



System Software

CSN-252

Program Linking

Chapter 3 L. L. Beck



```

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         *
                                Base 10
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	PROGA	START	0	H PROGA 000000 000063
	EXTDEF	LISTA, ENDA		D LISTA 000040 ENDA 000054
	EXTREF	LISTB, ENDB, LISTC, ENDC		R LISTB ENDB LISTC ENDC
		:		:
0020	REF1	LDA	LISTA	T0000200A03201D ... 050014
0023	REF2	+LDT	LISTB+4	:
0027	REF3	LDX	#ENDA-LISTA	T0000540F000014 ... FFFFC0
		:		M000024 05 +LISTB
0040	LISTA	EQU	*	M000054 06 +LISTC
		:		M000057 06 +ENDC
0054	ENDA	EQU	*	M000057 06 -LISTC
		:		M00005A 06 +ENDC
0054	REF4	WORD	ENDA-LISTA+LISTC	M00005A 06 -LISTC
		:		M00005A 06 +PROGA
0057	REF5	WORD	ENDC-LISTC-10	M00005D 06 -ENDB
005A	REF6	WORD	ENDC-LISTC+LISTA-1	M00005D 06+LISTB
005D	REF7	WORD	ENDA-LISTA-(ENDB-LISTB)	M000060 06 +LISTB
		:		M000060 06 -PROGA
0060	REF8	WORD	LISTB-LISTA	E000020
		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	FFFFFF6
0076	REF6	WORD	ENDC-LISTC+LISTA-1	FFFFFFF
0079	REF7	WORD	ENDA-LISTA-(ENDB-LISTB)	FFFFFF0
007C	REF8	WORD	LISTB-LISTA	000060
		END	REF1	

```

H PROGB 000000 00007F
D LISTB 000060 ENDB 000070
R LISTA ENDA LISTC ENDC
:
T000036 0B ...
:
T000070 0F...
M000037 05 +LISTA      M000079 06 -LISTA
M00003E 05 +ENDA      M00007C 06 +PROGB
M00003E 05 -LISTA      M00007C 06 -LISTA
M000070 06 +ENDA      E
M000070 06 -LISTA
M000070 06 +LISTC
M000073 06 +ENDC
M000073 06 -LISTC
M000076 06+ENDC
M000076 06 -LISTC
M000076 06 +LISTA
M000079 06 +ENDA

```

0000	PROGC START	0	
	EXTDEF	LISTC, ENDC	
	EXTREF	LISTB, ENDB, LISTA, ENDA	
	:		
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
0048	REF6 WORD	ENDC-LISTC+LISTA-1	000011
004B	REF7 WORD	ENDA-LISTA-(ENDB-LISTB)	000000
004E	REF8 WORD	LISTB-LISTA	000000
	END	REF1	

```

H PROGC 000000 000051
D LISTC 000030 ENDC 000042
R LISTA ENDA LISTB ENDB
:
T000018...
:
T000042---
M000019 05 +LISTA          M00004E 06 +LISTB
M00001D 05 +LISTB          M00004E 06 -LISTA
M000021 05 +ENDA          E
M000021 05 -LISTA
M000042 06 +ENDA
M000042 06 -LISTA
M000042 06 +PROGC
M000048 06 +LISTA
M00004B 06+ENDA
M00004B 06 -LISTA
M00004B 06 -ENDB
M00004B 06 +LISTB

```

Program Linking Example

- Load address for control sections
 - PROGA 004000 63
 - PROGB 004063 7F
 - PROGC 0040E2 51
- Load address for symbols
 - LISTA: PROGA+0040=4040 ENDA 4054
 - LISTB: PROGB+0060=40C3 ENDB 40D3
 - LISTC: PROGC+0030=4112 ENDC 4124
- REF4 in PROGA
 - **ENDA-LISTA+LISTC**=14+4112=4126
 - T0000540F**000014**FFFFFF600003F000014FFFC0
 - M00005406+LISTC

Load address for symbols

LISTA: PROGA+0040=4040	ENDA	4054
LISTB: PROGB+0060=40C3	ENDB	40D3
LISTC: PROGC+0030=4112	ENDC	4124

- REF4 ENDA-LISTA+LISTC
- REF4 in PROGB (000000 in text record)
M000070 06 +ENDA M000070 06 -LISTA
M000070 06 +LISTC
- REF4 in PROGC (000030 in text record)
M000042 06 +ENDA M000042 06 -LISTA
M000042 06 +PROGC

- Each of REF4 to REF8 has same value in all three CS
- For instruction operands – target addresses are same

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-LISC-10	FFFFF6
005A	REF6	WORD		ENDC-LISC+LISTA-1	00003F
005D	REF7	WORD		ENDA-LISTA-(ENDB-LISTB)	000014
0060	REF8	WORD		LISTB-LISTA	FFFFC0
		END		REF1	
4020 03201D 771040C7 050014					
.					
4054 000014 FFFFF6 00003F 000014 FFFFC0					
4054 004126 000008 004051 000004 000083					

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-LISC-10	FFFFF6
0076	REF6	WORD		ENDC-LISC+LISTA-1	FFFFFF
0079	REF7	WORD		ENDA-LISTA-(ENDB-LISTB)	FFFFF0
007C	REF8	WORD		LISTB-LISTA	000060
		END		REF1	
4099 03104040 772027 05100014					
.					
40D3 004126 000008 004051 000004 000083					

0000	PROGC	START	0		
		EXTDEF		LISTC, ENDC	
		EXTREF		LISTB, ENDB, LISTA, ENDA	
			:		
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
0048	REF6	WORD		ENDC-LISTC+LISTA-1	000011
004B	REF7	WORD		ENDA-LISTA-(ENDB-LISTB)	000000
004E	REF8	WORD		LISTB-LISTA	000000
		END		REF1	
40FA 03104040 771040C7 05100014					
.					
4124 004126 000008 004051 000004 000083					

4020 03201D 771040C7 050014					
.					
4054 004126 000008 004051 000004 000083					
.					
4099 03104040 772027 05100014					
.					
40D3 004126 000008 004051 000004 000083					
.					
40FA 03104040 771040C7 05100014					
.					
4124 004126 000008 004051 000004 000083					

- Two Passes Logic
 - Pass 1: assign addresses to all external symbols
 - Pass 2: perform the actual loading, relocation, and linking
- ESTAB (external symbol table)

Control section	Symbol	Address	Length
Program A		4000	63
	LISTA	4040	
	ENDA	4054	
Program B		4063	7F
	LISTB	40C3	
	ENDB	40D3	
Program C		40E2	51
	LISTC	4112	
	ENDC	4124	

Pass 1 Program Logic

- Pass 1:
 - assign addresses to all external symbols
- Variables
 - PROGADDR (program load address) from OS
 - CSADDR (control section address)
 - CSLTH (control section length)
 - ESTAB
- Mainly Process Define Record

Pass 2 Program Logic

- Pass 2:
 - » perform the actual loading, relocation, and linking
- Process Text record and Modification record
- Modification record
 - » lookup the symbol in ESTAB
- End record for a main program
 - » transfer address