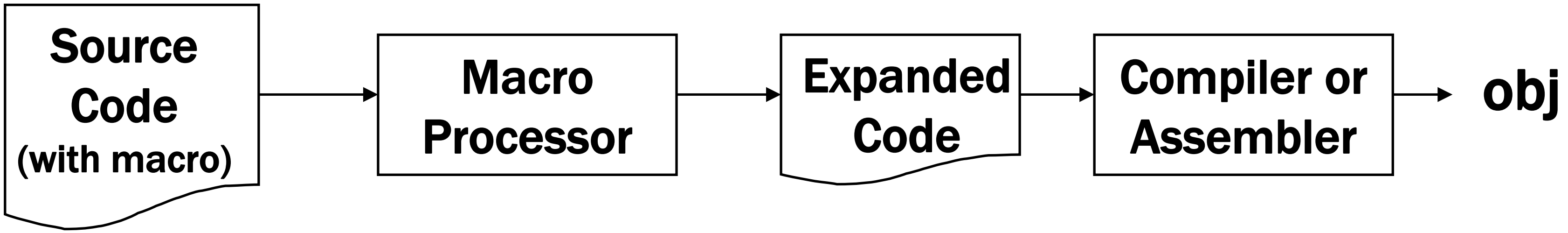
Chapter 4
Macro Processors



4.1 Basic Macro Processor Functions
4.1.1 Macro Definition and Expansion

- Fig. 4.1 shows an example of a SIC/XE program using macro instructions.
  - RDBUFF and WRBUFF
  - MACRO and MEND
  - RDBUFF is name
  - *Parameters* (參數) of the macro instruction, each parameter begins with the character &.
  - Macro invocation (引用) statement and the arguments (引數) to be used in expanding the macro.
- Fig. 4.2 shows the output that would be generated.

```
        COPY      START   0                   COPY FILE FROM INPUT TO OUTPUT
        RDBUFF    MACRO   &INDEV,&BUFADR,&RECLTH
        .
        .                 MACRO TO READ RECORD INTO BUFFER
        .
                  CLEAR   X                   CLEAR LOOP COUNTER
                  CLEAR   A
                  CLEAR   S
                 +LDT     #4096               SET MAXIMUM RECORD LENGTH
                  TD      =X'&INDEV'          TEST INPUT DEVICE
                  JEQ     *-3                 LOOP UNTIL READY
                  RD      =X'&INDEV'          READ CHARACTER INTO REG A
                  COMPR   A,S                 TEST FOR END OF RECORD
                  JEQ     *+11                EXIT LOOP IF EOR
                  STCH    &BUFADR,X           STORE CHARACTER IN BUFFER
                  TIXR    T                   LOOP UNLESS MAXIMUM LENGTH
                  JLT     *-19                  HAS BEEN REACHED
                  STX     &RECLTH             SAVE RECORD LENGTH
                  MEND
```

```
        WRBUFF   MACRO   &OUTDEV,&BUFADR,&RECLTH
        .
        .                MACRO TO WRITE RECORD FROM BUFFER
        .
                 CLEAR   X                  CLEAR LOOP COUNTER
                 LDT     &RECLTH
                 LDCH    &BUFADR,X          GET CHARACTER FROM BUFFER
                 TD      =X'&OUTDEV'        TEST OUTPUT DEVICE
                 JEQ     *-3                LOOP UNTIL READY
                 WD      =X'&OUTDEV'        WRITE CHARACTER
                 TIXR    T                  LOOP UNTIL ALL CHARACTERS
                 JLT     *-14                 HAVE BEEN WRITTEN
                 MEND
        .
        .        MAIN PROGRAM
        .
```

```
        FIRST    STL      RETADR              SAVE RETURN ADDRESS
        CLOOP    RDBUFF   F1,BUFFER,LENGTH    READ RECORD INTO BUFFER
                 LDA      LENGTH              TEST FOR END OF FILE
                 COMP     #0
                 JEQ      ENDFIL              EXIT IF EOF FOUND
                 WRBUFF   05,BUFFER,LENGTH    WRITE OUTPUT RECORD
                 J        CLOOP               LOOP
        ENDFIL   WRBUFF   05,EOF,THREE        INSERT EOF MARKER
                 J        @RETADR
        EOF      BYTE     C'EOF'
        THREE    WORD     3
        RETADR   RESW     1
        LENGTH   RESW     1                   LENGTH OF RECORD
        BUFFER   RESB     4096                4096-BYTE BUFFER AREA
                 END      FIRST
```

