310243: Systems Programming and Operating System

Course Objectives:

- To get acquainted with the basics of System Programming.
- To acquire knowledge of data structures used in the design of System Software.
- To be familiar with the format of object modules, the functions of linking, relocation, and loading.
- To comprehend the structures and functions of Operating Systems and process management.
- To deal with concurrency and deadlock in the Operating System.
- To learn and understand memory management of Operating System.

310243: Systems Programming and Operating System

Course Outcomes:

On completion of the course, learners should be able to-

CO1: Analyze and synthesize basic System Software and its functionality.

CO2: Identify suitable data structures and Design & Implement various System Software

CO3: Compare different loading schemes and analyze the performance of linker and loader

CO4: Implement and Analyze the performance of process scheduling algorithms

CO5: Identify the mechanism to deal with deadlock and concurrency issues

CO6: Demonstrate memory organization and memory management policies

Macro Processor and Compiler

UNIT-II

Syllabus

Introduction, **Features of a Macro facility**: Macro instruction arguments, Conditional Macro expansion, Macro calls within Macros, Macro instructions defining Macro, Design of two pass Macro processor, Concept of single pass Macro processor

Introduction to Compilers: Phases of Compiler with one example, Comparison of Compiler and Interpreter

#Exemplar/Case Studies: GNU M4 Macro Processor

Mapping of Course Outcomes for Unit II: CO1, CO2, CO3

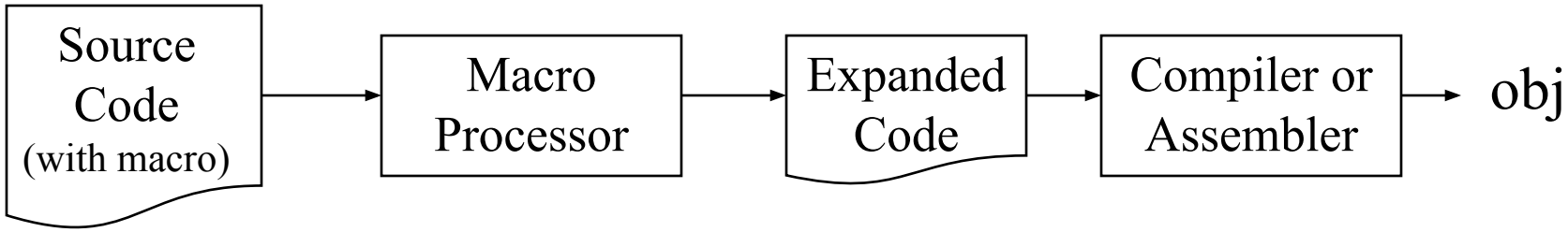
Introduction to Macro Processor

- Macro instructions are considered as the extension of the basic assembler language.
- A macro instruction is convenient for the programmer in terms of notation.
- A macro is a single-line abbreviation used for a group of instructions.
- It allows the programmer to write shorthand version of a program (*module programming*)
- The macro processor replaces each macro call with the corresponding sequence of statements (*expanding*)

Macro Processor

Working of Macro Processor

1. Recognizes macro definitions
2. Saves the macro definition
3. Recognizes macro calls
4. Expands macro calls



Macro Definition

MACRO → Start of Definition

<Macro Name> <List of Parameters [p1, p2, …pn]> →

Macro Name (with label or argument(s) which is optional)

→ Sequence to be abbreviated

MEND → End of Definition

Macro Definition (cont..)

Example:

```
MACRO
ADDS    &arg1, &arg2, &arg3
L    1, &arg1
A    1, &arg2
ST   1, &arg3
MEND
```

Macro Call

<Macro Name> <List of Actual parameters[a1, a2, …an]>

For Ex.

ADDS DATA1, DATA2, DATA3

Macro Expansion

//Source Code with Macro definition & macro call

```
MACRO
ADDS    &arg1,&arg2,&arg3
L       1, &arg1
A       1, &arg2
ST      1, &arg3
MEND
PROG    START   0
        BALR    15,0
        USING   *,15
        ADDS    DATA1, DATA2, DATA3
        SR      4,4
DATA1   DC      F'3'
DATA2   DC      F'4'
DATA3   DS      1F
        END
```

// Processed code after macro Expansion

```
PROG    START   0
        BALR    15,0
        USING   *,15
        L       1, DATA1
        A       1, DATA2
        ST      1,DATA3
        SR      4,4
DATA1   DC      F'3'
DATA2   DC      F'4'
DATA3   DS      1F
        END
```

} Macro Expansion

Macro Expansion (cont..)

Source program with Macro Definition & Macro call

```
MACRO
ADDS &arg1,&arg2,&arg3
L       1, &arg1
A       1, &arg2
ST      1, &arg3
MEND
PROG START      0
        BALR  15,0
        USING       *,15
        ADDS DATA1, DATA2, DATA3
        SR     4,4
        ADDS D4, D5, D6
DATA1       DC     F'3'
DATA2       DC     F'4'
DATA3       DS     1F
D4      DC     F'1'
D5      DC     F'2'
D6      DS     1F
        END
```

Source program after macro expansion

```
PROG      START     0
          BALR      15,0
          USING     *,15
          L      1, DATA1
          A      1, DATA2
          ST     1, DATA3
          SR     4, 4
          L      1, D4
          A      1, D5
          ST     1, D6
DATA1     DC     F'3'
DATA2     DC     F'4'
DATA3     DS     1F
D4        DC     F'1'
D5        DC     F'2'
D6        DS     1F
          END
```

1st Macro call

2nd Macro call

Parameter Substitution

- Positional Formal Argument
- Keyword Argument
- Default Argument

Positional Formal Argument

```
// MACRO DEFINITION

MACRO
ADDS    &arg1, &arg2, &arg3
L       1, &arg1
A       1, &arg2
ST      1, &arg3
MEND


/MACRO CALL

ADDS    DATA1, DATA2, DATA3
```

Formal Parameter	Actual Parameter
&arg1	DATA1
&arg2	DATA2
&arg3	DATA3

Keyword Argument

```
//MACRO DEFINITION

MACRO
ADDS    &arg1=, &arg2=, &arg3=
L       1, &arg1
A       1, &arg2
ST      1, &arg3
MEND


//MACRO CALL

ADDS    &arg1=DATA1, &arg2= DATA2, &arg3= DATA3
……

ADDS    &arg2= DATA2, &arg3= DATA3, &arg1=DATA1
```

Formal Parameter	Actual Parameter
&arg1	DATA1
&arg2	DATA2
&Arg3	DATA3

Default Argument

```
//MACRO DEFINITION

MACRO
ADDS    &arg1=, &arg2=, &arg3=4
L       1, &arg1
A       1, &arg2
ST      1, &arg3
MEND


/MACRO CALL

ADDS    &arg1=D1, &arg2= D2
……

ADDS    &arg2= D2, &arg1=D1

ADDS    &arg2= D2, &arg1=D1, &arg3=100      //it overrides  default value
```

Formal Parameter	Value
&arg1	D1
&arg2	D2
&arg3	100

Macro with Mixed Parameter Lists

Macro can use all three types of parameters together

Example:-

```
//MACRO DEFINITION

MACRO
ADDS    &arg1, &arg2=45, &arg3=
L       1, &arg1
A       1, &arg2
ST      1,&arg3
MEND

//MACRO CALL

ADDS    D1, &arg3= D3
……
ADDS    D1, &arg3=D6, &arg2=400
```

Macro vs. Subroutine

Macro:

- Every macro call is replaced by its definition.
- After expansion of program, length increases. So, more memory is required.
- Processing time is less as compared to subroutine processing, because there is no context switching during macro processing.

Subroutine

- Every Subroutine (function) call transfers control to the first instruction of subroutine which is called.
- After processing subroutine call, the program size remains same.
- Processing time is increased due to context switching.

Advanced Macro Facilities

- Macro Calls within Macros
  (Nested Macro Calls)
- Macro instruction defining Macros
- Conditional Macro Expansion
- Expansion time variables
- Expansion time Loops

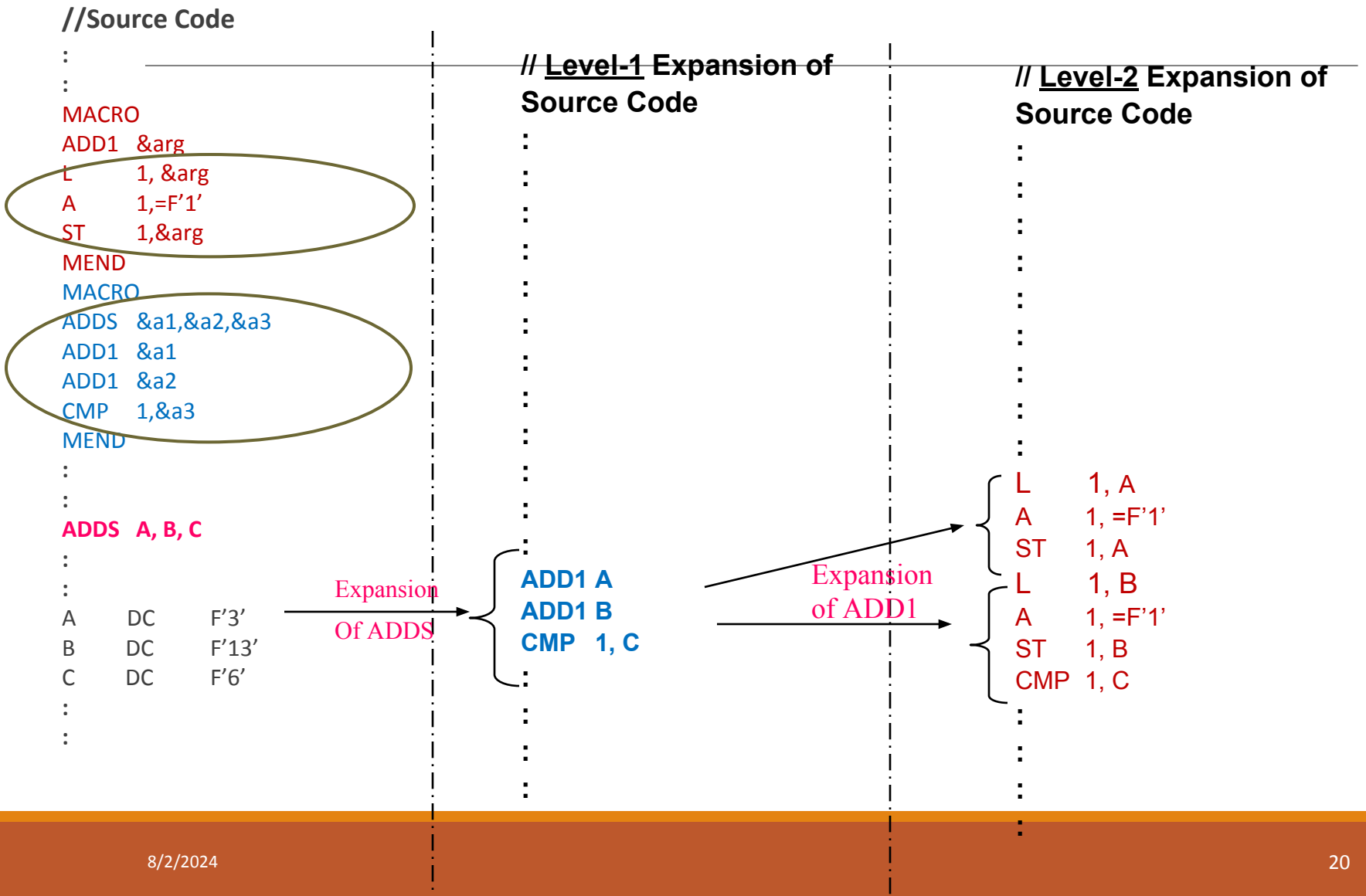
Macro Calls within Macros (Nested Macro Calls)

Macro definition of one macro may generate call to another macro is called as nested macro calls.

