Chapter 3

Loaders and Linkers

This Chapter gives you…

- Basic Loader Functions
- Machine-Dependent Loader Features
- Machine-Independent Loader Features
- Loader Design Options
- Implementation Examples

3.0 Introduction

The Source Program written in assembly language or high level language will be converted to object program, which is in the machine language form for execution. This conversion either from assembler or from compiler, contains translated instructions and data values from the source program, or specifies addresses in primary memory where these items are to be loaded for execution.

This contains the following three processes, and they are,

Loading - which allocates memory location and brings the object program into memory for execution - (Loader)

Linking- which combines two or more separate object programs and supplies the information needed to allow references between them - (Linker)

Relocation - which modifies the object program so that it can be loaded at an address different from the location originally specified - (Linking Loader)

3.1 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 is as shown in the figure 3.1. In figure 3.1 translator may be assembler/complier, which generates the object program and later loaded to the memory by the loader for execution. In figure 3.2 the translator is specifically an assembler, which generates the object loaded, which becomes input to the loader. The figure 3.3 shows the role of both loader and linker.

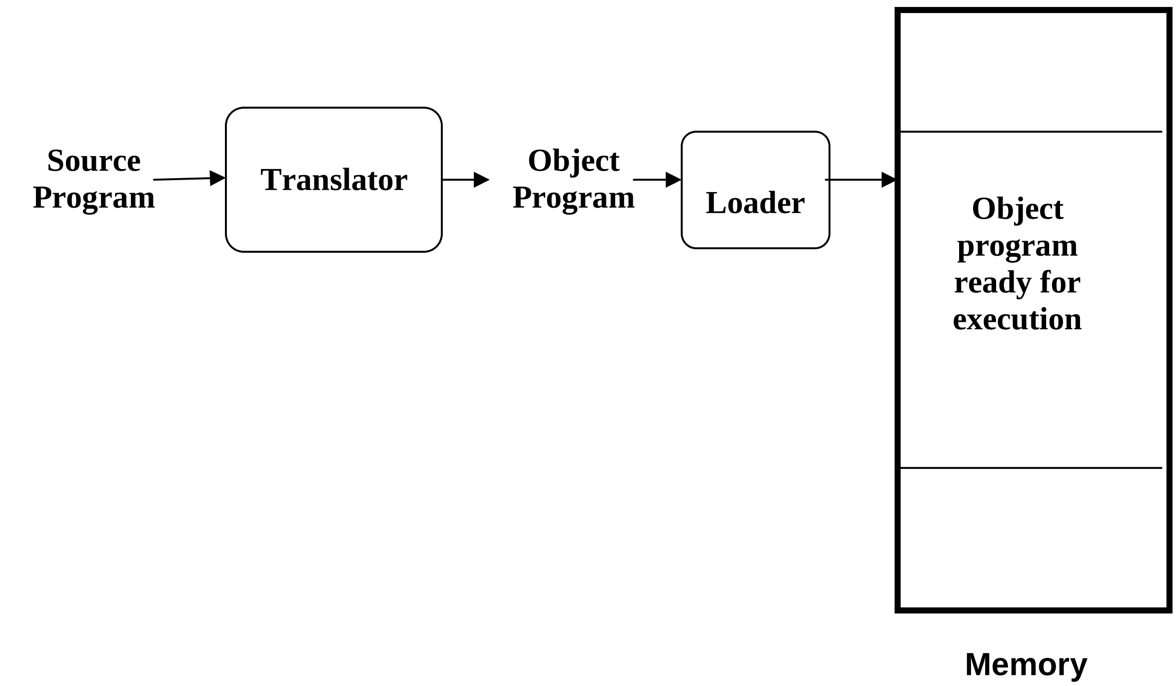


Figure 3.1 : The Role of Loader

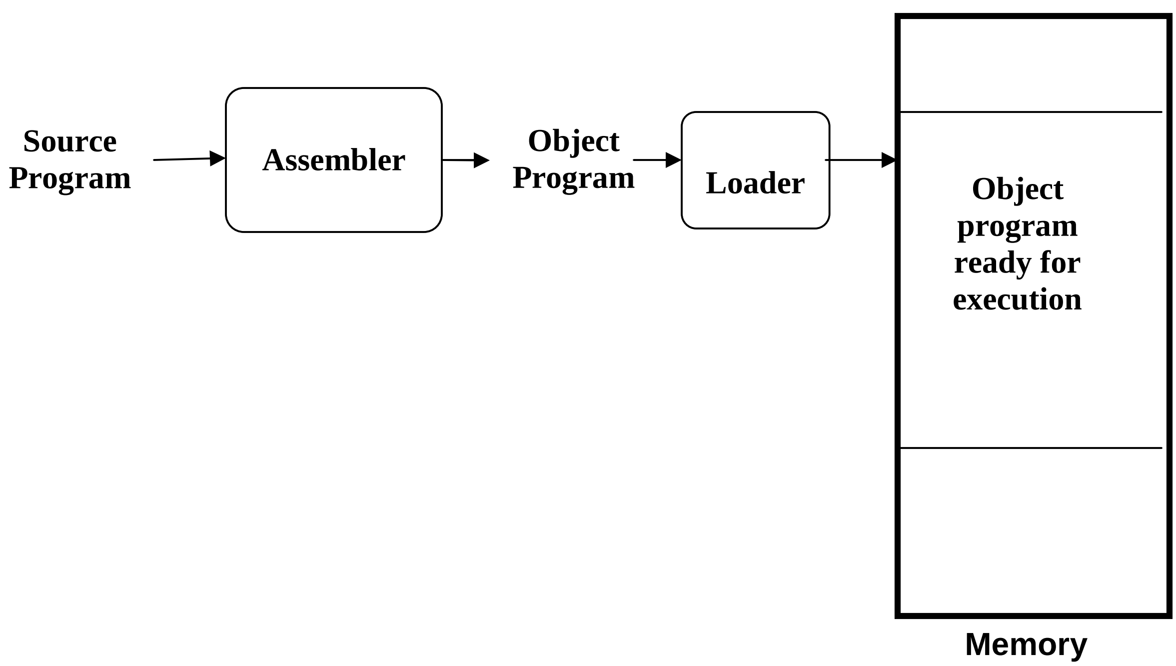


Figure 3.2: The Role of Loader with Assembler

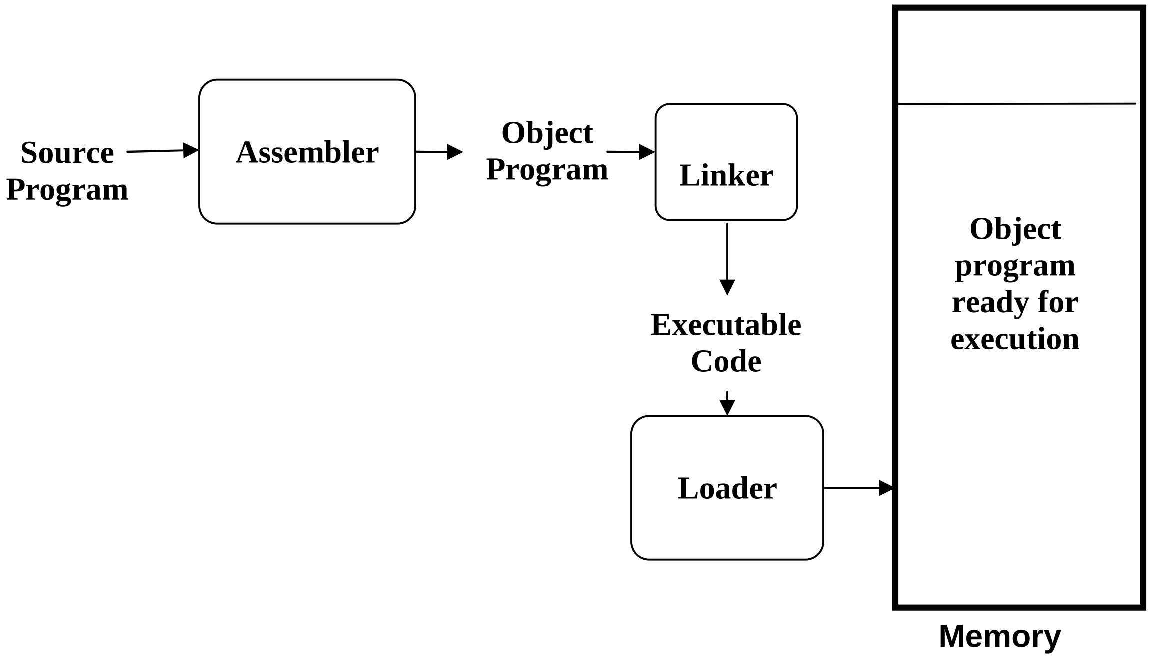


Figure 3.3 : The Role of both Loader and Linker

3.3 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.

3.3.1 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.

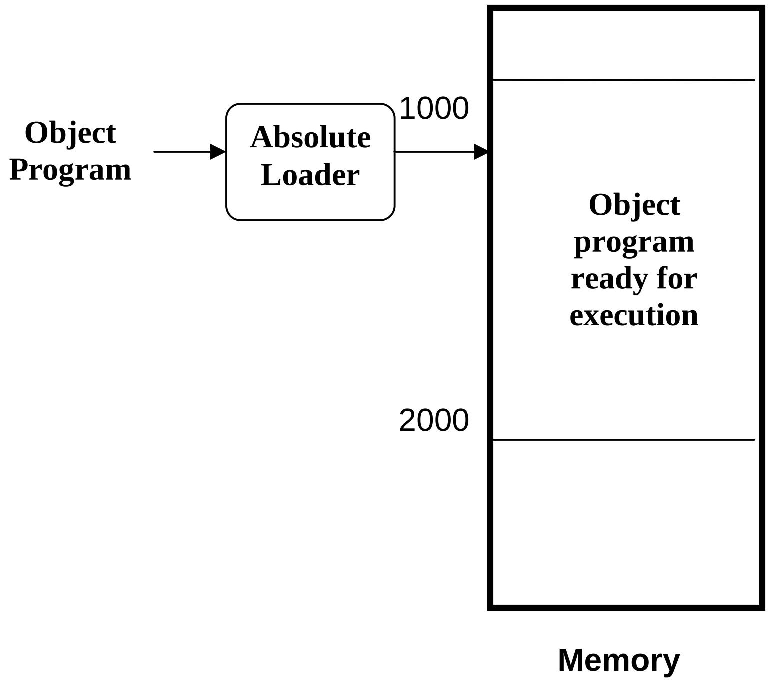


Figure 3.3.1: The Role of Absolute Loader

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
