Chapter 4 Macro Processors

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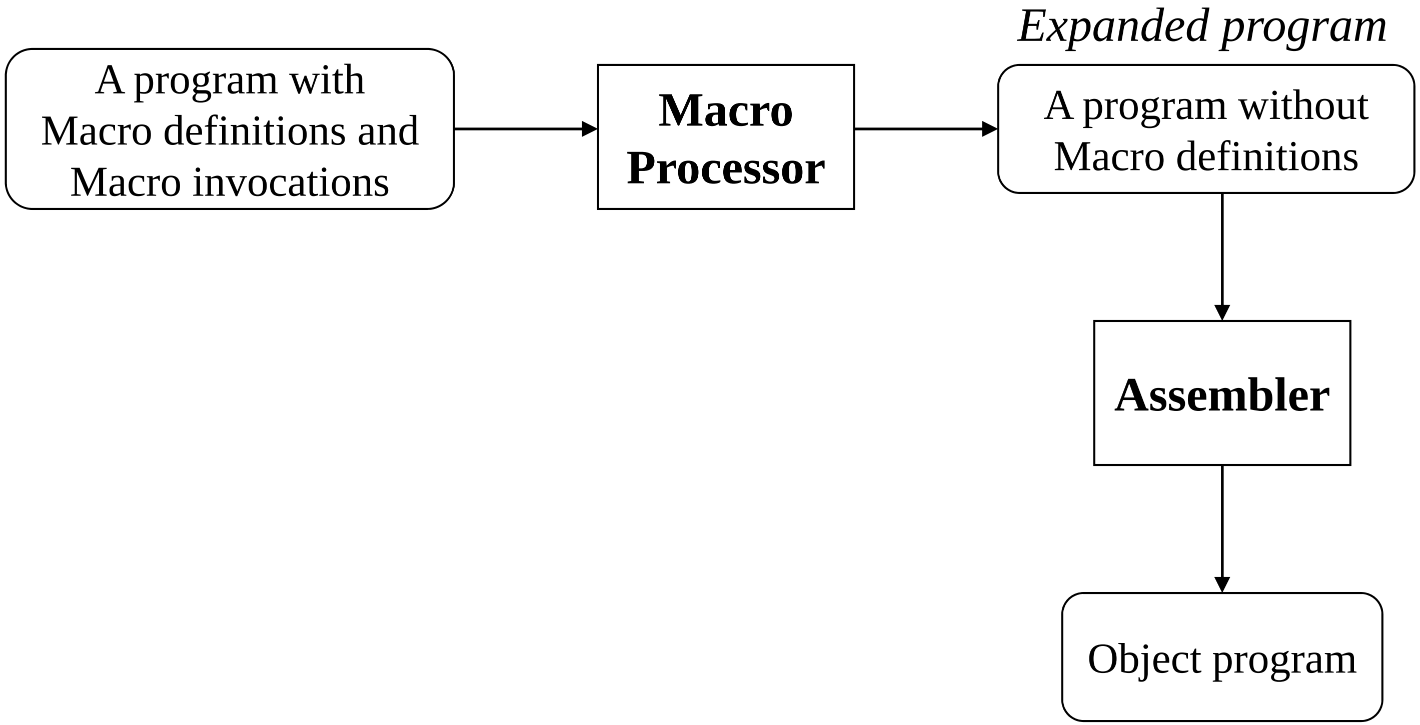
Introduction

- A macro instruction (abbreviated to *macro*) is simply a notational convenience for the programmer.
- A macro represents a commonly used group of statements in the source programming language
- Expanding a macros
  - Replace each macro instruction with the corresponding group of source language statements

Introduction (Cont’d)

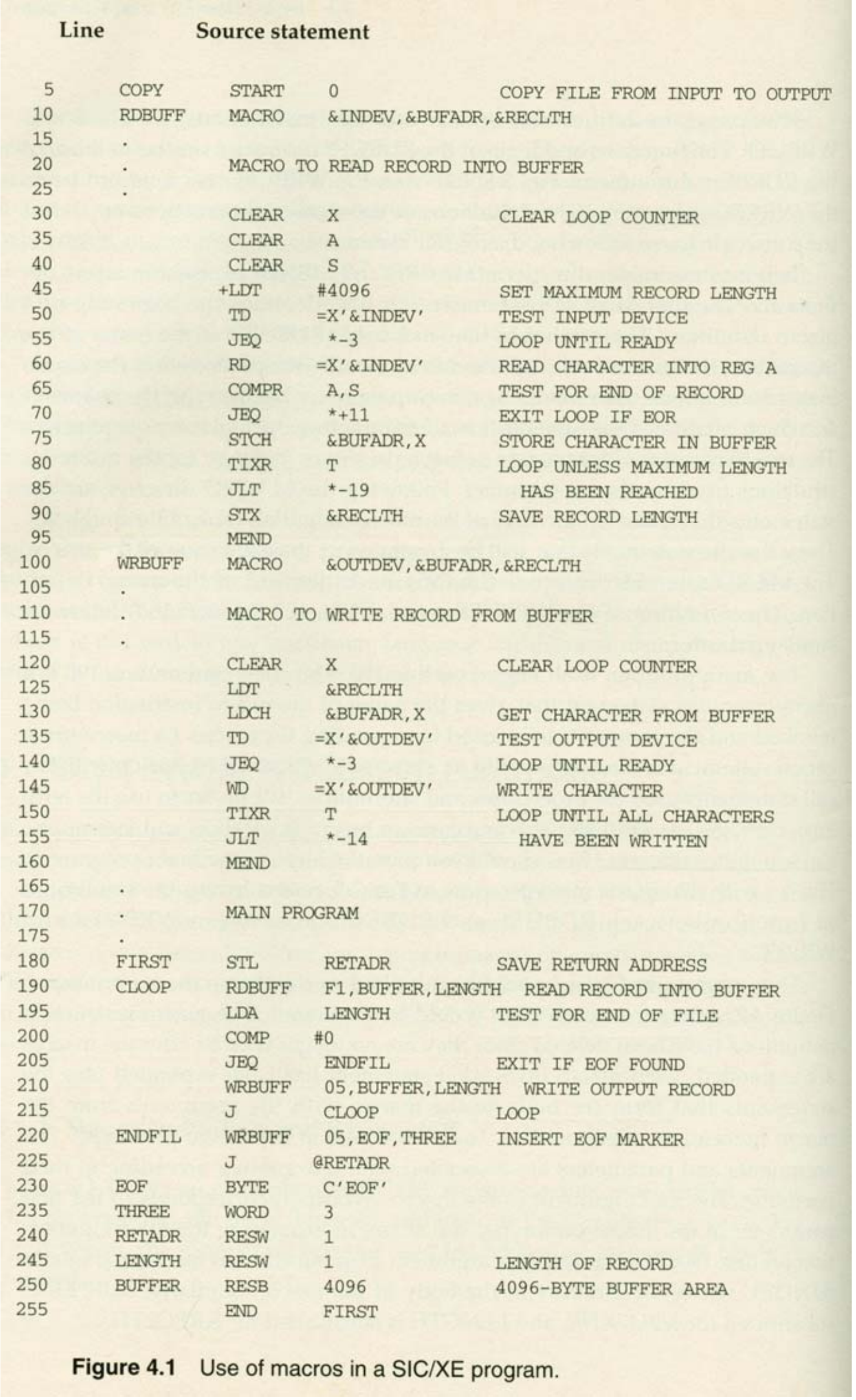
- E.g.
  - On SIC/XE requires a sequence of seven instructions to save the contents of all registers
    - Write one statement like SAVERGS
- A macro processor is not directly related to the architecture of the computer on which it is to run
- Macro processors can also be used with high-level programming languages, OS command languages, etc.