Example.

```
MACRO
ADD1    &arg
L       1, &arg
A       1, =F'1'
ST      1, &arg
MEND
MACRO
ADDS    &arg1, &arg2 ,&arg3
ADD1    &arg1
ADD1    &arg2
MEND
```

Macro Calls within Macros (Nested Macro Calls) (cont..)

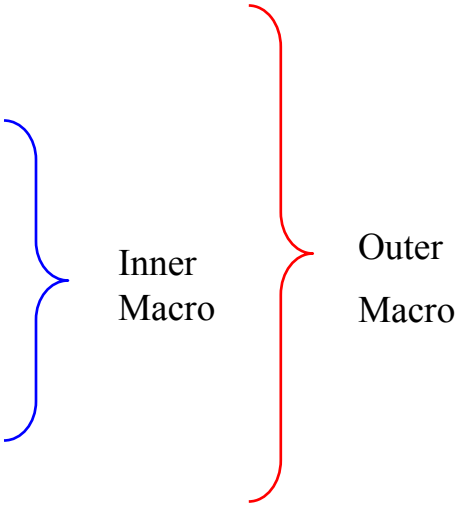


Macro Instruction Defining Macros

Macro definition may defines another macro

Ex.

```
MACRO
DEFINE    &SUB
MACRO
&SUB      &Y
CNOP      0,4
BAL       1,*+8
DC        A(&Y)
L         15,V(&SUB)
BALR14,15
MEND
MEND
```



Macro calls

- DEFINE COS
- COS AR

Conditional Macro Expansion

AIF & AGO are used for conditional macro expansion

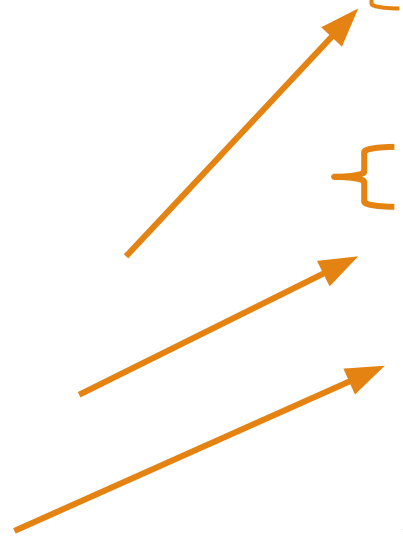
Need of Conditional Macro Expansion

Lets consider example:

```
        :
        :
LOOP1   A     1, A1
        A     2, A2
        A     3, A3
        :
        :
LOOP2   A     1, A3
        A     2, A2
        :
        :
LOOP3   A     1, A1
        :
        :
A1      DC    F'5'
A2      DC    F'15'
A3      DC    F'10'
```

Conditional Macro Expansion

```
        MACRO
&a0     VARY    &CNT, &a1, &a2, &a3
&a0     A   1, &a1
        AIF (&CNT EQ 1) .FINI
        A   2,& a2
        AIF (&CNT EQ 2) .FINI
        A   3, &a3
.FINI       MEND
        :
        :
LOOP1   VARY    3, A1, A2, A3
        :
        :
LOOP2   VARY    2, A3, A2
        :
        :
LOOP3   VARY    1, A1
        :
        :
A1      DC  F'5'
A2      DC  F'15'
A3      DC  F'10'
```



```
// Expanded Source code
        :
LOOP1   A   1, A1
        A   2, A2
        A   3, A3
        :
        :
LOOP2   A   1, A3
        A   2, A2
        :
        :
LOOP3   A   1, A1
        :
        :
A1      DC  F'5'
A2      DC  F'15'
A3      DC  F'10'
```

AIF , .FINI, AGO

.FINI :- it is macro label and don't appear in output of macro processor.

AIF(&count EQ 1).FINI:- The pseuodo op directs the macro processor to skip the statement labeled .FINI, if "&count" value is 1; otherwise , the macro processor is to continue with the statement following AIF pseuodo op.

AGO:- it is unconditional branch pseudo op like "go to".

Design of Two pass macro Processor

Pass-1 :

- Recognizes Macro Definition
- Stores Macro Instruction Definitions

Pass-2 :

- Recognizes Macro Calls
- Expands calls and substitute actual arguments

Specifications of Data Structures

Pass-1 Data structures/ programs :

- Source program with macro definitions and macro calls
- Output file without macro definitions & with macro calls
- Macro Definition Table (MDT)
- Macro Name Table (MNT)
- Argument List Array (ALA)
- Macro Definition Table Counter (MDTC) : Integer Variable
- Macro Name Table Counter (MNTC): Integer Variable

Pass-2 Data structures/programs :

- Input file without macro definitions & with macro calls
- Expanded output file without macro definitions & macro calls (Free from Macro)
- Refers Macro Definition Table (MDT) created by Pass-1
- Refers Macro Name Table (MNT) created by Pass-1
- Argument List Array (ALA) to map formal parameters with actual
- Macro Definition Table Pointer (MDTP): Integer Variable

Formats of Data Structures

- Macro Name Table (MNT)

MNTC	Macro Name	MDTC
1	ADDS	1
2		
. .		

Formats of Data Structures (Cont..)

- **Macro Definition Table (MDT)**

MDTC	Macro Definition Instruction Entry (80 bytes per entry)
1	& Lab ADDS &A1, &A2
2	#0 A 1, #1
3	A 1, #2
4	MEND
5	
:	
:	
:	

Formats of Data Structures (Cont..)

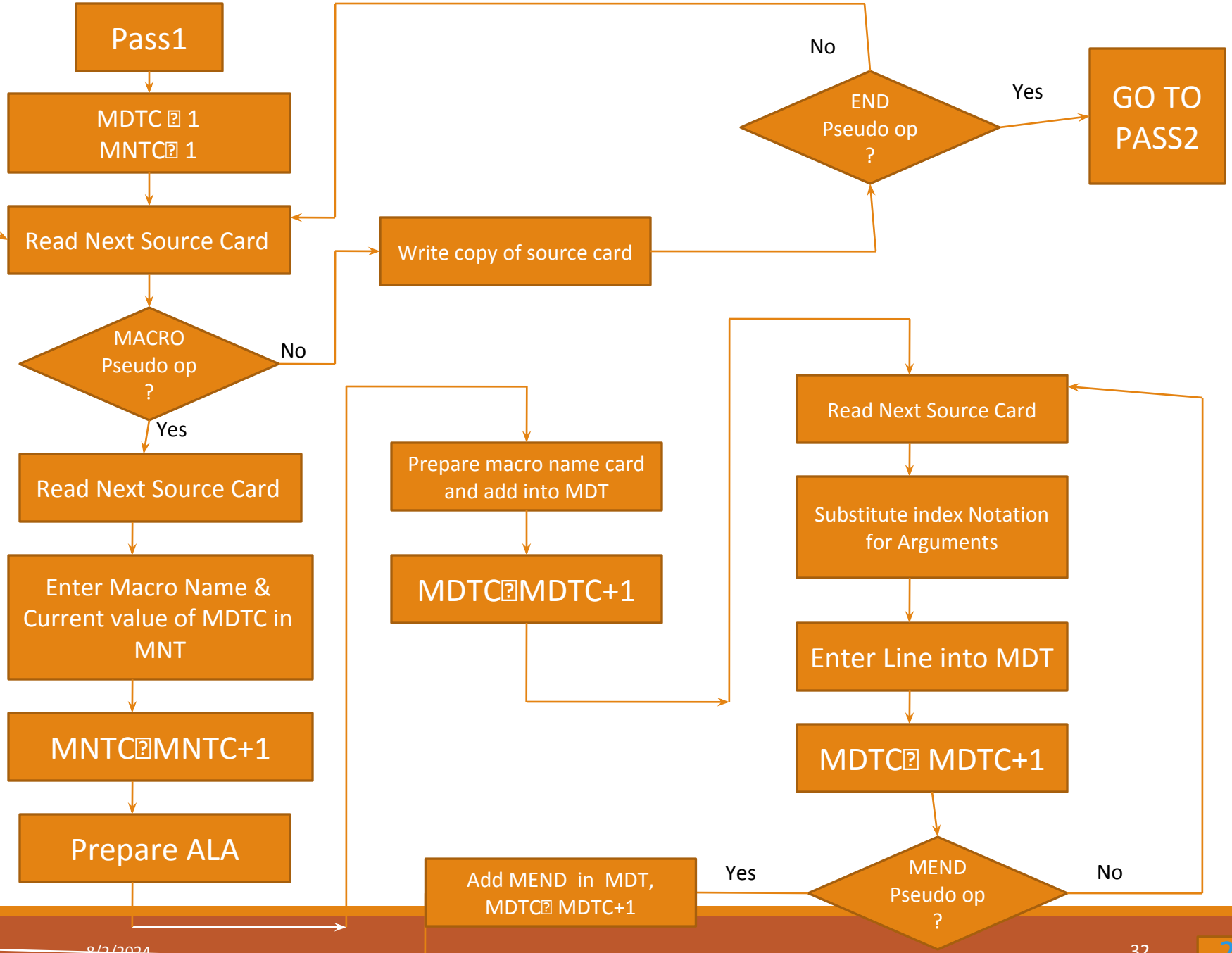
- **Arguments List Array (ALA)**

Index	Formal Arguments	Actual Arguments
0	&Lab	-
1	&A1	-
2	&A2	-
3		
:		
:		

Two Pass Macro Processor

Data structures used in two pass macro processor:-

1. Macro Definition Table(MDT) – Store definition of macro
2. Macro Name Table (MNT)– Store name of macro along with address of macro definition.
3. Argument List Array (ALA) – used to substitute index markers for dummy arguments before storing a macro definition.
4. Macro definition table counter (MDTC) – used to indicate the next available entry in the MDT
5. Macro name table counter (MNTC) – used to indicate the next available entry in MNT.
6. Macro definition table pointer (MDTP) – used to indicate the next line of text to be used during macro expansion.


