Linkers

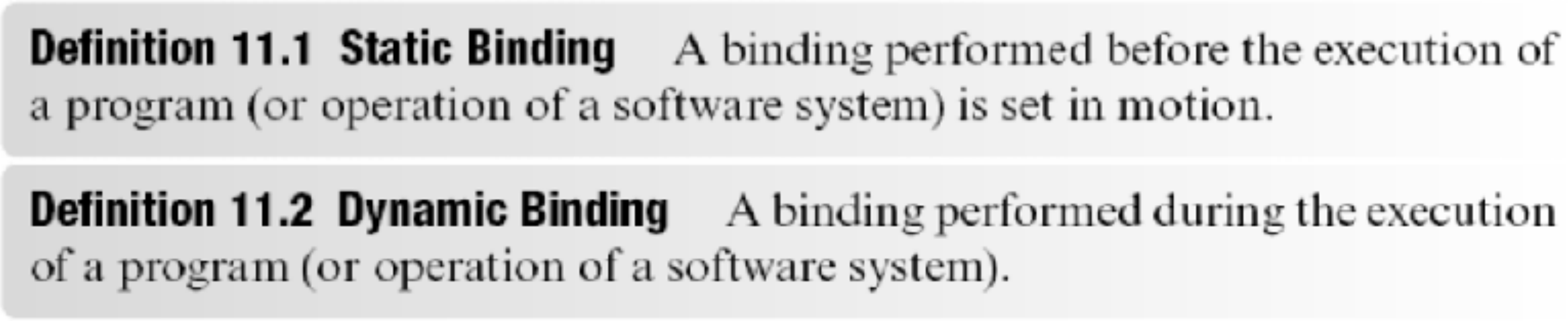
Execution of program

1. Translation of program.
2. Linking of one prog with another progs. Needed for its execution
3. Relocation of the program to execute form the specific memory area location
4. Loading of the program in memory to perform execution

Step 1 is perform by translator Steps 2 & 3 are performed by linker and step 4 is performed by loader

Static and Dynamic Bindings

- Memory allocation is an aspect of a more general action in software operation known as *binding*



Definition 11.1 Static Binding A binding performed before the execution of a program (or operation of a software system) is set in motion.

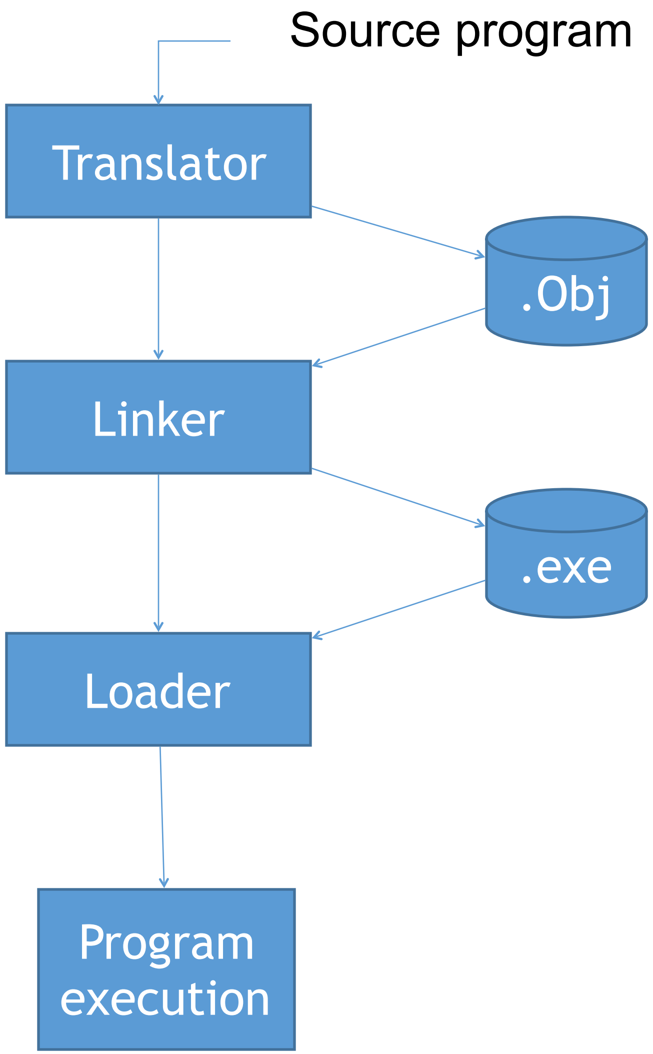
Definition 11.2 Dynamic Binding A binding performed during the execution of a program (or operation of a software system).

Introduction:

➢Translator translates source program to machine code and creates object file.

➢Linker receives set of object files and links them solving external reference problems and creates ready to execute file.(which is a binary file).