Figure 4.1 Use of macros in a SIC/XE program.

```
5      COPY      START     0                  COPY FILE FROM INPUT TO OUTPUT
180    FIRST     STL       RETADR             SAVE RETURN ADDRESS
190    .CLOOP    RDBUFF    F1,BUFFER,LENGTH   READ RECORD INTO BUFFER
190a   CLOOP     CLEAR     X                  CLEAR LOOP COUNTER
190b             CLEAR     A
190c             CLEAR     S
190d            +LDT      #4096               SET MAXIMUM RECORD LENGTH
190e             TD       =X'F1'              TEST INPUT DEVICE
190f             JEQ       *-3                LOOP UNTIL READY
190g             RD       =X'F1'              READ CHARACTER INTO REG A
190h             COMPR     A,S                TEST FOR END OF RECORD
190i             JEQ       *+11               EXIT LOOP IF EOR
190j             STCH      BUFFER,X           STORE CHARACTER IN BUFFER
190k             TIXR      T                  LOOP UNLESS MAXIMUM LENGTH
190l             JLT       *-19                 HAS BEEN REACHED
190m             STX       LENGTH             SAVE RECORD LENGTH
195              LDA       LENGTH             TEST FOR END OF FILE
200              COMP     #0
205              JEQ       ENDFIL             EXIT IF EOF FOUND
```

```
210          WRBUFF   05,BUFFER,LENGTH   WRITE OUTPUT RECORD
210a         CLEAR    X                  CLEAR LOOP COUNTER
210b         LDT      LENGTH
210c         LDCH     BUFFER,X           GET CHARACTER FROM BUFFER
210d         TD       =X'05'             TEST OUTPUT DEVICE
210e         JEQ      *-3                LOOP UNTIL READY
210f         WD       =X'05'             WRITE CHARACTER
210g         TIXR     T                  LOOP UNTIL ALL CHARACTERS
210h         JLT      *-14                 HAVE BEEN WRITTEN
215          J        CLOOP              LOOP
```

```
220         .ENDFIL    WRBUFF     05,EOF,THREE          INSERT EOF MARKER
220a        ENDFIL     CLEAR      X                     CLEAR LOOP COUNTER
220b                   LDT        THREE
220c                   LDCH       EOF,X                 GET CHARACTER FROM BUFFER
220d                   TD        =X'05'                 TEST OUTPUT DEVICE
220e                   JEQ        *-3                   LOOP UNTIL READY
220f                   WD        =X'05'                 WRITE CHARACTER
220g                   TIXR       T                     LOOP UNTIL ALL CHARACTERS
220h                   JLT        *-14                    HAVE BEEN WRITTEN
225                    J         @RETADR
230         EOF        BYTE       C'EOF'
235         THREE      WORD       3
240         RETADR     RESW       1
245         LENGTH     RESW       1                     LENGTH OF RECORD
250         BUFFER     RESB       4096                  4096-BYTE BUFFER AREA
255                    END        FIRST
```

Figure 4.2 Program from Fig. 4.1 with macros expanded.

Source

```
STRG   MACRO
       STA    DATA1
       STB    DATA2
       STX    DATA3
       MEND
   .
STRG
   .
STRG
   .
   .
```

Expanded source

```
   .
   .
   .
   .STRG
     { STA    DATA1
     { STB    DATA2
     { STX    DATA3
   .STRG
     { STA    DATA1
     { STB    DATA2
     { STX    DATA3
   .
```

4.1.2 Macro Processor Algorithm and Data Structures

- Two-pass macro processor
  - All macro definitions are processed during the first pass.
  - All macro invocation statements are expanded during the second pass.
  - Two-pass macro processor would not allow the body of one macro instruction to contain definitions of other macros.
- Such definitions of macros by other macros Fig. 4.3

```
1   MACROS    MACRO    {Defines SIC standard version macros}
2   RDBUFF    MACRO    &INDEV,&BUFADR,&RECLTH
              .
              .        {SIC  standard version}
              .
3             MEND     {End of RDBUFF}
4   WRBUFF    MACRO    &OUTDEV,&BUFADR,&RECLTH
              .
              .        {SIC standard version}
              .
5             MEND     {End of WRBUFF}
              .
              .
              .
6             MEND     {End of MACROS}
```

```
1   MACROX    MACRO      {Defines  SIC/XE macros}
2   RDBUFF    MACRO      &INDEV,&BUFADR,&RECLTH
                .
                .        {SIC/XE version}
                .
3             MEND       {End of RDBUFF}
4   WRBUFF    MACRO      &OUTDEV,&BUFADR,&RECLTH
                .
                .        {SIC/XE version}
                .
5             MEND       {End of WRBUFF}
                .
                .
                .
6             MEND       {End of MACROX}
```

(b)

Figure 4.3 Example of the definition of macros within a macro body.