Basic Macro Processor Functions



Basic Macro Processor Functions

- Macro Definition
  - Two new assembler directives
    - MACRO
    - MEND
  - A pattern or prototype for the macro instruction
    - Macro name and parameters
  - See figure 4.1

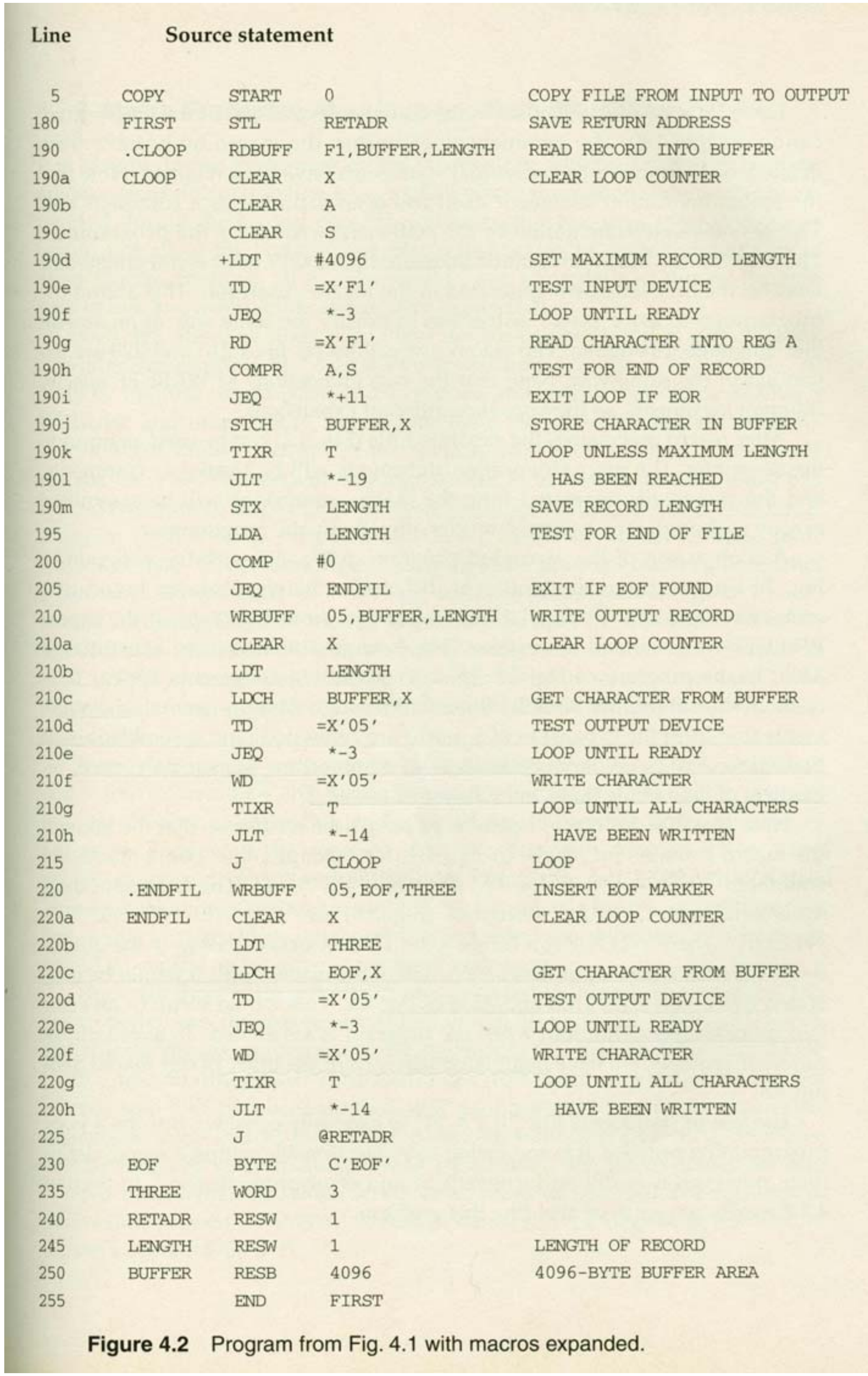


```
Line     Source statement

   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.

Basic Macro Processor Functions

- Macro invocation
  - Often referred to as a *macro call*
    - Need the name of the macro instruction begin invoked and the arguments to be used in expanding the macro
- Expanded program
  - Figure 4.2
  - No macro instruction definitions
  - Each macro invocation statement has been expanded into the statements that form the body of the macro, with the arguments from the macro invocation substituted for the parameters in the prototype



```
Line        Source statement

  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
```

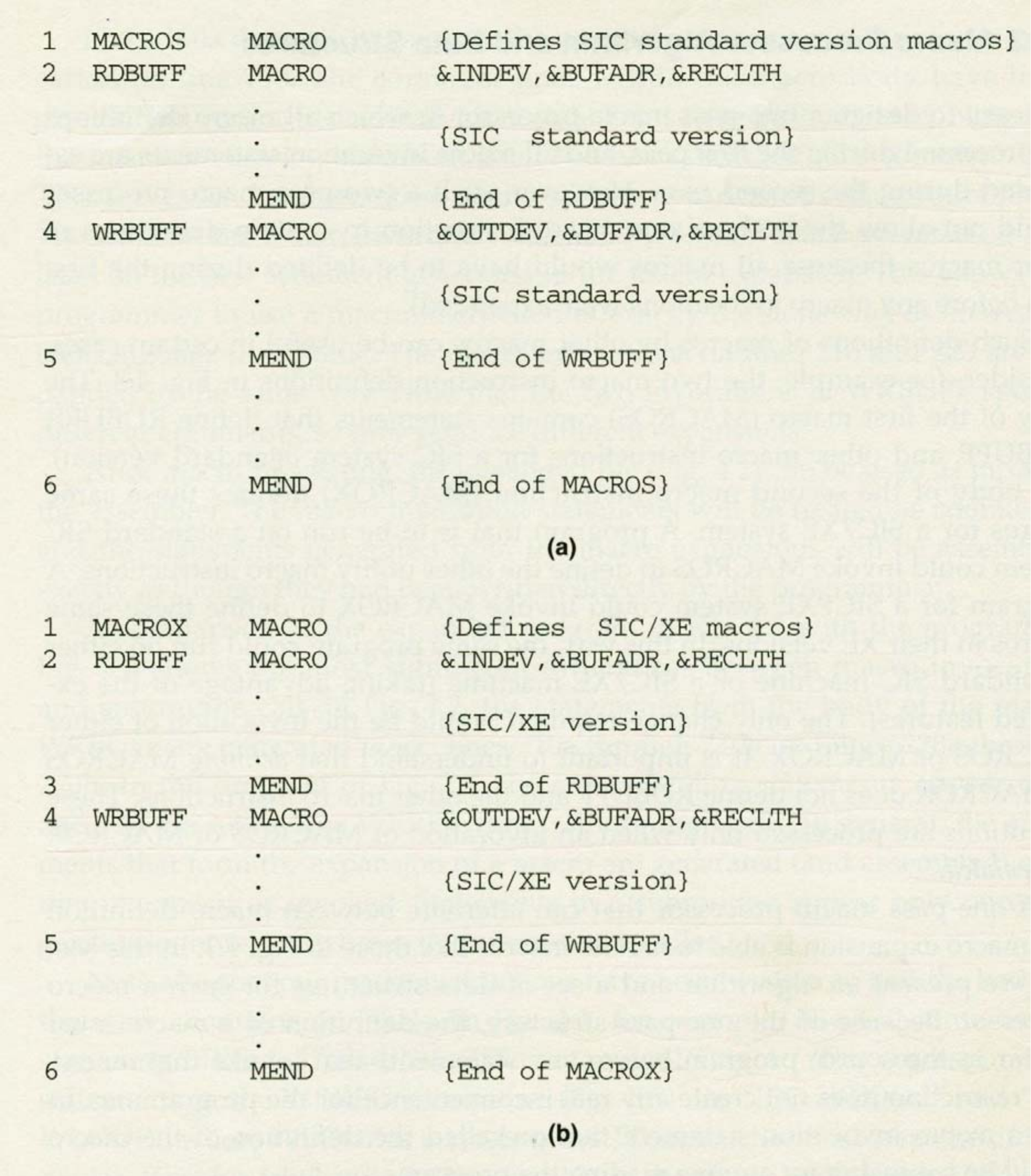
Figure 4.2 Program from Fig. 4.1 with macros expanded.

Basic Macro Processor Functions

- Macro invocations and subroutine calls are different
- Note also that the macro instructions have been written so that the body of the macro contains no label
  - Why?

Macro Processor Algorithm and Data Structures

- It is easy to design a two-pass macro processor
  - Pass 1:
    - All macro definitions are processed
  - Pass 2:
    - All macro invocation statements are expanded
- However, a two-pass macro processor would not allow the body of one macro instruction to contain definitions of other macros
  - See Figure 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}
```