Pass1
MDTC 1
MNTC 1
Read Next Source Card
MACRO Pseudo op ?
No
Yes
Read Next Source Card
Enter Macro Name & Current value of MDTC in MNT
MNTCMNTC+1
Prepare ALA
Write copy of source card
END Pseudo op ?
No
Yes
GO TO PASS2
Prepare macro name card and add into MDT
MDTCMDTC+1
Read Next Source Card
Substitute index Notation for Arguments
Enter Line into MDT
MDTC MDTC+1
MEND Pseudo op ?
Yes
No
Add MEND in MDT, MDTC MDTC+1

Source Code :

```
MAC     START  100
        MACRO
&A0     ADD1    &A1, &A2, &A3
&A0     L       1, &A1
        L       2, &A2
        AR      1, 2
        MUL     1, &A3
        ST      N, 1
        MEND
        MACRO
        SUB     &P1, &P2
        L       1, &P1
        S       1, &P2
        ST      2, 1
        MEND
TOTAL   EQU     5
        L       1,D1
        SR      2,2
        A       1,=F'5'
        ADD1    LOOP1, D1, D2, D3
        ST      2, 1
        AR      TOTAL, 2
        SUB     X, Y
        BR      14
D1      DC      F'3'
D2      DC      F'45'
D3      DC      F'21'
X       DC      F'10'
Y       DC      F'20'
        END
```

Intermediate Code after pass1:

```
MAC     START       100
TOTAL       EQU     5
            L       1, D1
            SR      2, 2
            A       1, =F'5'
            ADD1 LOOP1, D1, D2, D3
            ST      2, 1
            AR      TOTAL, 2
            SUB     X, Y
            BR      14
D1          DC      F'3'
D2          DC      F'45'
D3          DC      F'21'
X           DC      F'10'
Y           DC      F'20'

            END
```

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Macro Name Table :

MNTC	Macro Name	MDTC
1		

Argument List Array :

Index	Formal Args	Actual Args
1		
2		
3		
4		
5		
6		

Macro Definition Table :

MDTC	Macro Card
1	

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Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Formal Args	Actual Args.
1	&A0	
2	&A1	
3	&A2	
4	&A3	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1, &A2, &A3
2	

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Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Argument	Actual Args.
1	&A0	
2	&A1	
3	&A2	
4	&A3	
5		

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	

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Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1, 2
5	MUL 1 , #4
6	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2	SUB	8
3		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	&P1
6	&P2

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	SUB &P1, &P2
9	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2	SUB	8
3		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	&P1
6	&P2

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	SUB &P1, &P2
9	L 1, #5
10	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2	SUB	8
3		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	&P1
6	&P2

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	SUB &P1, &P2
9	L 1, #5
10	S 1, #6
11	

Macro Name Table :

MNTC	Macro Name	MDTC
1	ADD1	1
2	SUB	8
3		

Argument List Array :

Index	Argument
1	&A0
2	&A1
3	&A2
4	&A3
5	&P1
6	&P2

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	SUB &P1, &P2
9	L 1, #5
10	S 1, #6
11	ST 2, 1
12	

Macro Name Table :

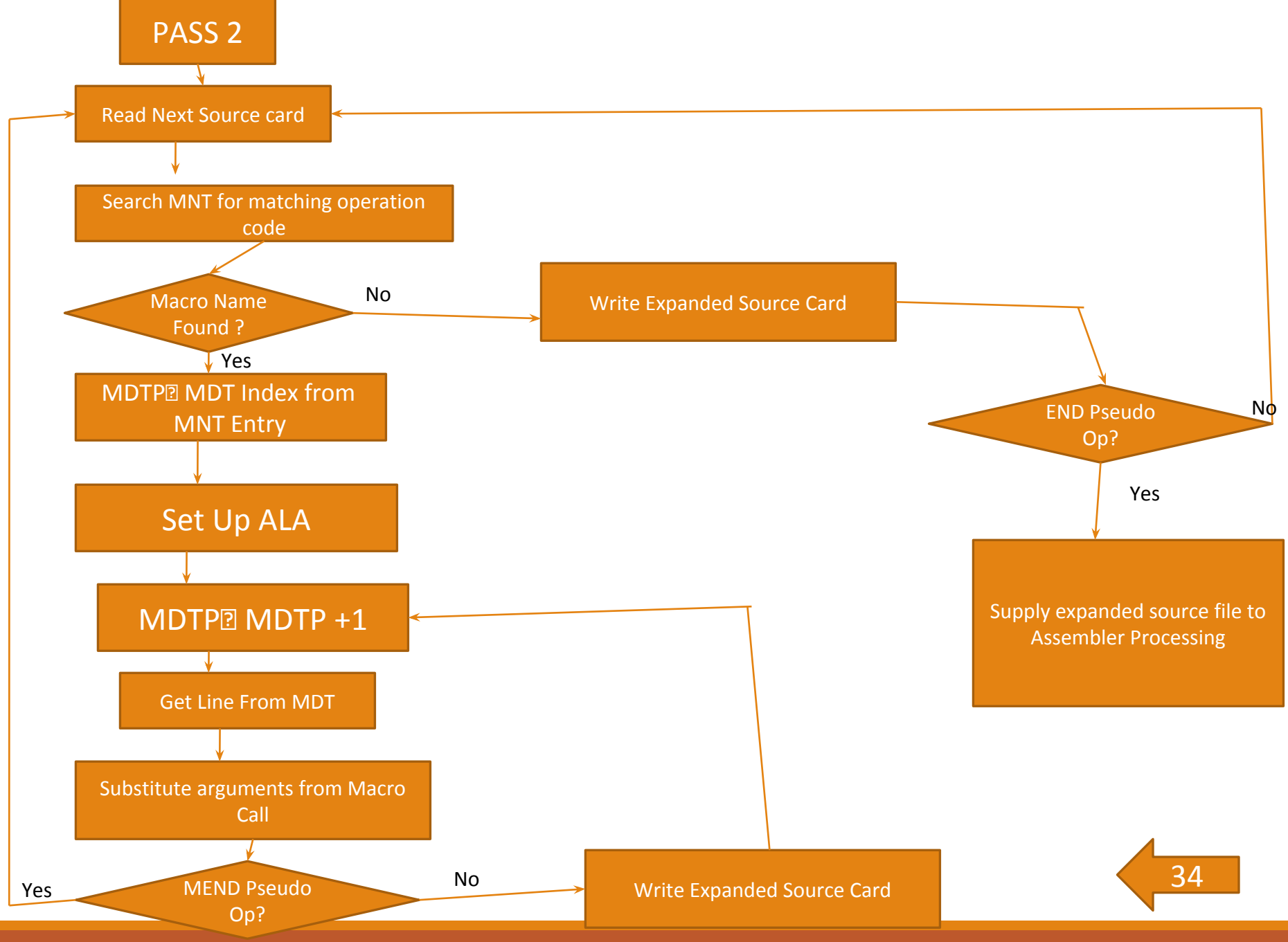
MNTC	Macro Name	MDTC
1	ADD1	1
2	SUB	8
3		

Argument List Array :

Index	Argument	Actual args
1	&A0	
2	&A1	
3	&A2	
4	&A3	
5	&P1	
6	&P2	

Macro Definition Table :

MDTC	Macro Card
1	&A0 ADD1 &A1,&A2,&A3
2	#1 L 1, #2
3	L 2, #3
4	AR 1,2
5	MUL 1 , #4
6	ST N,1
7	MEND
8	SUB &P1, &P2
9	L 1, #5
10	S 1, #6
11	ST 2, 1
12	MEND
13	


PASS 2
Read Next Source card
Search MNT for matching operation code
Macro Name Found ?
No
Yes
Write Expanded Source Card
END Pseudo Op?
No
Yes
MDTP MDT Index from MNT Entry
Set Up ALA
MDTP MDTP +1
Get Line From MDT
Substitute arguments from Macro Call
MEND Pseudo Op?
Yes
No
Write Expanded Source Card
Supply expanded source file to Assembler Processing
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ALA

Index	Formal	Actual
1	&A0	LOOP1
2	&A1	D1
3	&A2	D2
4	&A3	D3
5	&P1	X
6	&P2	Y

Intermediate Code after pass1 (input file for pass 2):

```
MAC START     100
TOTAL   EQU   5
        L     1, D1
        SR    2, 2
        A     1, =F'5'
        ADD1  LOOP1, D1, D2, D3
        ST    2, 1
        AR    TOTAL, 2
        SUB   X, Y
        BR    14
D1      DC    F'3'
D2      DC    F'45'
D3      DC    F'21'
X       DC    F'10'
Y       DC    F'20'

        END
```

Expanded Source Code :

```
MAC     START       100
TOTAL   EQU   5
        L     1, D1
        SR    2, 2
        A     1, =F'5'
LOOP1   L     1, D1
        L     2, D2
        AR    1, 2
        MUL   1, D3
        ST    N, 1
        ST    2, 1
        AR    TOTAL, 2
        L     1, X
        S     1, Y
        ST    2, 1

        BR    14
D1      DC    F'3'
D2      DC    F'45'
D3      DC    F'21'
X       DC    F'10'
Y       DC    F'20'
        END
```