4.1.2 Macro Processor Algorithm and Data Structures

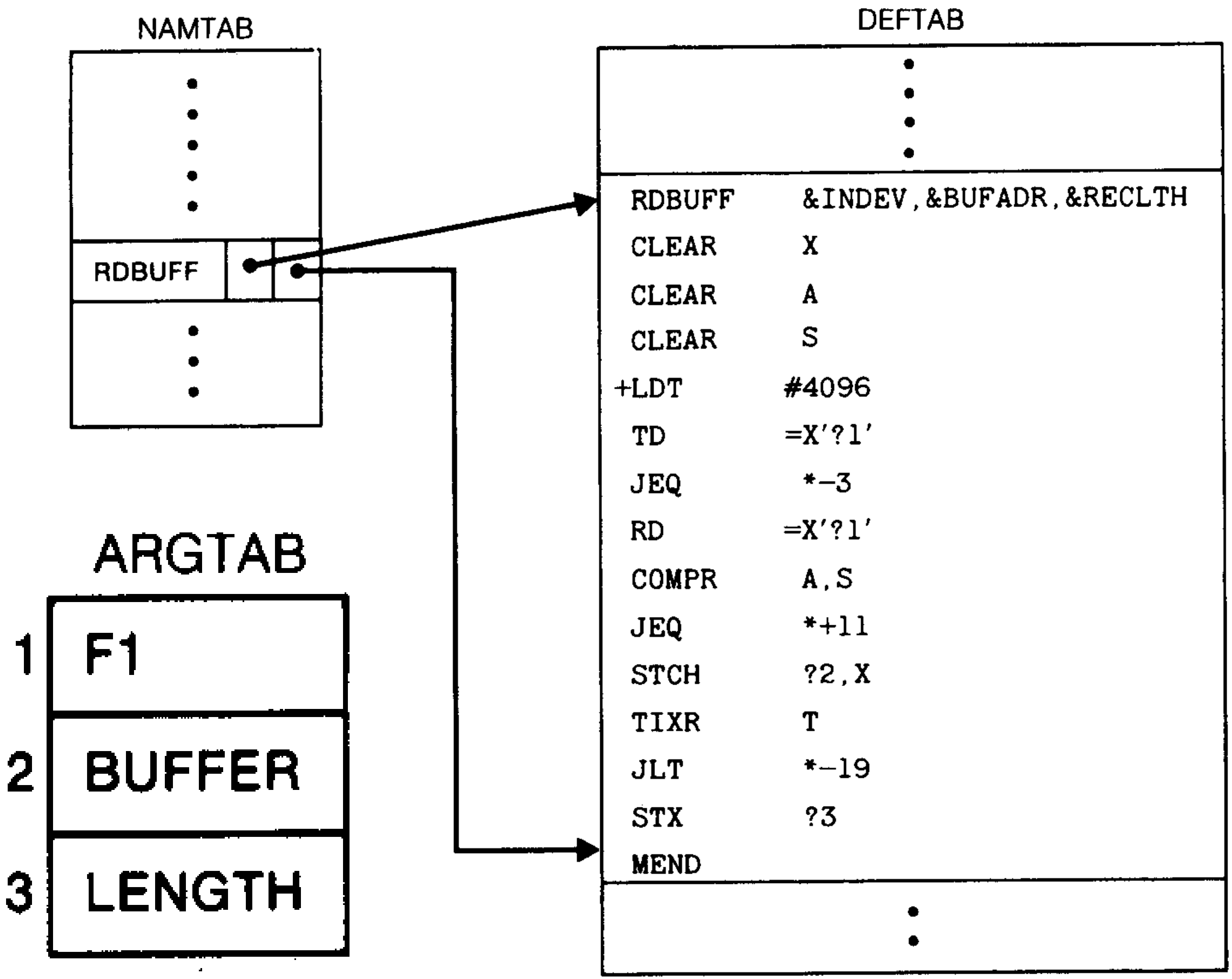
- A one-pass macro processor that can alternate between macro definition and macro expansion.
  - The definition of a macro must appear in the source program before any statements that invoke that macro.
  - Inconvenience of the programmer.
  - Macro definitions are stored in DEFTAB
  - Comment lines are not entered the DEFTAB.

4.1.2 Macro Processor Algorithm and Data Structures

- The macro names are entered into NAMTAB, NAMTAB contains two pointers to the beginning and the end of the definition in DEFTAB
- The third data structure is an argument table ARGTAB, which is used during the expansion of macro invocations.
- The arguments are stored in ARGTAB according to their position in the argument list.

4.1.2 Macro Processor Algorithm and Data Structures

- Fig. 4.4 shows positions of the contents of these tables during the processing.
  - Parameter &INDEV -> Argument ?1
  - Parameter &BUFADR -> Argument ?2
  - When the ?n notation is recognized in a line form DEFTAB, a simple indexing operation supplies the proper argument form ARGTAB.