```

```
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
⋮	⋮	⋮	⋮	⋮
2030	xxxxxxxx	xxxxxxxx	xx041030	001030E0
2040	205D3020	3FD8205D	28103030	20575490
2050	392C205E	38203F10	10364C00	00F10010
2060	00041030	E0207930	20645090	39DC2079
2070	2C103638	20644C00	0005xxxx	xxxxxxxx
2080	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx
⋮	⋮	⋮	⋮	⋮

COPY

(b) Program loaded in memory

3.3.2 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
```

3.4 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.

3.4.1 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.

3.4.2 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
```

```
HΛCOPY Λ000000 001077
TΛ000000 Λ1DΛ17202DΛ69202DΛ48101036Λ…Λ4B105DΛ3F2FECΛ032010
TΛ00001DΛ13Λ0F2016Λ010003Λ0F200DΛ4B10105DΛ3E2003Λ454F46
TΛ001035 Λ1DΛB410ΛB400ΛB440Λ75101000Λ…Λ332008Λ57C003ΛB850
TΛ001053Λ1DΛ3B2FEAΛ134000Λ4F0000ΛF1Λ..Λ53C003ΛDF2008ΛB850
TΛ00070Λ07Λ3B2FEFΛ4F0000Λ05
MΛ000007Λ05+COPY
MΛ000014Λ05+COPY
MΛ000027Λ05+COPY
EΛ000000
```

