# CS 2304 - SYSTEM SOFTWARE-PART-B QUESTIONS

-V+ 2013 EDTION

# CS 2304 - SYSTEM SOFTWARE-PART-B QUESTIONS

**CLASS:III CSE'A'** **ACADEMIC YEAR:2012-2013**
**SEM :V**

## UNIT – 1
## INTRODUCTION

**1. EXPLAIN THE ARCHITECTURE OF SIC MACHINE.**

## The Simplified Instructional Computer (SIC)

Simplified Instructional Computer (SIC) is a hypothetical computer that includes the hardware features most often found on real machines. There are two versions of SIC, they are, standard model (SIC), and, extension version (SIC/XE) (extra equipment or extra expensive).

## SIC MACHINE ARCHITECTURE

We discuss here the SIC machine architecture with respect to its Memory and Registers, Data Formats, Instruction Formats, Addressing Modes, Instruction Set, Input and Output

## Memory

There are $2^{15}$ bytes in the computer memory, that is 32,768 bytes , It uses Little Endian format to store the numbers, 3 consecutive bytes form a word , each location in memory contains 8-bit bytes.

## Registers

There are five registers, each 24 bits in length. Their mnemonic, number and use are given in the following table.

| Mnemonic | Number | Use |
|---|---|---|
| A | 0 | Accumulator; used for arithmetic operations |
| X | 1 | Index register; used for addressing |
| L | 2 | Linkage register; JSUB |

| | | |
|---|---|---|
| PC | 8 | Program counter |
| SW | 9 | Status word, including CC |

## Data Formats

Integers are stored as 24-bit binary numbers , 2's complement representation is used for negative values, characters are stored using their 8-bit ASCII codes, No floating-point hardware on the standard version of SIC.

### Instruction Formats

Opcode(8) x Address (15)

All machine instructions on the standard version of SIC have the 24-bit format as shown above

## Addressing Modes

| Mode | Indication | Target address calculation |
|---|---|---|
| Direct | x = 0 | TA = address |
| Indexed | x = 1 | TA = address + (x) |

There are two addressing modes available, which are as shown in the above table. Parentheses are used to indicate the contents of a register or a memory location.

## Instruction Set

SIC provides, load and store instructions (LDA, LDX, STA, STX, etc.). Integer arithmetic operations: (ADD, SUB, MUL, DIV, etc.). All arithmetic operations involve register A and a word in memory, with the result being left in the register. Two instructions are provided for subroutine linkage. COMP compares the value in register A with a word in memory, this instruction sets a condition code CC to indicate the result. There are conditional jump instructions: (JLT, JEQ, JGT), these instructions test the setting of CC and jump accordingly. JSUB jumps to the subroutine placing the return address in register L, RSUB returns by jumping to the address contained in register L.

## Input and Output

Input and Output are performed by transferring 1 byte at a time to or from the rightmost 8 bits of register A (accumulator). The Test Device (TD) instruction tests

whether the addressed device is ready to send or receive a byte of data. Read Data (RD), Write Data (WD) are used for reading or writing the data.

## Data movement and Storage Definition

LDA, STA, LDL, STL, LDX, STX ( A- Accumulator, L – Linkage Register, X – Index Register)**,** all uses 3-byte word. LDCH, STCH associated with characters uses 1-byte. There are no memory-memory move instructions.

Storage definitions are

- WORD - ONE-WORD CONSTANT
- RESW - ONE-WORD VARIABLE
- BYTE - ONE-BYTE CONSTANT
- RESB - ONE-BYTE VARIABLE

## Example Programs (SIC)

**Example 1(Simple data and character movement operation)**

```
            LDA FIVE
            STA  ALPHA
            LDCH      CHARZ
            STCH      C1
            .
ALPHA       RESW      1
FIVE        WORD      5
CHARZ       BYTE  C'Z'
C1          RESB      1
```

**Example 2( Arithmetic operations)**

```
            LDA  ALPHA
            ADD  INCR
            SUB  ONE
            STA  BEETA
            ……..
            ……..
            ……..
            ……..
ONE         WORD  1
ALPHA       RESW  1
BEETA       RESW  1
INCR        RESW  1
```

**Example 3(Looping and Indexing operation)**

```
            LDX     ZERO        :  X = 0
            MOVECH  LDCH   STR1, X      :  LOAD A FROM STR1
            STCH   STR2, X     :  STORE A TO STR2
            TIX      ELEVEN    :   ADD 1 TO X, TEST
            JLT      MOVECH
             .
             .
             .
STR1        BYTE     C 'HELLO WORLD'
STR2        RESB     11
ZERO        WORD     0
ELEVEN      WORD     11
```

**Example 4( Input and Output operation)**

```
INLOOP      TD      INDEV          : TEST INPUT DEVICE
            JEQ     INLOOP         : LOOP UNTIL DEVICE IS READY
            RD      INDEV          : READ ONE BYTE INTO A
            STCH DATA              :  STORE A TO DATA
            .
            .
OUTLP       TD      OUTDEV         : TEST OUTPUT DEVICE
            JEQ     OUTLP          : LOOP UNTIL DEVICE IS READY
            LDCH    DATA           : LOAD DATA INTO A
            WD      OUTDEV         : WRITE A TO OUTPUT DEVICE
             .
             .
INDEV       BYTE      X 'F5'       : INPUT DEVICE NUMBER
OUTDEV      BYTE      X '08'       : OUTPUT DEVICE NUMBER
DATA        RESB      1            : ONE-BYTE VARIABLE
```

**Example 5  (To transfer two hundred bytes of data from input device to memory)**

```
LDX    ZERO
CLOOP       TD      INDEV
            JEQ     CLOOP
            RD      INDEV
            STCH    RECORD, X
            TIX     B200
            JLT     CLOOP
            .
```

```
            .
INDEV       BYTE     X 'F5'
RECORD      RESB     200
ZERO        WORD     0
B200        WORD     200
```

**Example 6 (Subroutine to transfer two hundred bytes of data from input device to memory)**

```
            JSUB  READ
            ……
            ……
READ        LDX   ZERO
CLOOP       TD    INDEV
            JEQ   CLOOP
            RD    INDEV
            STCH  RECORD, X
            TIX   B200          : add 1 to index compare 200 (B200)
            JLT   CLOOP
            RSUB
            ……..
            ……..
INDEV       BYTE     X 'F5'
RECORD      RESB     200
ZERO        WORD     0
B200        WORD     200
```

---

**2. EXPLAIN THE ARCHITECTURE OF SIC/XE MACHINE.**

## Memory

Maximum memory available on a SIC/XE system is 1 Megabyte ($2^{20}$ bytes)

## Registers

Additional B, S, T, and F registers are provided by SIC/XE, in addition to the registers of SIC

| Mnemonic | Number | Special use |
|---|---|---|
| B | 3 | Base register |
| S | 4 | General working register |
| T | 5 | General working register |

| | | |
|---|---|---|
| F | 6 | Floating-point accumulator (48 bits) |

## Floating-point data type

There is a 48-bit floating-point data type, $F*2^{(e-1024)}$

| 1 | 11 | 36 |
|---|---|---|
| S | exponent | fraction |

## Instruction Formats

The new set of instruction formats fro SIC/XE machine architecture are as follows. Format 1 (1 byte): contains only operation code (straight from table). Format 2 (2 bytes): first eight bits for operation code, next four for register 1 and following four for register 2. The numbers for the registers go according to the numbers indicated at the registers section (ie, register T is replaced by hex 5, F is replaced by hex 6). Format 3 (3 bytes): First 6 bits contain operation code, next 6 bits contain flags, last 12 bits contain displacement for the address of the operand. Operation code uses only 6 bits, thus the second hex digit will be affected by the values of the first two flags (n and i). The flags, in order, are: n, i, x, b, p, and e. Its functionality is explained in the next section. The last flag e indicates the instruction format (0 for 3 and 1 for 4). Format 4 (4 bytes): same as format 3 with an extra 2 hex digits (8 bits) for addresses that require more than 12 bits to be represented.

**Format 1 (1 byte)**

| **8** |
|---|
| **Op** |

**Format 2 (2 bytes)**

| **8** | **4** | **4** |
|---|---|---|
| **Op** | **r1** | **r2** |

Formats 1 and 2 are instructions do not reference memory at all

**Format 3 (3 bytes)**

| 6 | 1 | 1 | 1 | 1 | 1 | 1 | 12 |
|---|---|---|---|---|---|---|---|
| **Op** | **N** | **i** | **x** | **b** | **P** | **e** | **Disp** |

**Format 4 (4 bytes)**

| 6 | 1 | 1 | 1 | 1 | 1 | 1 | 20 |
|---|---|---|---|---|---|---|---|
| **Op** | **n** | **i** | **x** | **b** | **P** | **e** | **Address** |

## Addressing modes & Flag Bits

Five possible addressing modes plus the combinations are as follows.

**Direct** (x, b, and p all set to 0): operand address goes as it is. n and i are both set to the same value, either 0 or 1. While in general that value is 1, if set to 0 for format 3 we can assume that the rest of the flags (x, b, p, and e) are used
as a part of the address of the operand, to make the format compatible to the
SIC format

**Relative** (either b or p equal to 1 and the other one to 0): the address of the operand should be added to the current value stored at the B register (if b = 1) or to the value stored at the PC register (if p = 1)

**Immediate** (i = 1, n = 0): The operand value is already enclosed on the instruction (ie. lies on the last 12/20 bits of the instruction)

**Indirect** (i = 0, n = 1): The operand value points to an address that holds the address for the operand value.

**Indexed** (x = 1): value to be added to the value stored at the register x to obtain real address of the operand. This can be combined with any of the previous modes except immediate.

The various flag bits used in the above formats have the following meanings

e - e = 0 means format 3, e = 1 means format 4

Bits x,b,p: Used to calculate the target address using relative, direct, and indexed addressing Modes

Bits i and n: Says, how to use the target address

b and p - both set to 0, disp field from format 3 instruction is taken to be the target address. For a format 4 bits b and p are normally set to 0, 20 bit address is the target address

x - x is set to 1, X register value is added for target address calculation
i=1, n=0 Immediate addressing, **TA**: TA is used as the operand value, no memory reference
i=0, n=1 Indirect addressing, **((TA))**: The word at the TA is fetched. Value of TA is taken as the address of the operand value

i=0, n=0 or i=1, n=1 Simple addressing, **(TA)**:TA is taken as the address of the operand value

Two new relative addressing modes are available for use with instructions assembled using format 3.

| **Mode** | **Indication** | **Target address calculation** |
|---|---|---|
| Base relative | b=1,p=0 | TA=(B)+ disp<br>(0≤disp ≤4095) |
| Program-counter relative | b=0,p=1 | TA=(PC)+ disp<br>(-2048≤disp ≤2047) |

## Instruction Set

SIC/XE provides all of the instructions that are available on the standard version. In addition we have, Instructions to load and store the new registers LDB, STB, etc, Floating-point arithmetic operations, ADDF, SUBF, MULF, DIVF, Register move instruction : RMO, Register-to-register arithmetic operations, ADDR, SUBR, MULR, DIVR and, Supervisor call instruction : SVC.

## Input and Output

There are I/O channels that can be used to perform input and output while the CPU is executing other instructions. Allows overlap of computing and I/O, resulting in more efficient system operation. The instructions SIO, TIO, and HIO are used to start, test and halt the operation of I/O channels.

## Example Programs (SIC/XE)

**Example 1 (Simple data and character movement operation)**

```
                LDA #5
                STA  ALPHA
                LDA      #90
                STCH         C1
            .
            .
ALPHA           RESW        1
C1              RESB  1
```

**Example 2(Arithmetic operations)**

```
        LDS   INCR
        LDA  ALPHA
        ADD  S,A
        SUB  #1
        STA  BEETA
        ……
       ……..
ALPHA RESW   1
BEETA RESW   1
INCR    RESW   1
```

**Example 3(Looping and Indexing operation)**

```
                LDT     #11
                LDX     #0              :   X = 0
 MOVECH     LDCH   STR1, X      :   LOAD A FROM STR1
                STCH    STR2, X     :   STORE A TO STR2
                TIXR     T              :    ADD 1 TO X, TEST (T)
                JLT       MOVECH
                …….
                …….
                ……
   STR1         BYTE     C ‘HELLO WORLD’
   STR2         RESB     11
```

**Example 4  (To transfer two hundred bytes of data from input device to memory)**

```
            LDT    #200
            LDX    #0
CLOOP      TD      INDEV
            JEQ    CLOOP
            RD      INDEV
```

```
            STCH   RECORD, X
            TIXR    T
            JLT     CLOOP
            .
            .
INDEV       BYTE    X 'F5'
RECORD      RESB    200
```

**Example 5 (Subroutine to transfer two hundred bytes of data from input device to memory)**

```
            JSUB   READ
            …….
            …….
READ        LDT    #200
            LDX    #0
CLOOP       TD     INDEV
            JEQ    CLOOP
            RD     INDEV
            STCH   RECORD, X
            TIXR   T              : add 1 to index compare T
            JLT    CLOOP
            RSUB
            ……..
            ……..
INDEV       BYTE    X 'F5'
RECORD      RESB    200
```

---

**3. EXPLAIN IN DETAIL ABOUT CISC MACHINES**

## CISC machines

Traditional (CISC) Machines, are nothing but, Complex Instruction Set Computers, has relatively large and complex instruction set, different instruction formats, different lengths, different addressing modes, and implementation of hardware for these computers is complex. VAX and Intel x86 processors are examples for this type of architecture.

## 3.1 VAX Architecture

**Memory** - The VAX memory consists of 8-bit bytes. All addresses used are byte addresses. Two consecutive bytes form a word, Four bytes form a longword, eight bytes form a quadword, sixteen bytes form a octaword. All VAX programs operate in a virtual address space of 232 bytes , One half is called system space, other half process space.

**Registers** – There are 16 general purpose registers (GPRs) , 32 bits each, named as R0 to R15, PC (R15), SP (R14), Frame Pointer FP ( R13), Argument Pointer AP (R12) ,Others available for general use. There is a Process status longword (PSL) – for flags.
**Data Formats** - Integers are stored as binary numbers in byte, word, longword, quadword, octaword. 2's complement notation is used for storing negative numbers. Characters are stored as 8-bit ASCII codes. Four different floating-point data formats are also available.

**Instruction Formats** - VAX architecture uses variable-length instruction formats – op code 1 or 2 bytes, maximum of 6 operand specifiers depending on type of instruction. Tabak – Advanced Microprocessors (2nd edition) McGraw-Hill, 1995, gives more information.

**Addressing Modes** - VAX provides a large number of addressing modes. They are Register mode, register deferred mode, autoincrement, autodecrement, base relative, program-counter relative, indexed, indirect, and immediate.

**Instruction Set** – Instructions are symmetric with respect to data type - Uses prefix – type of operation, suffix – type of operands, a modifier – number of operands. For example, ADDW2 - add, word length, 2 operands, MULL3 - multiply, longwords, 3 operands CVTCL - conversion from word to longword. VAX also provides instructions to load and store multiple registers.

**Input and Output** - Uses I/O device controllers. Device control registers are mapped to separate I/O space. Software routines and memory management routines are used for input/output operations.

## 3.2 Pentium Pro Architecture

Introduced by Intel in 1995.

**Memory** - consists of 8-bit bytes, all addresses used are byte addresses. Two consecutive bytes form a word, four bytes form a double word (dword). Viewed as collection of segments, and, address = segment number + offset. There are code, data, stack , extra segments.

**Registers** – There are 32-bit, eight GPRs, namely EAX, EBX, ECX, EDX, ESI, EDI, EBP, ESP. EAX, EBX, ECX, EDX – are used for data manipulation, other four are used to hold addresses. EIP – 32-bit contains pointer to next instruction to be executed. FLAGS is an 32 - bit flag register. CS, SS, DS, ES, FS, GS are the six 16-bit segment registers.

**Data Formats** - Integers are stored as 8, 16, or 32 bit binary numbers, 2's complement for negative numbers, BCD is also used in the form of unpacked BCD, packed BCD. There are three floating point data formats, they are single, double, and extended-precision. Characters are stored as one per byte – ASCII codes.

**Instruction Formats** – Instructions uses prefixes to specify repetition count, segment register, following prefix (if present), an opcode ( 1 or 2 bytes), then number of bytes to specify operands, addressing modes. Instruction formats varies in length from 1 byte to 10 bytes or more. Opcode is always present in every instruction

**Addressing Modes** - A large number of addressing modes are available. They are immediate mode, register mode, direct mode, and relative mode. Use of base register, index register with displacement is also possible.

**Instruction Set** – This architecture has a large and complex instruction set, approximately 400 different machine instructions. Each instruction may have one, two or three operands. For example Register-to-register, register-to-memory, memory-to-memory, string manipulation, etc…are the some the instructions.

**Input and Output** - Input is from an I/O port into register EAX. Output is from EAX to an I/O port

---

**4. EXPLAIN IN DETAIL ABOUT RISC MACHINES**

## RISC Machines

RISC means Reduced Instruction Set Computers. These machines are intended to simplify the design of processors. They have Greater reliability, faster execution and less expensive processors. And also they have standard and fixed instruction length. Number of machine instructions, instruction formats, and addressing modes relatively small. UltraSPARC Architecture and Cray T3E Architecture are examples of RISC machines.

## 4.1 UltraSPARC Architecture

Introduced by Sun Microsystems. SPARC – Scalable Processor ARChitecture. SPARC, SuperSPARC, UltraSPARC are upward compatible machines and share the same basic structure.

**Memory** - Consists of 8-bit bytes, all addresses used are byte addresses. Two consecutive bytes form a halfword, four bytes form a word , eight bytes form a double word. Uses virtual address space of $2^{64}$ bytes, divided into pages.

**Registers** - More than 100 GPRs, with 64 bits length each called Register file. There are 64 double precision floating-point registers, in a special floating-point unit (FPU). In addition to these, it contains PC, condition code registers, and control registers.

**Data Formats** - Integers are stored as 8, 16, 32 or 64 bit binary numbers. Signed, unsigned for integers and 2's complement for negative numbers. Supports both big-endian and little-endian byte orderings. Floating-point data formats – single, double and quad-precision are available. Characters are stored as 8-bit ASCII value.

**Instruction Formats** - 32-bits long, three basic instruction formats, first two bits identify the format. Format 1 used for call instruction. Format 2 used for branch instructions. Format 3 used for load, store and for arithmetic operations.
**Addressing Modes** - This architecture supports immediate mode, register-direct mode,PC-relative, Register indirect with displacement, and Register indirect indexed.

**Instruction Set** – It has fewer than 100 machine instructions. The only instructions that access memory are loads and stores. All other instructions are register-to-register operations. Instruction execution is pipelined – this results in faster execution, and hence speed increases.

**Input and Output** - Communication through I/O devices is accomplished through memory. A range of memory locations is logically replaced by device registers. When a load or store instruction refers to this device register area of memory, the corresponding device is activated. There are no special I/O instructions.

## 4.2 Cray T3E Architecture

Announced by Cray Research Inc., at the end of 1995 and is a massively parallel processing (MPP) system, contains a large number of processing elements (PEs), arranged in a three-dimensional network. Each PE consists of a DEC Alpha EV5 RISC processor, and local memory.

**Memory -** Each PE in T3E has its own local memory with a capacity of from 64 megabytes to 2 gigabytes, consists of 8-bit bytes, all addresses used are byte addresses. Two consecutive bytes form a word, four bytes form a longword, eight bytes form a quadword.

**Registers** – There are 32 general purpose registers(GPRs), with 64 bits length each called R0 through R31, contains value zero always. In addition to these, it has 32 floating-point registers, 64 bits long, and 64-bit PC, status , and control registers.

**Data Formats** - Integers are stored as long and quadword binary numbers. 2's complement notation for negative numbers. Supports only little-endian byte orderings. Two different floating-point data formats – VAX and IEEE standard. Characters stored as 8-bit ASCII value.