NAMTAB
RDBUFF
DEFTAB
RDBUFF &INDEV,&BUFADR,&RECLTH
CLEAR X
CLEAR A
CLEAR S
+LDT #4096
TD =X'?1'
JEQ *-3
RD =X'?1'
COMPR A,S
JEQ *+11
STCH ?2,X
TIXR T
JLT *-19
STX ?3
MEND
ARGTAB
1 F1
2 BUFFER
3 LENGTH

ARGTAB (b)

(a)

4.1.2 Macro Processor Algorithm and Data Structures

- The macro processor algorithm itself is presented in Fig. 4.5.
  - The procedure PROCESSING
  - The procedure DEFINE
    - Called when the beginning of a macro definition is recognized, makes the appropriate entries in DEFTAB and NAMTAB.
  - The procedure EXPAND
    - Called to set up the argument values in ARGTAB and expand a macro invocation statement.
  - The procedure GETLINE
    - Called at several points in the algorithm, gets the next line to be processed.
  - EXPANDING is set to TRUE or FALSE.

```
begin {macro processor}
    EXPANDING := FALSE
    while OPCODE ≠ 'END' do
        begin
            GETLINE
            PROCESSLINE
        end {while}
end {macro processor}


procedure PROCESSLINE
    begin
        search NAMTAB for OPCODE
        if found then
            EXPAND
        else if OPCODE = 'MACRO' then
            DEFINE
        else write source line to expanded file
    end {PROCESSLINE}
```

Figure 4.5 Algorithm for a one-pass macro processor.

```
procedure DEFINE
    begin
        enter macro name into NAMTAB
        enter macro prototype into DEFTAB
        LEVEL  := 1
        while LEVEL > 0 do
            begin
                GETLINE
                if this is not a comment line then
                    begin
                        substitute positional notation for parameters
                        enter line into DEFTAB
                        if OPCODE = 'MACRO' then
                            LEVEL := LEVEL + 1
                        else if OPCODE = 'MEND' then
                            LEVEL  := LEVEL - 1
                    end {if not comment}
            end {while}
        store in NAMTAB pointers to beginning and end of definition
    end {DEFINE}
```

```
procedure EXPAND
    begin
        EXPANDING  := TRUE
        get first line of macro definition {prototype} from DEFTAB
        set up arguments from macro invocation in ARGTAB
        write macro invocation to expanded file as a comment
        while not end of macro definition do
            begin
                GETLINE
                PROCESSLINE
            end {while}
        EXPANDING := FALSE
    end {EXPAND}


procedure GETLINE
    begin
        if EXPANDING then
           begin
                get next line of macro definition from DEFTAB
                substitute arguments from ARGTAB for positional notation
           end {if}
        else
            read next line from input file
    end {GETLINE}
```

Figure 4.5 *(cont'd)*

4.1.2 Macro Processor Algorithm and Data Structures

- To solve the problem is Fig. 4.3, our DEFINE procedure maintains a counter named LEVEL.
  - MACRO directive is read, the value of LEVEL is inc. by 1.
  - MEND directive is read, the value of LEVEL is dec. by 1.

4.2 Machine-Independent Macro Processor Features

4.2.1 Concatenation of Macro Parameters

- Most macro processors allow parameters to be concatenated with other character strings.
  - A program contains one series of variables named by the symbols XA1, XA2, XA3, …, another series named by XB1, XB2, XB3, …, etc.
  - The body of the macro definition might contain a statement like

```
SUM     Macro   &ID
        LDA     X&ID1
        LDA     X&ID2
        LDA     X&ID3
        LDA     X&IDS
```

4.2.1 Concatenation of Macro Parameters

- The beginning of the macro parameter is identified by the starting symbol &; however, the end of the parameter is not marked.
- The problem is that the end of the parameter is not marked. Thus X&ID1 may mean “X” + ID + “1” or “X” + ID1.
- In which the parameter &ID is concatenated after the character string X and before the character string 1.

4.2.1 Concatenation of Macro Parameters

- Most macro processors deal with this problem by providing a special concatenation operator (Fig. 4.6).
  - In SIC or SIC/XE, -> is used

```
1  SUM    MACRO   &ID
2         LDA     X&ID→1
3         ADD     X&ID→2
4         ADD     X&ID→3
5         STA     X&ID→S
6         MEND
```

(a)

4.2.2 Generation of Unique Labels

- As we discussed in Section 4.1, it is in general not possible for the body of a macro instruction to contain labels of usual kind.
  - WRBUFF (line 135) is called twice.
  - Fig. 4.7 illustrates one techniques for generating unique labels within a macro expansion.
  - Labels used within the macro body begin with the special character $.
  - Each symbol beginning with $ has been modified by replacing $ with $AA.