MDTP= 1, 2, 3, 4, 5, 6, 7 for ADD1
MDTP= 8, 9, 10, 11, 12, 13 for SUB

Macro calls within Macros

Macro Calls Within Macro

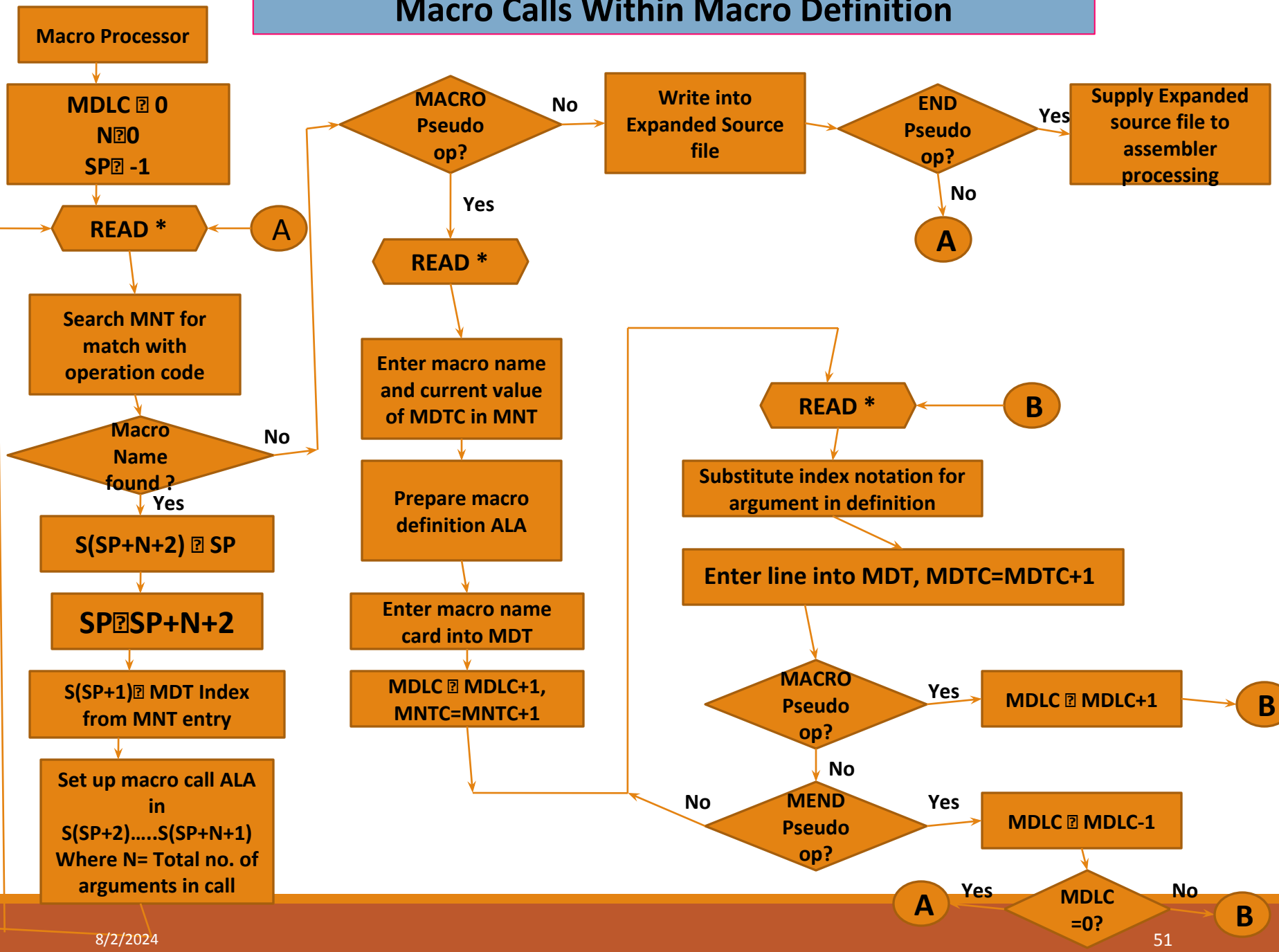
```
MACRO
ADD1    &ARG
L       1, &ARG
A       1, =F'1'
ST      1, &ARG
MEND
MACRO
ADDS    &ARG1, &ARG2, &ARG3
ADD1    &ARG1       ……
ADD1    &ARG2       ……
ADD1    &ARG3       ……
MEND
```

macro call in macro definition

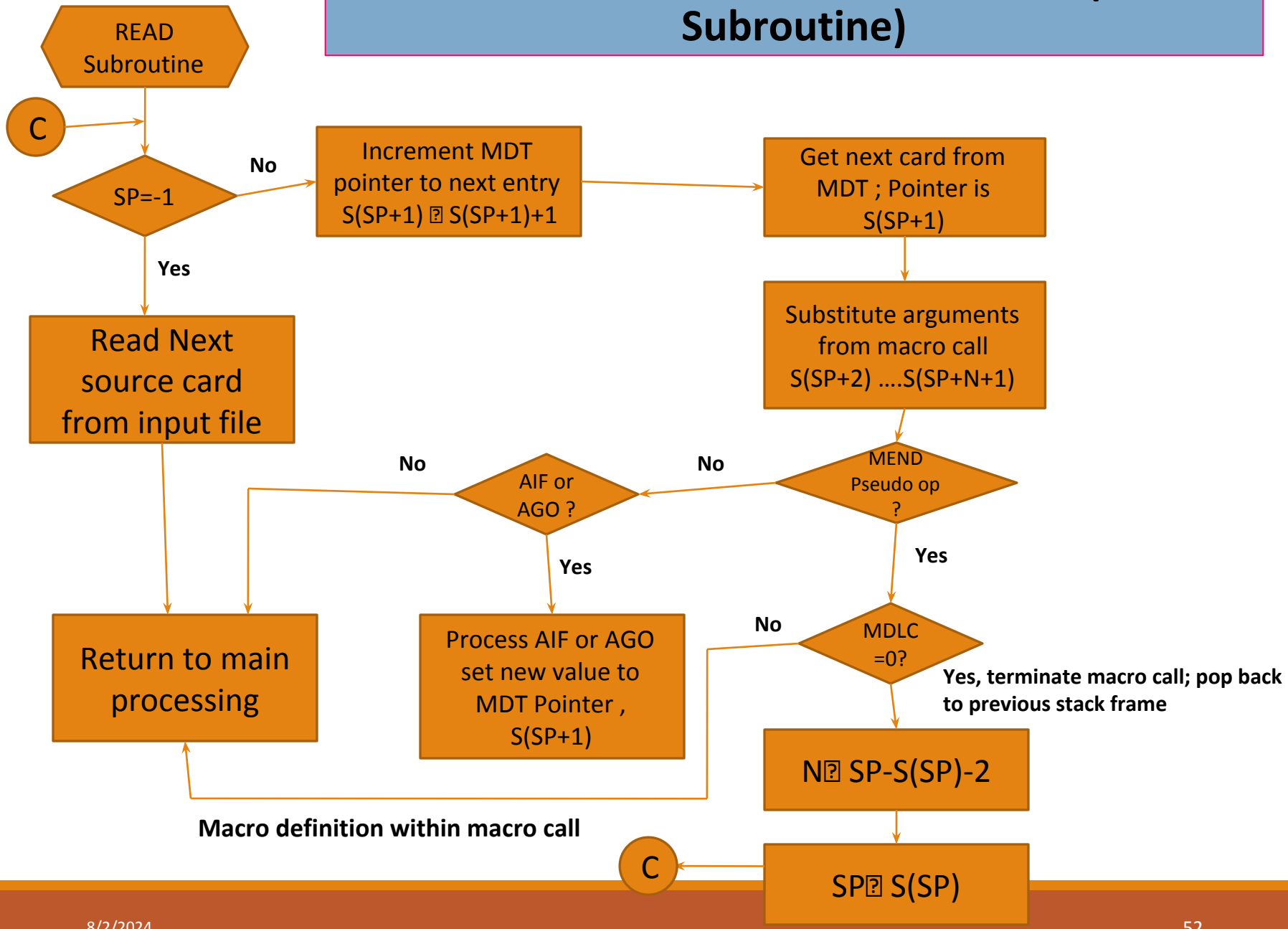
Macro Calls Within Macro (Cont….)

- To handle macro call within macros, macro processor has to work **recursively.**
- It uses **stack** to keep track of unfinished computations.
- For every macro call, **separate stack frame** is created.
- **SP**:- It is a **Stack Position**. It indicates the position or stack frame no. at the top of the stack. i.e. It is the **beginning position of current stack frame**.
- **S(SP):-** It refers to the beginning of the current stack frame. (i.e. the **contents of the stack at position "SP"**.
- **MDLC:-** Macro Definition Level Counter
- **N:-** no. of arguments in macro call along with label argument.