**Instruction Formats** - 32-bits long, five basic instruction formats. First six bits always identify the opcode.

**Addressing Modes** - This architecture supports, immediate mode, register-direct mode, PC-relative, and Register indirect with displacement.

**Instruction Set** - Has approximately 130 machine instructions. There are no byte or word load and store instructions. Smith and Weiss – "PowerPC 601 and Alpha 21064: A Tale of TWO RISCs " – Gives more information.

**Input and Output** - Communication through I/O devices is accomplished through multiple ports and I/O channels. Channels are integrated into the network that

interconnects the processing elements. All channels are accessible and controllable from all PEs.

---

## UNIT- 2

## ASSEMBLER DESIGN

### 1. EXPLAIN IN DETAIL ABOUT BASIC ASSEMBLER FUNCTIONS.

The basic assembler functions are:

- Translating mnemonic language code to its equivalent object code.
- Assigning machine addresses to symbolic labels.


- The design of assembler can be to perform the following:
  - Scanning (tokenizing)
  - Parsing (validating the instructions)
  - Creating the symbol table
  - Resolving the forward references
  - Converting into the machine language

- The design of assembler in other words:
  - Convert mnemonic operation codes to their machine language equivalents
  - Convert symbolic operands to their equivalent machine addresses
  - Decide the proper instruction format Convert the data constants to internal machine representations
  - Write the object program and the assembly listing

So for the design of the assembler we need to concentrate on the machine architecture of the SIC/XE machine. We need to identify the algorithms and the various data structures to be used. According to the above required steps for assembling the assembler also has to handle *assembler directives*, these do not generate the object code but directs the assembler to perform certain operation. These directives are:

- SIC Assembler Directive:
  - START: Specify name & starting address.
  - END: End of the program, specify the first execution instruction.
  - BYTE, WORD, RESB, RESW
  - End of record: a null char(00)

End of file: a zero length record

The assembler design can be done:

- Single pass assembler
- Multi-pass assembler

**Single-pass Assembler:**

In this case the whole process of scanning, parsing, and object code conversion is done in single pass. The only problem with this method is resolving forward reference. This is shown with an example below:

```
10      1000        FIRST       STL     RETADR          141033
--
--
--
--
95      1033        RETADR      RESW        1
```

In the above example in line number 10 the instruction STL will store the linkage register with the contents of RETADR. But during the processing of this instruction the value of this symbol is not known as it is defined at the line number 95. Since I single-pass assembler the scanning, parsing and object code conversion happens simultaneously. The instruction is fetched; it is scanned for tokens, parsed for syntax and semantic validity. If it valid then it has to be converted to its equivalent object code. For this the object code is generated for the opcode STL and the value for the symbol RETADR need to be added, which is not available.

Due to this reason usually the design is done in two passes. So a multi-pass assembler resolves the forward references and then converts into the object code. Hence the process of the multi-pass assembler can be as follows:

***Pass-1***

- Assign addresses to all the statements
- Save the addresses assigned to all labels to be used in *Pass-2*
- Perform some processing of assembler directives such as RESW, RESB to find the length of data areas for assigning the address values.
- Defines the symbols in the symbol table(generate the symbol table)

***Pass-2***

- Assemble the instructions (translating operation codes and looking up addresses).
- Generate data values defined by BYTE, WORD etc.
- Perform the processing of the assembler directives not done during *pass-1*.
- Write the object program and assembler listing.

**Assembler Design:**

The most important things which need to be concentrated is the generation of Symbol table and resolving *forward references*.

- Symbol Table:
  - This is created during pass 1
  - All the labels of the instructions are symbols
  - Table has entry for symbol name, address value.
- Forward reference:
  - Symbols that are defined in the later part of the program are called forward referencing.
  - There will not be any address value for such symbols in the symbol table in pass 1.

**Example Program:**

The example program considered here has a main module, two subroutines

- Purpose of example program
  - Reads records from input device (code F1)
  - Copies them to output device (code 05)
  - At the end of the file, writes EOF on the output device, then RSUB to the operating system
- Data transfer (RD, WD)
  - A buffer is used to store record
  - Buffering is necessary for different I/O rates
  - The end of each record is marked with a null character (00)16
  - The end of the file is indicated by a zero-length record
- Subroutines (JSUB, RSUB)
  - RDREC, WRREC
  - Save link register first before nested jump

| Line | Loc | Source statement | | | Object code |
|---|---|---|---|---|---|
| 5 | 1000 | COPY | START | 1000 | |
| 10 | 1000 | FIRST | STL | RETADR | 141033 |
| 15 | 1003 | CLOOP | JSUB | RDREC | 482039 |
| 20 | 1006 | | LDA | LENGTH | 001036 |
| 25 | 1009 | | COMP | ZERO | 281030 |
| 30 | 100C | | JEQ | ENDFIL | 301015 |
| 35 | 100F | | JSUB | WRREC | 482061 |
| 40 | 1012 | | J | CLOOP | 3C1003 |
| 45 | 1015 | ENDFIL | LDA | EOF | 00102A |
| 50 | 1018 | | STA | BUFFER | 0C1039 |
| 55 | 101B | | LDA | THREE | 00102D |
| 60 | 101E | | STA | LENGTH | 0C1036 |
| 65 | 1021 | | JSUB | WRREC | 482061 |
| 70 | 1024 | | LDL | RETADR | 081033 |
| 75 | 1027 | | RSUB | | 4C0000 |
| 80 | 102A | EOF | BYTE | C'EOF' | 454F46 |
| 85 | 102D | THREE | WORD | 3 | 000003 |
| 90 | 1030 | ZERO | WORD | 0 | 000000 |
| 95 | 1033 | RETADR | RESW | 1 | |
| 100 | 1036 | LENGTH | RESW | 1 | |
| 105 | 1039 | BUFFER | RESB | 4096 | |
| 110 | | . | | | |

The first column shows the line number for that instruction, second column shows the addresses allocated to each instruction. The third column indicates the labels given to the statement, and is followed by the instruction consisting of opcode and operand. The last column gives the equivalent object code.

The *object code* later will be loaded into memory for execution. The simple object program we use contains three types of records:

- Header record
  - Col. 1 H
  - Col. 2~7 Program name
  - Col. 8~13 Starting address of object program (hex)
  - Col. 14~19 Length of object program in bytes (hex)
- Text record
  - Col. 1 T
  - Col. 2~7 Starting address for object code in this record (hex)
  - Col. 8~9 Length of object code in this record in bytes (hex)

- Col. 10~69 Object code, represented in hex (2 col. per byte)

- End record
  - Col.1 E
  - Col.2~7 Address of first executable instruction in object program (hex) "^" is only for separation only

**The Algorithm for Pass 1:**

```
 Begin
read first input line
if OPCODE = „START‟ then begin
save #[Operand] as starting addr
 initialize LOCCTR to starting address
write line to intermediate file
 read next line
 end( if START)
 else
 initialize LOCCTR to 0
 While OPCODE != „END‟ do
begin
if this is not a comment line then
begin
 if there is a symbol in the LABEL field then
 begin
search SYMTAB for LABEL
 if found then
 set error flag (duplicate symbol)
else
 (if symbol)
search OPTAB for OPCODE
if found then
 add 3 (instr length) to LOCCTR
 else if OPCODE = „WORD‟ then
add 3 to LOCCTR
else if OPCODE = „RESW‟ then
add 3 * #[OPERAND] to LOCCTR
else if OPCODE = „RESB‟ then
add #[OPERAND] to LOCCTR
 else if OPCODE = „BYTE‟ then
begin
 find length of constant in bytes
add
 length to LOCCTR
end
else
 set error flag (invalid operation code)
```

end (if not a comment)
 write line to intermediate file
read next input line
 end { while not END}
write last line to intermediate file
 Save (LOCCTR – starting address) as program length
End {pass 1}

The algorithm scans the first statement START and saves the operand field (the address) as the starting address of the program. Initializes the LOCCTR value to this address. This line is written to the intermediate line. If no operand is mentioned the LOCCTR is initialized to zero. If a label is encountered, the symbol has to be entered in the symbol table along with its associated address value. If the symbol already exists that indicates an entry of the same symbol already exists. So an error flag is set indicating a duplication of the symbol. It next checks for the mnemonic code, it searches for this code in the OPTAB. If found then the length of the instruction is added to the LOCCTR to make it point to the next instruction. If the opcode is the directive WORD it adds a value 3 to the LOCCTR. If it is RESW, it needs to add the number of data word to the LOCCTR. If it is BYTE it adds a value one to the LOCCTR, if RESB it adds number of bytes. If it is END directive then it is the end of the program it finds the length of the program by evaluating current LOCCTR – the starting address mentioned in the operand field of the END directive. Each processed line is written to the intermediate file.

**The Algorithm for Pass 2:**

Begin
read 1st input line
 if OPCODE = „START‟ then
 begin
write listing line
read next input line
end
 write Header record to object program
initialize 1st Text record
while OPCODE != „END‟ do
 begin
 if this is not comment line then
begin
 search OPTAB for OPCODE
if found then
 begin
 if there is a symbol in OPERAND field then
begin
search SYMTAB for OPERAND field then
if found then
 begin

store symbol value as operand address
else
 begin
 store 0 as operand address
set error flag (undefined symbol)
 end
end (if symbol)

else store 0 as operand address assemble the object code instruction
else if OPCODE = „BYTE‟ or „WORD” then
 convert constant to object code if object code doesn‟t fit into current Text record then
 begin Write text record to object code
 initialize new Text record
end
 add object code to Text record
 end {if not comment}
 write listing line
read next input line
end
write listing line
read next input line
write last listing line
 End {Pass 2}

Here the first input line is read from the intermediate file. If the opcode is START, then this line is directly written to the list file. A header record is written in the object program which gives the starting address and the length of the program (which is calculated during pass 1). Then the first text record is initialized. Comment lines are ignored. In the instruction, for the opcode the OPTAB is searched to find the object code. If a symbol is there in the operand field, the symbol table is searched to get the address value for this which gets added to the object code of the opcode. If the address not found then zero value is stored as operands address. An error flag is set indicating it as undefined. If symbol itself is not found then store 0 as operand address and the object code instruction is assembled.

If the opcode is BYTE or WORD, then the constant value is converted to its equivalent object code( for example, for character EOF, its equivalent hexadecimal value „454f46‟ is stored). If the object code cannot fit into the current text record, a new text record is created and the rest of the instructions object code is listed. The text records are written to the object program. Once the whole program is assemble and when the END directive is encountered, the End record is written.

## 2. EXPLAIN ABOUT THE MACHINE-DEPENDENT ASSEMBLER FEATURES.

**Machine-Dependent Features:**

- Instruction formats and addressing modes
- Program relocation

**Instruction formats and Addressing Modes**

The instruction formats depend on the memory organization and the size of the memory. In SIC machine the memory is byte addressable. Word size is 3 bytes. So the size of the memory is $2^{12}$ bytes. Accordingly it supports only one instruction format. It has only two registers: register A and Index register. Therefore the addressing modes supported by this architecture are direct, indirect, and indexed. Whereas the memory of a SIC/XE machine is $2^{20}$ bytes (1 MB). This supports four different types of instruction types, they are:

- 1 byte instruction
- 2 byte instruction
- 3 byte instruction
- 4 byte instruction

- Instructions can be:
  - Instructions involving register to register
  - Instructions with one operand in memory, the other in Accumulator (Single operand instruction)
  - Extended instruction format
- Addressing Modes are:
  - Index Addressing(SIC): Opcode m, x
  - Indirect Addressing: Opcode @m
  - PC-relative: Opcode m
  - Base relative: Opcode m
  - Immediate addressing: Opcode #c

### *1. Translations for the Instruction involving Register-Register addressing mode:*

**During pass 1** the registers can be entered as part of the symbol table itself. The value for these registers is their equivalent numeric codes. **During pass 2,** these values are assembled along with the mnemonics object code. If required a separate table can be created with the register names and their equivalent numeric values.

### 2. Translation involving Register-Memory instructions:

In SIC/XE machine there are four instruction formats and five addressing modes. For formats and addressing modes refer chapter 1.

Among the instruction formats, format -3 and format-4 instructions are Register-Memory type of instruction. One of the operand is always in a register and the other operand is in the memory. The addressing mode tells us the way in which the operand from the memory is to be fetched.

There are two ways: 1.***Program-counter relative and Base-relative***. This addressing mode can be represented by either using format-3 type or format-4 type of instruction format. In format-3, the instruction has the opcode followed by a 12-bit displacement value in the address field. Where as in format-4 the instruction contains the mnemonic code followed by a 20-bit displacement value in the address field.

***2. Program-Counter Relative:*** In this usually format-3 instruction format is used. The instruction contains the opcode followed by a 12-bit displacement value. The range of displacement values are from 0 -2048. This displacement (should be small enough to fit in a 12-bit field) value is added to the current contents of the program counter to get the target address of the operand required by the instruction. This is relative way of calculating the address of the operand relative to the program counter. Hence the displacement of the operand is relative to the current program counter value. The following example shows how the address is calculated:

```
10      0000        FIRST       STL         RETADR
```

RETADR is at address $(0030)_{16}$
After the SIC fetches this instruction, $(PC) = (0003)_{16}$
$TA = (PC) + disp \Rightarrow disp = TA - (PC) = 0030 - 0003 = (02D)_{16}$

```
   op     n i x b p e      disp
000101    1 1 0 0 1 0      02D    ⇒ 17202D
```

***3. Base-Relative Addressing Mode:*** in this mode the base register is used to mention the displacement value. Therefore the target address is

TA = (base) + displacement value

This addressing mode is used when the range of displacement value is not sufficient. Hence the operand is not relative to the instruction as in PC-relative addressing mode. Whenever this mode is used it is indicated by using a directive BASE. The moment the assembler encounters this directive the next instruction uses base-relative addressing mode to calculate the target address of the operand.

When NOBASE directive is used then it indicates the base register is no more used to calculate the target address of the operand. Assembler first chooses PC-relative, when the displacement field is not enough it uses Base-relative.

```
LDB #LENGTH (instruction)
BASE LENGTH (directive)
:
```

NOBASE

For example:

```
12      0003    LDB         #LENGTH             69202D
13              BASE        LENGTH
: :
100     0033    LENGTH      RESW        1
105     0036    BUFFER      RESB        4096
: :
160     104E    STCH        BUFFER,     X       57C003
165     1051    TIXR        T           B850
```

In the above example the use of directive BASE indicates that Base-relative addressing mode is to be used to calculate the target address. PC-relative is no longer used. The value of the LENGTH is stored in the base register. If PC-relative is used then the target address calculated is:

The LDB instruction loads the value of length in the base register which 0033. BASE directive explicitly tells the assembler that it has the value of LENGTH.

BUFFER is at location $(0036)_{16}$
$(B) = (0033)_{16}$
$disp = 0036 - 0033 = (0003)_{16}$

```
   op     n i x b p e      disp
010101   1 1 1 1 0 0      003    ⇒ 57C003
```

```
20      000A            LDA         LENGTH          032026
: :
175     1056    EXIT    STX         LENGTH          134000
```

Consider Line 175. If we use PC-relative

Disp = TA – (PC) = 0033 –1059 = EFDA

PC relative is no longer applicable, so we try to use BASE relative addressing mode.

***4. Immediate Addressing Mode***

In this mode no memory reference is involved. If immediate mode is used the target address is the operand itself.

```
55    0020        LDA         #3
```
Immediate operand

$TA = (0003)_{16}$

| op | n | i | x | b | p | e | disp |
|---|---|---|---|---|---|---|---|
| 000000 | 0 | 1 | 0 | 0 | 0 | 0 | 003 ⇒ 010003 |

```
133   103C        +LDT        #4096
```
Extended instruction format

$TA = (01000)_{16}$

| op | n | i | x | b | p | e | disp(20 bits) |
|---|---|---|---|---|---|---|---|
| 011101 | 0 | 1 | 0 | 0 | 0 | 1 | 01000 ⇒ 75101000 |

If the symbol is referred in the instruction as the immediate operand then it is immediate with PC-relative mode as shown in the example below:

```
12    0003        LDB         #LENGTH
```

LENGTH is at address 0033

$TA = (PC) + disp \Rightarrow disp = 0033 - 0006 = (002D)_{16}$

| op | n | i | x | b | p | e | disp |
|---|---|---|---|---|---|---|---|
| 011010 | 0 | 1 | 0 | 0 | 1 | 0 | 02D ⇒ 69202D |

***5. Indirect and PC-relative mode*:**

In this type of instruction the symbol used in the instruction is the address of the location which contains the address of the operand. The address of this is found using PC-relative addressing mode. For example:

```
70    002A        J           @RETADR
                  :           :
95    0030 RETADR RESW        1
```

RETADR is at address 0030

$TA = (PC) + disp \Rightarrow disp = 0030 - 002D = (0003)_{16}$

| op | n | i | x | b | p | e | disp |
|---|---|---|---|---|---|---|---|
| 001111 | 1 | 0 | 0 | 0 | 1 | 0 | 003 ⇒ 3E2003 |

The instruction jumps the control to the address location RETADR which in turn has the address of the operand. If address of RETADR is 0030, the target address is then 0003 as calculated above.

**PROGRAM RELOCATION**

Sometimes it is required to load and run several programs at the same time. The system must be able to load these programs wherever there is place in the memory. Therefore the exact starting is not known until the load time.

**Absolute Program**

In this the address is mentioned during assembling itself. This is called *Absolute Assembly*. Consider the instruction:

55 101B LDA THREE 00102D

This statement says that the register A is loaded with the value stored at location 102D. Suppose it is decided to load and execute the program at location 2000 instead of location 1000. Then at address 102D the required value which needs to be loaded in the register A is no more available. The address also gets changed relative to the displacement of the program. Hence we need to make some changes in the address portion of the instruction so that we can load and execute the program at location 2000. Apart from the instruction which will undergo a change in their operand address value as the program load address changes. There exist some parts in the program which will remain same regardless of where the program is being loaded.

Since assembler will not know actual location where the program will get loaded, it cannot make the necessary changes in the addresses used in the program. However, the assembler identifies for the loader those parts of the program which need modification. An object program that has the information necessary to perform this kind of modification is called the relocatable program.

---

**3. DISCUSS IN DETAIL ABOUT THE MACHINE-INDEPENDENT ASSEMBLER FEATURES.**

**Machine-Independent features:**

These are the features which do not depend on the architecture of the machine. These are:

- Literals
- Expressions
- Program blocks
- Control sections

**Literals:**

A literal is defined with a prefix = followed by a specification of the literal value. Example:

```
45      001A        ENDFIL      LDA   =C‟EOF‟     032 010
-
-
93                  LTORG
        002D *                        =C‟EOF‟     454F46
```

The example above shows a 3-byte operand whose value is a character string EOF. The object code for the instruction is also mentioned. It shows the relative displacement value of the location where this value is stored. In the example the value is at location (002D) and hence the displacement value is (010). As another example the given statement below shows a 1-byte literal with the hexadecimal value ‘05’.

```
215     1062  WLOOP     TD          =X‟05‟      E32011
```

It is important to understand the difference between a constant defined as a literal and a constant defined as an immediate operand. In case of literals the assembler generates the specified value as a constant at some other memory location In immediate mode the operand value is assembled as part of the instruction itself. Example

```
55      0020  LDA #03     010003
```

All the literal operands used in a program are gathered together into one or more *literal pool*s. This is usually placed at the end of the program. The assembly listing of a program containing literals usually includes a listing of this literal pool, which shows the assigned addresses and the generated data values. In some cases it is placed at some other location in the object program. An assembler directive LTORG is used. Whenever the LTORG is encountered, it creates a literal pool that contains all the literal operands used since the beginning of the program. The literal pool definition is done after LTORG is encountered. It is better to place the literals close to the instructions

.

A literal table is created for the literals which are used in the program. The literal table contains the *literal name, operand value and length.* The literal table is usually created as a hash table on the literal name

.