4.2.2 Generation of Unique Labels

Because it was not possible to place a label on line 135 of this macro definition, the Jump instructions on lines 140 and 155 were written using the relative operands *–3 and *–14. This sort of relative addressing in a source statement may be acceptable for short jumps such as "JEQ *–3." However, for longer jumps spanning several instructions, such notation is very inconvenient, error-prone, and difficult to read. Many macro processors avoid these problems by allowing the creation of special types of labels within macro instructions.

4.2.2 Generation of Unique Labels

```
RDBUFF   MACRO    &INDEV,&BUFADR,&RECLTH
         CLEAR    X                      CLEAR LOOP COUNTER
         CLEAR    A
         CLEAR    S
        +LDT     #4096                   SET MAXIMUM RECORD LENGTH
$LOOP    TD      =X'&INDEV'              TEST INPUT DEVICE
         JEQ      $LOOP                  LOOP UNTIL READY
         RD      =X'&INDEV'              READ CHARACTER INTO REG A
         COMPR    A,S                    TEST FOR END OF RECORD
         JEQ      $EXIT                  EXIT LOOP IF EOR
         STCH     &BUFADR,X              STORE CHARACTER IN BUFFER
         TIXR     T                      LOOP UNLESS MAXIMUM LENGTH
         JLT      $LOOP                    HAS BEEN REACHED
$EXIT    STX      &RECLTH                SAVE RECORD LENGTH
         MEND
```

(a)

```
.          RDBUFF    F1,BUFFER,LENGTH

                 CLEAR     X                 CLEAR LOOP COUNTER
                 CLEAR     A
                 CLEAR     S
                +LDT       #4096             SET MAXIMUM RECORD LENGTH
      $AALOOP    TD        =X'F1'            TEST INPUT DEVICE
                 JEQ       $AALOOP           LOOP UNTIL READY
                 RD        =X'F1'            READ CHARACTER INTO REG A
                 COMPR     A,S               TEST FOR END OF RECORD
                 JEQ       $AAEXIT           EXIT LOOP IF EOR
                 STCH      BUFFER,X          STORE CHARACTER IN BUFFER
                 TIXR      T                 LOOP UNLESS MAXIMUM LENGTH
                 JLT       $AALOOP             HAS BEEN REACHED
      $AAEXIT    STX       LENGTH            SAVE RECORD LENGTH
```

(b)

Figure 4.7 Generation of unique labels within macro expansion.

4.2.3 Conditional Macro Expansion

- The use of one type of conditional macro expansion statement is illustrated in Fig. 4.8.
  - The definition of RDBUFF has two additional parameters: &EOR and &MAXLTH.
  - Macro processor directive SET
  - This SET statement assigns the value 1 to &EORCK.
  - The symbol &EORCK is a macro time variables, which can be used to store working values during the macro expansion.
  - `RDBUFF          F3,BUF,RECL,04,2048`
  - `RDBUFF          0E,BUFFER,LENGTH,,80`
  - `RDBUFF          F1,BUFF,RLENG,04`

```
RDBUFF   MACRO    &INDEV,&BUFADR,&RECLTH,&EOR,&MAXLTH
                  IF       (&EOR NE '')
1        &EORCK   SET      1
                  ENDIF
                  CLEAR    X                       CLEAR LOOP COUNTER
                  CLEAR    A
                  IF       (&EORCK EQ 1)
2                 LDCH     =X'&EOR'                SET EOR CHARACTER
                  RMO      A,S
                  ENDIF
                  IF       (&MAXLTH EQ '')
                 +LDT      #4096                   SET MAX LENGTH = 4096
3                 ELSE
                 +LDT      #&MAXLTH                SET MAXIMUM RECORD LENGTH
                  ENDIF
$LOOP             TD       =X'&INDEV'              TEST INPUT DEVICE
                  JEQ      $LOOP                   LOOP UNTIL READY
                  RD       =X'&INDEV'              READ CHARACTER INTO REG A
                  IF       (&EORCK EQ 1)
                  COMPR    A,S                     TEST FOR END OF RECORD
4                 JEQ      $EXIT                   EXIT LOOP IF EOR
                  ENDIF
                  STCH     &BUFADR,X               STORE CHARACTER IN BUFFER
                  TIXR     T                       LOOP UNLESS MAXIMUM LENGTH
                  JLT      $LOOP                     HAS BEEN REACHED
$EXIT             STX      &RECLTH                 SAVE RECORD LENGTH
                  MEND
```