Macro Calls Within Macro Definition

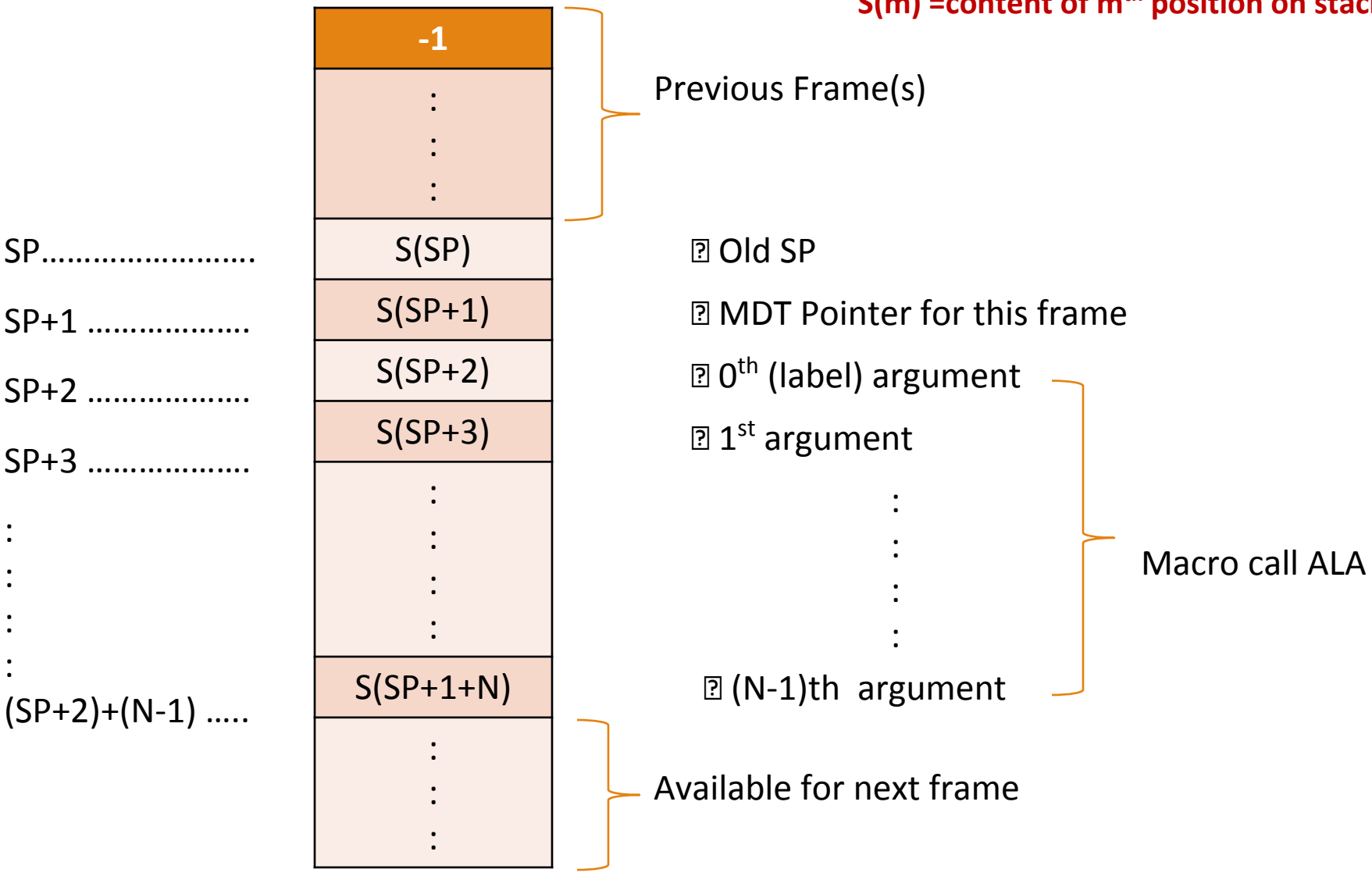


Macro Calls Within Macro Definition (READ Subroutine)



Stack Organization

N=No. of arg. On macro line
SP = current value of stack pointer
S(m) =content of m^{th} position on stack



SP=-1

S(1)	-1

index

SP=1

S(1)	-1
S(2)	6
S(3)	Blank
S(4)	D1
S(5)	D2
S(6)	D3

Call:- ADDS D1, D2, D3

Macro Call:- ADD1 D1

SP=7

S(1)	-1
.	7
.	Blank
.	D1
.	D2
.	D3
S(7)	1
S(8)	1
S(9)	Blank
S(10)	D1
.	
.	

previous stack frame

Current stack frame

```
MACRO
ADD1      &ARG
L1,&ARG
A      1,=F'1'
ST     1, &ARG
MEND
MACRO
ADDS      &A1, &A2, &A3
ADD1      &A1
ADD1      &A2
ADD1      &A3
MEND
ADDS      D1, D2, D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNT C	DEFINITION
1	

MNTC	NAME	MDTC	INDEX	ARGUMENT
1				

```
MACRO
ADD1      &ARG
L1,&ARG
A      1,=F'1'
ST     1, &ARG
MEND
MACRO
ADDS      &A1, &A2, &A3
ADD1      &A1
ADD1      &A2
ADD1      &A3
MEND
ADDS      D1, D2, D3
:
:
END
```

MDLC → 0
N → 0
SP → -1

MNTC	DEFINITION
1	

MNTC	NAME	MDTC	INDEX	ARGUMENT
1				

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNTC	DEFINITION
1	

MNTC	NAME	MDTC	INDEX	ARGUMENT
1	ADD1	1		
2				

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC ? 0

N ? 0

SP ? -1

MNTC	DEFINITION
1	

MNTC	NAME	MDTC	INDEX	ARGUMENT
1	ADD1	1	1	&ARG
2				

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0,1
N → 0
SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	

MNTC	NAME	MDTC	INDEX	ARGUMENT
1	ADD1	1	1	&ARG
2				

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0,1
N → 0
SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	

MNTC	NAME
1	ADD1
2	

MDTC
1

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0,1
N → 0
SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	

MNTC	NAME
1	ADD1
2	

MDTC
1

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0,1
N → 0
SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	

MNTC	NAME
1	ADD1
2	

MDTC
1

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	

MNTC	NAME
1	ADD1
2	

MDTC
1

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	

MNTC	NAME	MDTC
1	ADD1	1
2		

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MDLC → 0

N → 0

SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	

MNTC	NAME
1	ADD1
2	ADDS
3	

MDTC
1
6

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MDLC → 0, 1
N → 0
SP → -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MDLC ? 0, 1
N ? 0
SP ? -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MDLC → 0, 1
N → 0
SP → -1

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1     &ARG
L    1, &ARG
A    1, =F'1'
ST   1, &ARG
MEND
MACRO
ADDS     &A1, &A2, &A3
ADD1     &A1
ADD1     &A2
ADD1     &A3
MEND
ADDS     D1, D2, D3
:
:
END
```

MDLC → 0, 1
N → 0
SP → -1

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MDLC → 0
N → 0
SP → -1

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L       1, &ARG
A       1, =F'1'
ST      1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

1	-1
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

MDLC ? 0
N ? 0
SP ? -1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MDLC ? 0
N ? 0
SP ? -1, 1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

```
MACRO
ADD1     &ARG
L    1, &ARG
A    1, =F'1'
ST   1, &ARG
MEND
MACRO
ADDS     &A1, &A2, &A3
ADD1     &A1
ADD1     &A2
ADD1     &A3
MEND
ADDS     D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MDLC ? 0
N ? 0
SP ? -1, 1

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	6
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1     &ARG
L    1, &ARG
A    1, =F'1'
ST   1, &ARG
MEND
MACRO
ADDS     &A1, &A2, &A3
ADD1     &A1
ADD1     &A2
ADD1     &A3
MEND
ADDS     D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	6
3	Blk
4	D1
5	D2
6	D3
7	
8	
9	
10	
11	
12	

MDLC ? 0
N ? 0,4
SP ? -1,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MDLC ? 0
N ? 0,4
SP ? -1, 1

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	
8	
9	
10	
11	
12	

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	
8	
9	
10	
11	
12	

MDLC ? 0
N ? 0, 4
SP ? -1, 1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

ADD1 D1

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2, &A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

MDLC ? 0
N ? 0, 4
SP ? -1, 1

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	
9	
10	
11	
12	

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	
9	
10	
11	
12	

MDLC → 0
N → 0, 4
SP → -1, 1, 7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	1
9	
10	
11	
12	

MDLC → 0
N → 0,4
SP → -1,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	1
9	Blk
10	D1
11	
12	

MDLC ⍰ 0
N ⍰ 0,4,2
SP ⍰ -1,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	2
9	Blk
10	D1
11	
12	

MDLC → 0
N → 0,4,2
SP → -1,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A   1,=F'1'
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	3
9	Blk
10	D1
11	
12	

MDLC → 0
N → 0,4,2
SP → -1,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	4
9	Blk
10	D1
11	
12	

MDLC ⍰ 0
N ⍰ 0,4,2
SP ⍰ -1,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
```

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D1
11	
12	

MDLC ? 0
N ? 0,4,2,4
SP ? -1,1,7,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
```

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D1
11	
12	

MDLC ? 0
N ? 0,4,2,4
SP ? -1,1,7,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

ADD1 D2

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
```

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	1
9	Blk
10	D2
11	
12	

MDLC ? 0
N ? 0,4,2,4,2
SP ? -1,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

ADD1 D2

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
```

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	2
9	Blk
10	D2
11	
12	

MDLC ⍰ 0
N ⍰ 0,4,2,4,2
SP ⍰ -1,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	3
9	Blk
10	D2
11	
12	

MDLC → 0
N → 0,4,2,4,2
SP → -1,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L    1, &ARG
A    1, =F'1'
ST   1, &ARG
MEND
MACRO
ADDS    &A1, &A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L    1, D1
A  1, =F'1'
ST  1, D1
L    1, D2
A  1, =F'1'
ST  1, D2
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	4
9	Blk
10	D2
11	
12	

MDLC ⍰ 0
N ⍰ 0,4,2,4,2
SP ⍰ -1,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D2
11	
12	

MDLC → 0
N → 0,4,2,4,2,4,
SP → -1,1,7,1,7,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
```

1	-1
2	9
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D2
11	
12	

MDLC → 0
N → 0,4,2,4,2,4
SP → -1,1,7,1,7,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

ADD1 D3

```
MACRO
ADD1    &ARG
L   1, &ARG
A   1, =F'1'
ST  1, &ARG
MEND
MACRO
ADDS    &A1, &A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1, D2, D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1, D1
A  1, =F'1'
ST  1, D1
L   1, D2
A  1, =F'1'
ST  1,D2
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	8
3	Blk
4	D1
5	D2
6	D3
7	1
8	1
9	Blk
10	D3
11	
12	

MDLC → 0
N → 0,4,2,4,2,4,2
SP → -1,1,7,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

ADD1 D3

```
MACRO
ADD1&ARG
L     1, &ARG
A     1, =F'1'
ST    1, &ARG
MEND
MACRO
ADDS &A1, &A2, &A3
ADD1&A1
ADD1&A2
ADD1&A3
MEND
ADDS D1, D2, D31
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L    1,D1
A  1,=F'1'
ST  1,D1
L    1,D2
A  1,=F'1'
ST  1,D2
L    1,D3
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	2
9	Blk
10	D3
11	
12	

MDLC → 0
N → 0,4,2,4,2,4,2
SP → -1,1,7,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1, #1
3	A 1, =F'1'
4	ST 1, #1
5	MEND
6	ADDS &A1, &A2, &A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
L   1,D3
A  1,=F'1'
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	3
9	Blk
10	D3
11	
12	

MDLC → 0

N → 0,4,2,4,2,4,2

SP → -1,1,7,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
L   1,D3
A  1,=F'1'
ST  1,D3
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	4
9	Blk
10	D3
11	
12	

MDLC → 0

N → 0,4,2,4,2,4,2

SP → -1,1,7,1,7,1,7

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
L   1,D3
A  1,=F'1'
ST  1,D3
```

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

1	-1
2	7
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D3
11	
12	

MDLC → 0

N → 0,4,2,4,2,4,2,4

SP → -1,1,7,1,7,1,7,1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
L   1,D2
A  1,=F'1'
ST  1,D2
```

1	-1
2	10
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D3
11	
12	

MDLC → 0
N → 0,4,2,4,2,4,2,4,0
SP → -1,1,7,1,7,1,7,1,-1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

```
MACRO
ADD1    &ARG
L   1,&ARG
A   1,=F'1'
ST  1,&ARG
MEND
MACRO
ADDS    &A1,&A2,&A3
ADD1    &A1
ADD1    &A2
ADD1    &A3
MEND
ADDS    D1,D2,D3
:
:
END
```