➢Loader loads this binary file to execution area for its execution

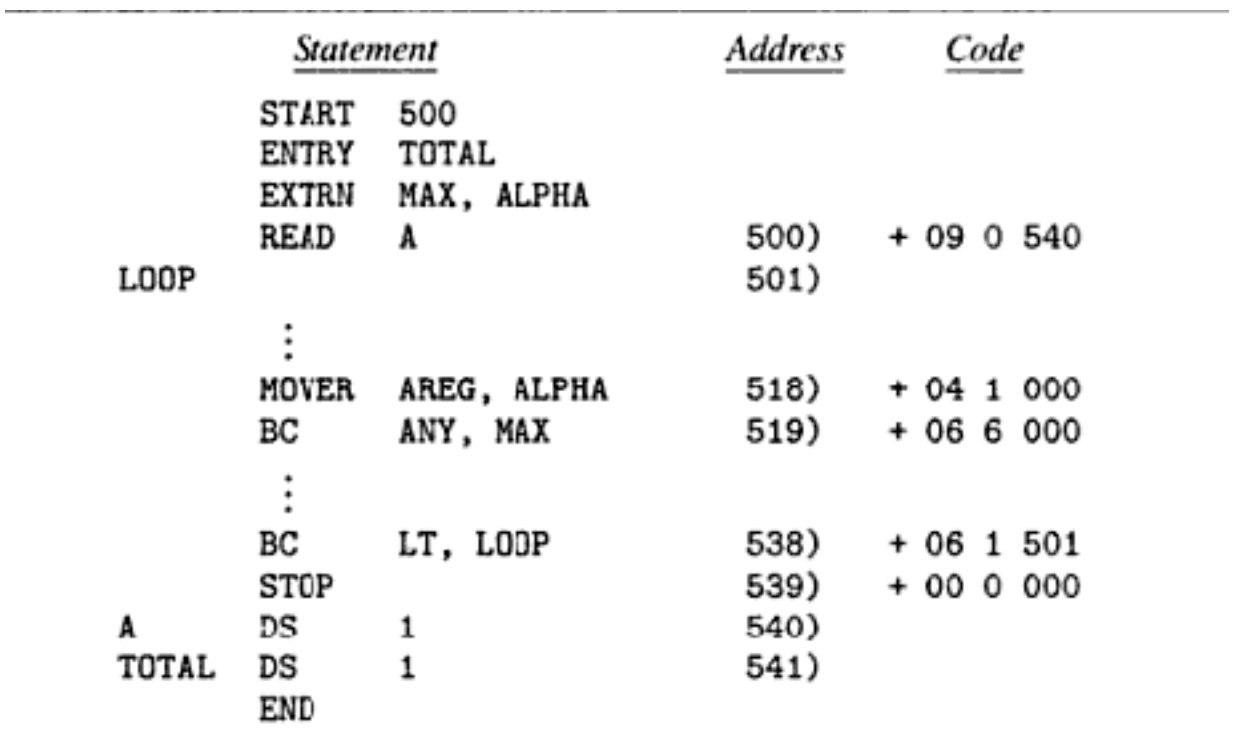


Some terminology used to refer to programing address

- Translation time address :address assign by translator
- Linked address : address assign by linker
- Load time address: address assign by loader

- Same terminology as assigning the origin of program
- Translated origin : Address of origin assumed by the translator.
  - This address is specified by ORIGIN.
- Linked address: Address of origin assign by the linker while generating binary program
- Load origin : Address of origin assign by the loader while loading program for execution.

- Assembly language program and its generated code



```
              Statement                  Address    Code
          START  500
          ENTRY  TOTAL
          EXTRN  MAX, ALPHA
          READ   A                        500)   + 09 0 540
LOOP                                      501)
            :
          MOVER  AREG, ALPHA              518)   + 04 1 000
          BC     ANY, MAX                 519)   + 06 6 000
            :
          BC     LT, LOOP                 538)   + 06 1 501
          STOP                            539)   + 00 0 000
A         DS     1                        540)
TOTAL     DS     1                        541)
          END
```

Relocation and linking

- Let AA be set of absolute addresses used in the program P.
- If AA!= Φ implies that program P assumes that instructions and data occupy specific addresses. a such program is called address sensitive program.

Address sensitive programs can execute correctly only if start address is same as translated origin. To execute correctly , addresses must be corrected.

Program relocation

- It is the process of modifying the addresses used in asi of a program such that the program can execute correctly from the designated area of memory
- Relocation can be done by the linker or loader
- If linked origin != translated origin then relocation is done by linker
- If load origin!= linked origin then relocation is done by loader
- In general linker performs relocation.