(a)

```
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)

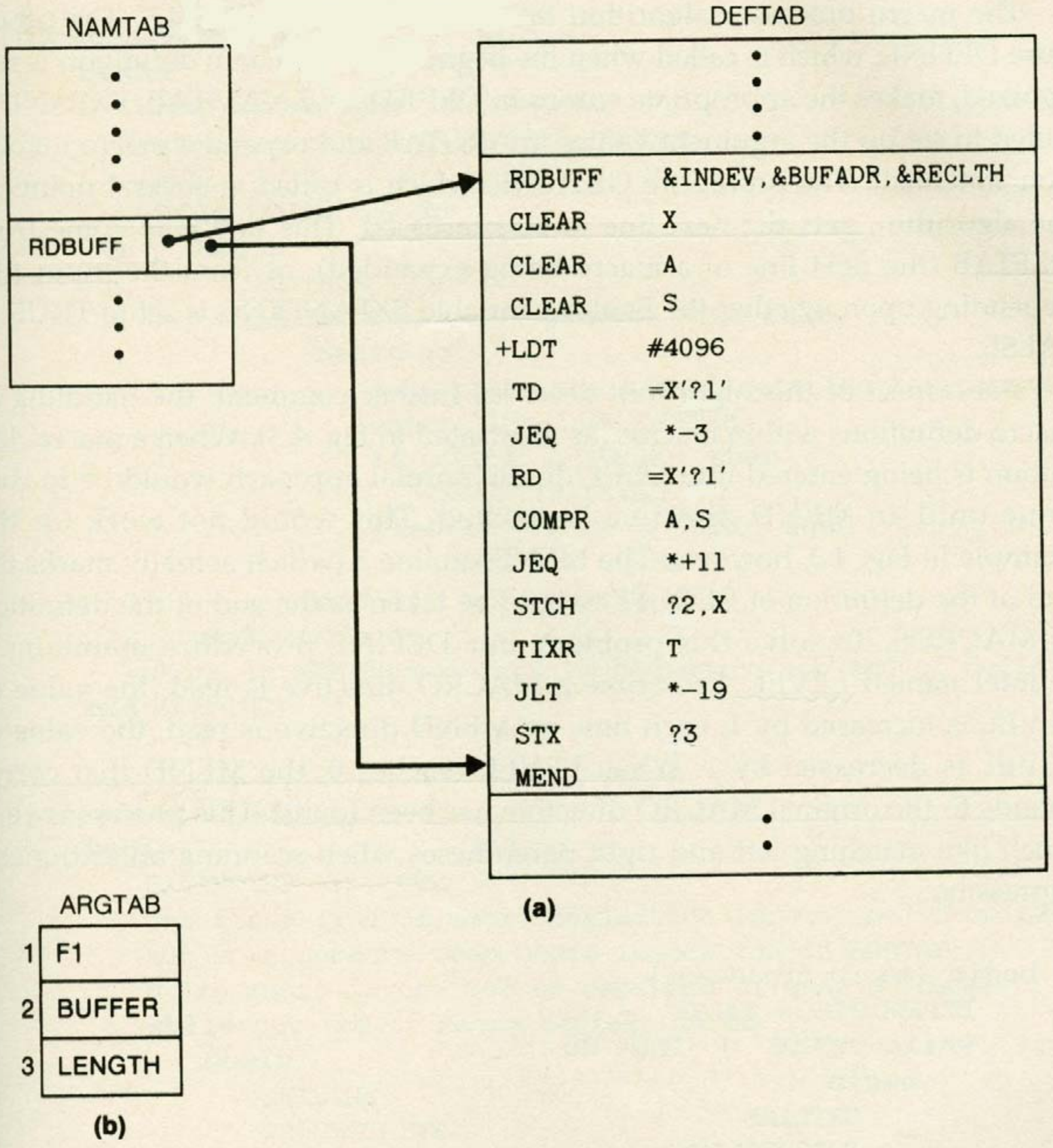
Figure 4.3 Example of the definition of macros within a macro body.

Macro Processor Algorithm and Data Structures

- Sub-Macro definitions are only processed when an invocation of their Super-Macros are expanded
  - See Figure 4.3: RDBUFF
- A one-pass macro processor that can alternate between macro definition and macro expansions able to handle macros like those in Figure 4.3

Macro Processor Algorithm and Data Structures

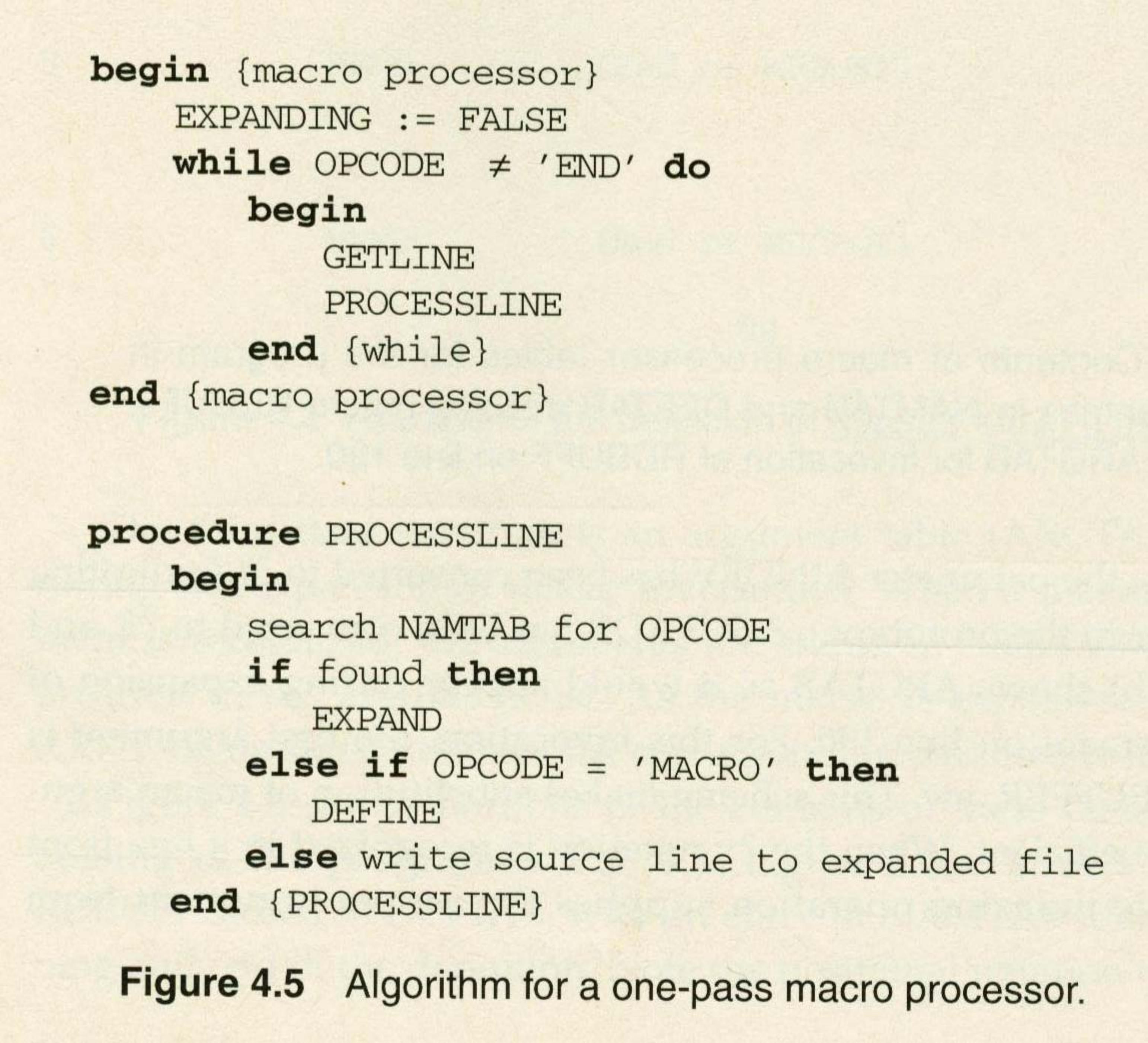
- Because of the one-pass structure, the definition of a macro must appear in the source program before any statements that invoke that macro
- Three main data structures involved in an one-pass macro processor
  - DEFTAB, NAMTAB, ARGTAB