INDEX	ARGUMENT
1	&ARG
2	&A1
3	&A2
4	&A3

```
L   1,D1
A  1,=F'1'
ST  1,D1
L   1,D2
A  1,=F'1'
ST  1,D2
L   1,D2
A  1,=F'1'
ST  1,D2
END
```

1	-1
2	10
3	Blk
4	D1
5	D2
6	D3
7	1
8	5
9	Blk
10	D3
11	
12	

MDLC → 0
N → 0,4,2,4,2,4,2,4,0
SP → -1,1,7,1,7,1,7,1,-1

MNTC	DEFINITION
1	ADD1 &ARG
2	L 1,#1
3	A 1,=F'1'
4	ST 1,#1
5	MEND
6	ADDS &A1,&A2,&A3
7	ADD1 #2
8	ADD1 #3
9	ADD1 #4
10	MEND
11	

MNTC	NAME	MDTC
1	ADD1	1
2	ADDS	6
3		

Single Pass Macro Processor

(Macro Definition Within Macro)

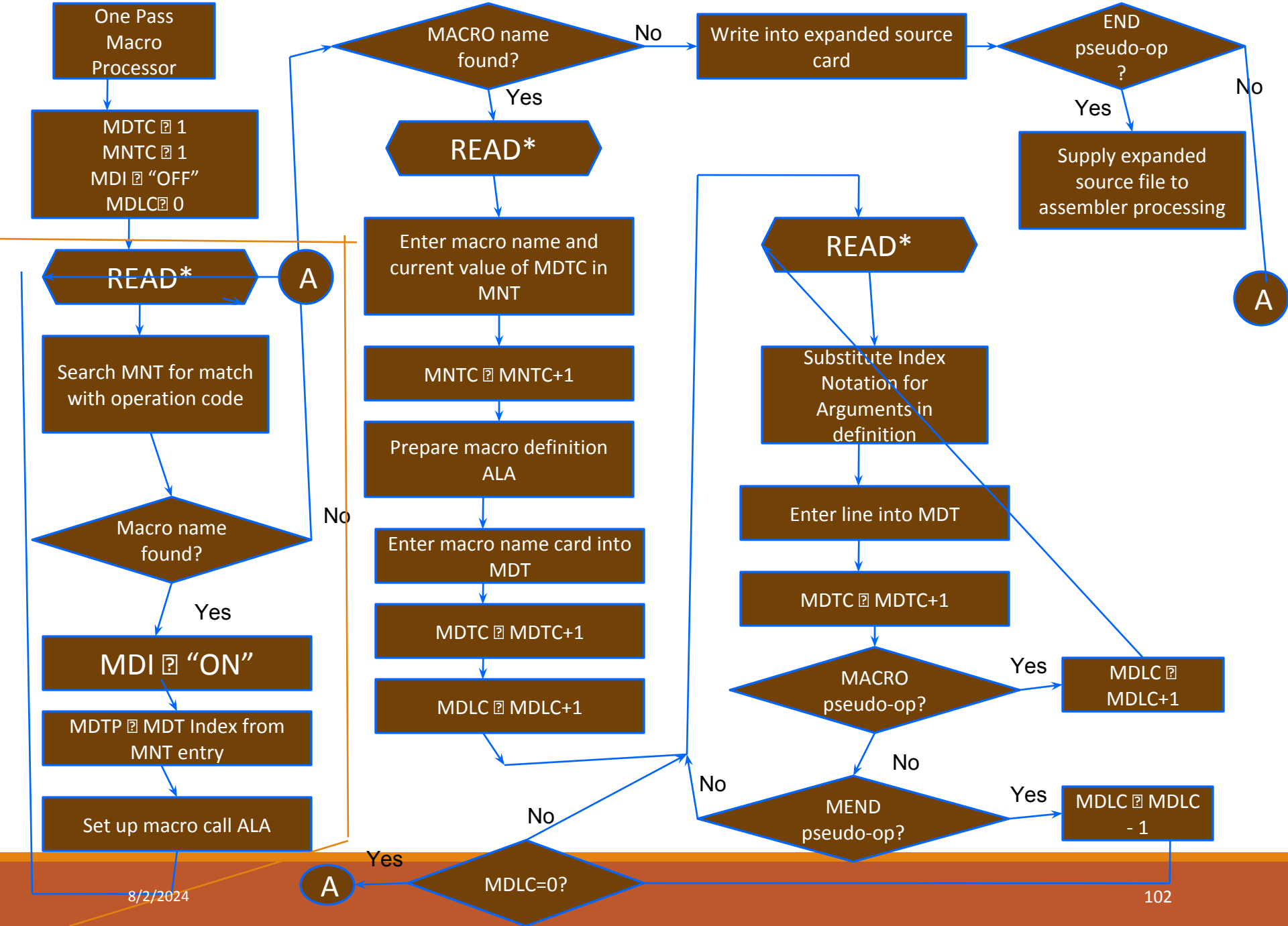
Example:

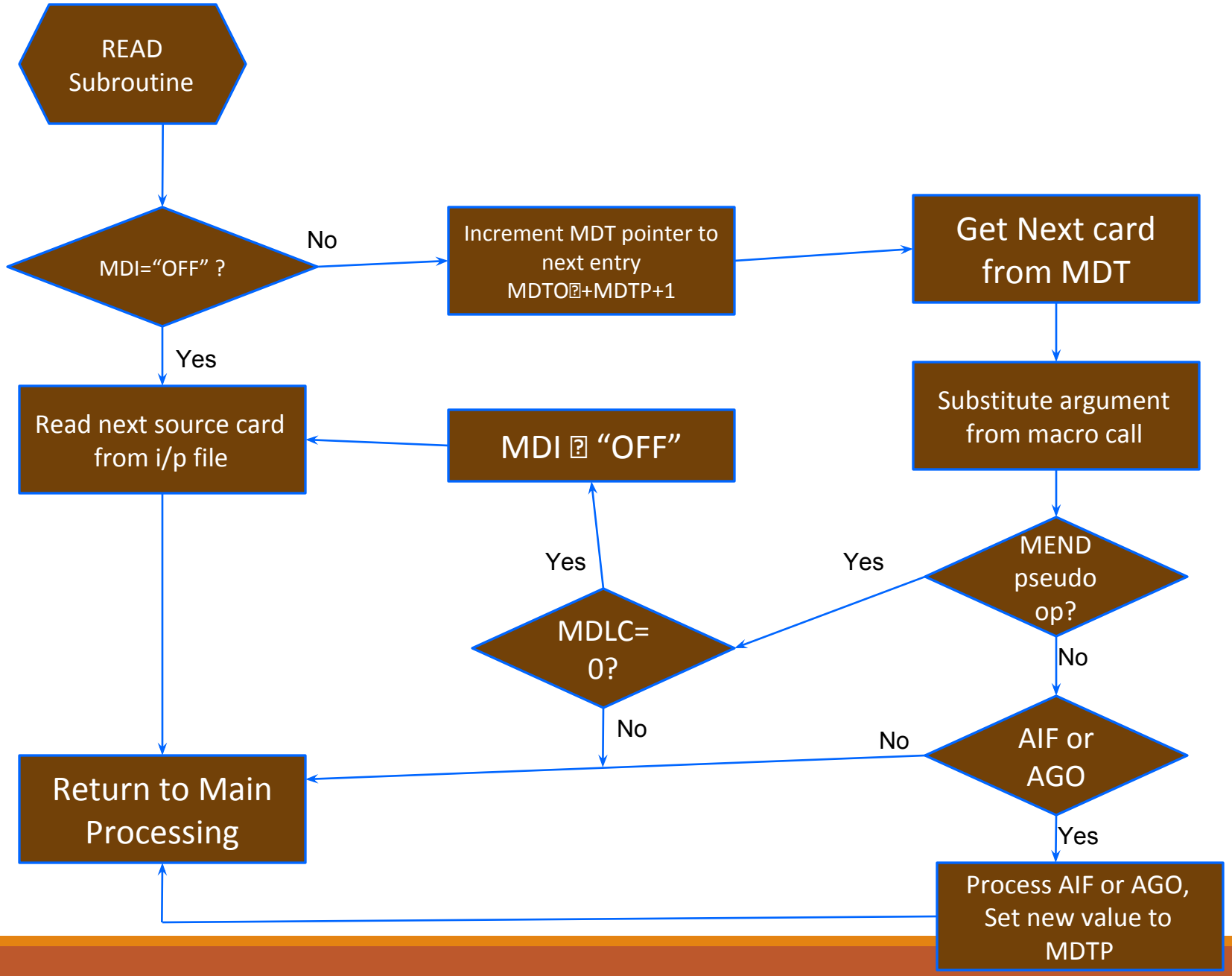
```
---------
---------
 MACRO
 DEFINE &SUB
 MACRO
 &SUB &Y
 CNOP 0, 4
 BAL 1, *+8
 DC A(&Y)
 L 15, =V(&SUB)
 BALR 14, 15
  MEND
  MEND
------
 DEFINE COS
 COS AR
```

inner macro definition

Outer macro definition

Macro call


One Pass Macro Processor
MDTC ⍰ 1
MNTC ⍰ 1
MDI ⍰ “OFF”
MDLC⍰ 0
READ*
A
Search MNT for match with operation code
Macro name found?
No
Yes
MDI ⍰ “ON”
MDTP ⍰ MDT Index from MNT entry
Set up macro call ALA
MACRO name found?
No
Yes
READ*
Enter macro name and current value of MDTC in MNT
MNTC ⍰ MNTC+1
Prepare macro definition ALA
Enter macro name card into MDT
MDTC ⍰ MDTC+1
MDLC ⍰ MDLC+1
Write into expanded source card
READ*
Substitute Index Notation for Arguments in definition
Enter line into MDT
MDTC ⍰ MDTC+1
MACRO pseudo-op?
Yes
MDLC ⍰ MDLC+1
No
MEND pseudo-op?
No
Yes
MDLC ⍰ MDLC - 1
MDLC=0?
No
Yes
A
END pseudo-op ?
Yes
No
Supply expanded source file to assembler processing
A


READ Subroutine
MDI="OFF" ?
No
Yes
Increment MDT pointer to next entry MDTO+MDTP+1
Get Next card from MDT
Substitute argument from macro call
MEND pseudo op?
Yes
No
AIF or AGO
No
Yes
Process AIF or AGO, Set new value to MDTP
MDLC= 0?
Yes
No
MDI "OFF"
Read next source card from i/p file
Return to Main Processing