**Implementation of Literals:**

**During Pass-1:** The literal encountered is searched in the literal table. If the literal already exists, no action is taken; if it is not present, the literal is added to the LITTAB and for the address value it waits till it encounters LTORG for literal definition. When Pass 1 encounters a LTORG statement or the end of the program, the assembler makes a scan of the literal table. At this time each literal currently in the table is assigned an

address. As addresses are assigned, the location counter is updated to reflect the number of bytes occupied by each literal.

**During Pass-2:**
The assembler searches the LITTAB for each literal encountered in the instruction and replaces it with its equivalent value as if these values are generated by BYTE or WORD. If a literal represents an address in the program, the assembler must generate a modification relocation for, if it all it gets affected due to relocation. The following figure shows the difference between the SYMTAB and LITTAB

SYMTAB

| Name | Value |
|---|---|
| COPY | 0 |
| FIRST | 0 |
| CLOOP | 6 |
| ENDFIL | 1A |
| RETADR | 30 |
| LENGTH | 33 |
| BUFFER | 36 |
| BUFEND | 1036 |
| MAXLEN | 1000 |
| RDREC | 1036 |
| RLOOP | 1040 |
| EXIT | 1056 |
| INPUT | 105C |
| WREC | 105D |
| WLOOP | 1062 |

LITTAB

| Literal | Hex Value | Length | Address |
|---|---|---|---|
| C'EOF' | 454F46 | 3 | 002D |
| X'05' | 05 | 1 | 1076 |

**Symbol-Defining Statements:**

**EQU Statement:** Most assemblers provide an assembler directive that allows the programmer to define symbols and specify their values. The directive used for this EQU (Equate). The general form of the statement is Symbol EQU value This statement defines the given symbol (i.e., entering in the SYMTAB) and assigning to it the value specified. The value can be a constant or an expression involving constants and any other symbol which is already defined. One common usage is to define symbolic names that can be used to improve readability in place of numeric values. For example

```
+LDT   #4096
```

This loads the register T with immediate value 4096, this does not clearly what exactly this value indicates. If a statement is included as:

```
MAXLEN    EQU    4096 and then
          +LDT   #MAXLEN
```

Then it clearly indicates that the value of MAXLEN is some maximum length value. When the assembler encounters EQU statement, it enters the symbol MAXLEN along

with its value in the symbol table. During LDT the assembler searches the SYMTAB for its entry and its equivalent value as the operand in the instruction. The object code generated is the same for both the options discussed, but is easier to understand. If the maximum length is changed from 4096 to 1024, it is difficult to change if it is mentioned as an immediate value wherever required in the instructions. We have to scan the whole program and make changes wherever 4096 is used. If we mention this value in the instruction through the symbol defined by EQU, we may not have to search the whole program but change only the value of MAXLENGTH in the EQU statement (only once).
Another common usage of EQU statement is for defining values for the general-purpose registers. The assembler can use the mnemonics for register usage like a-register A , X – index register and so on. But there are some instructions which requires numbers in place of names in the instructions. For example in the instruction RMO 0,1 instead of RMO A,X. The programmer can assign the numerical values to these registers using EQU directive.

```
A       EQU    0
X       EQU    1 and so on
```

These statements will cause the symbols A, X, L… to be entered into the symbol table with their respective values. An instruction RMO A, X would then be allowed. As another usage if in a machine that has many general purpose registers named as R1, R2,…, some may be used as base register, some may be used as accumulator. Their usage may change from one program to another. In this case we can define these requirement using EQU statements.

```
BASE          EQU   R1
INDEX EQU           R2
COUNT         EQU   R3
```

One restriction with the usage of EQU is whatever symbol occurs in the right hand side of the EQU should be predefined. For example, the following statement is not valid:

```
BETA          EQU   ALPHA
ALPHA         RESW        1
```

As the symbol ALPHA is assigned to BETA before it is defined. The value of ALPHA is not known.

**ORG Statement:**

This directive can be used to indirectly assign values to the symbols. The directive is usually called ORG (for origin). Its general format is:

```
        ORG          value
```

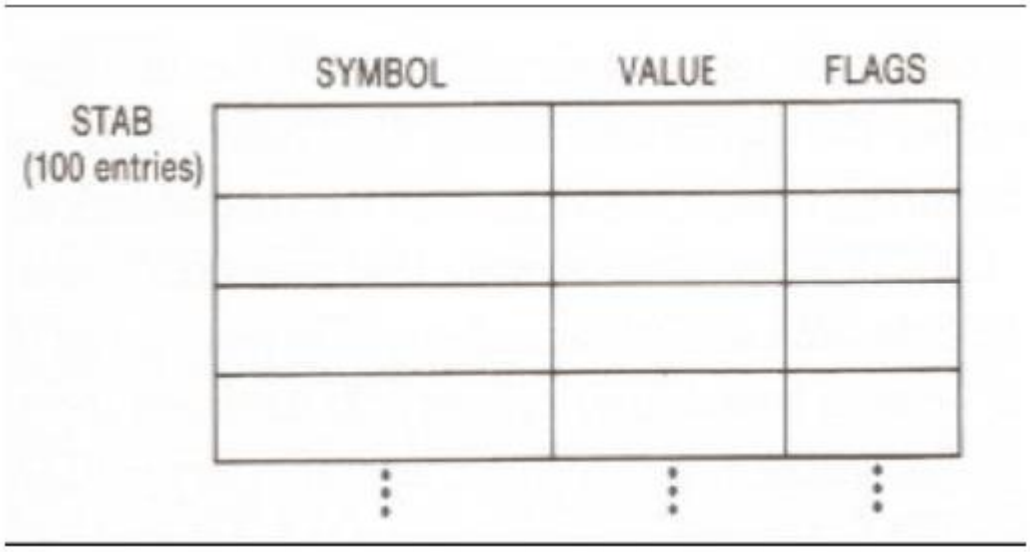
where value is a constant or an expression involving constants and previously defined symbols. When this statement is encountered during assembly of a program, the

assembler resets its location counter (LOCCTR) to the specified value. Since the values of symbols used as labels are taken from LOCCTR, the ORG statement will affect the values of all labels defined until the next ORG is encountered. ORG is used to control assignment storage in the object program. Sometimes altering the values may result in incorrect assembly.

ORG can be useful in label definition. Suppose we need to define a symbol table with the following structure:

SYMBOL 6 Bytes
VALUE 3 Bytes
FLAG 2 Bytes

The table looks like the one given below.




The symbol field contains a 6-byte user-defined symbol; VALUE is a one-word representation of the value assigned to the symbol; FLAG is a 2-byte field specifies symbol type and other information. The space for the ttable can be reserved by the statement:

```
STAB        RESB        1100
```

If we want to refer to the entries of the table using indexed addressing, place the offset value of the desired entry from the beginning of the table in the index register. To refer to the fields SYMBOL, VALUE, and FLAGS individually, we need to assign the values first as shown below:

```
SYMBOL      EQU      STAB
VALUE       EQU      STAB+6
FLAGS       EQU      STAB+9
```

To retrieve the VALUE field from the table indicated by register X, we can write a statement:

```
LDA         VALUE,    X
```

The same thing can also be done using ORG statement in the following way: S

```
TAB         RESB      1100
            ORG       STAB
SYMBOL      RESB      6
VALUE       RESW      1
FLAG        RESB      2
            ORG       STAB+1100
```

The first statement allocates 1100 bytes of memory assigned to label STAB. In the second statement the ORG statement initializes the location counter to the value of STAB. Now the LOCCTR points to STAB. The next three lines assign appropriate memory storage to each of SYMBOL, VALUE and FLAG symbols. The last ORG statement reinitializes the LOCCTR to a new value after skipping the required number of memory for the table STAB (i.e., STAB+1100).

While using ORG, the symbol occurring in the statement should be predefined as is required in EQU statement. For example for the sequence of statements below:

```
            ORG       ALPHA
BYTE1 RESB  1
BYTE2 RESB  1
BYTE3 RESB  1
            ORG
ALPHA       RESB      1
```

The sequence could not be processed as the symbol used to assign the new location counter value is not defined. In first pass, as the assembler would not know what value to assign to ALPHA, the other symbol in the next lines also could not be defined in the symbol table. This is a kind of problem of the forward reference.

**EXPRESSIONS:**

Assemblers also allow use of expressions in place of operands in the instruction. Each such expression must be evaluated to generate a single operand value or address. Assemblers generally arithmetic expressions formed according to the normal rules using arithmetic operators +, - *, /. Division is usually defined to produce an integer result. Individual terms may be constants, user-defined symbols, or special terms. The only special term used is * ( the current value of location counter) which indicates the value of the next unassigned memory location. Thus the statement

```
BUFFEND     EQU       *
```

Assigns a value to BUFFEND, which is the address of the next byte following the buffer area. Some values in the object program are relative to the beginning of the program and some are absolute (independent of the program location, like constants). Hence, expressions are classified as either absolute expression or relative expressions depending on the type of value they produce.

**Absolute Expressions:** The expression that uses only absolute terms is absolute expression. Absolute expression may contain relative term provided the relative terms occur in pairs with opposite signs for each pair. Example:

MAXLEN EQU BUFEND-BUFFER

In the above instruction the difference in the expression gives a value that does not depend on the location of the program and hence gives an absolute immaterial o the relocation of the program. The expression can have only absolute terms. Example:

MAXLEN EQU 1000

Relative Expressions: All the relative terms except one can be paired as described in "absolute". The remaining unpaired relative term must have a positive sign. Example:

STAB EQU OPTAB + (BUFEND – BUFFER)

Handling the type of expressions: to find the type of expression, we must keep track the type of symbols used. This can be achieved by defining the type in the symbol table against each of the symbol as shown in the table below:

| Symbol | Type | Value |
|---|---|---|
| RETADR | R | 0030 |
| BUFFER | R | 0036 |
| BUFEND | R | 1036 |
| MAXLEN | A | 1000 |

***Assembler Directive USE:***

USE [blockname]

At the beginning, statements are assumed to be part of the *unnamed* (default) block. If no USE statements are included, the entire program belongs to this single block. Each program block may actually contain several separate segments of the source program. Assemblers rearrange these segments to gather together the pieces of each block and assign address. Separate the program into blocks in a particular order. Large buffer area is

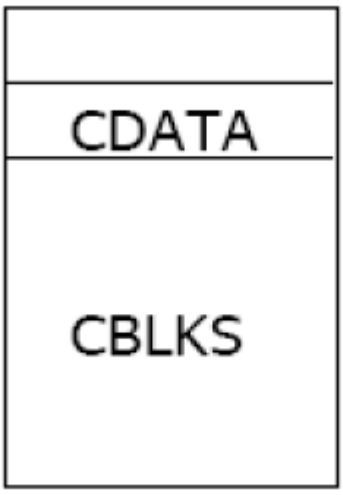
moved to the end of the object program. *Program readability is better* if data areas are placed in the source program close to the statements that reference them.

In the example below three blocks are used :

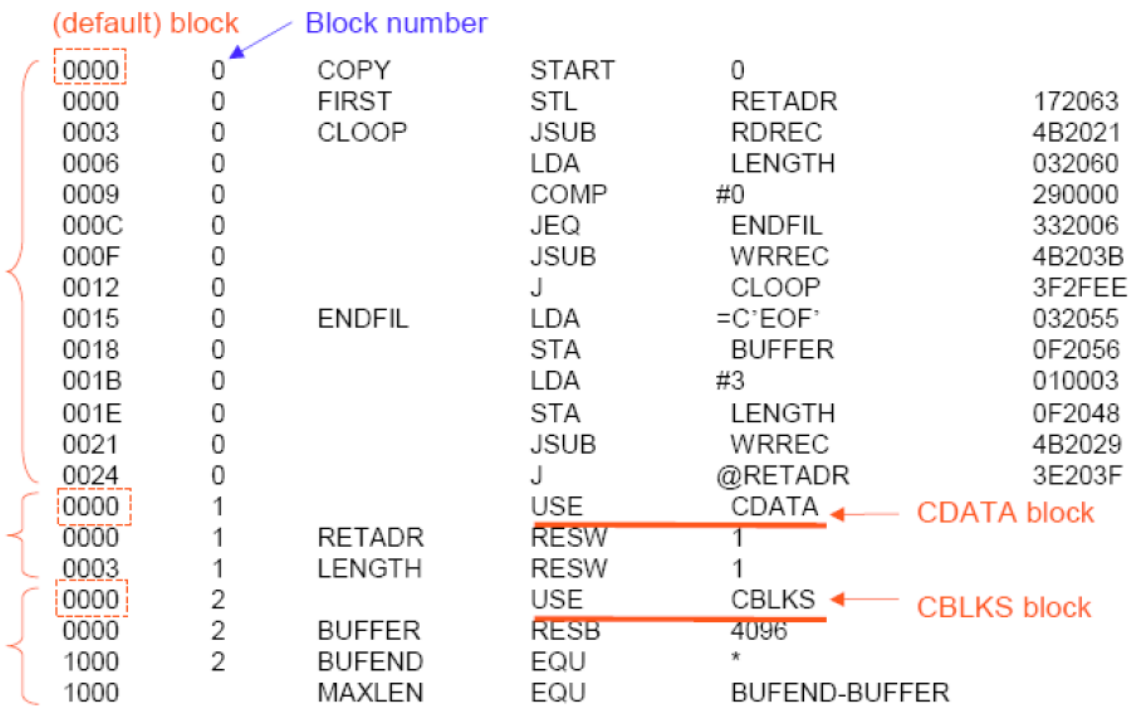
Default: executable instructions
CDATA: all data areas that are less in length
CBLKS: all data areas that consists of larger blocks of memory

**Program Blocks:**

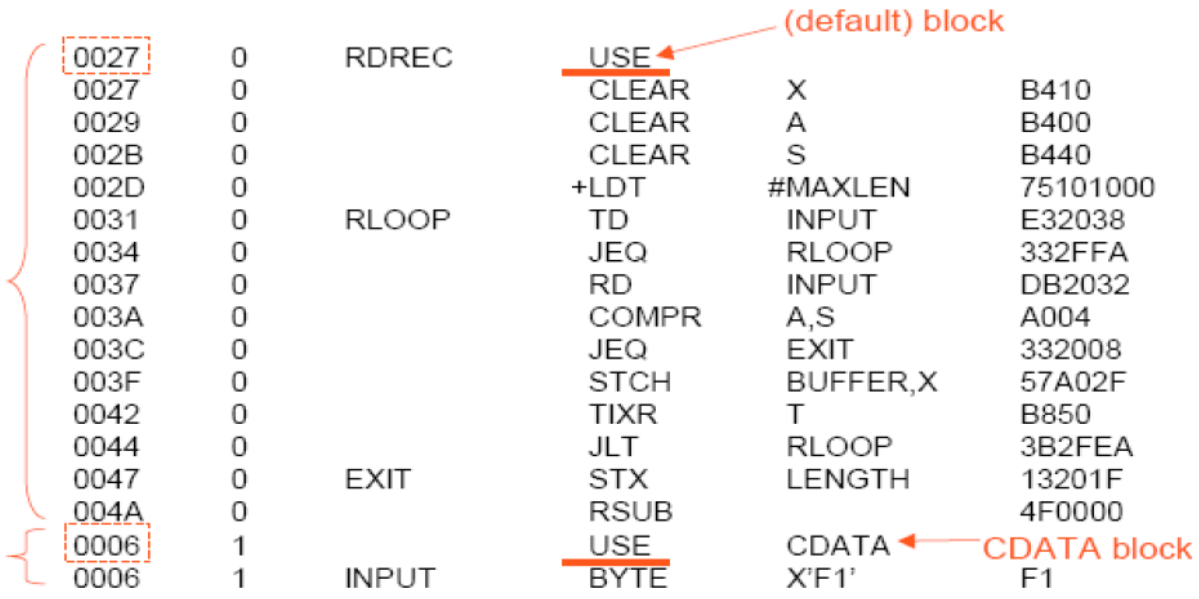
Program blocks allow the generated machine instructions and data to appear in the object program in a different order by Separating blocks for storing code, data, stack, and larger data block.



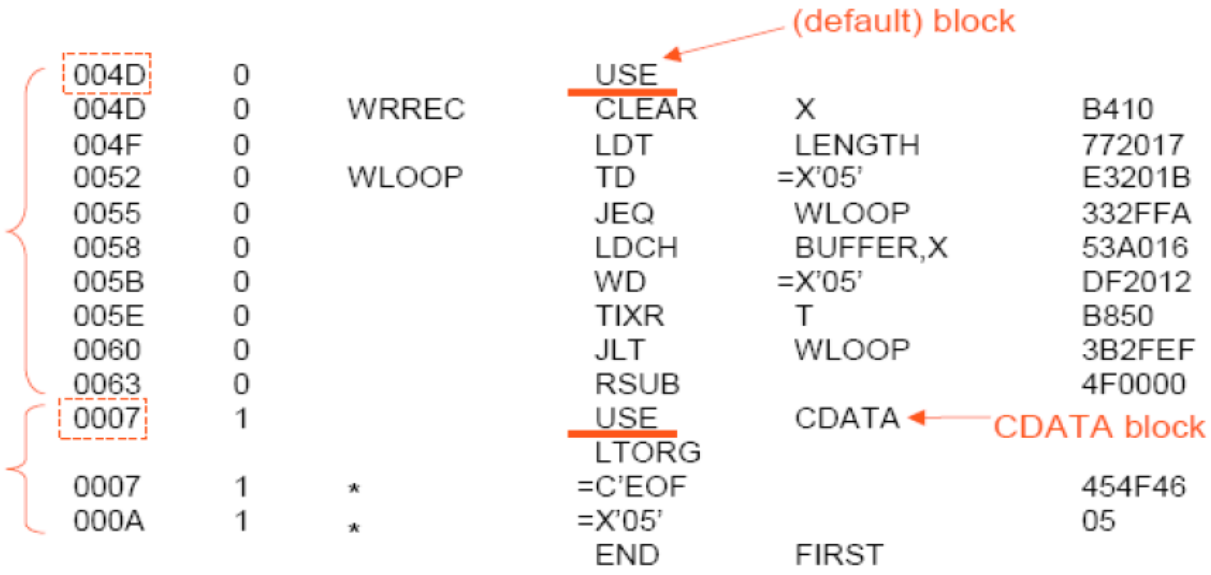

Sample code




```
0000  0  COPY    START   0
0000  0  FIRST   STL     RETADR          172063
0003  0  CLOOP   JSUB    RDREC           4B2021
0006  0          LDA     LENGTH          032060
0009  0          COMP    #0              290000
000C  0          JEQ     ENDFIL          332006
000F  0          JSUB    WRREC           4B203B
0012  0          J       CLOOP           3F2FEE
0015  0  ENDFIL  LDA     =C'EOF'         032055
0018  0          STA     BUFFER          0F2056
001B  0          LDA     #3              010003
001E  0          STA     LENGTH          0F2048
0021  0          JSUB    WRREC           4B2029
0024  0          J       @RETADR         3E203F
0000  1          USE     CDATA
0000  1  RETADR  RESW    1
0003  1  LENGTH  RESW    1
0000  2          USE     CBLKS
0000  2  BUFFER  RESB    4096
1000  2  BUFEND  EQU     *
1000     MAXLEN  EQU     BUFEND-BUFFER
```




```
0027  0  RDREC   USE
0027  0          CLEAR   X               B410
0029  0          CLEAR   A               B400
002B  0          CLEAR   S               B440
002D  0          +LDT    #MAXLEN         75101000
0031  0  RLOOP   TD      INPUT           E32038
0034  0          JEQ     RLOOP           332FFA
0037  0          RD      INPUT           DB2032
003A  0          COMPR   A,S             A004
003C  0          JEQ     EXIT            332008
003F  0          STCH    BUFFER,X        57A02F
0042  0          TIXR    T               B850
0044  0          JLT     RLOOP           3B2FEA
0047  0  EXIT    STX     LENGTH          13201F
004A  0          RSUB                    4F0000
0006  1          USE     CDATA
0006  1  INPUT   BYTE    X'F1'           F1
```




Arranging code into program blocks:

***Pass 1***

A separate location counter for each program block is maintained.
Save and restore LOCCTR when switching between blocks.
At the beginning of a block, LOCCTR is set to 0.
Assign each label an address relative to the start of the block.
Store the block name or number in the SYMTAB along with the assigned relative address of the label
Indicate the block length as the latest value of LOCCTR for each block at the end of Pass1
Assign to each block a starting address in the object program by concatenating the program blocks in a particular order

***Pass 2***

Calculate the address for each symbol relative to the start of the object program by adding
The location of the symbol relative to the start of its block
The starting address of this block

**Control Sections:**

A *control section* is a part of the program that maintains its identity after assembly; each control section can be loaded and relocated independently of the others. Different control sections are most often used for subroutines or other logical subdivisions. The programmer can assemble, load, and manipulate each of these control sections separately.