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

3.5 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

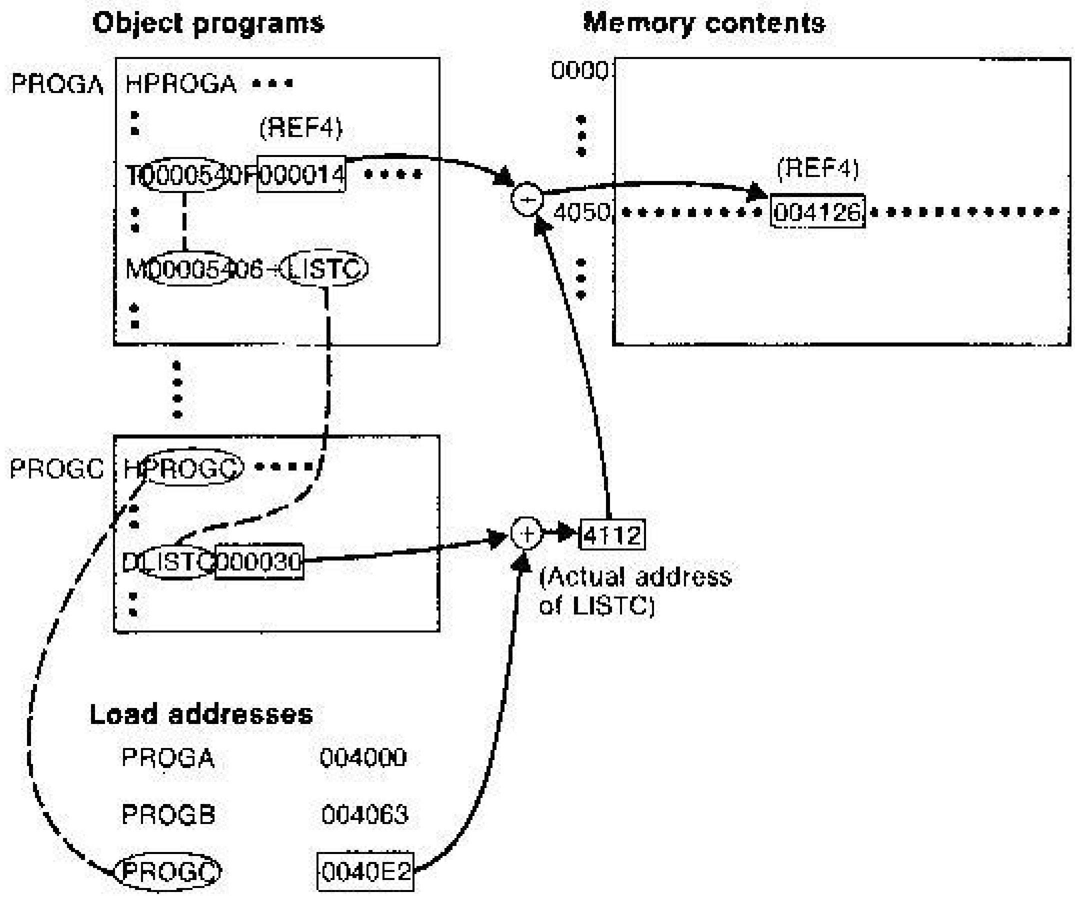
H **PROGC** 000000 000051
D LISTC 000030 ENDC 000042
R LISTA ENDA LISTB ENDB
.
T 000018 0C 03100000 77100004 05100000
.
T 000042 0F 000030 000008 000011 000000 000000
M000019 05+LISTA
M00001D 06+LISTB
M000021 06+ENDA
M000021 06 -LISTA
M000042 06+ENDA
M000042 06 -LISTA
M000042 06+PROGC
M000048 06+LISTA
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.