Source Code

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL  1,*+8
DC   A(&Y)
L    15,=V(&SUB)
BALR 14,15
MEND
MEND
PROG START
     SR     1,1
     DEFINE COS
     AR     1,4
     COS    AR
     L      1,X
     END
```

MDTC=1
MNTC=1
MDI="OFF"
MDLC=0
MDTP=

ALA

INDEX	ARG

MNT

MNTC	NAME	MDTC

MDT

MDTC	DEF

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR      1,1
DEFINE      COS
      AR      1,4
COS   AR
      L       1,X
END
```

MDTC=1
MNTC=1
MDI="OFF"
MDLC=0
MDTP=

ALA

INDEX	ARG

MNT

MNTC	NAME	MDTC

MDT

MDTC	DEF

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=2

MNTC=2

MDI="OFF"

MDLC=1

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=3

MNTC=2

MDI="OFF"

MDLC=2

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=4

MNTC=2

MDI="OFF"

MDLC=2

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=5
MNTC=2
MDI="OFF"
MDLC=2
MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL  1,*+8
DC   A(&Y)
L    15,=V(&SUB)
BALR 14,15
MEND
MEND
PROG START
     SR       1,1
DEFINE   COS
     AR       1,4
COS  AR
     L        1,X
END
```

MDTC=6
MNTC=2
MDI="OFF"
MDLC=2
MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL  1,*+8
DC   A(&Y)
L    15,=V(&SUB)
BALR 14,15
MEND
MEND
PROG START
     SR       1,1
DEFINE    COS
     AR       1,4
COS  AR
     L        1,X
END
```

MDTC=7

MNTC=2

MDI="OFF"

MDLC=2

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	

Reading Next source card after entering line into MDT

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL  1,*+8
DC   A(&Y)
L    15,=V(&SUB)
BALR 14,15
MEND
MEND
PROG START
     SR       1,1
DEFINE   COS
     AR       1,4
COS  AR
     L        1,X
END
```

MDTC=8
MNTC=2
MDI="OFF"
MDLC=2
MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=9
MNTC=2
MDI="OFF"
MDLC=2
MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=10

MNTC=2

MDI="OFF"

MDLC=1

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=11

MNTC=2

MDI="OFF"

MDLC=0

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=11

MNTC=2

MDI="OFF"

MDLC=0

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	

EXPANDED SOURCE FILE

```
PROG START
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=11

MNTC=2

MDI="OFF"

MDLC=0

MDTP=

ALA

INDEX	ARG
#0	&SUB

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR      1,1
DEFINE      COS
      AR      1,4
COS   AR
      L       1,X
END
```

MDTC=11
MNTC=2
MDI="ON"
MDLC=0
MDTP=1

ALA

INDEX	ARG
#0	COS

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	

EXPANDED SOURCE FILE

```
PROG START
      SR    1, 1
```


Reading Next source card i.e. call to outer MACRO

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=11

MNTC=2

MDI="ON"

MDLC=0

MDTP=2

ALA

INDEX	ARG
#0	COS

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0 &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=12

MNTC=3

MDI="ON"

MDLC=1

MDTP=3

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR      1,1
DEFINE      COS
      AR      1,4
COS   AR
      L       1,X
END
```

MDTC=13

MNTC=3

MDI="ON"

MDLC=1

MDTP=4

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	

EXPANDED SOURCE FILE

```
PROG START
      SR      1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=14

MNTC=3

MDI="ON"

MDLC=1

MDTP=5

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR      1,1
DEFINE      COS
      AR      1,4
COS   AR
      L       1,X
END
```

MDTC=15

MNTC=3

MDI="ON"

MDLC=1

MDTP=6

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	

EXPANDED SOURCE FILE

```
PROG START
      SR      1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR      1,1
DEFINE      COS
      AR      1,4
COS   AR
      L       1,X
END
```

MDTC=16

MNTC=3

MDI="ON"

MDLC=1

MDTP=7

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	

EXPANDED SOURCE FILE

```
PROG START
      SR      1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=17

MNTC=3

MDI="ON"

MDLC=1

MDTP=8

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	

EXPANDED SOURCE FILE

```
PROG START
        SR      1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=9

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

Reading Next source card which expansion of MACRO DEFINE & MDLC=0

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=10

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=10

ALA

INDEX	ARG
#0	COS
#1	&Y

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=11

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1, 1
      AR    1, 4
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=12

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15, =V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=13

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15, =V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
```


Expansion of MACRO COS started & written to expanded source file

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=14

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15, =V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC          A(AR)
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=15

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="ON"

MDLC=0

MDTP=16

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
      BALR  14,15
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=17

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
      BALR  14,15
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL  1,*+8
DC   A(&Y)
L    15,=V(&SUB)
BALR 14,15
MEND
MEND
PROG START
     SR       1,1
DEFINE      COS
     AR       1,4
COS  AR
     L        1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=17

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
      BALR  14,15
      L     1,X
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=17

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
      BALR  14,15
      L     1,X
      END
```

```
MACRO
DEFINE      &SUB
MACRO
&SUB &Y
CNOP 0,4
BAL   1,*+8
DC    A(&Y)
L     15,=V(&SUB)
BALR  14,15
MEND
MEND
PROG START
      SR          1,1
DEFINE      COS
      AR          1,4
COS   AR
      L           1,X
END
```

MDTC=18

MNTC=3

MDI="OFF"

MDLC=0

MDTP=17

ALA

INDEX	ARG
#0	COS
#1	AR

MNT

MNTC	NAME	MDTC
1	DEFINE	1
2	COS	11
3		

MDT

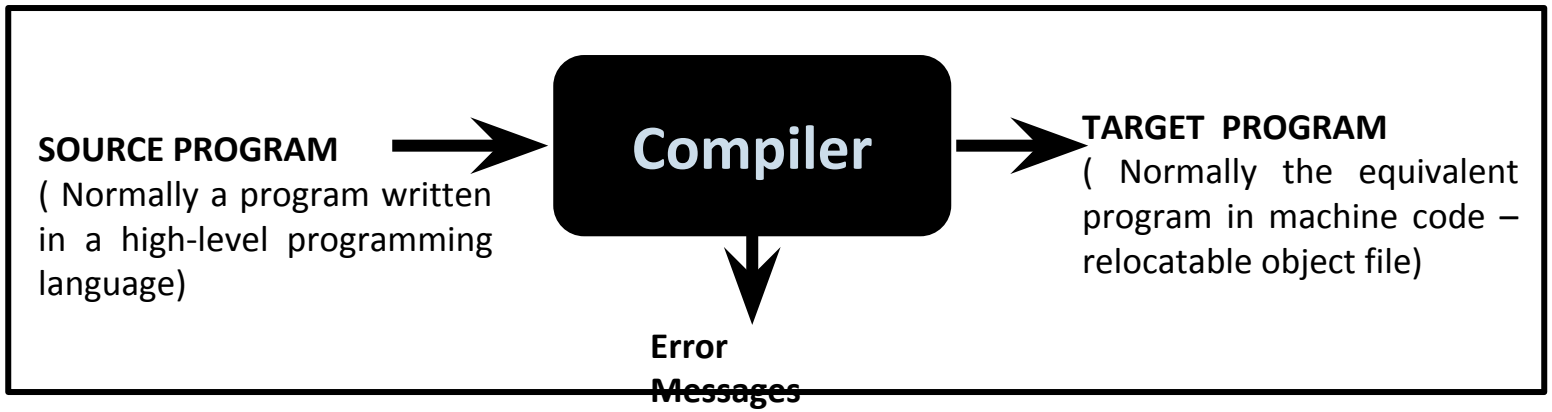
MDTC	DEF
1	DEFINE &SUB
2	MACRO
3	#0/COS &Y
4	CNOP 0,4
5	BAL 1,*+8
6	DC A(&Y)
7	L 15,=V(#0)
8	BALR 14,15
9	MEND
10	MEND
11	COS &Y
12	CNOP 0,4
13	BAL 1,*+8
14	DC A(#1)
15	L 15,=V(COS)
16	BALR 14,15
17	MEND
18	

EXPANDED SOURCE FILE

```
PROG START
      SR    1,1
      AR    1,4
      CNOP  0,4
      BAL   1,*+8
      DC    A(AR)
      L     15,=V(COS)
      BALR  14,15
      L     1,X
      END
```

Output Expanded source file is ready (END of processing)