Because of this, there should be some means for linking control sections together. For example, instructions in one control section may refer to the data or instructions of

other control sections. Since control sections are independently loaded and relocated, the assembler is unable to process these references in the usual way. Such references between different control sections are called *external references.*

The assembler generates the information about each of the external references that will allow the loader to perform the required linking. When a program is written using multiple control sections, the beginning of each of the control section is indicated by an assembler directive

- assembler directive: **CSECT**

**The syntax**

**secname CSECT**

- separate location counter for each control section

Control sections differ from program blocks in that they are handled separately by the assembler. Symbols that are defined in one control section may not be used directly another control section; they must be identified as external reference for the loader to handle. The external references are indicated by two assembler directives:

**EXTDEF (external Definition):**

It is the statement in a control section, names symbols that are defined in this section but may be used by other control sections. Control section names do not need to be named in the EXTREF as they are automatically considered as external symbols.

**EXTREF (external Reference):**

It names symbols that are used in this section but are defined in some other control section.

The order in which these symbols are listed is not significant. The assembler must include proper information about the external references in the object program that will cause the loader to insert the proper value where they are required.

**Handling External Reference**

**Case 1**

15 0003 CLOOP +JSUB RDREC 4B100000

- The operand RDREC is an external reference.
  - The assembler has no idea where RDREC is
  - inserts an address of zero
  - can only use extended format to provide enough room (that is, relative addressing for external reference is invalid)
- The assembler generates information for each external reference that will allow the loader to perform the required linking.

**Case 2**

190 0028 MAXLEN WORD BUFEND-BUFFER 000000

- There are two external references in the expression, BUFEND and BUFFER.
- The assembler inserts a value of zero
- passes information to the loader
- Add to this data area the address of BUFEND
- Subtract from this data area the address of BUFFER

**Case 3**

On line 107, BUFEND and BUFFER are defined in the same control section and the expression can be calculated immediately.

```
107     1000  MAXLEN    EQU         BUFEND-BUFFER
```

**Object Code for the example program:**

The assembler must also include information in the object program that will cause the loader to insert the proper value where they are required. The assembler maintains two new record in the object code and a changed version of modification record.

Define record (EXTDEF)

- Col. 1 D
- Col. 2-7 Name of external symbol defined in this control section
- Col. 8-13 Relative address within this control section (hexadecimal)
- Col.14-73 Repeat information in Col. 2-13 for other external symbols

Refer record (EXTREF)

- Col. 1 R
- Col. 2-7 Name of external symbol referred to in this control section
- Col. 8-73 Name of other external reference symbols

Modification record

- Col. 1 M
- Col. 2-7 Starting address of the field to be modified (hexadecimal)
- Col. 8-9 Length of the field to be modified, in half-bytes (hexadecimal)
- Col.11-16 External symbol whose value is to be added to or subtracted from the indicated field

A define record gives information about the external symbols that are defined in this control section, i.e., symbols named by EXTDEF.

A refer record lists the symbols that are used as external references by the control section, i.e., symbols named by EXTREF.

The new items in the modification record specify the modification to be performed: adding or subtracting the value of some external symbol. The symbol used for modification my be defined either in this control section or in another section.

The object program is shown below. There is a separate object program for each of the control sections. In the *Define Record* and *refer record* the symbols named in EXTDEF and EXTREF are included.

In the case of *Define*, the record also indicates the relative address of each external symbol within the control section.

For EXTREF symbols, no address information is available. These symbols are simply named in the *Refer record.*

**Handling Expressions in Multiple Control Sections:**

The existence of multiple control sections that can be relocated independently of one another makes the handling of expressions complicated. It is required that in an expression that all the relative terms be paired (for absolute expression), or that all except one be paired (for relative expressions).

When it comes in a program having multiple control sections then we have an extended restriction that:

- Both terms in each pair of an expression must be within the same control section
    - If two terms represent relative locations within the same control section , their difference is an absolute value (regardless of where the control section is located.
        - **Legal:** BUFEND-BUFFER (both are in the same control section)
    - If the terms are located in different control sections, their difference has a value that is unpredictable.
        - **Illegal:** RDREC-COPY (both are of different control section) it is the difference in the load addresses of the two control sections. This value depends on the way run-time storage is allocated; it is unlikely to be of any use.

- **How to enforce this restriction**
    - When an expression involves external references, the assembler cannot determine whether or not the expression is legal.
    - The assembler evaluates all of the terms it can, combines these to form an initial expression value, and generates Modification records.
    - The loader checks the expression for errors and finishes the evaluation.

## 4.EXPLAIN IN DETAIL ABOUT THE ASSEMBLER DESIGN OPTIONS.

## ASSEMBLER DESIGN

Here we are discussing

- The structure and logic of one-pass assembler. These assemblers are used when it is necessary or desirable to avoid a second pass over the source program.
- Notion of a multi-pass assembler, an extension of two-pass assembler that allows an assembler to handle forward references during symbol definition.

### One-Pass Assembler

The main problem in designing the assembler using single pass was to resolve forward references. We can avoid to some extent the forward references by:

- Eliminating forward reference to data items, by defining all the storage reservation statements at the beginning of the program rather at the end.
- Unfortunately, forward reference to labels on the instructions cannot be avoided. (forward jumping)
- To provide some provision for handling forward references by prohibiting forward references to data items.

There are two types of one-pass assemblers:

- One that produces object code directly in memory for immediate execution (Load-and-go assemblers).
- The other type produces the usual kind of object code for later execution.

### Load-and-Go Assembler

- Load-and-go assembler generates their object code in memory for immediate execution.
- No object program is written out, no loader is needed.
- It is useful in a system with frequent program development and testing
    - The efficiency of the assembly process is an important consideration.
- Programs are re-assembled nearly every time they are run; efficiency of the assembly process is an important consideration.

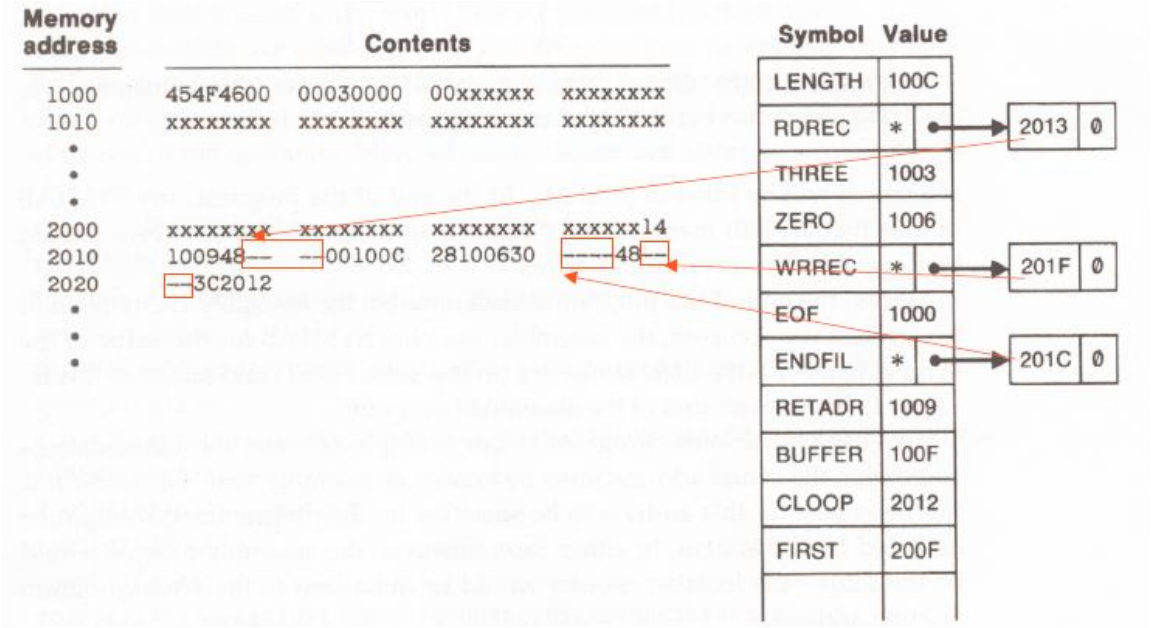
**Forward Reference in One-Pass Assemblers:** In load-and-Go assemblers when a forward reference is encountered :

- Omits the operand address if the symbol has not yet been defined
- Enters this undefined symbol into SYMTAB and indicates that it is undefined
- Adds the address of this operand address to a list of forward references associated with the SYMTAB entry
- When the definition for the symbol is encountered, scans the reference list and inserts the address.

- At the end of the program, reports the error if there are still SYMTAB entries indicated undefined symbols.
- For Load-and-Go assembler
    - Search SYMTAB for the symbol named in the END statement and jumps to this location to begin execution if there is no error

**After Scanning line 40 of the program:**
**40 2021 J` CLOOP 302012**

The status is that upto this point the symbol RREC is referred once at location 2013, ENDFIL at 201F and WRREC at location 201C. None of these symbols are defined. The figure shows that how the pending definitions along with their addresses are included in the symbol table.



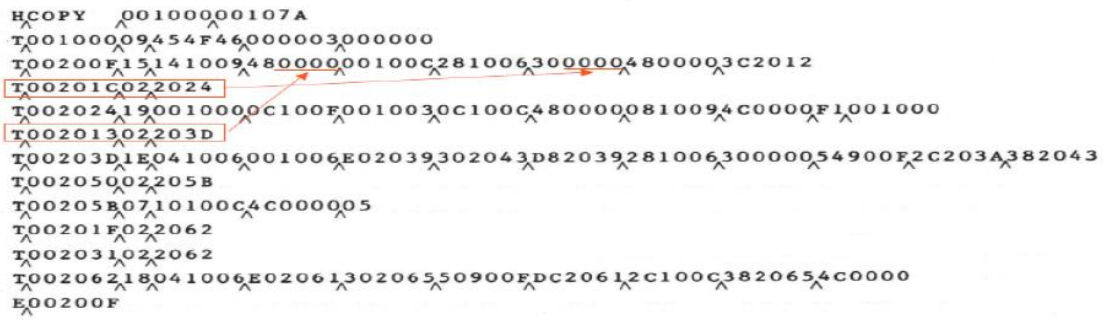

**The status after scanning line 160, which has encountered the definition of RDREC and ENDFIL is as given below:**

**If One-Pass needs to generate object code:**

- If the operand contains an undefined symbol, use 0 as the address and write the Text record to the object program.
- Forward references are entered into lists as in the load-and-go assembler.

- When the definition of a symbol is encountered, the assembler generates another Text record with the correct operand address of each entry in the reference list.
- When loaded, the incorrect address 0 will be updated by the latter Text record containing the symbol definition.

Object Code Generated by One-Pass Assembler:




**Multi_Pass Assembler:**

- For a two pass assembler, forward references in symbol definition are not allowed:

```
ALPHA   EQU  BETA
BETA    EQU  DELTA
DELTA   RESW 1
```

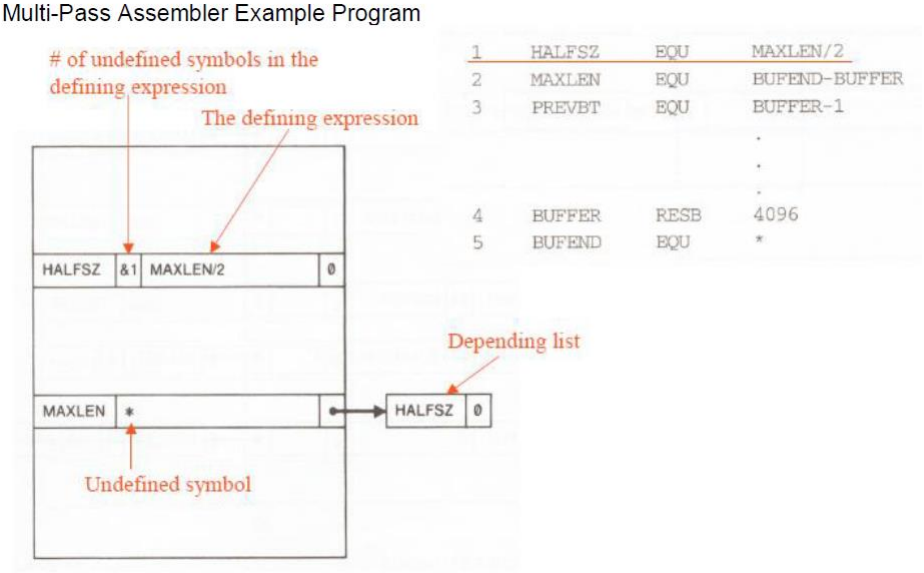
  - Symbol definition must be completed in pass 1.
- Prohibiting forward references in symbol definition is not a serious inconvenience.
  - Forward references tend to create difficulty for a person reading the program.

**Implementation Issues for Modified Two-Pass Assembler:**

Implementation Isuues when forward referencing is encountered in *Symbol Defining statements* :

- For a forward reference in symbol definition, we store in the SYMTAB:
  - The symbol name
  - The defining expression
  - The number of undefined symbols in the defining expression
- The undefined symbol (marked with a flag *) associated with a list of symbols depend on this undefined symbol.
- When a symbol is defined, we can recursively evaluate the symbol expressions depending on the newly defined symbol.

Multi-Pass Assembler Example Program




---

## UNIT 3
## LOADERS AND LINKERS

### 1. EXPLAIN IN DETAIL ABOUT BASIC LOADER FUNCTIONS.

### Basic Loader Functions

A loader is a system program that performs the loading function. It brings object program into memory and starts its execution. The role of loader,which generates the object program and later loaded to the memory by the loader for execution.fig 3.1 represents the role of loader and fig 3.2 represents role of loader with assembler and fig 3.3 represents both loader and linker.

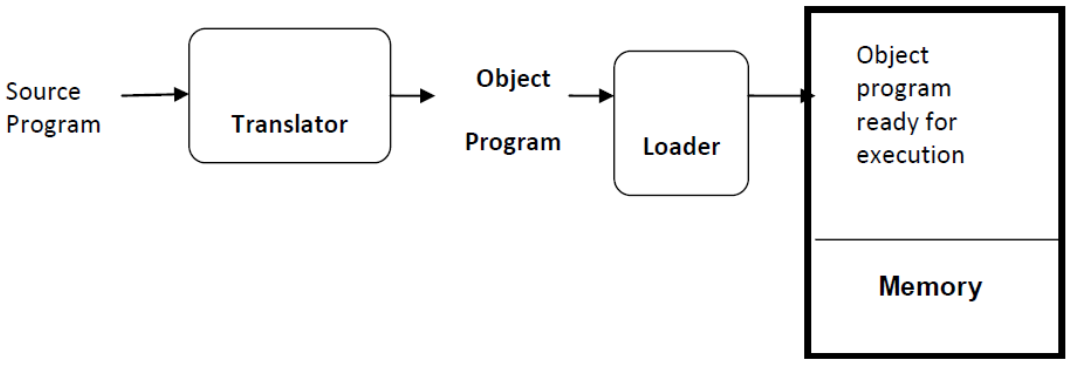



**Figure 3.1 : The Role of Loader**

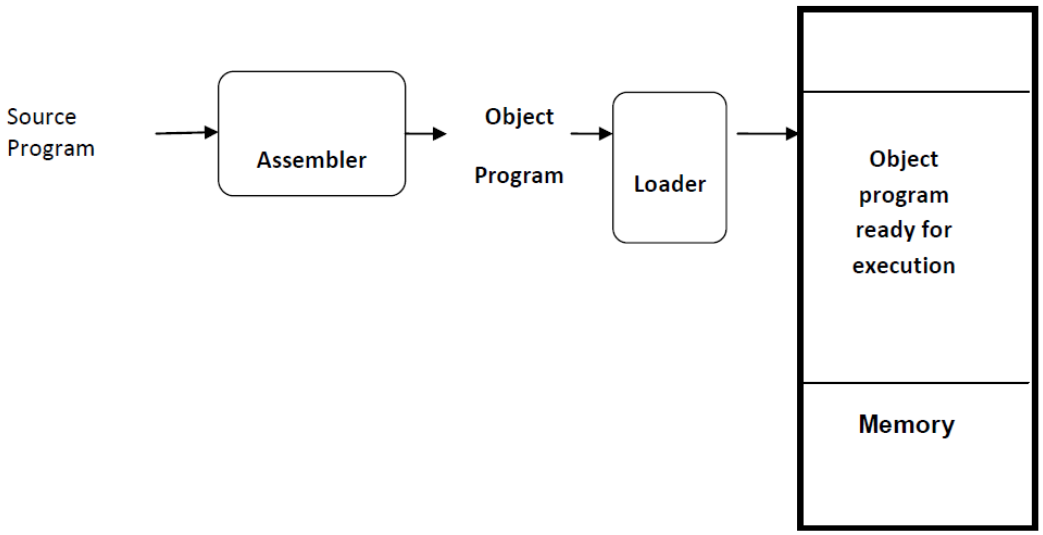



**Figure 3.2: The Role of Loader with Assembler**

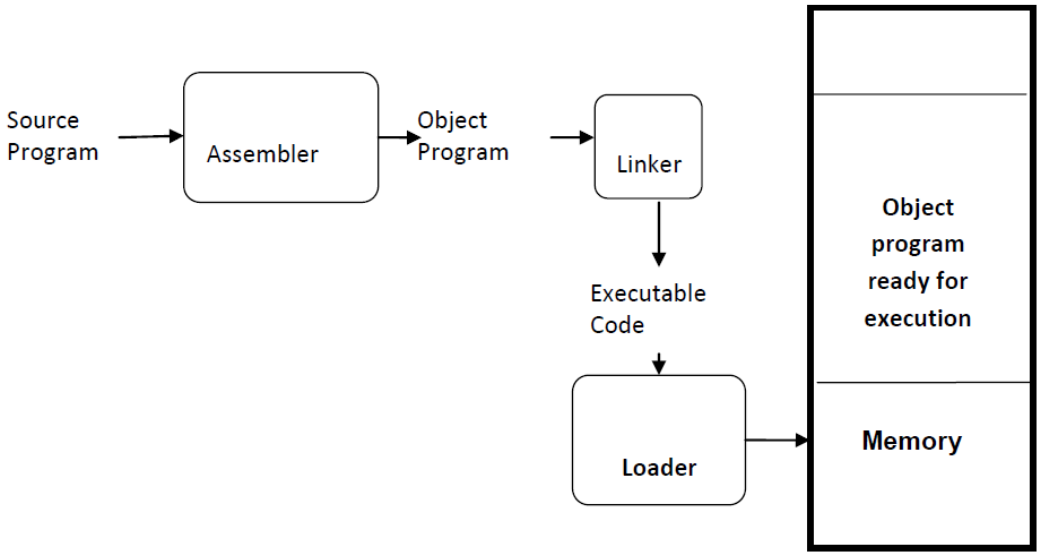



**Figure 3.3 : The Role of both Loader and Linker**

## Type of Loaders

The different types of loaders are, absolute loader, bootstrap loader, relocating loader (relative loader), and, direct linking loader. The following sections discuss the functions and design of all these types of loaders.