(a)

```
.           RDBUFF    F3,BUF,RECL,04,2048

30                CLEAR    X            CLEAR LOOP COUNTER
35                CLEAR    A
40                LDCH     =X'04'       SET EOR CHARACTER
42                RMO      A,S
47               +LDT      #2048        SET MAXIMUM RECORD LENGTH
50    $AALOOP     TD       =X'F3'       TEST INPUT DEVICE
55                JEQ      $AALOOP      LOOP UNTIL READY
60                RD       =X'F3'       READ CHARACTER INTO REG A
65                COMPR    A,S          TEST FOR END OF RECORD
70                JEQ      $AAEXIT      EXIT LOOP IF EOR
75                STCH     BUF,X        STORE CHARACTER IN BUFFER
80                TIXR     T            LOOP UNLESS MAXIMUM LENGTH
85                JLT      $AALOOP        HAS BEEN REACHED
90    $AAEXIT     STX      RECL         SAVE RECORD LENGTH
```

(b)

Figure 4.8 Use of macro-time conditional statements.

```
 .              RDBUFF    0E,BUFFER,LENGTH,,80

                CLEAR     X               CLEAR LOOP COUNTER
                CLEAR     A
      3        +LDT      #80              SET MAXIMUM RECORD LENGTH
 $ABLOOP        TD       =X'0E'           TEST INPUT DEVICE
                JEQ       $ABLOOP         LOOP UNTIL READY
                RD       =X'0E'           READ CHARACTER INTO REG A
                STCH      BUFFER,X        STORE CHARACTER IN BUFFER
                TIXR      T               LOOP UNLESS MAXIMUM LENGTH
                JLT       $ABLOOP           HAS BEEN REACHED
 $ABEXIT        STX       LENGTH          SAVE RECORD LENGTH
```

(c)

```
.           RDBUFF    F1,BUFF,RLENG,04

            CLEAR     X           CLEAR LOOP COUNTER
            CLEAR     A
2           LDCH      =X'04'      SET EOR CHARACTER
            RMO       A,S
3          +LDT       #4096       SET MAX LENGTH = 4096
$ACLOOP     TD        =X'F1'      TEST INPUT DEVICE
            JEQ       $ACLOOP     LOOP UNTIL READY
            RD        =X'F1'      READ CHARACTER INTO REG A
4           COMPR     A,S         TEST FOR END OF RECORD
            JEQ       $ACEXIT     EXIT LOOP IF EOR
            STCH      BUFF,X      STORE CHARACTER IN BUFFER
            TIXR      T           LOOP UNLESS MAXIMUM LENGTH
            JLT       $ACLOOP       HAS BEEN REACHED
$ACEXIT     STX       RLENG       SAVE RECORD LENGTH
```

(d)

4.2.3 Conditional Macro Expansion

- A different type of conditional macro expansion statement is illustrated in Fig. 4.9.
  - There is a list (00, 03, 04) corresponding to &EOR.
  - %NITEMS is a macro processor function that returns as its value the number of members in an argument list.
  - %NITEMS(&EOR) is equal to 3.
  - &CTR is used to count the number of times the lines following the WHILE statement have been generated.
  - Thus on the first iteration the expression &EOR[&CTR] on line 65 has the value 00 = &EOR[1]; on the second iteration it has the value 03, and so on.
  - How to implement nesting WHILE structures?

```
RDBUFF   MACRO   &INDEV,&BUFADR,&RECLTH,&EOR
&EORCT   SET     %NITEMS(&EOR)
         CLEAR   X                    CLEAR LOOP COUNTER
         CLEAR   A
        +LDT     #4096                SET MAX LENGTH = 4096
$LOOP    TD      =X'&INDEV'           TEST INPUT DEVICE
         JEQ      $LOOP               LOOP UNTIL READY
         RD      =X'&INDEV'           READ CHARACTER INTO REG A
&CTR     SET      1
         WHILE    (&CTR LE &EORCT)
         COMP    =X'0000&EOR[&CTR]'
         JEQ      $EXIT
&CTR     SET      &CTR+1
         ENDW
         STCH     &BUFADR,X           STORE CHARACTER IN BUFFER
         TIXR     T                   LOOP UNLESS MAXIMUM LENGTH
         JLT      $LOOP                  HAS BEEN REACHED
$EXIT    STX      &RECLTH             SAVE RECORD LENGTH
         MEND
```