```
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
```

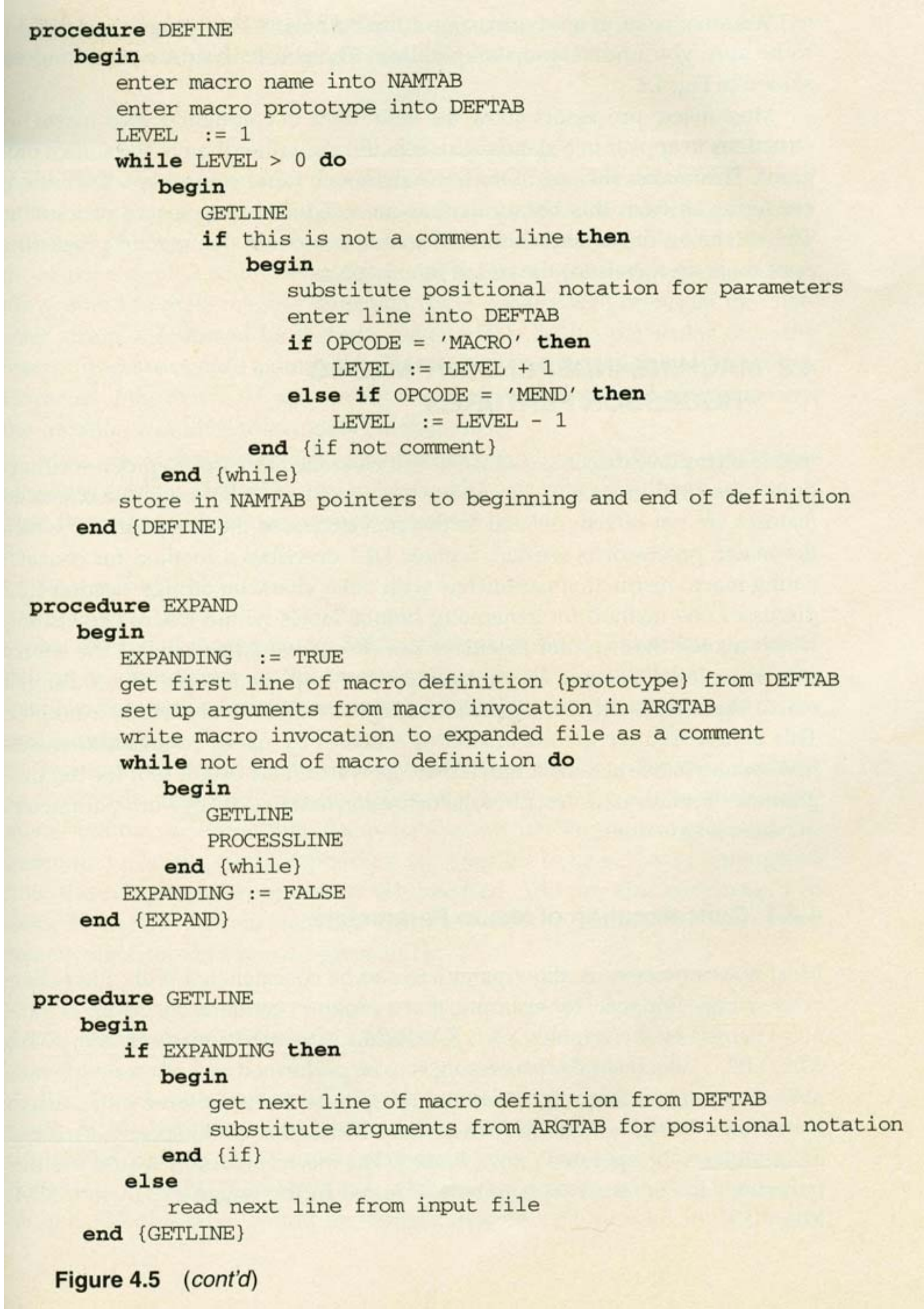
1	F1
2	BUFFER
3	LENGTH

Figure 4.4 Contents of macro processor tables for the program in Fig. 4.1: (a) entries in NAMTAB and DEFTAB defining macro RDBUFF, (b) entries in ARGTAB for invocation of RDBUFF on line 190.



```
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}
```

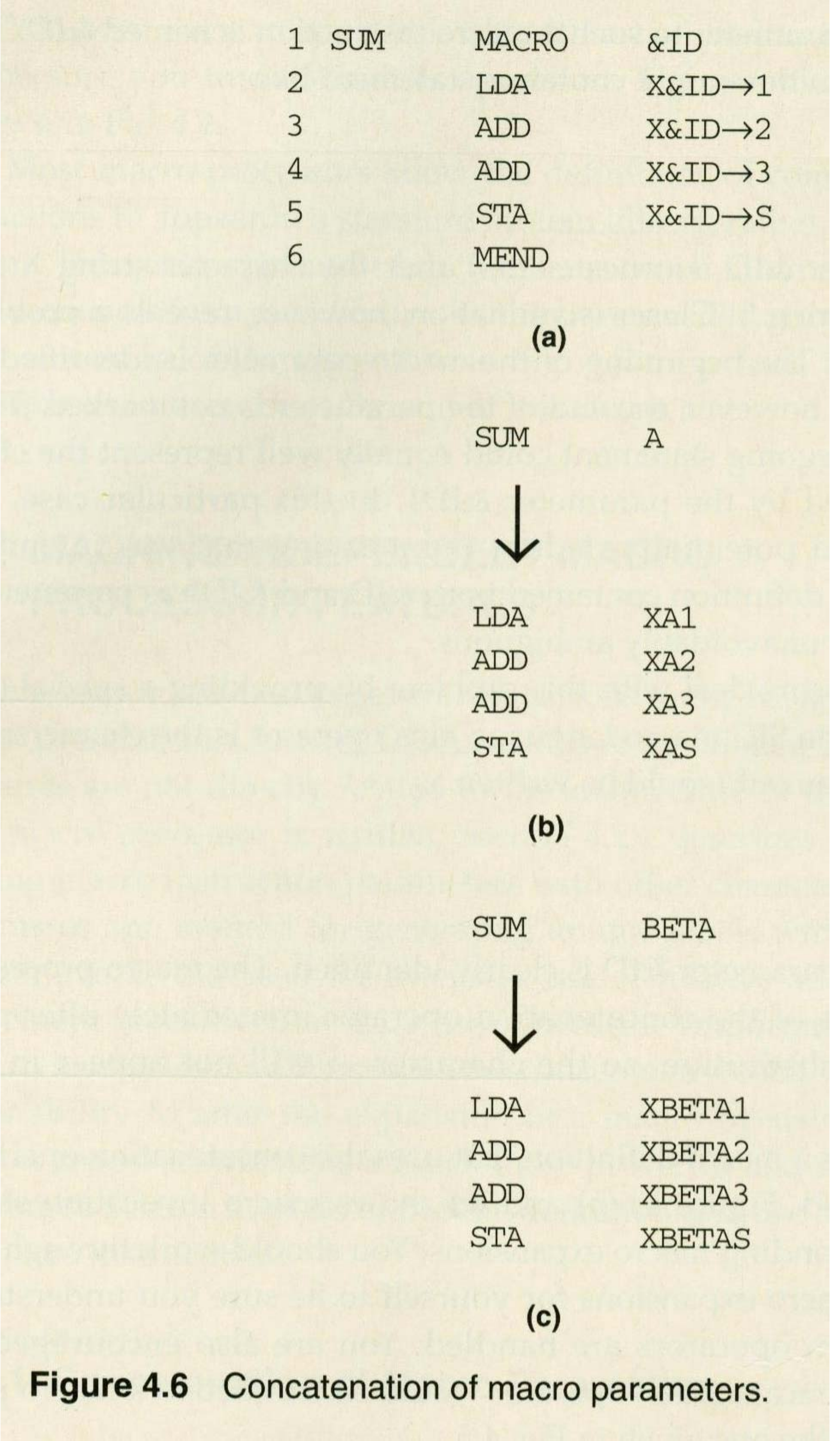
Figure 4.5 *(cont'd)*

Machine-Independent Macro Processor Feature

- Concatenation of Macro Parameters
- Generation of Unique Labels
- Conditional Macro Expansion
- Keyword Macro Parameters

Concatenation of Macro Parameters

- Most macro processors allow parameters to be concatenated with other character strings
  - The need of a special catenation operator
    - LDA X&ID1
    - LDA X&ID
  - The catenation operator
    - LDA X&ID→1
- See figure 4.6



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

(a)