- Relocation factor=l_origin$_p$ - t_origin (1)

- If statement uses symbol as an operand,then
- tsymb=t_origin+d$_{symb}$

- d$_{symb}$ is the offset of a program

- For link symbol
- Lsymb = l_origin+dsymb

- Lsymb=t_origin +relocation factor+dsymb
- =t_orgin +dsymb+relocation factor
- =tsymb+relocation factor

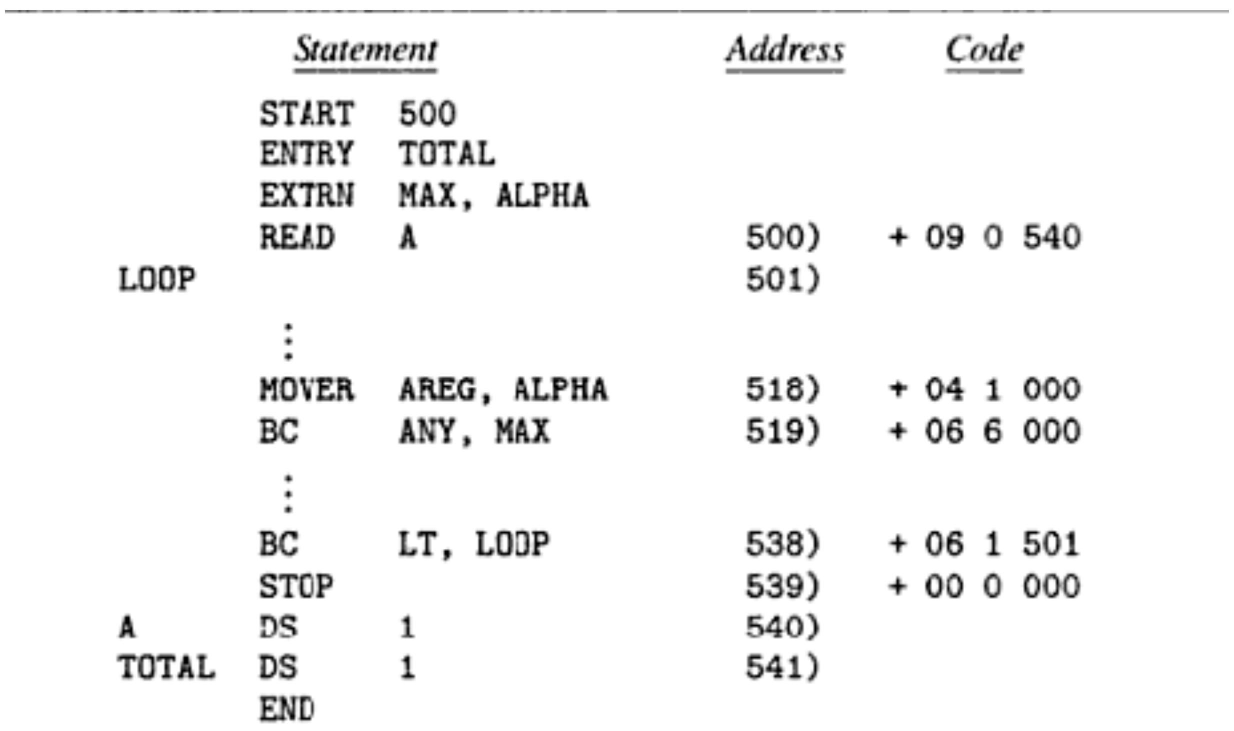
IRR=Instructions requiring relocation.

- Ex: Let IRR for prog P has dispalcement(dsymb)=40,t_origin=500,l_origin=900 then
- Relocation factor=900-500=400
- tsymb=500+40=540;lsymb=900+40=940
- lsymb=540+400=940

Linking

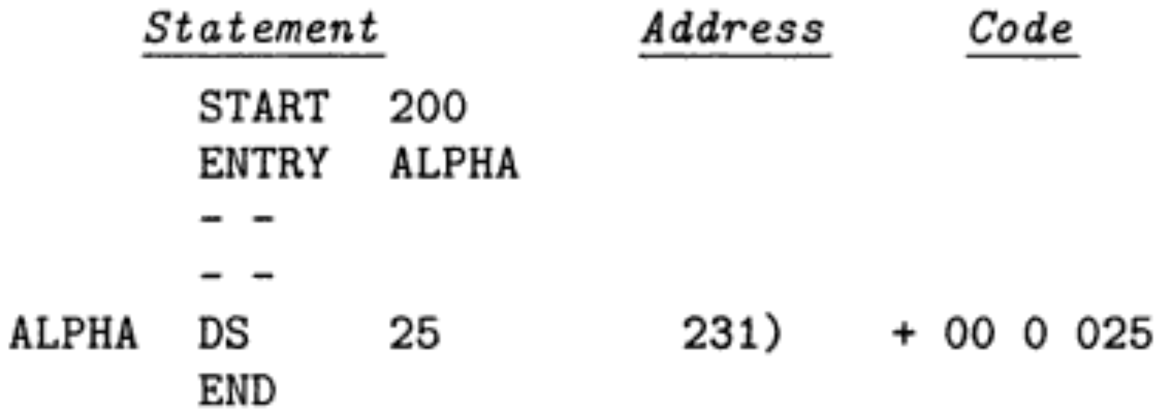
- ***Linking***: Linking is a process of binding an external reference to the correct link time address
- An Application Program AP consists of a set of program unit SP={x}
- Suppose that prog. **x** interact with other prog. **y** by using address of y's instruction and data of its own.
- This interaction contains public def. and ext ref.
- Public definition: a symbol defined in a program unit which may be referenced in other program units.
- Ext. ref : a ref to a symbol which is not defined in the program unit containing the references.