Memory address	Contents				
0000	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx	
⋮	⋮	⋮	⋮	⋮	
3FF0	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx	
4000	....	....	....	....	
4010	....	....	....	....	
4020	03201D77	1040C705	0014....	....	←PROGA
4030	....	....	....	....	
4040	....	....	....	....	
4050	....	00412600	00080040	51000004	
4060	000083..	....	....	....	
4070	....	....	....	....	
4080	....	....	....	....	
4090	....	....	..031040	40772027	←PROGB
40A0	05100014	....	....	....	
40B0	....	....	....	....	
40C0	....	....	....	....	
40D0	00	41260000	08004051	00000400	
40E0	0083....	....	....	....	
40F0	....	....	0310	40407710	
4100	40C70510	0014....	....	....	←PROGC
4110	....	....	....	....	
4120	....	00412600	00080040	51000004	
4130	000083xx	xxxxxxxx	xxxxxxxx	xxxxxxxx	
4140	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx	
⋮	⋮	⋮	⋮	⋮	

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.

3.6 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	

3.6.1 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}
```

3.6.2 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 progra
end  {Pass 2}
```

3.6.3 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).

```
HPROGA 000000000063
DLISTA 000040ENDA  000054
R02LISTB 03ENDB  04LISTC 05ENDC
.
.
T0000200A03201D77100004050014
.
.
T0000540F000014FFFF600003F000014FFFFC0
M00002405+02
M00005406+04
M00005706+05
M00005706-04
```

```
HPROGB 00000000007F
DLISTB 000060ENDB  000070
R02LISTA 03ENDA  04LISTC 05ENDC
.
.
T0000360B0310000077202705100000
.
.
T0000700F000000FFFFF6FFFFFFFFFFF0000060
M00003705+02
M00003E05+03
M00003E05-02
M00007006+03
M00007006-02
M00007006+04
M00007306+05
M00007306-04
M00007606+05
M00007606-04
M00007606+02
M00007906+03
M00007906-02
M00007C06+01
M00007C06-02
E
```

```
H^PROGC ^000000^000051
D^LISTC ^000030^ENDC  ^000042
R^02LISTA ^03ENDA  ^04LISTB ^05ENDB
.
.
T^000018^0C^03100000^77100004^05100000
.
.
T^000042^0F^000030^000008^000011^000000^000000
M^000019^05^+02
M^00001D^05^+04
M^000021^05^+03
M^000021^05^-02
M^000042^06^+03
M^000042^06^-02
M^000042^06^+01
M^000048^06^+02
M^00004B^06^+03
M^00004B^06^-02
M^00004B^06^-05
M^00004B^06^+04
M^00004E^06^+04
M^00004E^06^-02
E
```

Symbol 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

3.7 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.

3.7.1 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.

3.7.2 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.

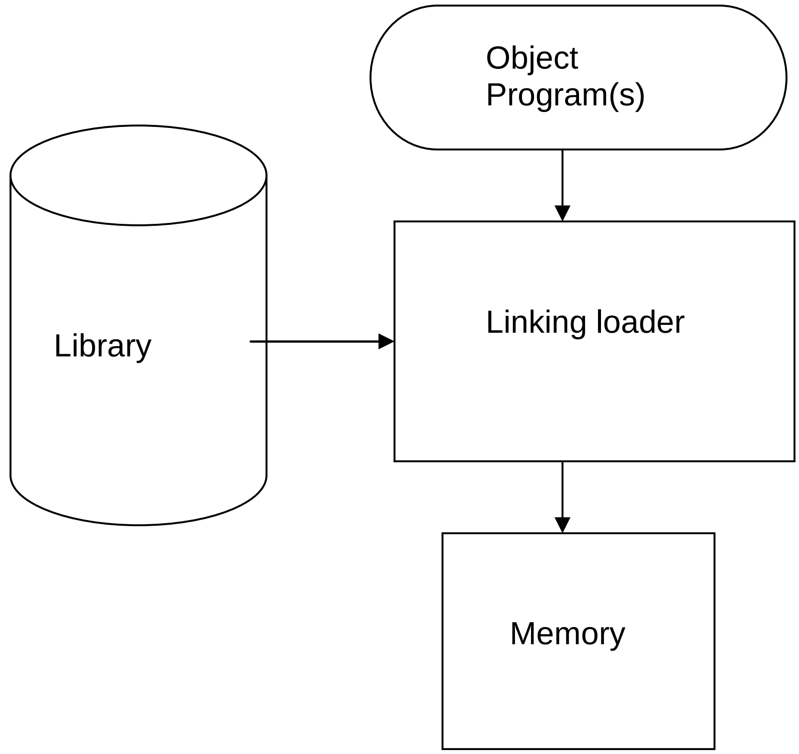
```
LIBRARY UTLIB
INCLUDE READ (UTLIB)
INCLUDE WRITE (UTLIB)
DELETE RDREC, WRREC
CHANGE RDREC, READ
CHANGE WRREC, WRITE
NOCALL  SQRT, PLOT
```

