows independent translations of the programs.

- **DISADVATAGES::**

1) It is necessary to allocate, relocate, link & load all of the subroutines each time in order to execute a program.
2) These loading are Time-consuming.
3) Although loader is smaller than assembler, it occupies some memory space.

OTHER LOADING SCHEMES

- These includes Binders, linking loaders, Overlays & Dynamic loaders.
- **Binders::** - A Binder is a program that performs the same functions as that of a direct-linking loader in binding subroutines together, but rather than placing the relocated & linked text directly into memory, it outputs the text as a file or a card deck.
- This o/p file to be loaded is called as “load-module”.
- The functions of binders are ::
  - Allocation, Relocation, Linking & Loading.
- There are 2 major classes of Binders::
  - Core – image module.(fast & simple)
  - Linkage Editor.(complex)

Dynamic Loading overlays

- Each of the previous loader schemes assume that all of the subroutines are loaded into core at the same time. It the total amount of memory available is less than memory required by all needed subroutines, then there will be trouble.

Solution to above problem can be-

- Some hardware techniques like paging and segmentation are used to solve this problem
- There is loading scheme called as dynamic loading which is also available to solve above problem.

- Usually different subroutines are needed at different times. E.g. PASS1 & PASS2 of assembler are mutually exclusive. Both can be loaded one after another, need not to be loaded at the same time.
- By determining which subroutines call another, which are exclusive , we can produce an overlay structure, that will help to use memory economically.

Consider a program containing 5 subroutines A,B,C,D,E. which require total 100kb memory.

Subprogram A calls B,D &E.

Subprogram B calls C & E

D call E

C and E do not call any other program.

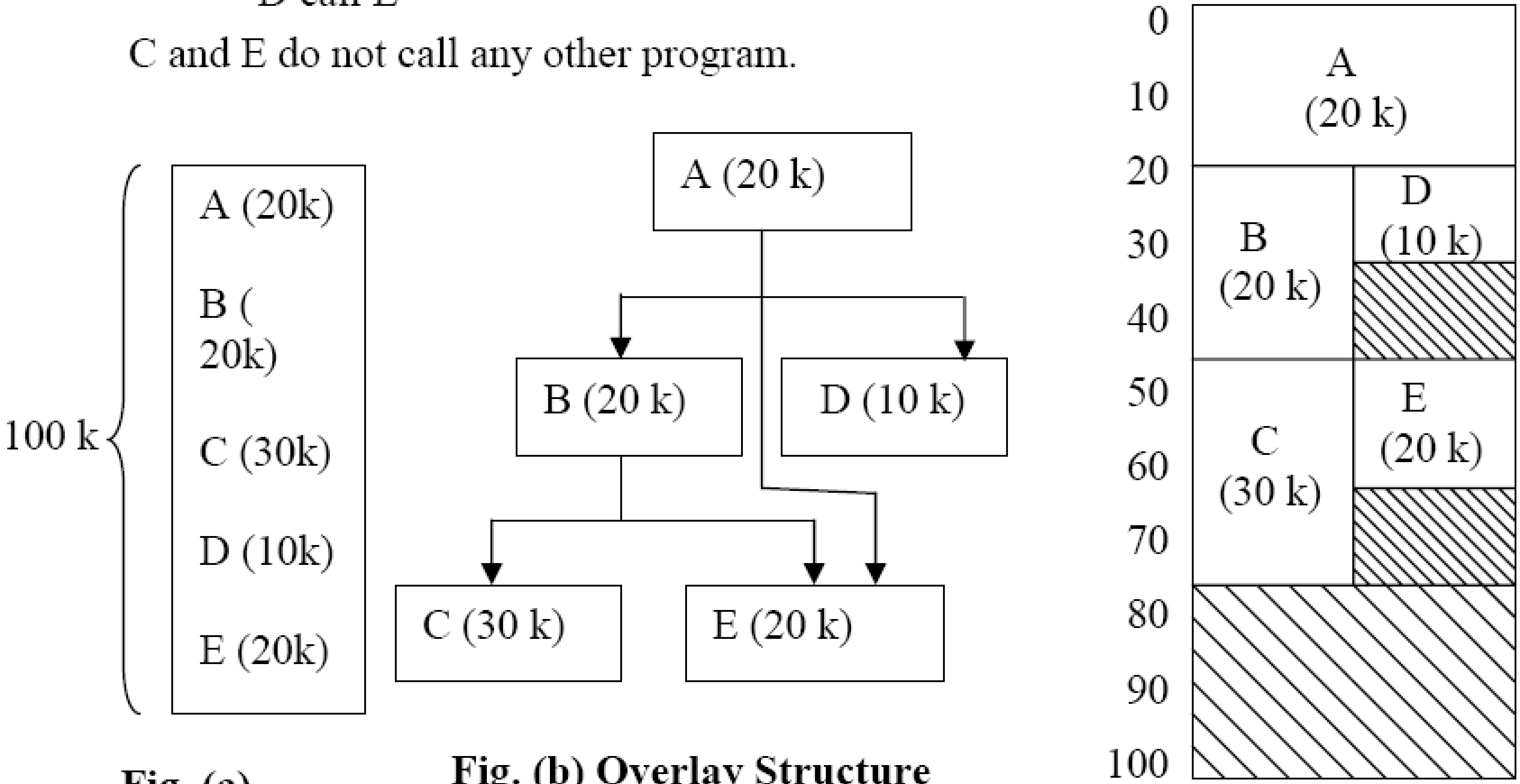


Fig. (a)

Fig. (b) Overlay Structure

Fig. (c) Possible storage assignment of each procedure

Fig. 2.9