- Assembly language program and its generated code



```
                   Statement                     Address      Code
        START   500
        ENTRY   TOTAL
        EXTRN   MAX, ALPHA
        READ    A                                 500)    + 09 0 540
LOOP                                              501)
          :
        MOVER   AREG, ALPHA                       518)    + 04 1 000
        BC      ANY, MAX                          519)    + 06 6 000
          :
        BC      LT, LOOP                          538)    + 06 1 501
        STOP                                      539)    + 00 0 000
A       DS      1                                 540)
TOTAL   DS      1                                 541)
        END
```

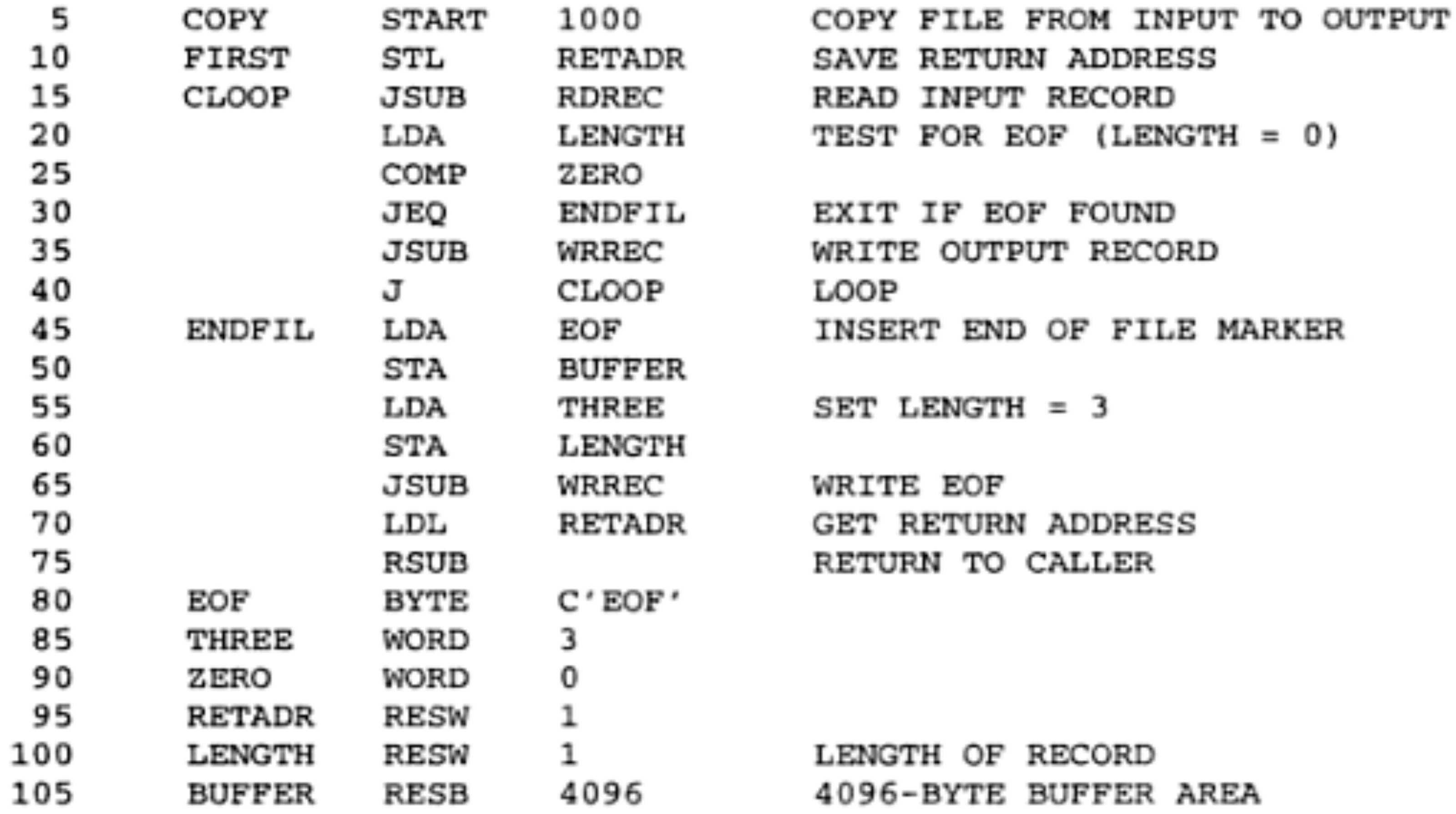