(a)

```
.               RDBUFF   F2,BUFFER,LENGTH,(00,03,04)


                CLEAR     X                      CLEAR LOOP COUNTER
                CLEAR     A
               +LDT      #4096                   SET MAX LENGTH = 4096
      $AALOOP   TD       =X'F2'                  TEST INPUT DEVICE
                JEQ       $AALOOP                LOOP UNTIL READY
                RD       =X'F2'                  READ CHARACTER INTO REG A
                COMP     =X'000000'
                JEQ       $AAEXIT
                COMP     =X'000003'
                JEQ       $AAEXIT
                COMP     =X'000004'
                JEQ       $AAEXIT
                STCH      BUFFER,X               STORE CHARACTER IN BUFFER
                TIXR      T                      LOOP UNLESS MAXIMUM LENGTH
                JLT       $AALOOP                  HAS BEEN REACHED
      $AAEXIT   STX       LENGTH                 SAVE RECORD LENGTH
```

(b)

4.2.4 Keyword Macro Parameters

- Positional parameters
  - Parameters and arguments were associated with each other according to their positions in the macro prototype and the macro invocation statements.
  - A certain macro instruction GENER has 10 possible parameters.

```
GENER MACRO &1, &2, &type, …, &channel, &10

GENER     , , DIRECT, , , , , , 3
```

4.2.4 Keyword Macro Parameters

- Keyword parameters
  - Each argument value is written with a keyword that names the corresponding parameter.
  - Arguments may appear in any order.

```
GENER     , , DIRECT, , , , , , 3
GENER     TYPE=DIRECT, CHANNEL=3
GENER     CHANNEL=3, TYPE=DIRECT
```

parameter=argument

  - Fig. 4.10 shows a version of the RDBUFF using keyword.

```
RDBUFF   MACRO   &INDEV=F1,&BUFADR=,&RECLTH=,&EOR=04,&MAXLTH=4096
         IF      (&EOR NE '')
&EORCK   SET     1
         ENDIF
         CLEAR   X              CLEAR LOOP COUNTER
         CLEAR   A
         IF      (&EORCK EQ 1)
         LDCH    =X'&EOR'       SET EOR CHARACTER
2
         RMO     A,S
         ENDIF
        +LDT     #&MAXLTH       SET MAXIMUM RECORD LENGTH
$LOOP    TD      =X'&INDEV'     TEST INPUT DEVICE
         JEQ     $LOOP          LOOP UNTIL READY
         RD      =X'&INDEV'     READ CHARACTER INTO REG A
         IF      (&EORCK EQ 1)
         COMPR   A,S            TEST FOR END OF RECORD
3
         JEQ     $EXIT          EXIT LOOP IF EOR
         ENDIF
         STCH    &BUFADR,X      STORE CHARACTER IN BUFFER
         TIXR    T              LOOP UNLESS MAXIMUM LENGTH
         JLT     $LOOP            HAS BEEN REACHED
$EXIT    STX     &RECLTH        SAVE RECORD LENGTH
         MEND
```

```
   .            RDBUFF    BUFADR=BUFFER,RECLTH=LENGTH

30              CLEAR     X             CLEAR LOOP COUNTER
35              CLEAR     A
40   2          LDCH     =X'04'         SET EOR CHARACTER
42              RMO       A,S
47             +LDT      #4096          SET MAXIMUM RECORD LENGTH
50   $AALOOP    TD       =X'F1'         TEST INPUT DEVICE
55              JEQ       $AALOOP       LOOP UNTIL READY
60              RD       =X'F1'         READ CHARACTER INTO REG A
65              COMPR     A,S           TEST FOR END OF RECORD
70   3          JEQ       $AAEXIT       EXIT LOOP IF EOR
75              STCH      BUFFER,X      STORE CHARACTER IN BUFFER
80              TIXR      T             LOOP UNLESS MAXIMUM LENGTH
85              JLT       $AALOOP         HAS BEEN REACHED
90   $AAEXIT    STX       LENGTH        SAVE RECORD LENGTH
```

(b)

Figure 4.10 Use of keyword parameters in macro instructions.

```
.             RDBUFF    RECLTH=LENGTH,BUFADR=BUFFER,EOR=,INDEV=F3

                CLEAR    X                 CLEAR LOOP COUNTER
                CLEAR    A
               +LDT     #4096              SET MAXIMUM RECORD LENGTH
      $ABLOOP   TD      =X'F3'             TEST INPUT DEVICE
                JEQ      $ABLOOP           LOOP UNTIL READY
                RD      =X'F3'             READ CHARACTER INTO REG A
                STCH     BUFFER,X          STORE CHARACTER IN BUFFER
                TIXR     T                 LOOP UNLESS MAXIMUM LENGTH
                JLT      $ABLOOP             HAS BEEN REACHED
      $ABEXIT   STX      LENGTH            SAVE RECORD LENGTH
```

(c)