```
        SUM     A
          ↓
        LDA     XA1
        ADD     XA2
        ADD     XA3
        STA     XAS
```

(b)

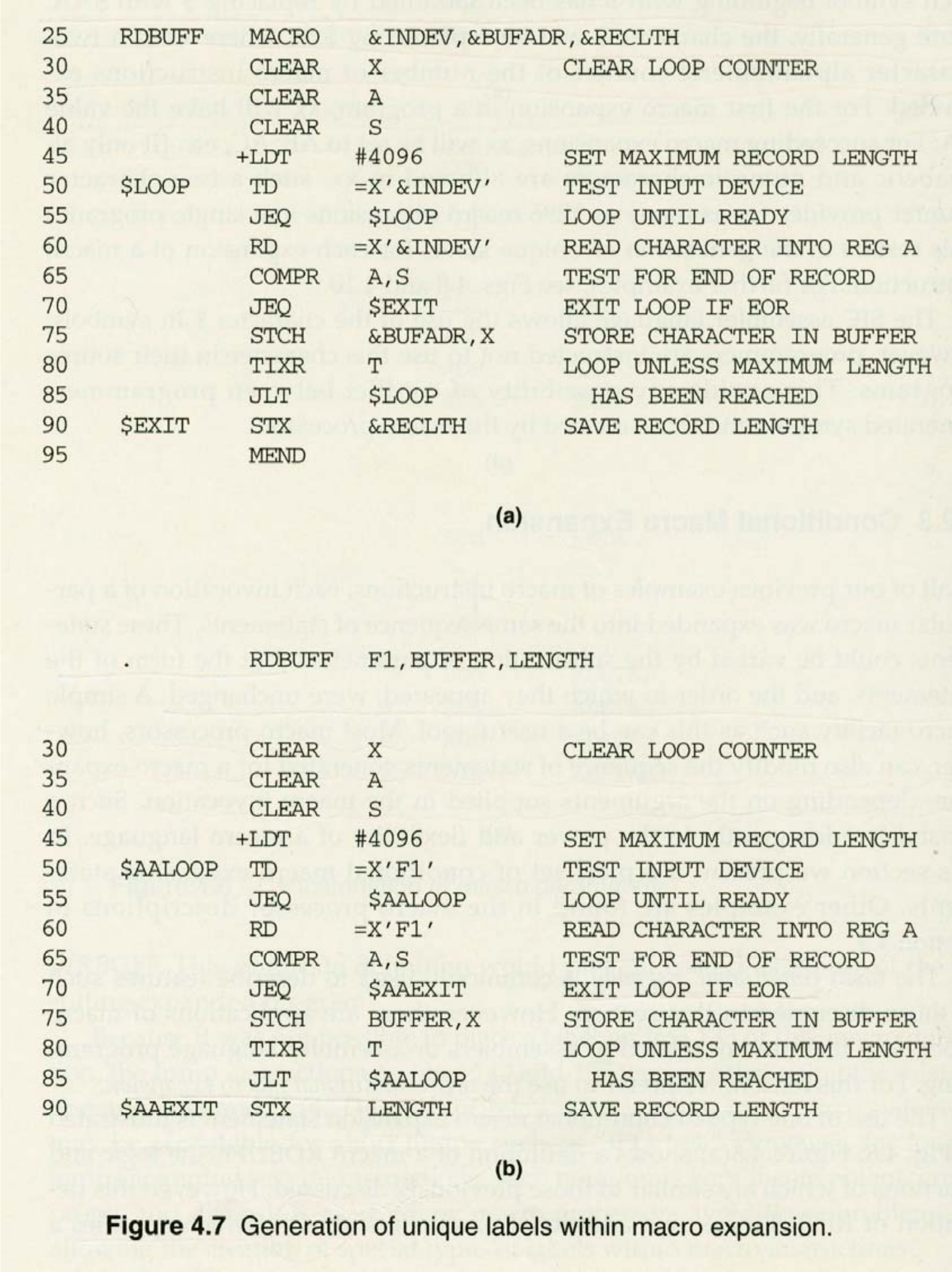
```
        SUM     BETA
          ↓
        LDA     XBETA1
        ADD     XBETA2
        ADD     XBETA3
        STA     XBETAS
```

(c)

Figure 4.6 Concatenation of macro parameters.

Generation of Unique Labels

- It is in general not possible for the body of a macro instruction to contain labels of the usual kind
  - Leading to the use of relative addressing at the source statement level
    - Only be acceptable for short jumps
- Solution:
  - Allowing the creation of special types of labels within macro instructions
  - See Figure 4.7



```
25   RDBUFF   MACRO   &INDEV,&BUFADR,&RECLTH
30            CLEAR   X               CLEAR LOOP COUNTER
35            CLEAR   A
40            CLEAR   S
45           +LDT     #4096           SET MAXIMUM RECORD LENGTH
50   $LOOP    TD      =X'&INDEV'      TEST INPUT DEVICE
55            JEQ     $LOOP           LOOP UNTIL READY
60            RD      =X'&INDEV'      READ CHARACTER INTO REG A
65            COMPR   A,S             TEST FOR END OF RECORD
70            JEQ     $EXIT           EXIT LOOP IF EOR
75            STCH    &BUFADR,X       STORE CHARACTER IN BUFFER
80            TIXR    T               LOOP UNLESS MAXIMUM LENGTH
85            JLT     $LOOP             HAS BEEN REACHED
90   $EXIT    STX     &RECLTH         SAVE RECORD LENGTH
95            MEND
```

(a)

```
     .        RDBUFF  F1,BUFFER,LENGTH

30            CLEAR   X               CLEAR LOOP COUNTER
35            CLEAR   A
40            CLEAR   S
45           +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            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)

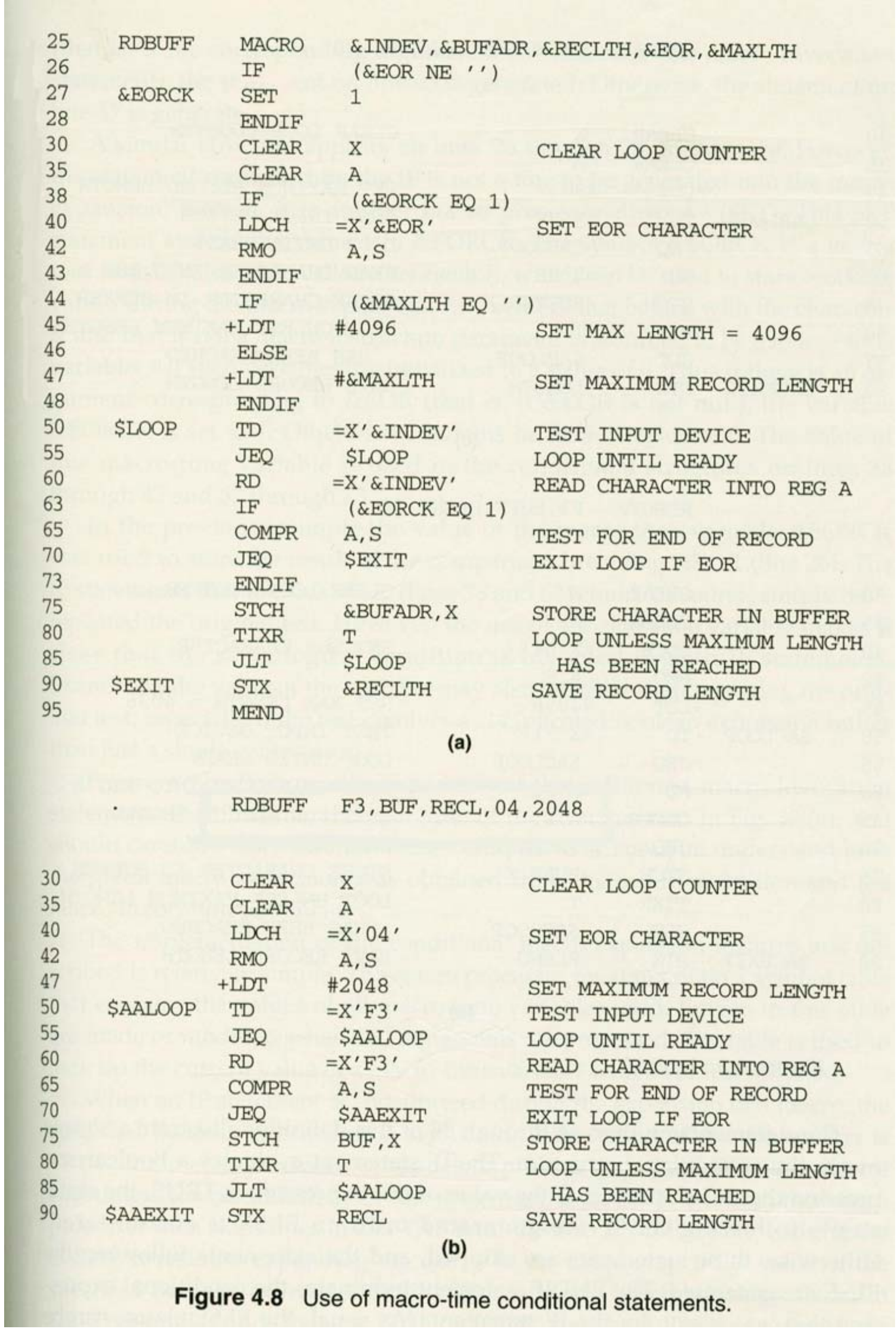
Figure 4.7 Generation of unique labels within macro expansion.