- Ad



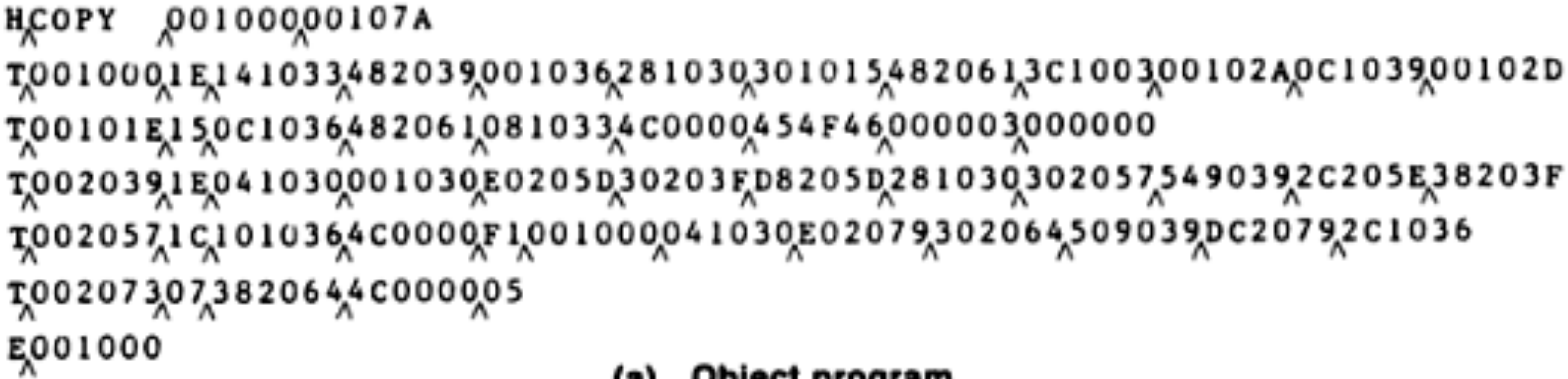
```
          Statement               Address     Code
        START   200
        ENTRY   ALPHA
        - -
        - -
ALPHA   DS      25                  231)     + 00 0 025
        END
```

Absolute loader

- Absolute loader doesn’t need to perform functions like linking and program relocation.
- For example take assembly language example of **Simplified Instructional Compute (SIC)** instruction as shown in figure.
- All functions are accomplished in a single pass assembler
- First the header record is checked to verify that correct program has been represented for loading.
- Input is read ,when the end record is encountered the loader jumps to the specified address to begin the execution of the loaded program.