## ABSOLUTE LOADER

The operation of absolute loader is very simple. The object code is loaded to specified locations in the memory. At the end the loader jumps to the specified address to begin execution of the loaded program. The role of absolute loader is as shown in the figure 3.3.1. The advantage of absolute loader is simple and efficient. But the disadvantages are, the need for programmer to specify the actual address, and, difficult to use subroutine libraries.

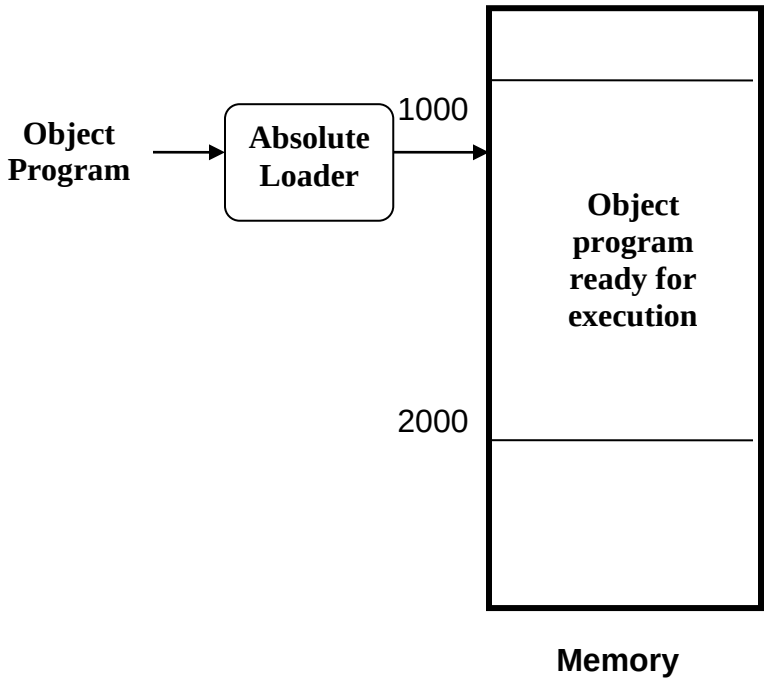



**Figure 3.1: The Role of Absolute Loader**

The algorithm for this type of loader is given here. The object program and, the object program loaded into memory by the absolute loader are also shown. Each byte of assembled code is given using its hexadecimal representation in character form. Easy to read by human beings. Each byte of object code is stored as a single byte. Most machine store object programs in a binary form, and we must be sure that our file and device conventions do not cause some of the program bytes to be interpreted as control characters.

**Begin**
read Header record
verify program name and length
read first Text record

```
while record type is <> 'E' do
        begin
        {if object code is in character form, convert into internal representation}
        move object code to specified location in memory
        read next object program record
        end
jump to address specified in End record
end
```

## A SIMPLE BOOTSTRAP LOADER

When a computer is first turned on or restarted, a special type of absolute loader, called bootstrap loader is executed. This bootstrap loads the first program to be run by the computer -- usually an operating system. The bootstrap itself begins at address 0. It loads the OS starting address 0x80. No header record or control information, the object code is consecutive bytes of memory.

The algorithm for the bootstrap loader is as follows

```
Begin
X=0x80 (the address of the next memory location to be loaded
Loop
        A←–GETC (and convert it from the ASCII character
       code to the value of the hexadecimal digit)
        save the value in the high-order 4 bits of S
        A←–GETC
        combine the value to form one byte A← (A+S)
        store the value (in A) to the address in register X
        X←–X+1
End
```

It uses a subroutine GETC, which is

```
GETC    A←–read one character
        if A=0x04 then jump to 0x80
        if A<48 then GETC
        A ← A-48 (0x30)
        if A<10 then return
        A ← A-7
        return
```

## 2. EXPLAIN ABOUT MACHINE-DEPENDENT LOADER FEATURES.

### Machine-Dependent Loader Features

Absolute loader is simple and efficient, but the scheme has potential disadvantages One of the most disadvantage is the programmer has to specify the actual starting address, from where the program to be loaded. This does not create difficulty, if one program to run, but not for several programs. Further it is difficult to use subroutine libraries efficiently.

This needs the design and implementation of a more complex loader. The loader must provide program relocation and linking, as well as simple loading functions.

## RELOCATION

The concept of program relocation is, the execution of the object program using any part of the available and sufficient memory. The object program is loaded into memory wherever there is room for it. The actual starting address of the object program is not known until load time. Relocation provides the efficient sharing of the machine with larger memory and when several independent programs are to be run together. It also supports the use of subroutine libraries efficiently. Loaders that allow for program relocation are called relocating loaders or relative loaders.

### Methods for specifying relocation

Use of modification record and, use of relocation bit, are the methods available for specifying relocation. In the case of modification record, a modification record M is used in the object program to specify any relocation. In the case of use of relocation bit, each instruction is associated with one relocation bit and, these relocation bits in a Text record is gathered into bit masks.

Modification records are used in complex machines and is also called Relocation and Linkage Directory (RLD) specification. The format of the modification record (M) is as follows. The object program with relocation by Modification records is also shown here.

Modification record
- col 1: M
- col 2-7: relocation address
- col 8-9: length (halfbyte)
- col 10: flag (+/-)
- col 11-17: segment name

H∧COPY ∧000000 001077
T∧000000 ∧1D∧17202D∧69202D∧48101036∧…∧4B105D∧3F2FEC∧032010

T∧00001D∧13∧0F2016∧010003∧0F200D∧4B10105D∧3E2003∧454F46
T∧001035 ∧1D∧B410∧B400∧B440∧75101000∧…∧332008∧57C003∧B850
T∧001053∧1D∧3B2FEA∧134000∧4F0000∧F1∧..∧53C003∧DF2008∧B850
T∧00070∧07∧3B2FEF∧4F0000∧05
M∧000007∧05+COPY
M∧000014∧05+COPY
M∧000027∧05+COPY
E∧000000

The relocation bit method is used for simple machines. Relocation bit is 0: no modification is necessary, and is 1: modification is needed. This is specified in the columns 10-12 of text record (T), the format of text record, along with relocation bits is as follows.

Text record
- col 1: T
- col 2-7: starting address
- col 8-9: length (byte)
- col 10-12: relocation bits
- col 13-72: object code

Twelve-bit mask is used in each Text record (col:10-12 – relocation bits), since each text record contains less than 12 words, unused words are set to 0, and, any value that is to be modified during relocation must coincide with one of these 3-byte segments. For absolute loader, there are no relocation bits column 10-69 contains object code. The object program with relocation by bit mask is as shown below. Observe FFC - means all ten words are to be modified and, E00 - means first three records are to be modified.

H∧COPY ∧000000 00107A
T∧000000∧1E∧FFC∧140033∧481039∧000036∧280030∧300015∧…∧3C0003 ∧ …
T∧00001E∧15∧E00∧0C0036∧481061∧080033∧4C0000∧…∧000003∧000000
T∧001039∧1E∧FFC∧040030∧000030∧…∧30103F∧D8105D∧280030∧...
T∧001057∧0A∧ 800∧100036∧4C0000∧F1∧001000
T∧001061∧19∧FE0∧040030∧E01079∧…∧508039∧DC1079∧2C0036∧...
E∧000000

## PROGRAM LINKING

The Goal of program linking is to resolve the problems with external references (EXTREF) and external definitions (EXTDEF) from different control sections.

**EXTDEF (external definition)** - The EXTDEF statement in a control section names symbols, called external symbols, that are defined in this (present) control section and may be used by other sections.

ex: EXTDEF BUFFER, BUFFEND, LENGTH
EXTDEF LISTA, ENDA

**EXTREF (external reference)** - The EXTREF statement names symbols used in this (present) control section and are defined elsewhere.

ex: EXTREF RDREC, WRREC
EXTREF LISTB, ENDB, LISTC, ENDC

**How to implement EXTDEF and EXTREF**

The assembler must include information in the object program that will cause the loader to insert proper values where they are required – in the form of Define record (D) and, Refer record(R).

**Define record**

The format of the Define record (D) along with examples is as shown here**.**

| | |
|---|---|
| Col. 1 | D |
| Col. 2-7 | Name of external symbol defined in this control section |
| Col. 8-13 | Relative address within this control section (hexadecimal) |
| Col.14-73 | Repeat information in Col. 2-13 for other external symbols |

**Example records**

**D LISTA 000040 ENDA 000054**
**D LISTB 000060 ENDB 000070**

**Refer record**

The format of the Refer record (R) along with examples is as shown here**.**

| | |
|---|---|
| Col. 1 | R |
| Col. 2-7 | Name of external symbol referred to in this control section |
| Col. 8-73 | Name of other external reference symbols |

**Example records**

**R LISTB ENDB LISTC ENDC**
**R LISTA ENDA LISTC ENDC**
**R LISTA ENDA LISTB ENDB**

Here are the three programs named as PROGA, PROGB and PROGC, which are separately assembled and each of which consists of a single control section. LISTA, ENDA in PROGA, LISTB, ENDB in PROGB and LISTC, ENDC in PROGC are external definitions in each of the control sections. Similarly LISTB, ENDB, LISTC, ENDC in PROGA, LISTA, ENDA, LISTC, ENDC in PROGB, and LISTA, ENDA, LISTB, ENDB in PROGC, are external references. These sample programs given here are used to illustrate linking and relocation. The following figures give the sample programs and their corresponding object programs. Observe the object programs, which contain D and R records along with other records.

```
0000  PROGA     START   0
               EXTDEF  LISTA, ENDA
               EXTREF  LISTB, ENDB, LISTC, ENDC
               ……….
               …….
0020  REF1     LDA     LISTA                          03201D
0023  REF2     +LDT    LISTB+4                        77100004
0027  REF3     LDX     #ENDA-LISTA                    050014
                  .
                  .
0040  LISTA    EQU     *

0054  ENDA     EQU     *
0054  REF4     WORD        ENDA-LISTA+LISTC           000014
0057  REF5     WORD        ENDC-LISTC-10              FFFFF6
005A  REF6     WORD        ENDC-LISTC+LISTA-1         00003F
005D  REF7     WORD        ENDA-LISTA-(ENDB-LISTB)    000014
0060  REF8     WORD        LISTB-LISTA                FFFFC0
               END     REF1
```

```
0000  PROGB     START   0
               EXTDEF  LISTB, ENDB
               EXTREF  LISTA, ENDA, LISTC, ENDC
               ……….
               …….
0036  REF1     +LDA    LISTA                          03100000
003A  REF2     LDT     LISTB+4                        772027
003D  REF3     +LDX    #ENDA-LISTA                    05100000
                  .
                  .
```

```
0060    LISTB     EQU       *

0070    ENDB      EQU       *
0070    REF4      WORD            ENDA-LISTA+LISTC          000000
0073    REF5      WORD            ENDC-LISTC-10             FFFFF6
0076    REF6      WORD            ENDC-LISTC+LISTA-1        FFFFFF
0079    REF7      WORD            ENDA-LISTA-(ENDB-LISTB)   FFFFF0
007C    REF8      WORD            LISTB-LISTA               000060
                  END
```

```
0000    PROGC     START           0
                  EXTDEF    LISTC, ENDC
                  EXTREF    LISTA, ENDA, LISTB, ENDB
                  ……..
                  ……..
0018    REF1      +LDA      LISTA                     03100000
001C    REF2      +LDT      LISTB+4                   77100004
0020    REF3      +LDX      #ENDA-LISTA               05100000
                      .
                      .
0030    LISTC     EQU       *

0042    ENDC      EQU       *
0042    REF4      WORD            ENDA-LISTA+LISTC          000030
0045    REF5      WORD            ENDC-LISTC-10             000008
0045    REF6      WORD            ENDC-LISTC+LISTA-1        000011
004B    REF7      WORD            ENDA-LISTA-(ENDB-LISTB)    000000
004E    REF8      WORD            LISTB-LISTA               000000
                   END
```

H **PROGA** 000000 000063
**D LISTA 000040 ENDA 000054**
**R LISTB ENDB LISTC ENDC**
.
.
T 000020 0A 03201D 77100004 050014
.
.
T 000054 0F 000014 FFFF6 00003F 000014 FFFFC0

M000024 05+LISTB
M000054 06+LISTC
M000057 06+ENDC
M000057 06 -LISTC
M00005A06+ENDC
M00005A06 -LISTC
M00005A06+PROGA
M00005D06-ENDB
M00005D06+LISTB
M00006006+LISTB
M00006006-PROGA
E000020

H **PROGB** 000000 00007F
**D LISTB 000060 ENDB 000070**
**R LISTA ENDA LISTC ENDC**
.
T 000036 0B 03100000 772027 05100000
.
T 000007 0F 000000 FFFFF6 FFFFFF FFFFF0 000060
M000037 05+LISTA
M00003E 06+ENDA
M00003E 06 -LISTA
M000070 06 +ENDA
M000070 06 -LISTA
M000070 06 +LISTC
M000073 06 +ENDC
M000073 06 -LISTC
M000073 06 +ENDC
M000076 06 -LISTC
M000076 06+LISTA
M000079 06+ENDA
M000079 06 -LISTA
M00007C 06+PROGB
M00007C 06-LISTA
E

H **PROGC** 000000 000051
**D LISTC 000030 ENDC 000042**
**R LISTA ENDA LISTB ENDB**
.
T 000018 0C 03100000 77100004 05100000
.
T 000042 0F 000030 000008 000011 000000 000000
M000019 05+LISTA
M00001D 06+LISTB

M000021 06+ENDA
M000021 06 -LISTA
M000042 06+ENDA
M000042 06 -LISTA
M000042 06+PROGC
M000048 06+LISTA
M00004B 06+ENDA
M00004B 006-LISTA
M00004B 06-ENDB
M00004B 06+LISTB
M00004E 06+LISTB
M00004E 06-LISTA
E

The following figure shows these three programs as they might appear in memory after loading and linking. PROGA has been loaded starting at address 4000, with PROGB and PROGC immediately following.

For example, the value for REF4 in PROGA is located at address 4054 (the beginning address of PROGA plus 0054, the relative address of REF4 within PROGA). The following figure shows the details of how this value is computed.

The initial value from the Text record
T0000540F000014FFFFF600003F000014FFFFC0 is 000014.

To this is added the address assigned to LISTC, which is 4112 (the beginning address of PROGC plus 30). The result is 004126.

That is REF4 in PROGA is ENDA-LISTA+LISTC=4054-4040+4112=4126.

Similarly the load address for symbols LISTA: PROGA+0040=4040, LISTB: PROGB+0060=40C3 and LISTC: PROGC+0030=4112

Keeping these details work through the details of other references and values of these references are the same in each of the three programs.

**Algorithm and Data structures for a Linking Loader**

The algorithm for a linking loader is considerably more complicated than the absolute loader program, which is already given. The concept given in the program linking section is used for developing the algorithm for linking loader. The modification records are used for relocation so that the linking and relocation functions are performed using the same mechanism.

Linking Loader uses two-passes logic. ESTAB (external symbol table) is the main data structure for a linking loader.

**Pass 1**: Assign addresses to all external symbols
**Pass 2**: Perform the actual loading, relocation, and linking

**ESTAB** - ESTAB for the example (refer three programs PROGA PROGB and PROGC) given is as shown below. The ESTAB has four entries in it; they are name of the control section, the symbol appearing in the control section, its address and length of the control section.

| Control section | Symbol | Address | Length |
|---|---|---|---|
| PROGA | | 4000 | 63 |
| | LISTA | 4040 | |
| | ENDA | 4054 | |
| PROGB | | 4063 | 7F |
| | LISTB | 40C3 | |
| | ENDB | 40D3 | |
| PROGC | | 40E2 | 51 |
| | LISTC | 4112 | |
| | ENDC | 4124 | |

## Program Logic for Pass 1

Pass 1 assign addresses to all external symbols. The variables & Data structures used during pass 1 are, PROGADDR (program load address) from OS, CSADDR (control section address), CSLTH (control section length) and ESTAB. The pass 1 processes the Define Record. The algorithm for Pass 1 of Linking Loader is given below.

**Pass 1:**

```
begin
get PROGADDR from operating system
set CSADDR to PROGADDR {for first control section}
while not end of input do
    begin
        read next input record {Header record for control section}
        set CSLTH to control section length
        search ESTAB for control section name
        if found then
            set error flag {duplicate external symbol}
        else
            enter control section name into ESTAB with value CSADDR
        while record type <> 'E' do
            begin
                read next input record
                if record type = 'D' then
                    for each symbol in the record do
                        begin
                            search ESTAB for symbol name
                            if found then
                                set error flag {duplicate external symbol}
                            else
                                enter symbol into ESTAB with value
                                    (CSADDR + indicated address)
                        end {for}
            end {while <> 'E'}
        add CSLTH to CSADDR {starting address for next control section}
    end {while not EOF}
end {Pass 1}
```

## Program Logic for Pass 2

Pass 2 of linking loader perform the actual loading, relocation, and linking. It uses modification record and lookup the symbol in ESTAB to obtain its addres. Finally it uses end record of a main program to obtain transfer address, which is a starting address needed for the execution of the program. The pass 2 process Text record and Modification record of the object programs. The algorithm for Pass 2 of Linking Loader is given below.

**Pass 2:**

```
begin
set CSADDR to PROGADDR
set EXECADDR to PROGADDR
while not end of input do
    begin
        read next input record   {Header record}
        set CSLTH to control section length
        while record type <> 'E' do
            begin
                read next input record
                if record type = 'T' then
                    begin
                        {if object code is in character form, convert
                             into internal representation}
                        move object code from record to location
                             (CSADDR + specified address)
                    end {if 'T'}
                else if record type = 'M' then
                    begin
                        search ESTAB for modifying symbol name
                        if found then
                            add or subtract symbol value at location
                                (CSADDR + specified address)
                        else
                            set error flag (undefined external symbol)
                    end  {if 'M'}
            end  {while <> 'E'}
        if an address is specified (in End record) then
            set EXECADDR to (CSADDR + specified address)
        add CSLTH to CSADDR
    end  {while not EOF}
jump to location given by EXECADDR (to start execution of loaded program)
end  {Pass 2}
```

## Improve Efficiency, How?

The question here is can we improve the efficiency of the linking loader. Also observe that, even though we have defined Refer record (R), we haven't made use of it. The efficiency can be improved by the use of local searching instead of multiple searches of ESTAB for the same symbol. For implementing this we assign a reference number to each external symbol in the Refer record. Then this reference number is used in Modification records instead of external symbols. 01 is assigned to control section name, and other numbers for external reference symbols.

The object programs for PROGA, PROGB and PROGC are shown below, with above modification to Refer record ( Observe R records).

ymbol and Addresses in PROGA, PROGB and PROGC are as shown below. These are the entries of ESTAB. The main advantage of reference number mechanism is that it avoids multiple searches of ESTAB for the same symbol during the loading of a control section

| Ref No. | Symbol | Address |
|---|---|---|
| 1 | PROGA | 4000 |
| 2 | LISTB | 40C3 |
| 3 | ENDB | 40D3 |
| 4 | LISTC | 4112 |
| 5 | ENDC | 4124 |

| Ref No. | Symbol | Address |
|---|---|---|
| 1 | PROGB | 4063 |
| 2 | LISTA | 4040 |
| 3 | ENDA | 4054 |
| 4 | LISTC | 4112 |
| 5 | ENDC | 4124 |

| Ref No. | Symbol | Address |
|---|---|---|
| 1 | PROGC | 4063 |
| 2 | LISTA | 4040 |
| 3 | ENDA | 4054 |
| 4 | LISTB | 40C3 |
| 5 | ENDB | 40D3 |

## 3. DISCUSS IN DETAIL ABOUT MACHINE-INDEPENDENT LOADER FEATURES

### Machine-independent Loader Features

Here we discuss some loader features that are not directly related to machine architecture and design. Automatic Library Search and Loader Options are such Machine-independent Loader Features.