Generation of Unique Labels

- Solution:
  - Allowing the creation of special types of labels within macro instructions
  - See Figure 4.7
    - Labels used within he macro body begin with the special character $
  - Programmers are instructed no to use $ in their source programs

Conditional Macro Expansion

- Most macro processors can modify the sequence of statements generated for a macro expansion, depending on the arguments supplied in the macro invocation
- See Figure 4.8



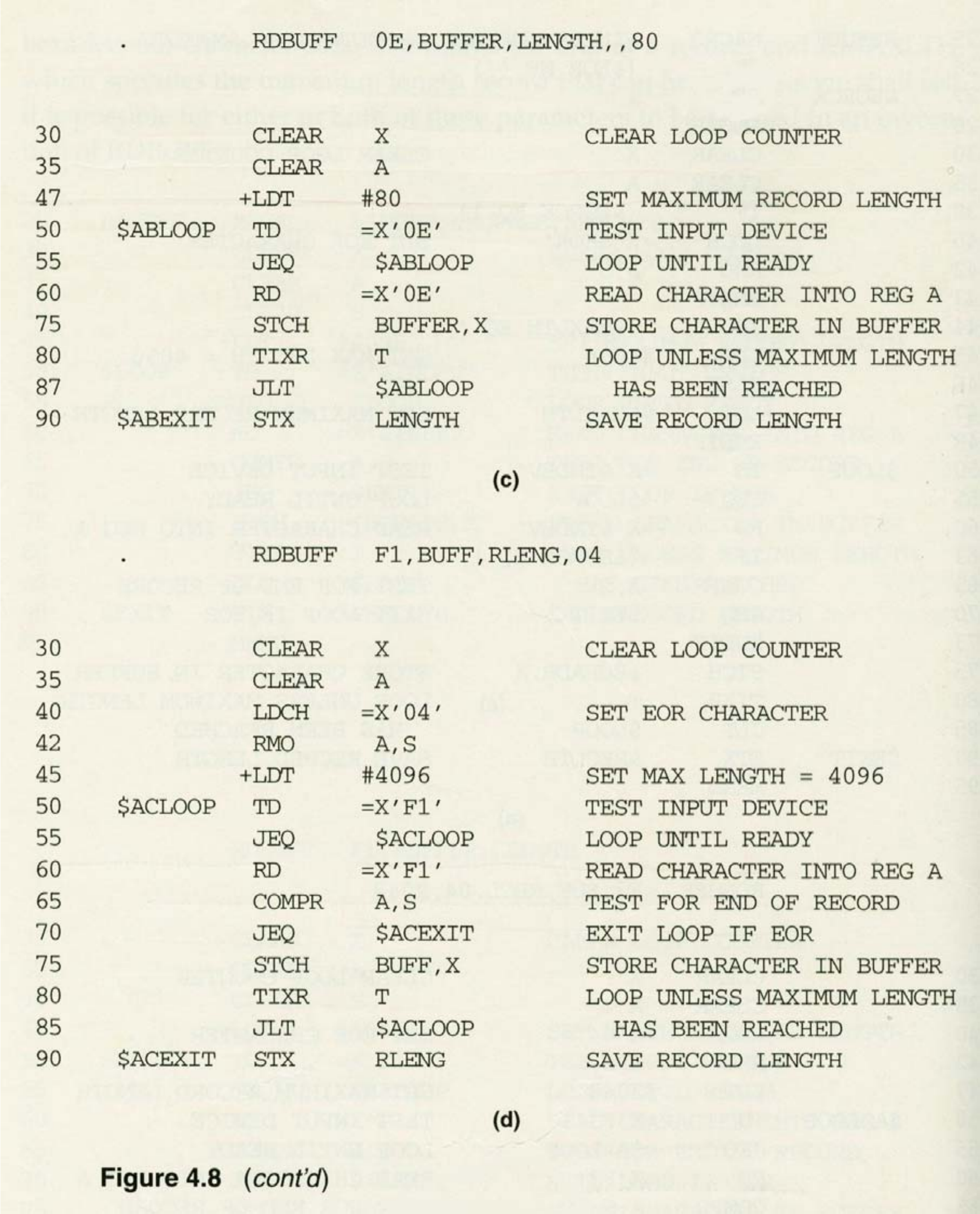
```
25  RDBUFF    MACRO  &INDEV,&BUFADR,&RECLTH,&EOR,&MAXLTH
26            IF     (&EOR NE '')
27  &EORCK    SET    1
28            ENDIF
30            CLEAR  X                 CLEAR LOOP COUNTER
35            CLEAR  A
38            IF     (&EORCK EQ 1)
40            LDCH   =X'&EOR'          SET EOR CHARACTER
42            RMO    A,S
43            ENDIF
44            IF     (&MAXLTH EQ '')
45           +LDT    #4096             SET MAX LENGTH = 4096
46            ELSE
47           +LDT    #&MAXLTH          SET MAXIMUM RECORD LENGTH
48            ENDIF
50  $LOOP     TD     =X'&INDEV'        TEST INPUT DEVICE
55            JEQ    $LOOP             LOOP UNTIL READY
60            RD     =X'&INDEV'        READ CHARACTER INTO REG A
63            IF     (&EORCK EQ 1)
65            COMPR  A,S               TEST FOR END OF RECORD
70            JEQ    $EXIT             EXIT LOOP IF EOR
73            ENDIF
75            STCH   &BUFADR,X         STORE CHARACTER IN BUFFER
80            TIXR   T                 LOOP UNLESS MAXIMUM LENGTH
85            JLT    $LOOP               HAS BEEN REACHED
90  $EXIT     STX    &RECLTH           SAVE RECORD LENGTH
95            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

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

(c)

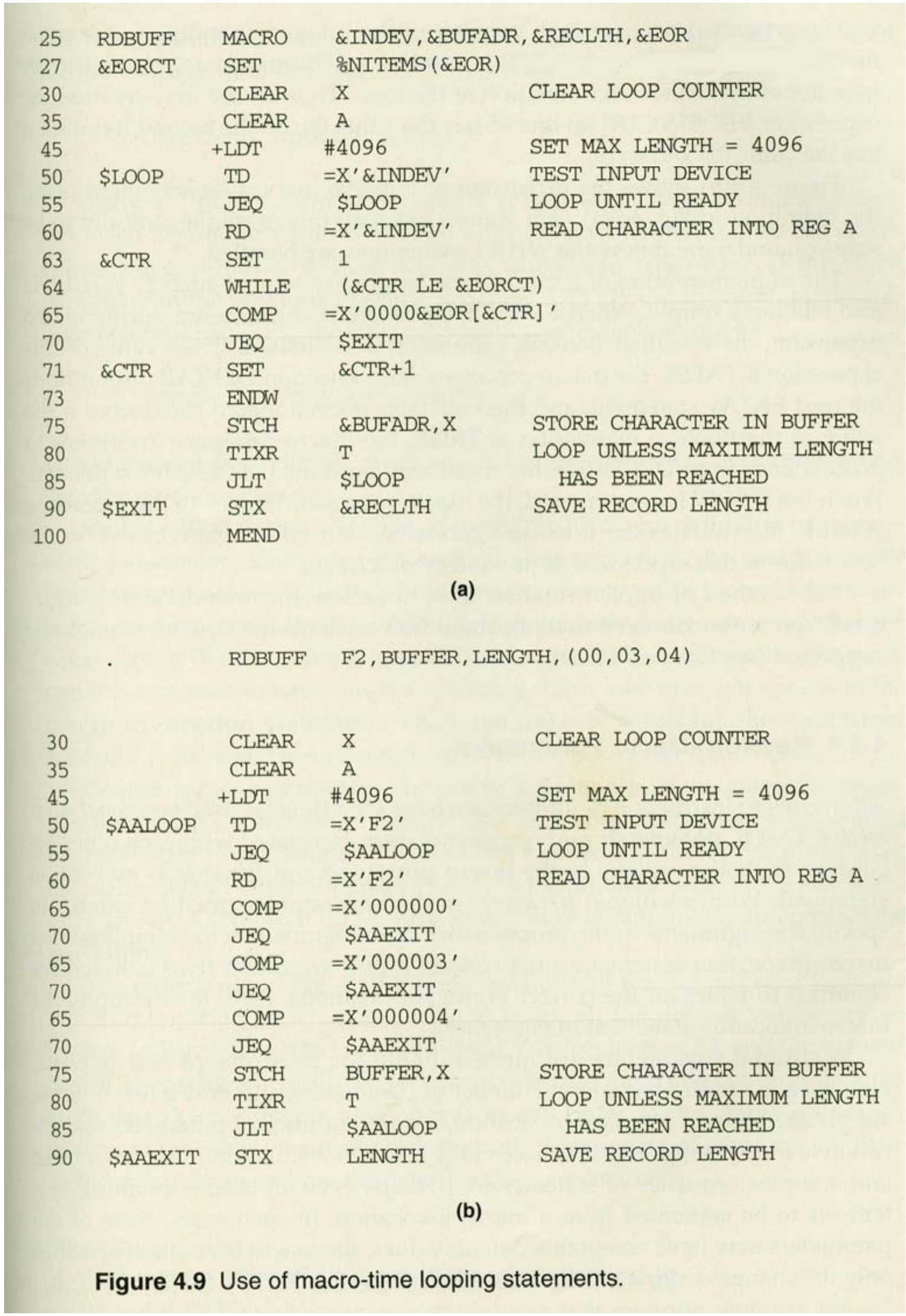
```
.            RDBUFF   F1,BUFF,RLENG,04

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

(d)