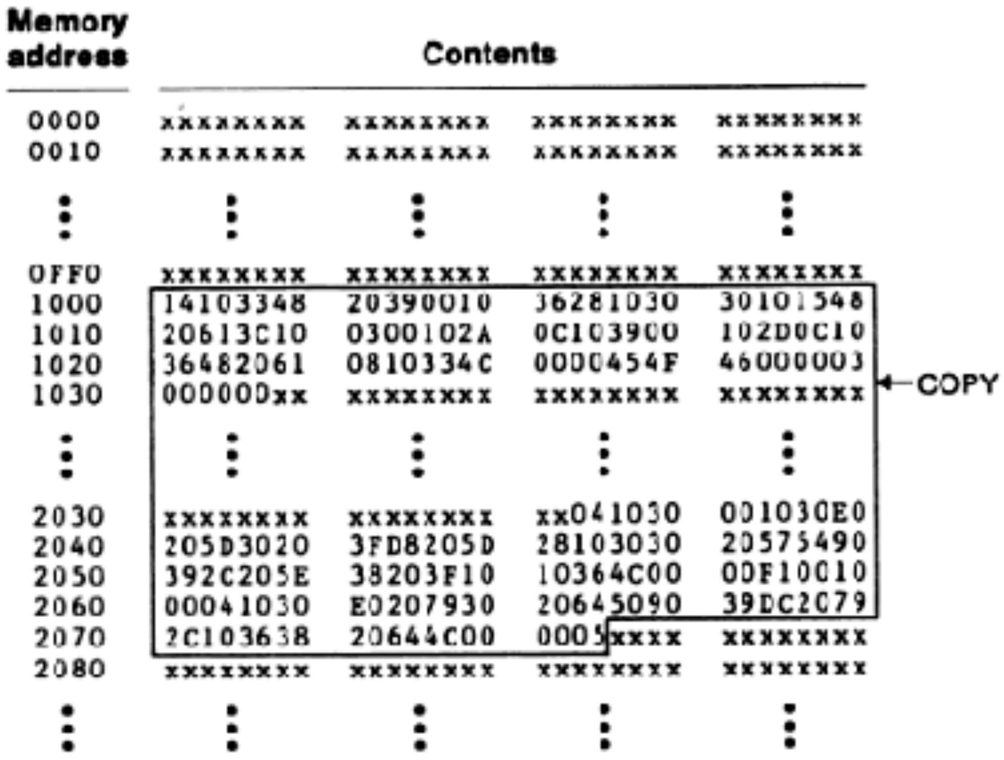


```
  5    COPY     START   1000        COPY FILE FROM INPUT TO OUTPUT
 10    FIRST    STL     RETADR      SAVE RETURN ADDRESS
 15    CLOOP    JSUB    RDREC       READ INPUT RECORD
 20             LDA     LENGTH      TEST FOR EOF (LENGTH = 0)
 25             COMP    ZERO
 30             JEQ     ENDFIL      EXIT IF EOF FOUND
 35             JSUB    WRREC       WRITE OUTPUT RECORD
 40             J       CLOOP       LOOP
 45    ENDFIL   LDA     EOF         INSERT END OF FILE MARKER
 50             STA     BUFFER
 55             LDA     THREE       SET LENGTH = 3
 60             STA     LENGTH
 65             JSUB    WRREC       WRITE EOF
 70             LDL     RETADR      GET RETURN ADDRESS
 75             RSUB                RETURN TO CALLER
 80    EOF      BYTE    C'EOF'
 85    THREE    WORD    3
 90    ZERO     WORD    0
 95    RETADR   RESW    1
100    LENGTH   RESW    1           LENGTH OF RECORD
105    BUFFER   RESB    4096        4096-BYTE BUFFER AREA
```



```
H^COPY  ^001000^00107A
T^001000^1E^141033^482039^001036^281030^301015^482061^3C1003^00102A^0C1039^00102D
T^00101E^15^0C1036^482061^081033^4C0000^454F46^000003^000000
T^002039^1E^041030^001030^E0205D^30203F^D8205D^281030^302057^549039^2C205E^38203F
T^002057^1C^101036^4C0000^F1^001000^041030^E02079^302064^509039^DC2079^2C1036
T^002073^07^382064^4C0000^05
E^001000
```

(a) Object program



```
Memory
address                          Contents

 0000     xxxxxxxx   xxxxxxxx   xxxxxxxx   xxxxxxxx
 0010     xxxxxxxx   xxxxxxxx   xxxxxxxx   xxxxxxxx
   :          :          :          :          :
 0FF0     xxxxxxxx   xxxxxxxx   xxxxxxxx   xxxxxxxx
 1000     14103348   20390010   36281030   30101548
 1010     20613C10   0300102A   0C103900   102D0C10
 1020     36482061   0810334C   0000454F   46000003
 1030     000000xx   xxxxxxxx   xxxxxxxx   xxxxxxxx   ←COPY
   :          :          :          :          :
 2030     xxxxxxxx   xxxxxxxx   xx041030   001030E0
 2040     205D3020   3FD8205D   28103030   20575490
 2050     392C205E   38203F10   10364C00   0DF10010
 2060     00041030   E0207930   20645090   39DC2079
 2070     2C103638   20644C00   0005xxxx   xxxxxxxx
 2080     xxxxxxxx   xxxxxxxx   xxxxxxxx   xxxxxxxx
   :          :          :          :          :
```

(b) Program loaded in memory

Bootstrap loader

- Alternatively referred to as **bootstrapping**, **bootloader**, or **boot program**, a **bootstrap** loader is a program that resides in the computers EPROM, ROM, or other non-volatile memory that automatically executed by the processor when turning on the computer.
- The bootstrap loader reads the hard drives boot sector to continue the process of loading the computers operating system.