### Automatic Library Search

This feature allows a programmer to use standard subroutines without explicitly including them in the program to be loaded. The routines are automatically retrieved from a library as they are needed during linking. This allows programmer to use subroutines from one or more libraries. The subroutines called by the program being loaded are automatically fetched from the library, linked with the main program and loaded. The loader searches the library or libraries specified for routines that contain the definitions of these symbols in the main program.

### Loader Options

Loader options allow the user to specify options that modify the standard processing. The options may be specified in three different ways. They are, specified using a command language, specified as a part of job control language that is processed by the operating system, and an be specified using loader control statements in the source program.

Here are the some examples of how option can be specified.

INCLUDE program-name (library-name) - read the designated object program from a library

DELETE csect-name – delete the named control section from the set pf programs being loaded

CHANGE name1, name2 - external symbol name1 to be changed to name2 wherever it appears in the object programs

LIBRARY MYLIB – search MYLIB library before standard libraries

NOCALL STDDEV, PLOT, CORREL – no loading and linking of unneeded routines

Here is one more example giving, how commands can be specified as a part of object file, and the respective changes are carried out by the loader.

```
LIBRARY UTLIB

INCLUDE READ (UTLIB)

INCLUDE WRITE (UTLIB)

DELETE RDREC, WRREC

CHANGE RDREC, READ

CHANGE WRREC, WRITE

NOCALL  SQRT, PLOT
```

The commands are, use UTLIB ( say utility library), include READ and WRITE control sections from the library, delete the control sections RDREC and WRREC from the load, the change command causes all external references to the symbol RDREC to be changed to the symbol READ, similarly references to WRREC is changed to WRITE, finally, no call to the functions SQRT, PLOT, if they are used in the program.

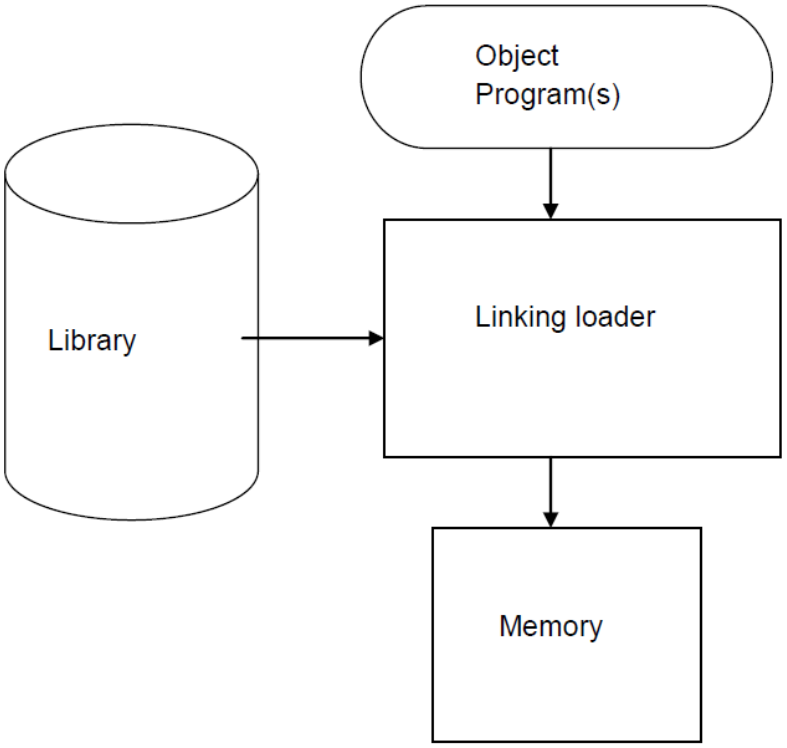
---

## 4. EXPLAIN ABOUT THE LOADER DESIGN OPTIONS.

### Loader Design Options

There are some common alternatives for organizing the loading functions, including relocation and linking. Linking Loaders – Perform all linking and relocation at load time. The Other Alternatives are Linkage editors, which perform linking prior to load time and, Dynamic linking, in which linking function is performed at execution time

## Linking Loaders

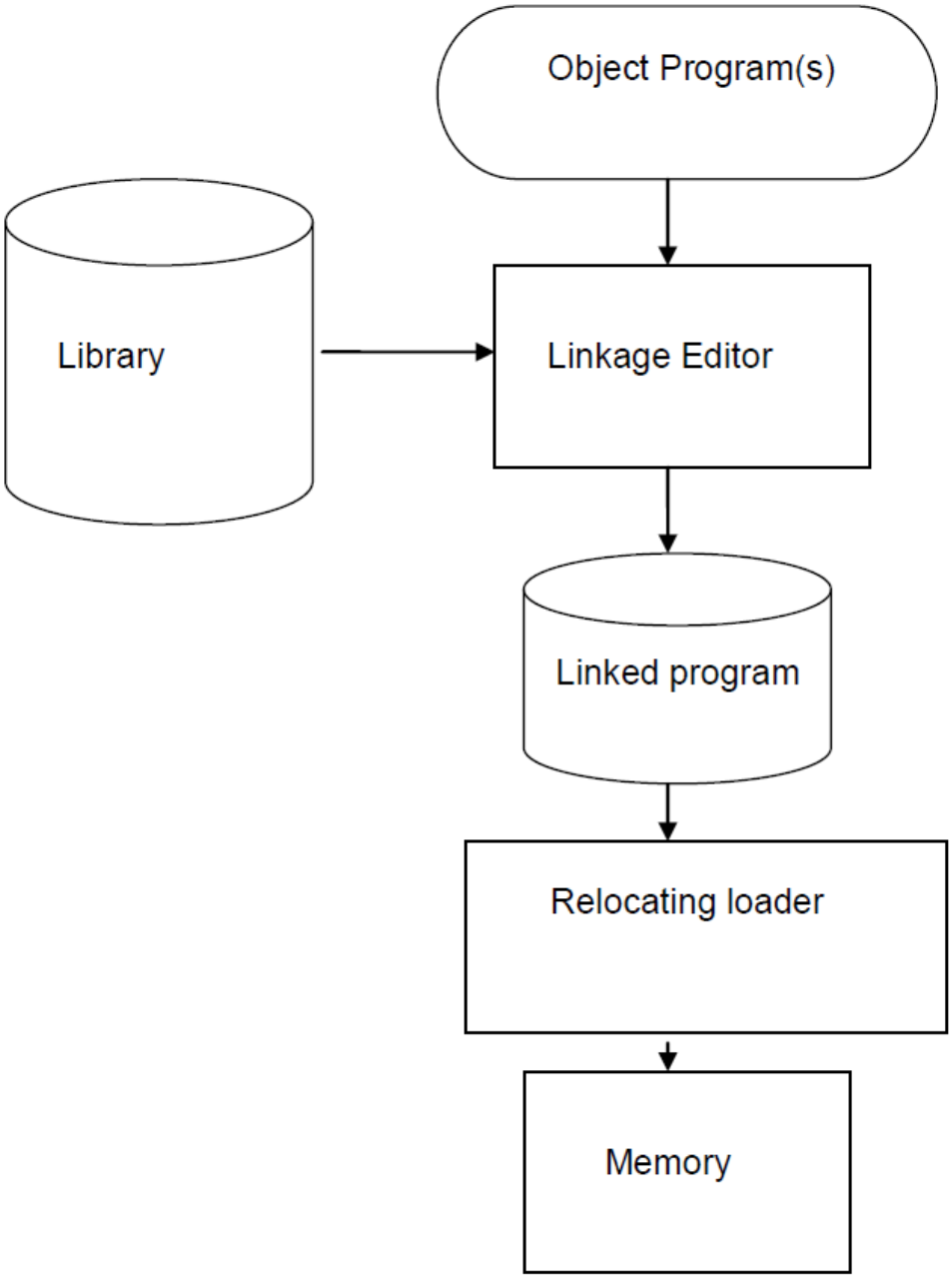



The above diagram shows the processing of an object program using Linking Loader. The source program is first assembled or compiled, producing an object program. A linking loader performs all linking and loading operations, and loads the program into memory for execution.

### Linkage Editors

The figure below shows the processing of an object program using Linkage editor. A linkage editor produces a linked version of the program – often called a load module or an executable image – which is written to a file or library for later execution. The linked program produced is generally in a form that is suitable for processing by a relocating loader.

Some useful functions of Linkage editor are, an absolute object program can be created, if starting address is already known. New versions of the library can be included without changing the source program. Linkage editors can also be used to build packages of subroutines or other control sections that are generally used together. Linkage editors often allow the user to specify that external references are not to be resolved by automatic library search – linking will be done later by linking loader – linkage editor + linking loader – savings in space


Object Program(s)
Library
Linkage Editor
Linked program
Relocating loader
Memory

Dynamic Linking

The scheme that postpones the linking functions until execution. A subroutine is loaded and linked to the rest of the program when it is first called – usually called dynamic linking, dynamic loading or load on call. The advantages of dynamic linking are, it allow several executing programs to share one copy of a subroutine or library. In an object oriented system, dynamic linking makes it possible for one object to be shared by several programs. Dynamic linking provides the ability to load the routines only when (and if) they are needed. The actual loading and linking can be accomplished using operating system service request.

**Bootstrap Loaders**

If the question, how is the loader itself loaded into the memory ? is asked, then the answer is, when computer is started – with no program in memory, a program present in ROM ( absolute address) can be made executed – may be OS itself or A Bootstrap loader, which in turn loads OS and prepares it for execution. The first record ( or records) is generally referred to as a bootstrap loader – makes the OS to be loaded. Such a loader is added to the beginning of all object programs that are to be loaded into an empty and idle system.

---

## 5. EXPLAIN IN DETAIL ABOUT MS-DOS LINKER

**MS-DOS Linker**

This explains some of the features of Microsoft MS-DOS linker, which is a linker for Pentium and other x86 systems. Most MS-DOS compilers and assemblers (MASM) produce object modules, and they are stored in .OBJ files. MS-DOS LINK is a linkage editor that combines one or more object modules to produce a complete executable program - .EXE file; this file is later executed for results.

The following table illustrates the typical MS-DOS object module

| Record Types | Description |
|---|---|
| THEADR | Translator Header |
| TYPDEF,PUBDEF, EXTDEF | External symbols and references |
| LNAMES, SEGDEF, GRPDEF | Segment definition and grouping |
| LEDATA, LIDATA | Translated instructions and data |
| FIXUPP | Relocation and linking information |
| MODEND | End of object module |

THEADR specifies the name of the object module. MODEND specifies the end of the module. PUBDEF contains list of the external symbols (called public names). EXTDEF contains list of external symbols referred in this module, but defined elsewhere. TYPDEF the data types are defined here. SEGDEF describes segments in the object module ( includes name, length, and alignment). GRPDEF includes how segments are combined into groups. LNAMES contains all segment and class names. LEDATA contains translated instructions and data. LIDATA has above in repeating pattern. Finally, FIXUPP is used to resolve external references.

**SunOS Linkers**

SunOS Linkers are developed for SPARC systems. SunOS provides two different linkers – link-editor and run-time linker.

Link-editor is invoked in the process of assembling or compiling a program – produces a single output module – one of the following types

A relocatable object module – suitable for further link-editing

A static executable – with all symbolic references bound and ready to run

A dynamic executable – in which some symbolic references may need to be bound at run time

A shared object – which provides services that can be, bound at run time to one ore more dynamic executables

An object module contains one or more sections – representing instructions and data area from the source program, relocation and linking information, external symbol table.

Run-time linker uses dynamic linking approach. Run-time linker binds dynamic executables and shared objects at execution time. Performs relocation and linking operations to prepare the program for execution.

**Cray MPP Linker**

Cray MPP (massively parallel processing) Linker is developed for Cray T3E systems. A T3E system contains large number of parallel processing elements (PEs) – Each PE has local memory and has access to remote memory (memory of other PEs). The processing is divided among PEs - contains shared data and private data. The loaded program gets copy of the executable code, its private data and its portion of the shared data. The MPP linker organizes blocks containing executable code, private data and shared data. The linker then writes an executable file that contains the relocated and linked blocks. The executable file also specifies the number of PEs required and other control information. The linker can create an executable file that is targeted for a fixed number of PEs, or one that allows the partition size to be chosen at run time. Latter type is called plastic executable.

---

# UNIT – 4

## MACRO PROCESSOR

### 1)EXPLIAN IN DETAIL ABOUT THE BASIC MACRO PROCESSOR FUNCTIONS

**Basic Macro Processor Functions:**

- *Macro Definition and Expansion*
- *Macro Processor Algorithms and Data structures*

***Macro Definition and Expansion*:**

The figure shows the MACRO expansion. The left block shows the MACRO definition and the right block shows the expanded macro replacing the MACRO call with its block of executable instruction.

M1 is a macro with two parameters D1 and D2. The MACRO stores the contents of register A in D1 and the contents of register B in D2. Later M1 is invoked with the parameters DATA1 and DATA2, Second time with DATA4 and DATA3. Every call of MACRO is expended with the executable statements.

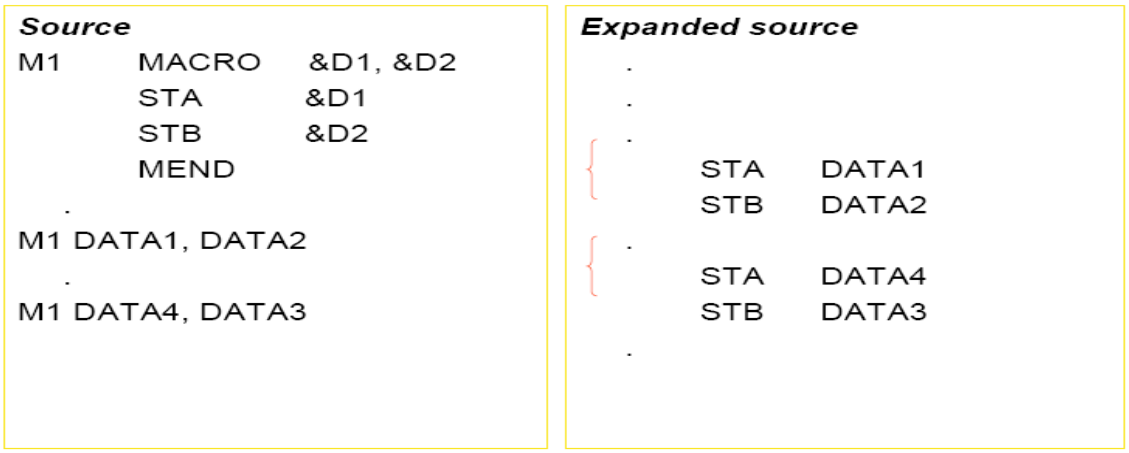



**Fig 4.1**

The statement M1 DATA1, DATA2 is a macro invocation statements that gives the name of the macro instruction being invoked and the arguments (M1 and M2) to be used in expanding. A macro invocation is referred as a Macro Call or Invocation.

***Macro Expansion:***

The program with macros is supplied to the macro processor. Each macro invocation statement will be expanded into the statement s that form the body of the macro, with the arguments from the macro invocation substituted for the parameters in the macro prototype. During the expansion, the macro definition statements are deleted since they are no longer needed.

The arguments and the parameters are associated with one another according to their positions. The first argument in the macro matches with the first parameter in the macro prototype and so on.

After *macro processing* the expanded file can become the input for the *Assembler*. The *Macro Invocation* statement is considered as comments and the statement generated from expansion is treated exactly as though they had been written directly by the programmer.

The difference between *Macros* and *Subroutines* is that the statement s from the body of the Macro is expanded the number of times the macro invocation is encountered, whereas the statement of the subroutine appears only once no matter how many times the subroutine is called. Macro instructions will be written so that the body of the macro contains no labels.

- Problem of the label in the body of macro:
  - If the same macro is expanded multiple times at different places in the program …
  - There will be *duplicate labels*, which will be treated as errors by the assembler.
- Solutions:
  - Do not use labels in the body of macro.
  - Explicitly use PC-relative addressing instead.
- Ex, in RDBUFF and WRBUFF macros,
  - JEQ *+11
  - JLT *-14
- It is inconvenient and error-prone.

The following program shows the concept of Macro Invocation and Macro Expansion.

```
170  .                      MAIN PROGRAM
175  .
180         FIRST   STL     RETADR          SAVE RETURN ADDRESS
190         CLOOP   RDBUFF  F1,BUFFER,LENGTH READ RECORD INTO BUFFER
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
215                 J       CLOOP           LOOP
220         ENDFIL  WRBUFF  05,EOF,THREE    INSERT EOF MARKER
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
```

```
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 MAXIMUN RECORD LENGTH
190e            TD      =X'F1'          TEST INPUT DEVICE
190f            JEQ     *-3             LOOP UNTIL READY
190g            RD      =X'F1'          TEST FOR END OF RECORD
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 MAXIMUN LENGTH
190l            JLT     *-19            HAS BEEN REACHED
190M            STX     LENGTH          SAVE RECORD LENGTH
```

**Fig 4.2**

## Macro Processor Algorithm and Data Structure:

Design can be done as two-pass or a one-pass macro. In case of two-pass assembler.

Two-pass macro processor

- You may design a two-pass macro processor
  - Pass 1:
    - Process all macro definitions
  - Pass 2:
    - Expand all macro invocation statements
- However, one-pass may be enough
  - Because all macros would have to be defined during the first pass before any macro invocations were expanded.
    - The definition of a macro must appear before any statements that invoke that macro.
- Moreover, the body of one macro can contain definitions of the other macro
- Consider the example of a Macro defining another Macro.
- In the example below, the body of the first Macro (MACROS) contains statement that define RDBUFF, WRBUFF and other macro instructions for SIC machine.
- The body of the second Macro (MACROX) defines the se same macros for SIC/XE machine.
- A proper invocation would make the same program to perform macro invocation to run on either SIC or SIC/XEmachine.

MACROS for SIC machine

```
1        MACROS   MACOR     {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}
```

**Fig 4.3(a)**

MACROX for SIC/XE Machine

```
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}
```

**Fig 4.3(b)**

- A program that is to be run on SIC system could invoke MACROS whereas a program to be run on SIC/XE can invoke MACROX.
- However, defining MACROS or MACROX does not define RDBUFF and WRBUFF.
- These definitions are processed only when an invocation of MACROS or MACROX is expanded.

**One-Pass Macro Processor:**

- A one-pass macro processor that alternate between *macro definition* and *macro expansion* in a recursive way is able to handle recursive macro definition.
- Restriction
    - The definition of a macro must appear in the source program before any statements that invoke that macro.
    - This restriction does not create any real inconvenience.

The design considered is for one-pass assembler. The data structures required are:

- DEFTAB (Definition Table)
    - Stores the macro definition including *macro prototype* and *macro body*
    - Comment lines are omitted.
    - References to the macro instruction parameters are converted to a positional notation for efficiency in substituting arguments.
- NAMTAB (Name Table)
    - Stores macro names
    - Serves as an index to DEFTAB
        - Pointers to the beginning and the end of the macro definition (DEFTAB)

- ARGTAB (Argument Table)
    - Stores the arguments according to their positions in the argument list.
    - As the macro is expanded the arguments from the Argument table are substituted for the corresponding parameters in the macro body.
    - The figure below shows the different data structures described and their relationship.