Figure 4.8 *(cont'd)*

Conditional Macro Expansion

- Most macro processors can modify the sequence of statements generated for a macro expansion, depending on the arguments supplied in the macro invocation
- See Figure 4.8
  - Macro processor directive
    - IF, ELSE, ENDIF
    - SET
  - Macro-time variable (set symbol)
- WHILE-ENDW
  - See Figure 4.9



```
 25  RDBUFF   MACRO    &INDEV,&BUFADR,&RECLTH,&EOR
 27  &EORCT   SET      %NITEMS(&EOR)
 30           CLEAR    X                    CLEAR LOOP COUNTER
 35           CLEAR    A
 45          +LDT      #4096                SET MAX LENGTH = 4096
 50  $LOOP    TD       =X'&INDEV'           TEST INPUT DEVICE
 55           JEQ      $LOOP                LOOP UNTIL READY
 60           RD       =X'&INDEV'           READ CHARACTER INTO REG A
 63  &CTR     SET      1
 64           WHILE    (&CTR LE &EORCT)
 65           COMP     =X'0000&EOR[&CTR]'
 70           JEQ      $EXIT
 71  &CTR     SET      &CTR+1
 73           ENDW
 75           STCH     &BUFADR,X            STORE CHARACTER IN BUFFER
 80           TIXR     T                    LOOP UNLESS MAXIMUM LENGTH
 85           JLT      $LOOP                  HAS BEEN REACHED
 90  $EXIT    STX      &RECLTH              SAVE RECORD LENGTH
100           MEND
```

(a)

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

 30           CLEAR    X                    CLEAR LOOP COUNTER
 35           CLEAR    A
 45          +LDT      #4096                SET MAX LENGTH = 4096
 50  $AALOOP  TD       =X'F2'               TEST INPUT DEVICE
 55           JEQ      $AALOOP              LOOP UNTIL READY
 60           RD       =X'F2'               READ CHARACTER INTO REG A
 65           COMP     =X'000000'
 70           JEQ      $AAEXIT
 65           COMP     =X'000003'
 70           JEQ      $AAEXIT
 65           COMP     =X'000004'
 70           JEQ      $AAEXIT
 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 4.9 Use of macro-time looping statements.

Keyword Macro Parameters

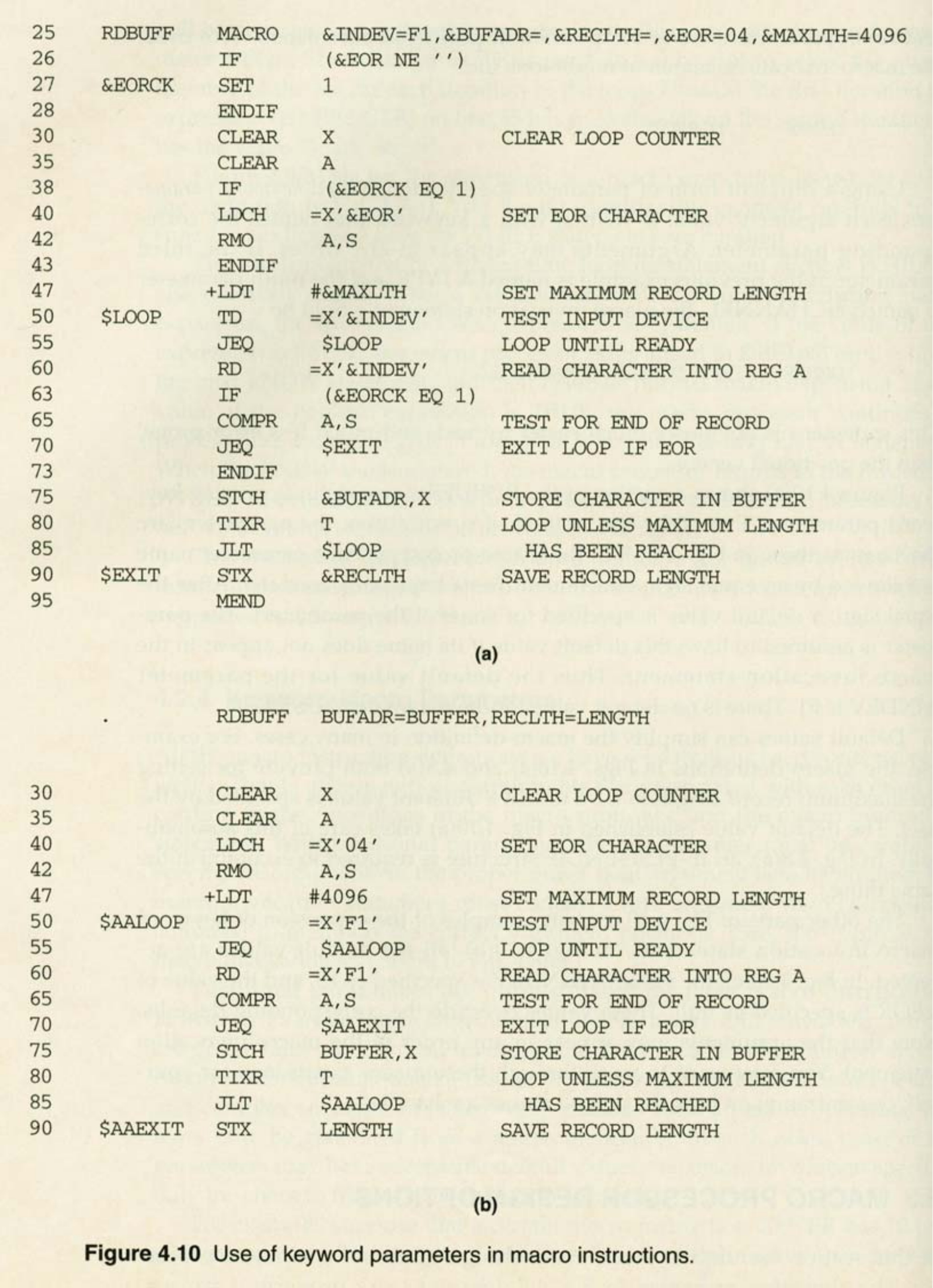
- Positional parameters
  - Parameters and arguments were associated with each other according to their positions in the macro prototype and the macro invocation statement
  - Consecutive commas is necessary for a null argument

    GENER ,,DIRECT,,,,,,3

Keyword Macro Parameters

- Keyword parameters
  - Each argument value is written with a keyword that names the corresponding parameter
  - A macro may have a large number of parameters , and only a few of these are given values in a typical invocation