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.

3.8 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

3.8.1 Linking Loaders

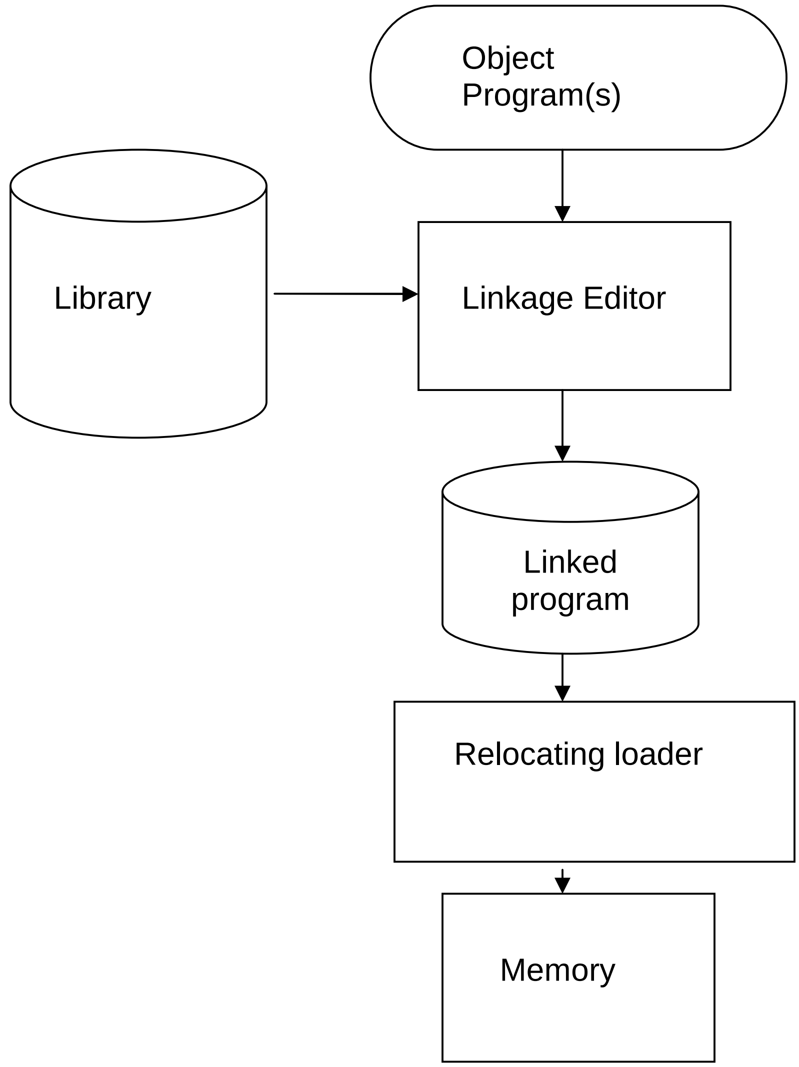


The above diagram shows the processing of an object program using Linking Loader. The source program is first assembled or compiled, producing an object program. A linking loader performs all linking and loading operations, and loads the program into memory for execution.

3.8.2 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



3.8.3 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.

3.8.4 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.

3.9 Implementation Examples

This section contains brief description of loaders and linkers for actual computers. They are, MS-DOS Linker - Pentium architecture, SunOS Linkers - SPARC architecture, and, Cray MPP Linkers – T3E architecture.

3.9.1 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.

3.9.2 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.

3.9.3 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.