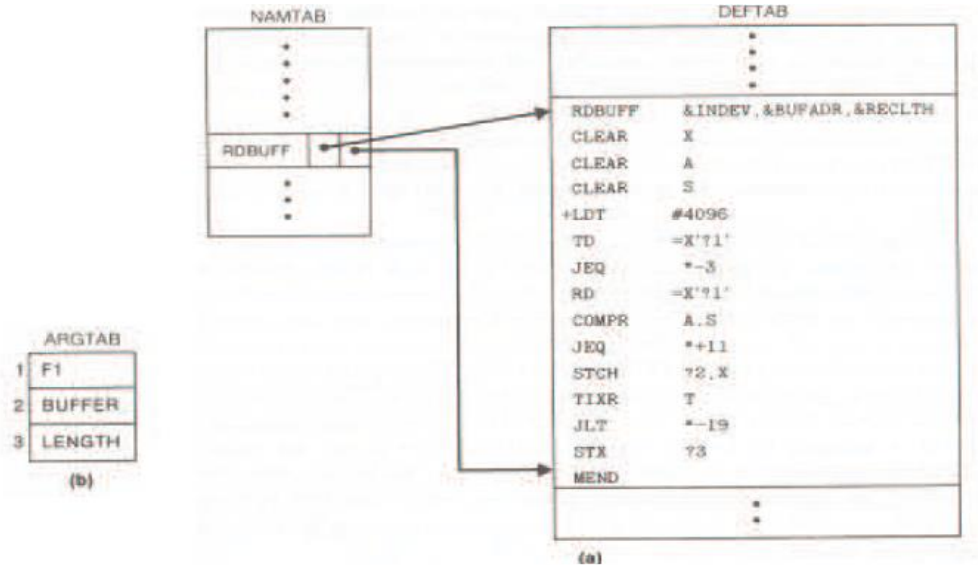



**Fig 4.4**

The above figure shows the portion of the contents of the table during the processing of the program in page no. 3. In fig 4.4(a) definition of RDBUFF is stored in DEFTAB, with an entry in NAMTAB having the pointers to the beginning and the end of the definition. The arguments referred by the instructions are denoted by the their positional notations. For example,

TD =X'?1'

The above instruction is to test the availability of the device whose number is given by the parameter &INDEV. In the instruction this is replaced by its positional value? 1.
Figure 4.4(b) shows the ARTAB as it would appear during expansion of the RDBUFF statement as given below:

CLOOP RDBUFF F1, BUFFER, LENGTH

For the invocation of the macro RDBUFF, the first parameter is F1 (input device code), second is BUFFER (indicating the address where the characters read are stored), and the third is LENGTH (which indicates total length of the record to be read). When the ?n notation is encountered in a line fro DEFTAB, a simple indexing operation supplies the proper argument from ARGTAB.

The algorithm of the Macro processor is given below. This has the procedure DEFINE to make the entry of *macro name* in the NAMTAB, *Macro Prototype* in DEFTAB. EXPAND is called to set up the argument values in ARGTAB and expand a *Macro Invocation* statement. Procedure GETLINE is called to get the next line to be processed either from the DEFTAB or from the file itself.

When a macro definition is encountered it is entered in the DEFTAB. The normal approach is to continue entering till MEND is encountered. If there is a program having a Macro defined within another Macro. While defining in the DEFTAB the very first MEND is taken as the end of the Macro definition. This does not complete the definition as there is another outer Macro which completes the difintion of Macro as a whole. Therefore the DEFINE procedure keeps a counter variable LEVEL. Every time a Macro directive is encountered this counter is incremented by 1. The moment the innermost Macro ends indicated by the directive MEND it starts decreasing the value of the counter variable by one. The last MEND should make the counter value set to zero. So when LEVEL becomes zero, the MEND corresponds to the original MACRO directive.

Most macro processors allow thr definitions of the commonly used instructions to appear in a standard system library, rather than in the source program. This makes the use of macros convenient; definitions are retrieved from the library as they are needed during macro processing.

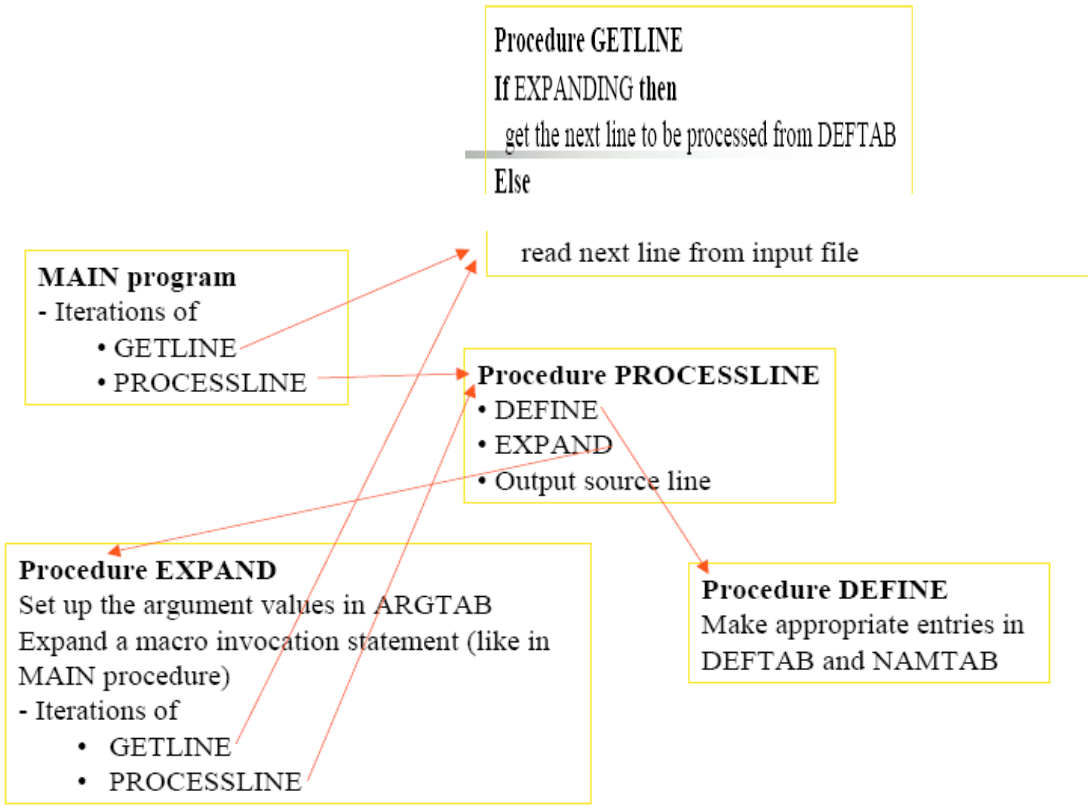

Procedure GETLINE
If EXPANDING then
get the next line to be processed from DEFTAB
Else
read next line from input file
MAIN program
- Iterations of
• GETLINE
• PROCESSLINE
Procedure PROCESSLINE
• DEFINE
• EXPAND
• Output source line
Procedure EXPAND
Set up the argument values in ARGTAB
Expand a macro invocation statement (like in MAIN procedure)
- Iterations of
• GETLINE
• PROCESSLINE
Procedure DEFINE
Make appropriate entries in DEFTAB and NAMTAB

**Fig 4.5**

**Algorithms**

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


Procedure PROCESSLINE
        begin
          search MAMTAB for OPCODE
          if found then
                EXPAND
          else if OPCODE = 'MACRO' then
                DEFINE
          else write source line to expanded file
        end {PRCOESSOR}

Procedure DEFINE
        begin
          enter macro name into NAMTAB
          enter macro prototype into DEFTAB
          LEVEL   :- 1
          while LEVEL > 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
            while 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}
```

---

**2) COMPARISON OF MACRO PROCESSOR DESIGN**

- *One-pass algorithm*
  - Every macro must be defined before it is called
  - One-pass processor can alternate between macro definition and macro expansion
  - Nested macro definitions are allowed but nested calls are not allowed.
- *Two-pass algorithm*
  - Pass1: Recognize macro definitions
  - Pass2: Recognize macro calls
  - Nested macro definitions are not allowed

---

## 3. DISCUSS IN DETAIL ABOUT THE MACHINE-INDEPENDENT MACRO PROCESSOR FEATURES.

### Machine-independent Macro-Processor Features.

The design of macro processor doesn't depend on the architecture of the machine. We will be studying some extended feature for this macro processor. These features are:

- Concatenation of Macro Parameters
- Generation of unique labels
- Conditional Macro Expansion
- Keyword Macro Parameters

### Concatenation of unique labels:

Most macro processor allows parameters to be concatenated with other character strings. Suppose that a program contains a series of variables named by the symbols XA1, XA2, XA3,…, another series of variables named XB1, XB2, XB3,…, etc. If similar processing is to be performed on each series of labels, the programmer might put this as a macro instruction. The parameter to such a macro instruction could specify the series of variables to be operated on (A, B, etc.). The macro processor would use this parameter to construct the symbols required in the macro expansion (XA1, Xb1, etc.).

Suppose that the parameter to such a macro instruction is named &ID. The body of the macro definition might contain a statement like

```
LDA     X&ID1
```


**Fig 4.7**

& is the starting character of the macro instruction; but the end of the parameter is not marked. So in the case of &ID1, the macro processor could deduce the meaning that was intended. If the macro definition contains contain &ID and &ID1 as parameters, the situation would be unavoidably ambiguous.

Most of the macro processors deal with this problem by providing a special concatenation operator. In the SIC macro language, this operator is the character →. Thus the statement LDA X&ID1 can be written as

```
LDA     X&ID→
```

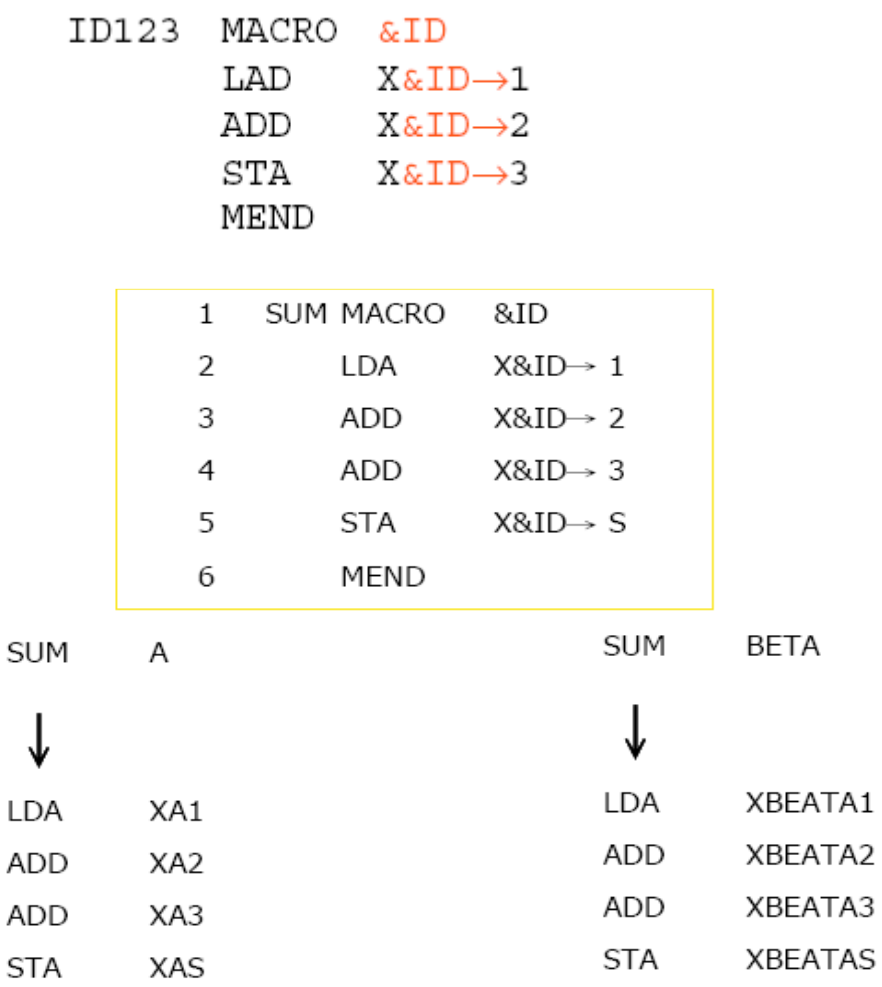



**Fig 4.8**

The above figure shows a macro definition that uses the concatenation operator as previously described. The statement SUM A and SUM BETA shows the invocation statements and the corresponding macro expansion.

## Generation of Unique Labels

As discussed it is not possible to use labels for the instructions in the macro definition, since every expansion of macro would include the label repeatedly which is not allowed by the assembler. This in turn forces us to use relative addressing in the jump instructions. Instead we can use the technique of generating unique labels for every macro invocation and expansion. During macro expansion each $ will be replaced with $XX, where xx is a two-character alphanumeric counter of the number of macro instructions expansion.

For example,

XX = AA, AB, AC…

This allows 1296 macro expansions in a single program.

The following program shows the macro definition with labels to the instruction.

```
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 INTI 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     $LOOP                HAS BEEN REACHED
90        $EXIT    STX      &RECLTH              SAVE RECORD LENGTH
                   MEND
```

The following figure shows the macro invocation and expansion first time.

```
          .        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 INTI 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
```

If the macro is invoked second time the labels may be expanded as $ABLOOP $ABEXIT.

## Conditional Macro Expansion

There are applications of macro processors that are not related to assemblers or assembler programming.

Conditional assembly depends on parameters provides

```
MACRO &COND
……..
  IF (&COND NE ‘’)
        part I
  ELSE
        part II
  ENDIF
……
ENDM
```

Part I is expanded if condition part is true, otherwise part II is expanded. Compare operators: NE, EQ, LE, GT.

*Macro-Time Variables:*

Macro-time variables (often called as SET Symbol) can be used to store working values during the macro expansion. Any symbol that begins with symbol & and not a macro instruction parameter is considered as *macro-time variable.* All such variables are initialized to zero.

```
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 COUNTER
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 INTI 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 MAXIMUN LENGTH
85                 JLT     $LOOP                HAS BEEN REACHED
90        $EXIT    STX     &RECLTH              SAVE RECORD LENGTH
95                 MEND
```

Macro-time variable

**Fig 4.9(a)**

Figure 4.5(a) gives the definition of the macro RDBUFF with the parameters &INDEV, &BUFADR, &RECLTH, &EOR, &MAXLTH. According to the above program if &EOR has any value, then &EORCK is set to 1 by using the directive SET, otherwise it retains its default value 0.

```
                .       RDBUFF   F31 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 INTI REG A
65                      COMPR    A, S           TEST FOR END OF RECORD
70                      JEQ      $AAEXIT        EXIT LOOP IF EOR
75                      STCH     BUF, X         STORE CHARACTE IN BUFFER
80                      TIXR     T              LOOP UNLESS MAXIMUM LENGTH
85                      JLT      $AALOOP        HAS BEEN REACHED
90      $AAEXIT         STX      RECL           SAVE RECORD LENGTH
```

**Fig 4.9(b) Use of Macro-Time Variable with EOF being NOT NULL**

```
                .       RDBUFF   OE, 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 IN 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
```

**Fig 4.9(c) Use of Macro-Time conditional statement with EOF being NULL**

```
.           RDBUFF    F1. BUFF, ELENG, 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 INTI 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 LOOP REACHED
90          $ACEXIT   STX       RLENG             SAVE RECORD LENGTH
```

**Fig 4.9(d) Use of Time-variable with EOF NOT NULL and MAXLENGTH being NULL**

The above programs show the expansion of Macro invocation statements with different values for the time variables. In figure 4.9(b) the &EOF value is NULL. When the macro invocation is done, IF statement is executed, if it is true EORCK is set to 1, otherwise normal execution of the other part of the program is continued.

The macro processor must maintain a symbol table that contains the value of all macro-time variables used. Entries in this table are modified when SET statements are processed. The table is used to look up the current value of the macro-time variable whenever it is required.

When an IF statement is encountered during the expansion of a macro, the specified Boolean expression is evaluated.

**If the value of this expression TRUE,**

- The macro processor continues to process lines from the DEFTAB until it encounters the ELSE or ENDIF statement.
- If an ELSE is found, macro processor skips lines in DEFTAB until the next ENDIF.
- Once it reaches ENDIF, it resumes expanding the macro in the usual way.

**If the value of the expression is FALSE,**

- The macro processor skips ahead in DEFTAB until it encounters next ELSE or ENDIF statement.
- The macro processor then resumes normal macro expansion.

The *macro-time* IF-ELSE-ENDIF structure provides a mechanism for either generating(once) or skipping selected statements in the macro body. There is another

construct WHILE statement which specifies that the following line until the next ENDW statement, are to be generated repeatedly as long as a particular condition is true. The testing of this condition, and the looping are done during the macro is under expansion. The example shown below shows the usage of Macro-Time Looping statement.

**WHILE-ENDW structure**

- When an WHILE statement is encountered during the expansion of a macro, the specified Boolean expression is evaluated.
- TRUE
  - The macro processor continues to process lines from DEFTAB until it encounters the next ENDW statement.
  - When ENDW is encountered, the macro processor returns to the preceding WHILE, re-evaluates the Boolean expression, and takes action based on the new value.
- FALSE
  - The macro processor skips ahead in DEFTAB until it finds the next ENDW statement and then resumes normal macro expansion.

---

## 4. EXPLAIN ABOUT MACRO PROCESSOR DESIGN OPTIONS

## RECURSIVE MACRO EXPANSION

**Recursive Macro Expansion**

We have seen an example of the *definition* of one macro instruction by another. But we have not dealt with the *invocation* of one macro by another. The following example shows the invocation of one macro by another macro.