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

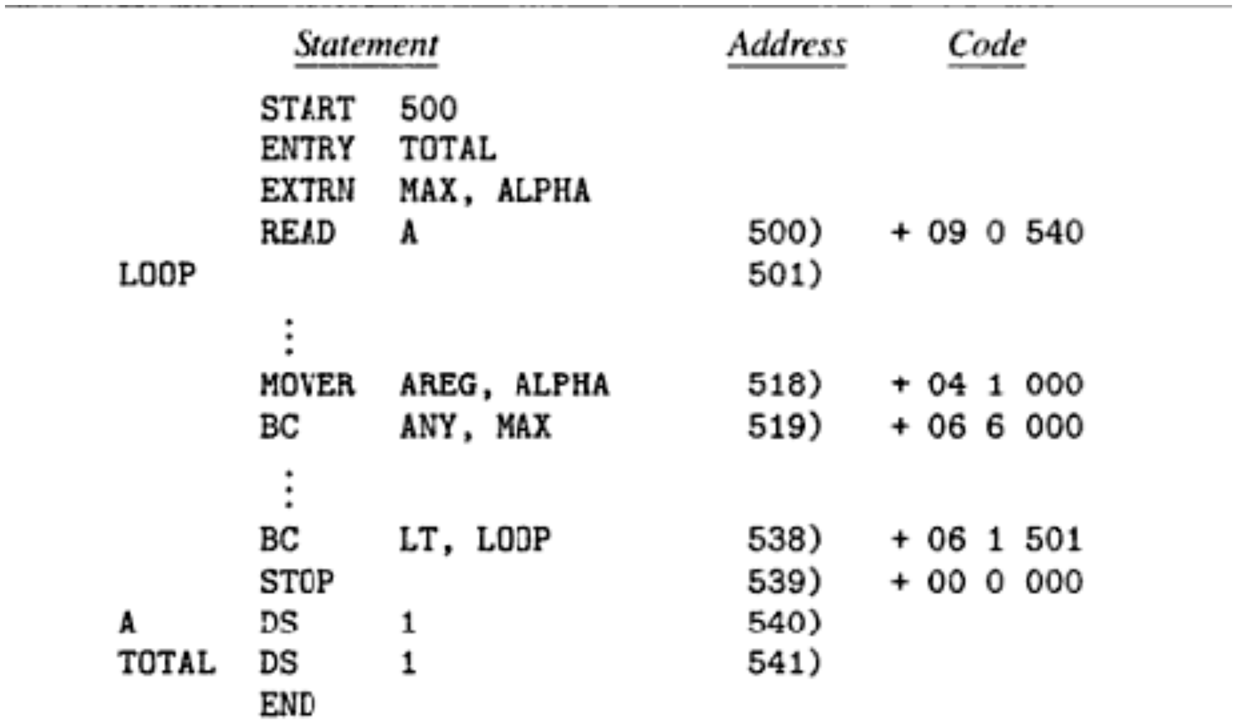
Binary programs

- It is machine language program contains a set of program units (SP) such that for all **Pi** belongs to **SP**
- i) Pi has been relocated to the memory area starting at link origin
- ii) Linking has been performed for each external reference
- To create binary program from object modules linker invocation is required
- Linker<link origin>,<object module name>[,<execution start address>]

Design of linker:

- Object module: It contains all information necessary to relocate and link the program. It consists of following elements:

- 1)**Header:**Contains translated origin ,size and execution start addtress of program.
- 2)**Program**:Contains the machine code corresponding to program.
- 3)**RELOCTAB**: Descibes IRR.It cntains single field:translated address.
- 4)**LINKTAB**(Symbol,Type,translated address):Contains information concerningpublic definitions.
- Type:PD/EXT



```
                Statement              Address    Code

          START   500
          ENTRY   TOTAL
          EXTRN   MAX, ALPHA
          READ    A                    500)    + 09 0 540
LOOP                                   501)
            ⋮
          MOVER   AREG, ALPHA          518)    + 04 1 000
          BC      ANY, MAX             519)    + 06 6 000
            ⋮
          BC      LT, LOOP             538)    + 06 1 501
          STOP                         539)    + 00 0 000
A         DS      1                    540)
TOTAL     DS      1                    541)
          END
```

Object module header

T_origin	size	Exe_start_ address
500	42	500

LINKTAB

RELOCTAB

Translated Address
500
538

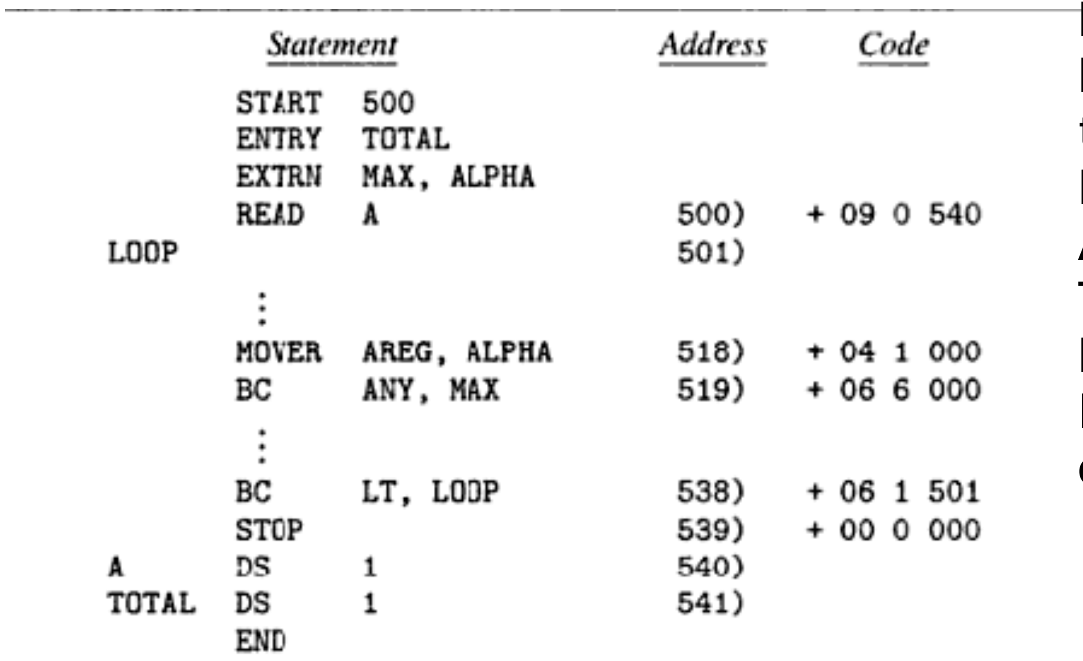
Symbol	Type	Translated address
ALPHA	EXT	518
MAX	EXT	519
TOTAL	PD	541