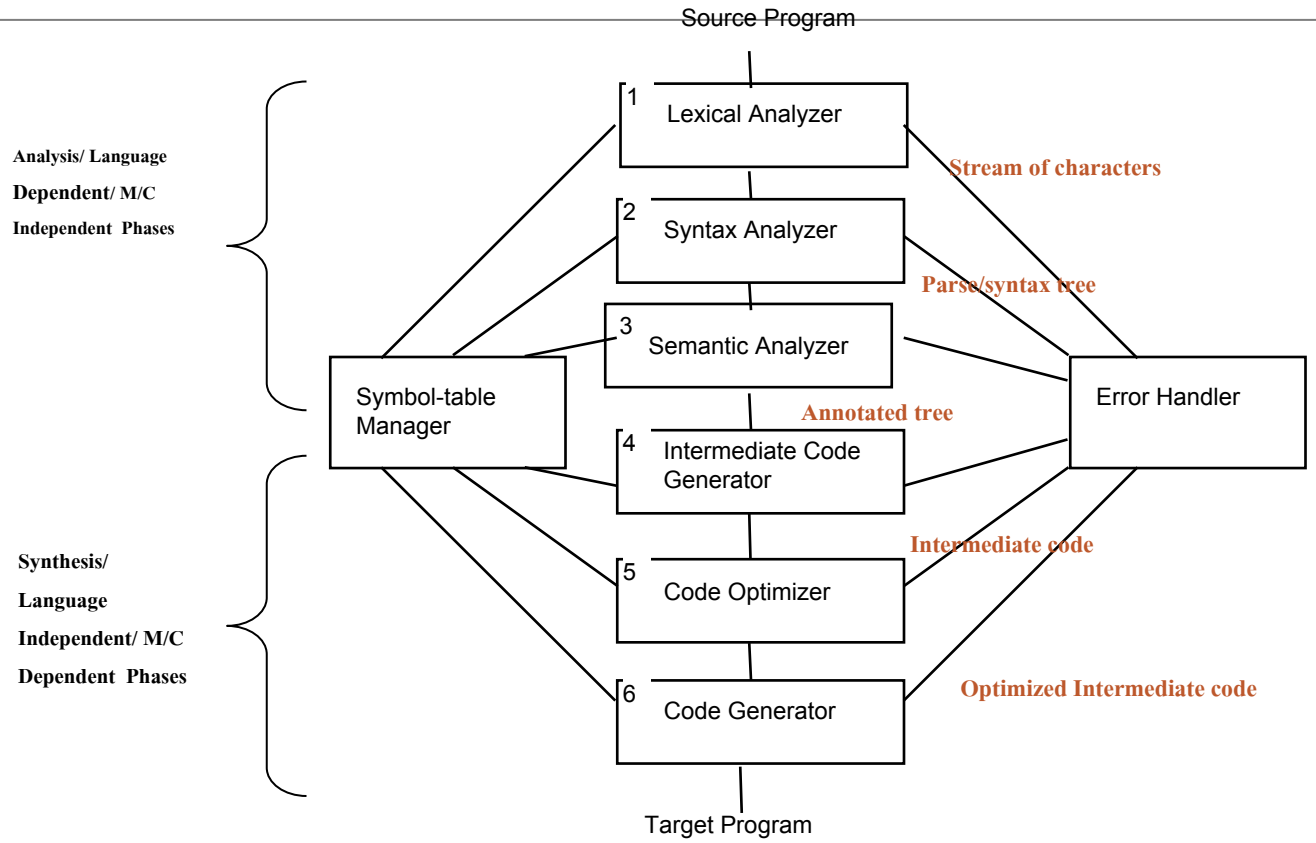
Compiler



Syllabus

Let’s have a look at, what happens inside Black Box

General Model of Compiler



The Structure of a Compiler

```
position := initial + rate * 60
```

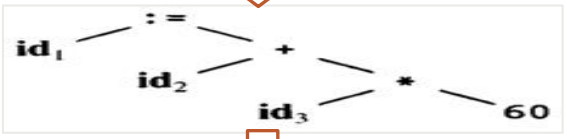
Scanner
[Lexical Analyzer]

Tokens

$id_1 := id_2 + id_3 * 60$

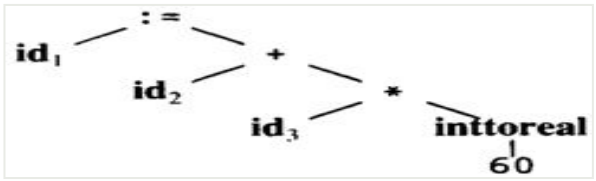
Parser
[Syntax Analyzer]

Parse tree



Semantic Process
[Semantic analyzer]

Abstract Syntax Tree w/ Attributes



SYMBOL TABLE

1	position	...
2	initial	...
3	rate	...
4		

Code Generator
[Intermediate Code Generator]

Non-optimized Intermediate Code

```
temp1 := inttoreal(60)
temp2 := id3 * temp1
temp3 := id2 + temp2
id1 := temp3
```

Code Optimizer

Optimized Intermediate Code

```
temp1 := id3 * 60.0
id1 := id2 + temp1
```

Code Generator

Target machine code

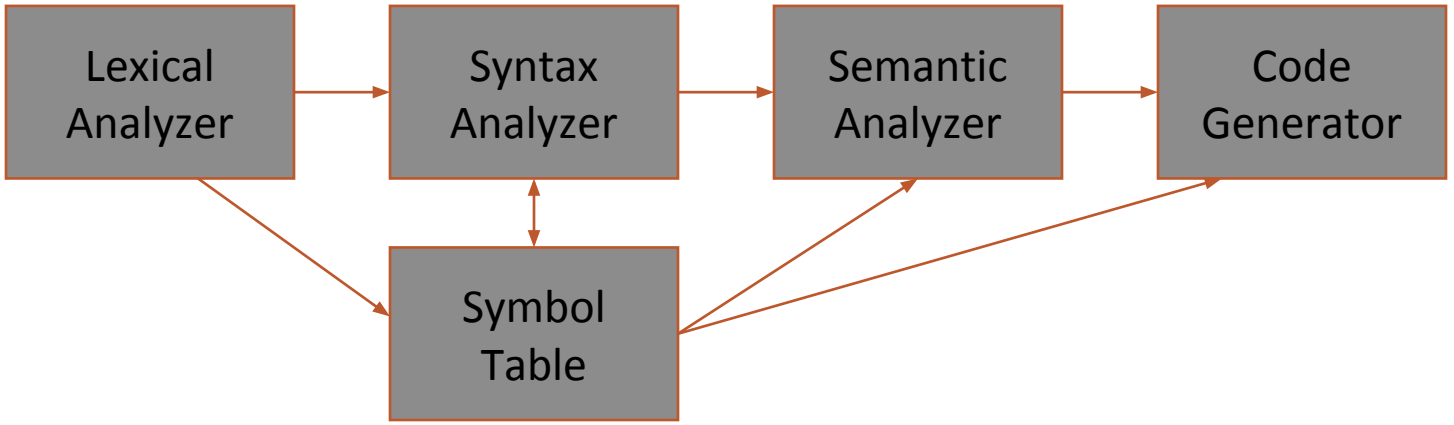
```
MOVF id3, R2
MULF #60.0, R2
MOVF id2, R1
ADDF R2, R1
MOVF R1, id1
```

Symbol Table

- Compiler uses symbol table to keep track of scope and binding information about names.
- Symbol table is searched every time when a name is encountered in source text.
- Changes occur in symbol table if a new name or new info about existing name is discovered.
- Two symbol table mechanisms are presented generally, linear list, hash tables.
- Compiler should grow S.T. dynamically at compile time or the symbol table can be kept fixed.

The Symbol Table

- When identifiers are found, they will be entered into a symbol table, which will hold all relevant information about identifiers.
- When the symbol is first encountered by the lexer, we do not yet know the scope.
- That is determined later by the parser.
- This information will be used later by the semantic analyzer and the code generator.



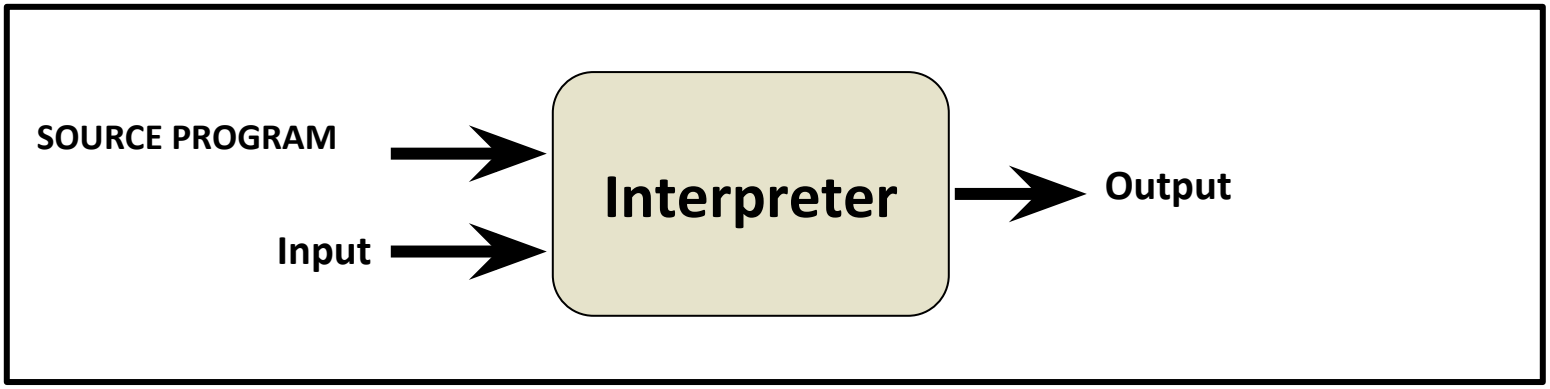
Symbol Table Entries

We will store the following information about identifiers.

- The name (as a string).
- The data type and value.
- The block level.
- Its scope (global, local, or parameter).
- Its offset from the base pointer (for local variables and parameters only).

Interpreter

It is a translator (language processor) which directly executes operations specified in source program on input supplied by user.



Interpreter vs Compiler

Interpreter	Compiler
Translates program by one statement at a time.	Scans the entire program and translates it as a whole into machine code.
It takes less amount of time to analyze the source code but the overall execution time is slower.	It takes large amount of time to analyze the source code but the overall execution time is comparatively faster.
No intermediate object code is generated, hence are memory efficient.	Generates intermediate object code which further requires linking, hence requires more memory.
Continues translating the program until the first error is met, in which case it stops. Hence debugging is easy.	It generates the error message only after scanning the whole program. Hence debugging is comparatively hard.
Programming language like Python, Ruby use interpreters.	Programming language like C, C++ use compilers.

Case Study- GNU m4 Macro Processor

- m4 is a macro processor, it copies its input to the output, expanding macros as it goes.
- Macros are either built-in or user-defined, and can take any number of arguments.
- Besides just doing macro expansion, m4 has built-in functions for including named files in UNIX commands, **doing integer arithmetic, manipulating text** in various ways, recursion, etc.
- m4 can be used either as a **front-end to a compiler**, or as a macro processor in its own right.
- The most popular GNU Autoconf pre-requires GNU m4 for generating the 'configure' scripts.
- While these people will not themselves program in m4. GNU m4 is mostly compatible with the System V, Release 3 version, except for some minor differences.
- A General Purpose Macro generator (GPM) an important ancestor of m4 . m4 is mostly SVR4 compatible.

Case Study- GNU m4 Macro Processor

The format of the m4 command is:

m4 [*option*...] [*macro-definitions*...] [*input-file*...]

m4 --def foo --debug a is equivalent to

m4 --define=foo --debug= -- ./a

References

1) John Donovan, “Systems Programming”, McGraw Hill, ISBN 978-0--07-460482-3

2) Dhamdhere D., "Systems Programming and Operating Systems", McGraw Hill, ISBN 0 - 07 - 463579 – 4

3) https://www.gnu.org/software/m4/manual/m4.html#Syntax

Ebooks:

- https://www.elsevier.com/books/systems-programming/anthony/978-0-12-800729-7
- https://www.kobo.com/us/en/ebook/linux-system-programming-1
- https://www.e-booksdirectory.com/details.php?ebook=9907

MOOCs Courses Links:

- nptel video lecture link: https://nptel.ac.in/courses/106/105/106105214/
- https://onlinecourses.nptel.ac.in/noc19_cs50/preview
- https://www.udemy.com/course/system-programming/

Thank You !!