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



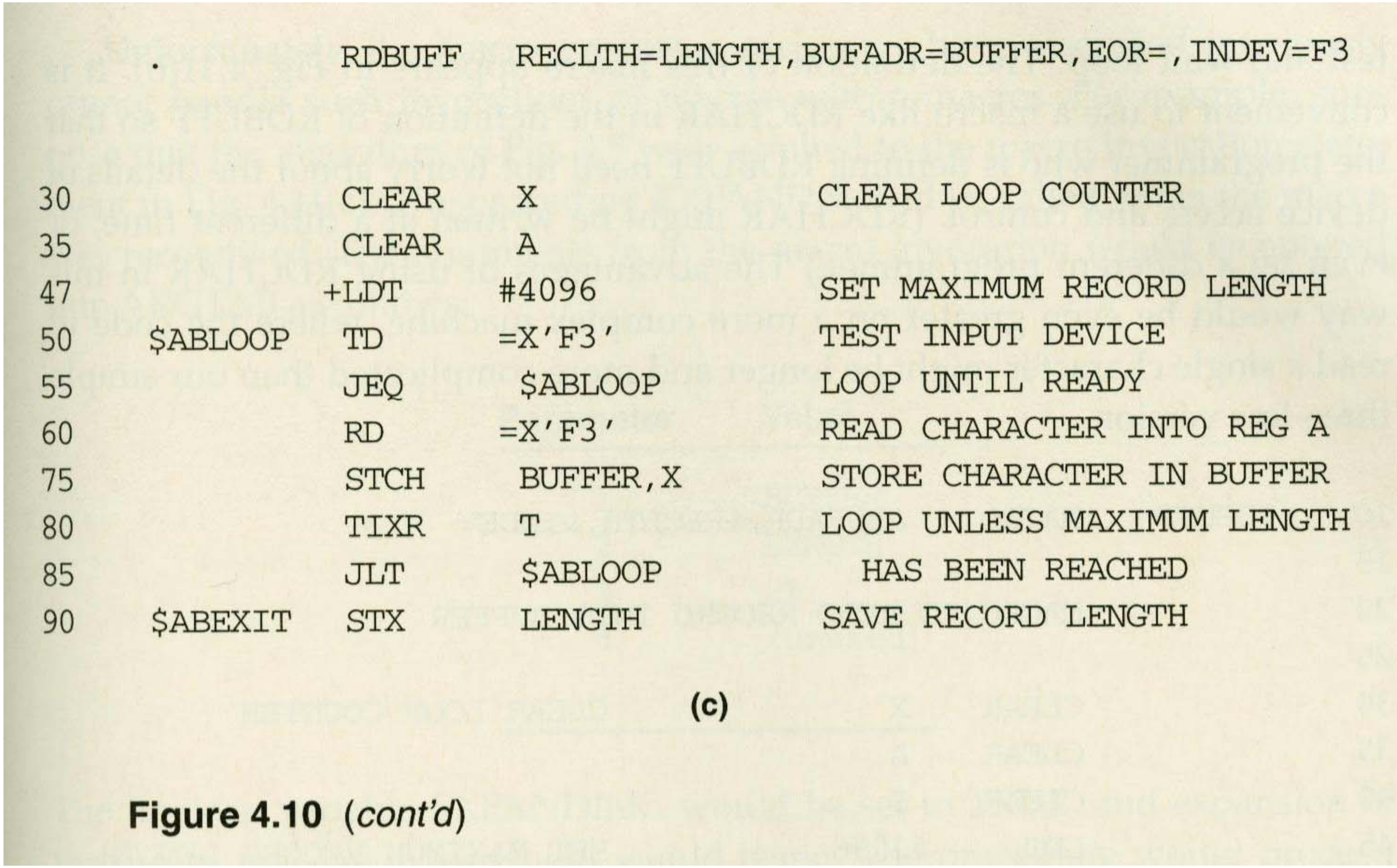
```
25  RDBUFF   MACRO   &INDEV=F1,&BUFADR=,&RECLTH=,&EOR=04,&MAXLTH=4096
26           IF      (&EOR NE '')
27  &EORCK   SET     1
28           ENDIF
30           CLEAR   X                CLEAR LOOP COUNTER
35           CLEAR   A
38           IF      (&EORCK EQ 1)
40           LDCH    =X'&EOR'         SET EOR CHARACTER
42           RMO     A,S
43           ENDIF
47          +LDT     #&MAXLTH         SET MAXIMUM RECORD LENGTH
50  $LOOP    TD      =X'&INDEV'       TEST INPUT DEVICE
55           JEQ     $LOOP            LOOP UNTIL READY
60           RD      =X'&INDEV'       READ CHARACTER INTO REG A
63           IF      (&EORCK EQ 1)
65           COMPR   A,S              TEST FOR END OF RECORD
70           JEQ     $EXIT            EXIT LOOP IF EOR
73           ENDIF
75           STCH    &BUFADR,X        STORE CHARACTER IN BUFFER
80           TIXR    T                LOOP UNLESS MAXIMUM LENGTH
85           JLT     $LOOP              HAS BEEN REACHED
90  $EXIT    STX     &RECLTH          SAVE RECORD LENGTH
95           MEND
```

(a)

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

30           CLEAR   X                CLEAR LOOP COUNTER
35           CLEAR   A
40           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           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.



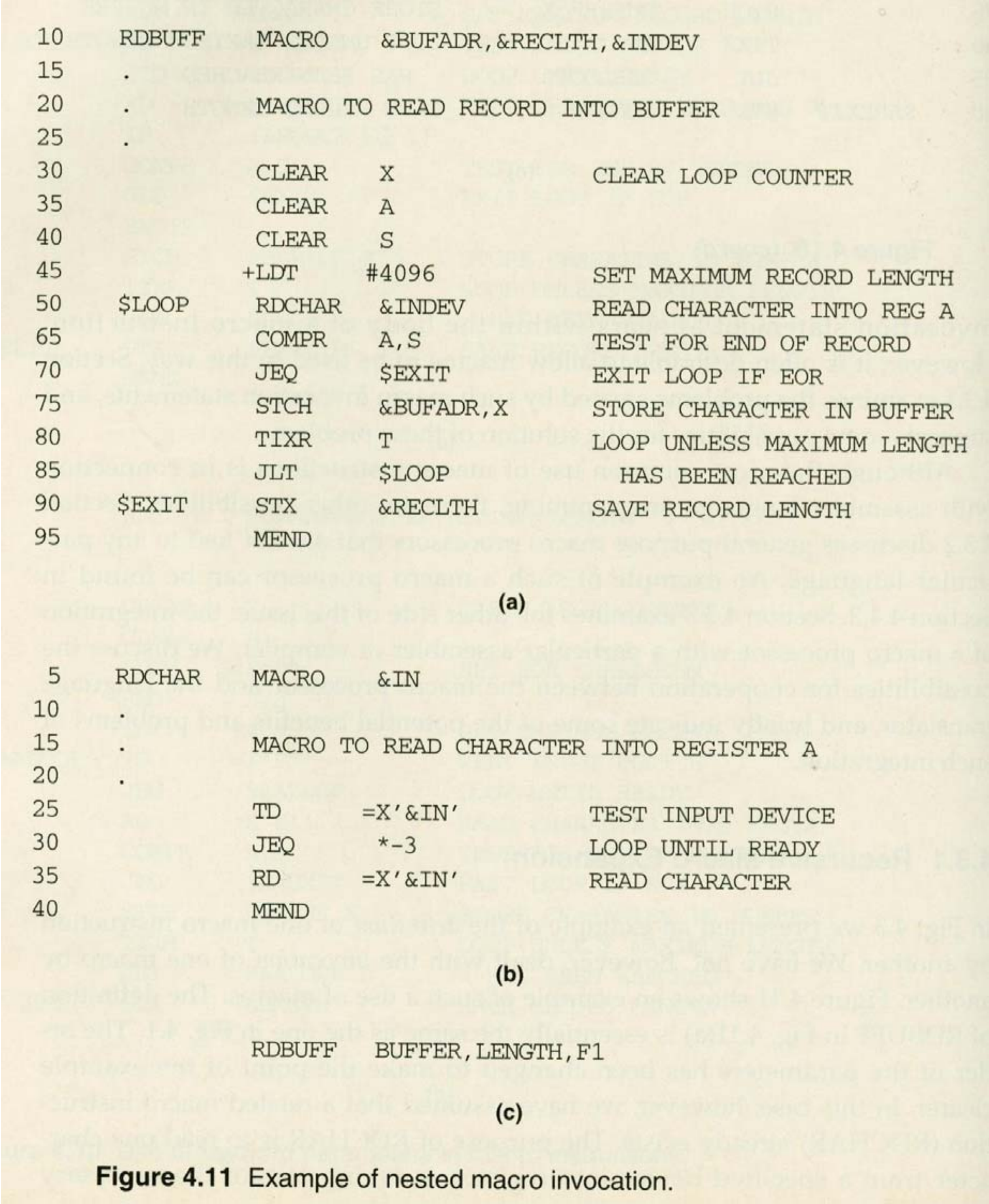
```
.          RDBUFF   RECLTH=LENGTH,BUFADR=BUFFER,EOR=,INDEV=F3

           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*)

Macro Processor Design Options

- Recursive Macro Expansion
  - In Figure 4.3, we presented an example of the definition of on macro instruction by another.
    - We have not dealt with the invocation of one macro by another **(nested macro invocation)**
  - See Figure 4.11



```
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
```

(a)

```
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
```

(c)

Figure 4.11 Example of nested macro invocation.

Macro Processor Design Options

- Recursive Macro Expansion Applying Algorithm of Fig. 4.5
  - Problem:
    - The processing would proceed normally until line 50, which contains a statement invoking RDCHAR
    - In addition, the argument from the original macro invocation (RDBUFF) would be lost because the values in ARGTAB were overwritten with the arguments from the invocation of RDCHAR
  - Solution:
    - These problems are not difficult to solve if the macro processor is begin written in a programming language that allows recursive call

General-Purpose Macro Processors

- Macro processors have been developed for some high-level programming languages
- These special-purpose macro processors are similar in general function and approach; however, the details differ from language to language

General-Purpose Macro Processors

- The advantages of such a general-purpose approach to macro processing are obvious
  - The programmer does not need to learn about a different macro facility for each compiler or assembler language, so much of the time and expense involved in training are eliminated
  - A substantial overall saving in software development cost

General-Purpose Macro Processors

- In spite of the advantages noted, there are still relatively few general-purpose macro processors. Why?

  1. In a typical programming language, there are several situations in which normal macro parameter substitution should no occur
     - E.g. comments should usually be ignored by a macro processor

General-Purpose Macro Processors

2. Another difference between programming languages is related to their facilities for grouping together terms, expressions, or statements
   - E.g. Some languages use keywords such as begin and end for grouping statements. Others use special characters such as { and }.

General-Purpose Macro Processors

3. A more general problem involves the tokens of the programming language
    - E.g. identifiers, constants, operators, and keywords
    - E.g. blanks

General-Purpose Macro Processors

4. Another potential problem with general-purpose macro processors involves the syntax used for macro definitions and macro invocation statements. With most special-purpose macro processors, macro invocations are very similar in form to statements in the source programming language

The end.