Design of linker:

Relocation algorithm:

```
1.program_linked_origin:=<link origin>
2.For each object module
    a)t_origin:=translated origin of the object module.
      OM_size:=size of the object module;
    b)relocation_factor:= program_linked_origin - t_orgin;
    c)Read the m/c lang. prog. In work area;
    d)Read RELOCTAB of the object module
    e)For each entry in RELOCTAB
     i)Translated_addr:=Address in theRELOCTAB entry
    ii)Addr_in _work_area:=Addr_of _work_area+Translated_addr-t_orgin;
    iii)Add relocation_factor to the operand address in the word with the addr. in work area.

    f) program_linked_origin:=   program_linked_origin+OM_size;
```



```
              Statement                 Address     Code
         START   500
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         EXTRN   MAX, ALPHA
         READ    A                       500)    + 09 0 540
LOOP                                     501)
           :
         MOVER   AREG, ALPHA             518)    + 04 1 000
         BC      ANY, MAX                519)    + 06 6 000
           :
         BC      LT, LOOP                538)    + 06 1 501
         STOP                            539)    + 00 0 000
A        DS      1                       540)
TOTAL    DS      1                       541)
         END
```

Ex: Let addr in work area=300,
Link origin=900,t_origin=500 ,size=42
then
Relocation factor=900-500=400
Addr_in _work_area=300+500-500=300
This word contains the instruction for
READ A
It is relocated by adding 400 to the operand address in it.

Design of linker:

Linking algorithm:

```
1.program_linked_origin:=<link origin>
2.For each object module
        a)t_origin:=translated origin of the object module.
          OM_size:=size of the object module;

        b)relocation_factor:= program_linked_origin - t_orgin;
        c)Read the m/c lang. prog. In work area;
        d)Read LINKTAB of the object module

        e)For each entry in LINKTAB with type=PD
         i)name:=symbol;
           linked_address:=translated_address+relocation factor;
           Enter(name,linked_address)in NTAB
        f)Enter(object module name,Prog_linked_origin)in NTAB
        g)Program_linked_origin:=Program_linked_origin+OM_size;
3.For each object module
        a)t_origin:=translated origin of the object module
           program_linked_origin:=load address from NTAB;
        b)For each LINKTAB entry with type=EXT
        i)Addr_in_work_area:=Addr of work area+Program_linked_origin-Link_origin+translated addr. –t_orgin;
        ii)Search symbol in NTAB and copy its linked address. Add this linked address to operand address in the word with the address with address_in_work_area.
```

LINKTAB

Symbol	Type	Translated address
ALPHA	EXT	518
MAX	EXT	519
TOTAL	PD	541

NTAB

Symbol	Linked address
Total	941
P	900
Q	942
Alpha	973

SELF RELOCATION PROGRAMS

Non relocating programs

is a program which cannot be executed in any memory area other than area starting on its translated origin

Relocatable program Can be processed to relocate it to a desired area of memory

Self- relocating programs

Program which can perform the relocation of its own address sensitive instructions.

It Contains

A table of information concerning address sensitive instructions

Code to perform relocation of ASI. This is called relocating logic

Linking for overlays

- An overlay is a part of a program which has same load origin as some other part of the program

- Used to reduce memory requirements of the program

- Program containing overlays is called overlay

- structured program.

It consists of

1. Permanently resident portion, called root
2. Set of overlays

- First root is loaded and given control for execution
- Other overlays are loaded when its needed.
- Loading new overlay overwrites old overlays coz we have same load origin for all overlays
- The structure of program is designed by identifying mutually exclusive modules i.e modules do not call each other.
- Sould be avoided to reside simultaneously in memory.

- Ex
- Program with six section name as init, read ,prog_a,prog_b , prog_c and print.
- How overlay is done for this program..?