```
10      RDBUFF  MACRO   &BUFADR, &RECLTH, &INDEV
15      .
20      .       MACRO TO READ RECORD INTO BUFFER
25      .
30              CLEAR   X               CLEAR LOOP COUNTER
35              CLEAR   A
40              CLEAR   S
45              +LDT    #4096           SET MAXIMUN RECORD LENGTH
50      $LOOP   RDCHAR  &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 MAXIMUN LENGTH
85              JLT     $LOOP           HAS BEEN REACHED
90      $EXIT   STX     &RECLTH         SAVE RECORD LENGTH
95              MEND
```

```
5    RDCHAR      MACRO   &IN
10   .
15   .    MACROTO READ CHARACTER INTO REGISTER A
20   .
25                TD      =X'&IN'                 TEST INPUT DEVICE
30                JEQ     *-3                     LOOP UNTIL READY
35                RD      =X'&IN'                 READ CHARACTER
40                MEND
```

**Problem of Recursive Expansion**

- Previous macro processor design cannot handle such kind of recursive macro invocation and expansion
  - The procedure EXPAND would be called recursively, thus the invocation arguments in the ARGTAB will be overwritten. (P.201)
  - The Boolean variable EXPANDING would be set to FALSE when the "inner" macro expansion is finished, *i.e.*, the macro process would forget that it had been in the middle of expanding an "outer" macro.
- Solutions
  - Write the macro processor in a programming language that allows recursive calls, thus local variables will be retained.
  - If you are writing in a language without recursion support, use a stack to take care of pushing and popping local variables and return addresses.

The procedure EXPAND would be called when the macro was recognized. The arguments from the macro invocation would be entered into ARGTAB as follows:

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) |
| - | - |

The Boolean variable EXPANDING would be set to TRUE, and expansion of the macro invocation statement would begin. The processing would proceed normally until statement invoking RDCHAR is processed. This time, ARGTAB would look like

| Parameter | Value |
|---|---|
| 1 | F1 |
| 2 | (Unused) |
| -- | -- |

At the expansion, when the end of RDCHAR is recognized, EXPANDING would be set to FALSE. Thus the macro processor would 'forget' that it had been in the middle of expanding a macro when it encountered the RDCHAR statement. In addition, the arguments from the original macro invocation (RDBUFF) would be lost because the value in ARGTAB was overwritten with the arguments from the invocation of RDCHAR.

## GENERAL PURPOSE MACRO PROCESSORS

**General-Purpose Macro Processors**

- Macro processors that do not dependent on any particular programming language, but can be used with a variety of different languages
- **Pros**
  - Programmers do not need to learn many macro languages.
  - Although its development costs are somewhat greater than those for a language specific macro processor, this expense does not need to be repeated for each language, thus save substantial overall cost.
- **Cons**
  - Large number of details must be dealt with in a real programming language
    - Situations in which normal macro parameter substitution should not occur, e.g., comments.
    - Facilities for grouping together terms, expressions, or statements
    - Tokens, e.g., identifiers, constants, operators, keywords
    - Syntax had better be consistent with the source programming language

## MACRO PROCESSING WITHIN LANGUAGE TRANSLATORS

**Macro Processing within Language Translators**

- The macro processors we discussed are called "Preprocessors".
  - Process macro definitions
  - Expand macro invocations
  - Produce an expanded version of the source program, which is then used as input to an assembler or compiler
- You may also combine the macro processing functions with the language translator:
  - Line-by-line macro processor
  - Integrated macro processor

**Line-by-Line Macro Processor**

- Used as a sort of input routine for the assembler or compiler
- Read source program
- Process macro definitions and expand macro invocations
- Pass output lines to the assembler or compiler

Benefits

- Avoid making an extra pass over the source program.
- Data structures required by the macro processor and the language translator can be combined (e.g., OPTAB and NAMTAB)
- Utility subroutines can be used by both macro processor and the language translator.
  - Scanning input lines
  - Searching tables
  - Data format conversion
- It is easier to give diagnostic messages related to the source statements

**Integrated Macro Processor**

- An integrated macro processor can potentially make use of any information about the source program that is extracted by the language translator.
  - Ex (blanks are not significant in FORTRAN)
    - DO 100 I = 1,20
      - a DO statement
    - DO 100 I = 1
      - An assignment statement
      - DO100I: variable (blanks are not significant in FORTRAN)
- An integrated macro processor can support macro instructions that depend upon the context in which they occur.

---

## UNIT-V

## TEXT-EDITORS

### 1. EXPLAIN IN DETAIL ABOUT THE FOLLOWING

i) Editing process
ii) User Interface

**OVERVIEW OF THE EDITING PROCESS.**

An interactive editor is a computer program that allows a user to create and revise a target document.The term document includes objects such as computer programs, texts, equations, tables, diagrams, line art and photographs-anything that one might find on a printed page. Text editor is one in which the primary elements being edited are character strings of the target text.

The document editing process is an interactive user-computer dialogue designed to accomplish four tasks:

1) Select the part of the target document to be viewed and manipulated
2) Determine how to format this view on-line and how to display it.
3) Specify and execute operations that modify the target document.
4) Update the view appropriately.

**Traveling** – Selection of the part of the document to be viewed and edited. It involves first **traveling** through the document to locate the area of interest such as "next screenful", "bottom",and "find pattern". Traveling specifies where the area of interest is;

**Filtering -** The selection of what is to be viewed and manipulated is controlled by filtering. Filtering extracts the relevant subset of the target document at the point of interest such as next screenful of text or next statement.

**Formatting:** Formatting determines how the result of filtering will be seen as a visible representation (the view) on a display screen or other device.

**Editing:** In the actual editing phase, the target document is created or altered with a set of operations such as insert, delete, replace, move or copy.

**Manuscript oriented editors** operate on elements such as single characters, words, lines, sentences and paragraphs;

**Program-oriented editors** operates on elements such as identifiers, keywords and statements

## THE USER-INTERFACE OF AN EDITOR.

The user of an interactive editor is presented with a conceptual model of the editing system. The model is an abstract framework on which the editor and the world on which the operations are based.

The **line editors** simulated the world of the keypunch they allowed operations on numbered sequence of 80-character card image lines.

The **Screen-editors** define a world in which a document is represented as a quarter-plane of text lines, unbounded both down and to the right. The user sees, through a cutout, only a rectangular subset of this plane on a multi line display terminal. The cutout can be moved left or right, and up or down, to display other portions of the document.

The user interface is also concerned with the input devices, the output devices, and the interaction language of the system.

**INPUT DEVICES**: The input devices are used to enter elements of text being edited, to enter commands, and to designate editable elements.

Input devices are categorized as:

1) Text devices

2) Button devices

3) Locator devices

**1) Text or string devices** are typically typewriter like keyboards on which user presses and release keys, sending unique code for each key. Virtually all computer key boards are of the QWERTY type.

**2) Button or Choice devices** generate an interrupt or set a system flag, usually causing an invocation of an associated application program. Also special function keys are also available on the key board. Alternatively, buttons can be simulated in software by displaying text strings or symbols on the screen. The user chooses a string or symbol instead of pressing a button.

**3) Locator devices:** They are two-dimensional analog-to-digital converters that position a cursor symbol on the screen by observing the user's movement of the device. The most common such devices are the **mouse** and the **tablet.**

**The Data Tablet** is a flat, rectangular, electromagnetically sensitive panel. Either the ballpoint pen like stylus or a puck, a small device similar to a mouse is moved over the surface. The tablet returns to a system program the co-ordinates of the position on the data tablet at which the stylus or puck is currently located. The program can then map these data-tablet coordinates to screen coordinates and move the cursor to the corresponding screen position.

Text devices with arrow (Cursor) keys can be used to simulate locator devices. Each of these keys shows an arrow that point up, down, left or right. Pressing an arrow key typically generates an appropriate character sequence; the program interprets this sequence and moves the cursor in the direction of the arrow on the key pressed.

**VOICE-INPUT DEVICES**: which translate spoken words to their textual equivalents, may prove to be the text input devices of the future. Voice recognizers are currently available for command input on some systems.

**OUTPUT DEVICES**

The output devices let the user view the elements being edited and the result of the editing operations.

- The first output devices were **teletypewriters** and other character-printing terminals that generated output on paper.
- Next "**glass teletypes**" based on Cathode Ray Tube (CRT) technology which uses CRT screen essentially to simulate the hard-copy teletypewriter.
- Today's **advanced CRT terminals** use hardware assistance for such features as moving the cursor, inserting and deleting characters and lines, and scrolling lines and pages.
- The modern **professional workstations** are based on personal computers with high resolution displays; support multiple proportionally spaced character fonts to produce realistic facsimiles of hard copy documents.

**INTERACTION LANGUAGE**:

The interaction language of the text editor is generally one of several common types.

**The typing oriented or text command-oriented method**

It is the oldest of the major editing interfaces. The user communicates with the editor by typing text strings both for command names and for operands. These strings are sent to the editor and are usually echoed to the output device.

Typed specification often requires the user to remember the exact form of all commands, or at least their abbreviations. If the command language is complex, the user must continually refer to a manual or an on-line Help function. The typing required can be time consuming for in-experienced users.

**Function key interfaces:**

Each command is associated with marked key on the key board. This eliminates much typing. E.g.: Insert key, Shift key, Control key

**Disadvantages:**

Have too many unique keys

Multiple key stroke commands

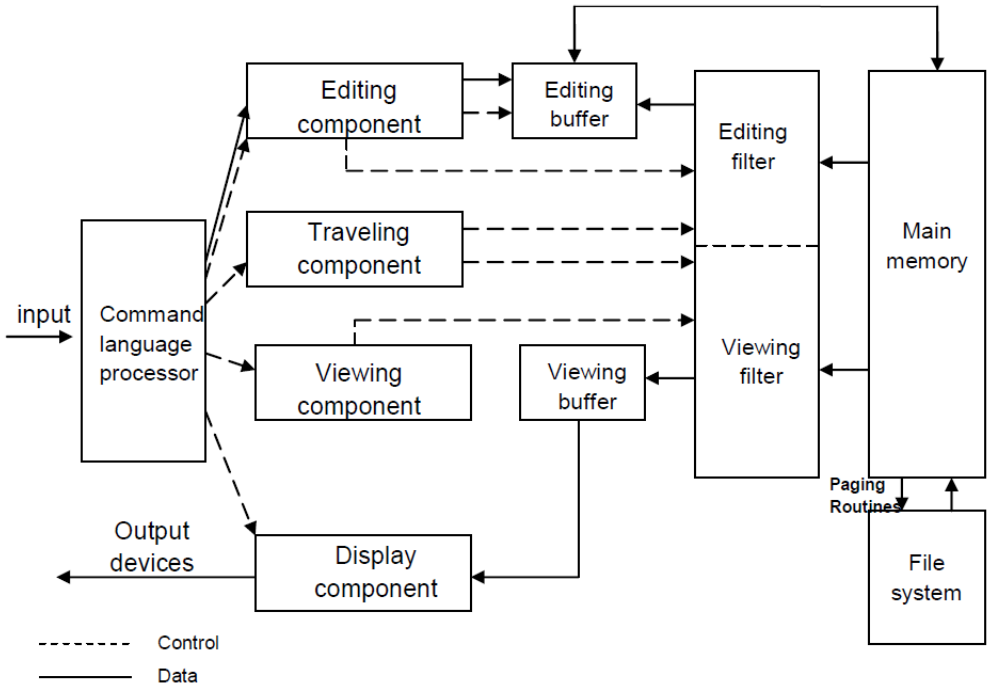
**Menu oriented interface**

A menu is a multiple choice set of text strings or icons which are graphical symbols that represent objects or operations. The user can perform actions by selecting items for the menus. The editor prompts the user with a menu. One problem with menu oriented system can arise when there are many possible actions and several choices are required to complete an action. The display area of the menu is rather limited

---

## 2. EXPLAIN ABOUT THE EDITOR STRUCTURE.

**EDITOR STRUCTURE**



The command Language Processor

It accepts input from the user's input devices, and analyzes the tokens and syntactic structure of the commands. It functions much like the lexical and syntactic phases of a compiler. The command language processor may invoke the semantic routines directly. In a text editor, these semantic routines perform functions such as editing and viewing.

The semantic routines involve traveling, editing, viewing and display functions. Editing operations are always specified by the user and display operations are specified implicitly by the other three categories of operations. Traveling and viewing operations may be invoked either explicitly by the user or implicitly by the editing operations.

Editing Component

In editing a document, the start of the area to be edited is determined by the **current editing pointer** maintained by the editing component, which is the collection of modules dealing with editing tasks. The current editing pointer can be set or reset explicitly by the user using travelling commands, such as next paragraph and next screen, or implicitly as a side effect of the previous editing operation such as delete paragraph.

Traveling Component

The traveling component of the editor actually performs the setting of the current editing and viewing pointers, and thus determines the point at which the viewing and /or editing filtering begins.

Viewing Component

The start of the area to be viewed is determined by the current viewing pointer. This pointer is maintained by the viewing component of the editor, which is a collection of modules responsible for determining the next view. The current viewing pointer can be set or reset explicitly by the user or implicitly by system as a result of previous editing operation.

The viewing component formulates an ideal view, often expressed in a device independent intermediate representation. This view may be a very simple one consisting of a window's worth of text arranged so that lines are not broken in the middle of the words.

Display Component

It takes the idealized view from the viewing component and maps it to a physical output device in the most efficient manner. The display component produces a display by mapping the buffer to a rectangular subset of the screen. usually a window

Editing Filter

Filtering consists of the selection of contiguous characters beginning at the current point. The editing filter filters the document to generate a new editing buffer based on the current editing pointer as well as on the editing filter parameters

Editing Buffer

It contains the subset of the document filtered by the editing filter based on the editing pointer and editing filter parameters

Viewing Filter

When the display needs to be updated, the viewing component invokes the viewing filter. This component filters the document to generate a new viewing buffer based on the current viewing pointer as well as on the viewing filter parameters.

Viewing Buffer

It contains the subset of the document filtered by the viewing filter based on the viewing pointer and viewing filter parameters.

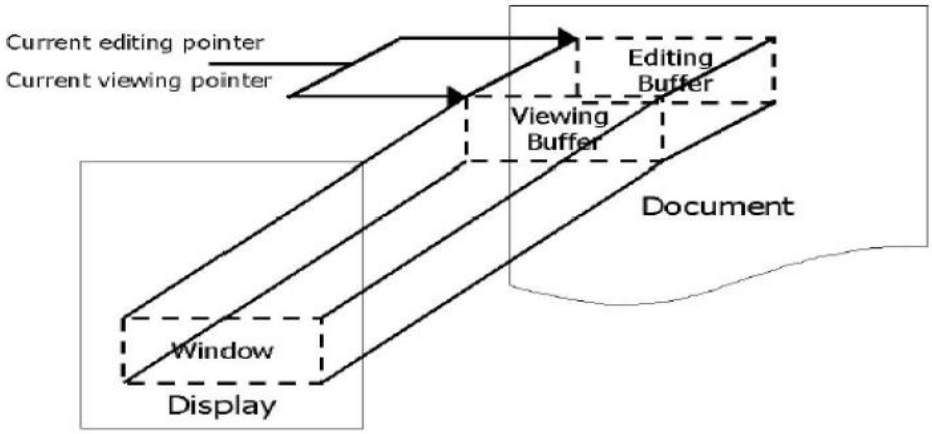
E.g. The user of a certain editor might travel to line 75,and after viewing it, decide to change all occurrences of “ugly duckling” to “swan” in lines 1 through 50 of the file by using a change command such as

[1,50] c/ugly duckling/swan/

As a part of the editing command there is implicit travel to the first line of the file. Lines 1 through 50 are then filtered from the document to become the editing buffer. Successive substitutions take place in this editing buffer without corresponding updates of the view

In *Line editors*, the viewing buffer may contain the current line; in *screen editors*, this buffer may contain rectangular cut out of the quarter-plane of text. This viewing buffer is then passed to the display component of the editor, which produces a display by mapping the buffer to a rectangular subset of the screen, usually called a *window.*

The editing and viewing buffers, while independent, can be related in many ways. In a simplest case, they are identical: the user edits the material directly on the screen. On the other hand, the editing and viewing buffers may be completely disjoint.




Simple relationship between editing and viewing buffers

**Windows** typically cover the entire screen or rectangular portion of it. Mapping viewing buffers to windows that cover only part of the screen is especially useful for editors on modern graphics based workstations. Such systems can support multiple windows, simultaneously showing different portions of the same file or portions of different file. This approach allows the user to perform inter-file editing operations much more effectively than with a system only a single window.

The mapping of the viewing buffer to a window is accomplished by two components of the system.

(i) First, the viewing component formulates an ideal view often expressed in a device **independent intermediate representation**. This view may be a very simple one consisting of a windows worth of text arranged so that lines are not broken in the middle of words. At the other extreme, the idealized view may be a facsimile of a page of fully formatted and typeset text with equations, tables and figures.

(ii) Second the display component takes these idealized views from the viewing component and maps it to a physical output device the most efficient manner possible.

The components of the editor deal with a user document on two levels:

(i) **In main memory and**

**(ii) In the disk file system**.

Loading an entire document into main memory may be infeasible. However if only part of a document is loaded and if many user specified operations require a disk read by the editor to locate the affected portions, editing might be unacceptably slow. In some systems this problem is solved by the mapping the entire file into **virtual memory** and letting the operating system perform efficient demand paging.

An alternative is to provide is the editor paging routines which read one or more logical portions of a document into memory as needed. Such portions are often termed **pages**, although there is usually no relationship between these pages and the hard copy document pages or virtual memory pages. These pages remain resident in main memory until a user operation requires that another portion of the document be loaded.

Editors function in three basic types of computing environment:

(i) **Time-sharing environment**
(ii) **Stand-alone environment and**
(iii) **Distributed environment**.

Each type of environment imposes some constraint on the design of an editor.

The Time –Sharing Environment

The time sharing editor must function swiftly within the context of the load on the computer's processor, central memory and I/O devices.

The Stand alone Environment

The editor on a stand-alone system must have access to the functions that the time sharing editors obtain from its host operating system. This may be provided in pare by a small local operating system or they may be built into the editor itself if the stand alone system is dedicated to editing.

Distributed Environment

The editor operating in a distributed resource sharing local network must, like a standalone editor, run independently on each user's machine and must, like a time sharing editor, content for shared resources such as files.

---

## 3. DISCUSS IN DETAIL ABOUT DEBUGGING FUNCTIONS AND CAPABILITIES.

An interactive debugging system provides programmers with facilities that aid in testing and debugging of programs interactively.

**DEBUGGING FUNCTIONS AND CAPABILITIES**

Execution sequencing:

It is the observation and control of the flow of program execution. For example, the program may be halted after a fixed number of instructions are executed.

**Breakpoints** – The programmer may define break points which cause execution to be suspended, when a specified point in the program is reached. After execution is suspended, the debugging command is used to analyze the progress of the program and to diagnose errors detected. Execution of the program can then be removed.

**Conditional Expressions** – Programmers can define some conditional expressions, evaluated during the debugging session, program execution is suspended, when conditions are met, analysis is made, later execution is resumed

**Gaits-** Given a good graphical representation of program progress may even be useful in running the program in various speeds called gaits.

A Debugging system should also provide functions such as tracing and traceback.

Tracing can be used to track the flow of execution logic and data modifications. The control flow can be traced at different levels of detail – procedure, branch, individual instruction, and so on…

Traceback can show the path by which the current statement in the program was reached. It can also show which statements have modified a given variable or parameter. The statements are displayed rather than as hexadecimal displacements.

Program-display Capabilities

It is also important for a debugging system to have good program display capabilities. It must be possible to display the program being debugged, complete with statement numbers.

Multilingual Capability

A debugging system should consider the language in which the program being debugged is written. Most user environments and many applications systems involve the use of different programming languages. A single debugging tool should be available to multilingual situations.

Context Effects

The context being used has many different effects on the debugging interaction.

For example. The statements are different depending on the language

COBOL - MOVE 6.5 TO X

FORTRAN - X = 6.5

Likewise conditional statements should use the notation of the source language

COBOL - IF A NOT EQUAL TO B

FORTRAN - IF (A .NE. B)

Similar differences exist with respect to the form of statement labels, keywords and so on.

Display of source code

The language translator may provide the source code or source listing tagged in some standard way so that the debugger has a uniform method of navigating about it.

For eg.

- invariant expressions can be removed from loop
- separate loops can be combined into a single loop
- redundant expression may be eliminated
- elimination of unnecessary branch instructions

The debugging of optimized code requires a substantial amount of cooperation from the optimizing compiler.

Optimization:

It is also important that a debugging system be able to deal with optimized code. Many optimizations involve the rearrangement of segments of code in the program.

---

## 4. EXPLAIN IN DETAIL ABOUT THE FOLLOWING

i)Relationships with other parts of the system
ii)User Interface criteria

**Relationship with Other Parts of the System**

An interactive debugger must be related to other parts of the system in many different ways.

Availability

Interactive debugger must appear to be a part of the run-time environment and an integral part of the system. When an error is discovered, immediate debugging must be possible because it may be difficult or impossible to reproduce the program failure in some other environment or at some other times.

Consistency with security and integrity components

User need to be able to debug in a production environment. When an application fails during a production run, work dependent on that application stops. Since the production environment is often quite different from the test environment, many program failures cannot be repeated outside the production environment.

Debugger must also exist in a way that is consistent with the security and integrity components of the system. Use of debugger must be subjected to the normal authorization mechanism and must leave the usual audit trails. Someone (unauthorized user) must not access any data or code. It must not be possible to use the debuggers to interface with any aspect of system integrity.

Coordination with existing and future systems

The debugger must co-ordinate its activities with those of existing and future language compilers and interpreters.

It is assumed that debugging facilities in existing language will continue to exist and be maintained. The requirement of cross-language debugger assumes that such a facility would be installed as an alternative to the individual language debuggers.

**USER- INTERFACE CRITERIA**

The interactive debugging system should be user friendly. The facilities of debugging system should be organized into few basic categories of functions which should closely reflect common user tasks.

Full – screen displays and windowing systems

- The user interaction should make use of full-screen display and windowing systems. The advantage of such interface is that the information can be should displayed and changed easily and quickly.

Menus:

- With menus and full screen editors, the user has far less information to enter and remember
- It should be possible to go directly to the menus without having to retrace an entire hierarchy.
- When a full-screen terminal device is not available, user should have an equivalent action in a linear debugging language by providing commands.

Command language:

- The command language should have a clear, logical, simple syntax. Parameters names should be consistent across set of commands
- Parameters should automatically be checked for errors for type and range values.
- Defaults should be provided for parameters.
- Command language should minimize punctuations such as parenthesis, slashes, and special characters.

On Line HELP facility

- Good interactive system should have an on-line HELP facility that should provide help for all options of menu
- Help should be available from any state of the debugging system.