Figure 4.10 *(cont'd)*

4.3 Macro Processor Design Options
4.3.1 Recursive Macro Expansion

- In Fig. 4.3 we presented an example of the definition of one macro instruction by another.
- Fig. 4.11(a) shows an example - Dealt with the invocation of one macro by another.
- The purpose of RDCHAR Fig. 4.11(b) is to read one character from a specified device into register A, taking care of the necessary test-and-wait loop.

```
RDCHAR   MACRO   &IN
         .
         .       MACRO TO READ CHARACTER INTO REGISTER A
         .
         TD      =X'&IN'            TEST INPUT DEVICE
         JEQ      *-3               LOOP UNTIL READY
         RD      =X'&IN'            READ CHARACTER
         MEND
```

(b)

```
         RDBUFF  BUFFER,LENGTH,F1
```

```
RDBUFF   MACRO    &BUFADR,&RECLTH,&INDEV
         .
         .        MACRO TO READ RECORD INTO BUFFER
         .
         CLEAR    X                    CLEAR LOOP COUNTER
         CLEAR    A
         CLEAR    S
        +LDT      #4096                SET MAXIMUM RECORD LENGTH
$LOOP    RDCHAR   &INDEV               READ CHARACTER INTO REG A
         COMPR    A,S                  TEST FOR END OF RECORD
         JEQ      $EXIT                EXIT LOOP IF EOR
         STCH     &BUFADR,X            STORE CHARACTER IN BUFFER
         TIXR     T                    LOOP UNLESS MAXIMUM LENGTH
         JLT      $LOOP                  HAS BEEN REACHED
$EXIT    STX      &RECLTH              SAVE RECORD LENGTH
         MEND
```

4.3.1 Recursive Macro Expansion

- Fig. 4.11(c), applied to the macro invocation statement
  RDBUFF   BUFFER, LENGTH, F1
- The procedure EXPAND would be called when the macro was recognized.
- The arguments from the macro invocation would be entered into ARGTAB as follows:

Parameter	Value
1	BUFFER
2	LENGTH
3	F1
4	(unused)
.	.

4.3.1 Recursive Macro Expansion

- The Boolean variable EXPANDING would be set to TRUE, and expansion of the macro invocation statement would be begin.
- The processing would proceed normally until line 50, which contains a statement invoking RDCHAR. At that point, PROCESSLINE would call EXPAND again.
- This time, ARGTAB would look like

Parameter	Value
1	F1
2	(unused)
.	.

4.3.1 Recursive Macro Expansion

- At the end of this expansion, however, a problem would appear. When the end of the definition of RDCHAR was recognized, EXPANDING would be set to FALSE.
- Thus the macro processor would "forget" that it had been in middle of expanding a macro when it encountered the RDCHAR statement.
- Use a Stack to save ARGTAB.
- Use a counter to identify the expansion.

Pages 208-209, MASM

```
ABSDIF     MACRO     OP1,OP2,SIZE
           LOCAL     EXIT
           IFNB      <SIZE>           ;; IF SIZE IS NOT BLANK
           IFDIF     <SIZE>,<E>       ;;   THEN IT MUST BE E
           ; ERROR -- SIZE MUST BE E OR BLANK
           .ERR
           EXITM
           ENDIF                      ;; END OF IFDIF
           ENDIF                      ;; END OF IFNB
           MOV       SIZE&AX,OP1      ; COMPUTE ABSOLUTE DIFFERENCE
           SUB       SIZE&AX,OP2      ;; SUBTRACT OP2 FROM OP1
           JNS       EXIT             ;; EXIT IF RESULT GE 0
           NEG       SIZE&AX          ;;   OTHERWISE CHANGE SIGN
  EXIT:
           ENDM
```

(a)

```
        ABSDIF  J,K
```

↓

```
        MOV     AX,J        ; COMPUTE ABSOLUTE DIFFERENCE
        SUB     AX,K
        JNS     ??0000
        NEG     AX
??0000:
```

(b)

```
        ABSDIF  M,N,E
```

↓

```
        MOV     EAX,M       ; COMPUTE ABSOLUTE DIFFERENCE
        SUB     EAX,N
        JNS     ??0001
        NEG     EAX
??0001:
```

(c)

```
ABSDIF   P,Q,X
   ↓
; ERROR -- SIZE MUST BE E OR BLANK
```

(d)

Figure 4.12 Examples of MASM macro and conditional statements.

```
NODE      MACRO     NAME
          IRP       S,<'LEFT','DATA','RIGHT'>
NAME&S    DW        0
          ENDM                         ;; END OF IRP
          ENDM                         ;; END OF MACRO
```

(a)

```
          NODE      X
```

↓

```
XLEFT     DW        0
XDATA     DW        0
XRIGHT    DW        0
```

(b)

Figure 4.13 Example of MASM iteration statement.