Common Bus System

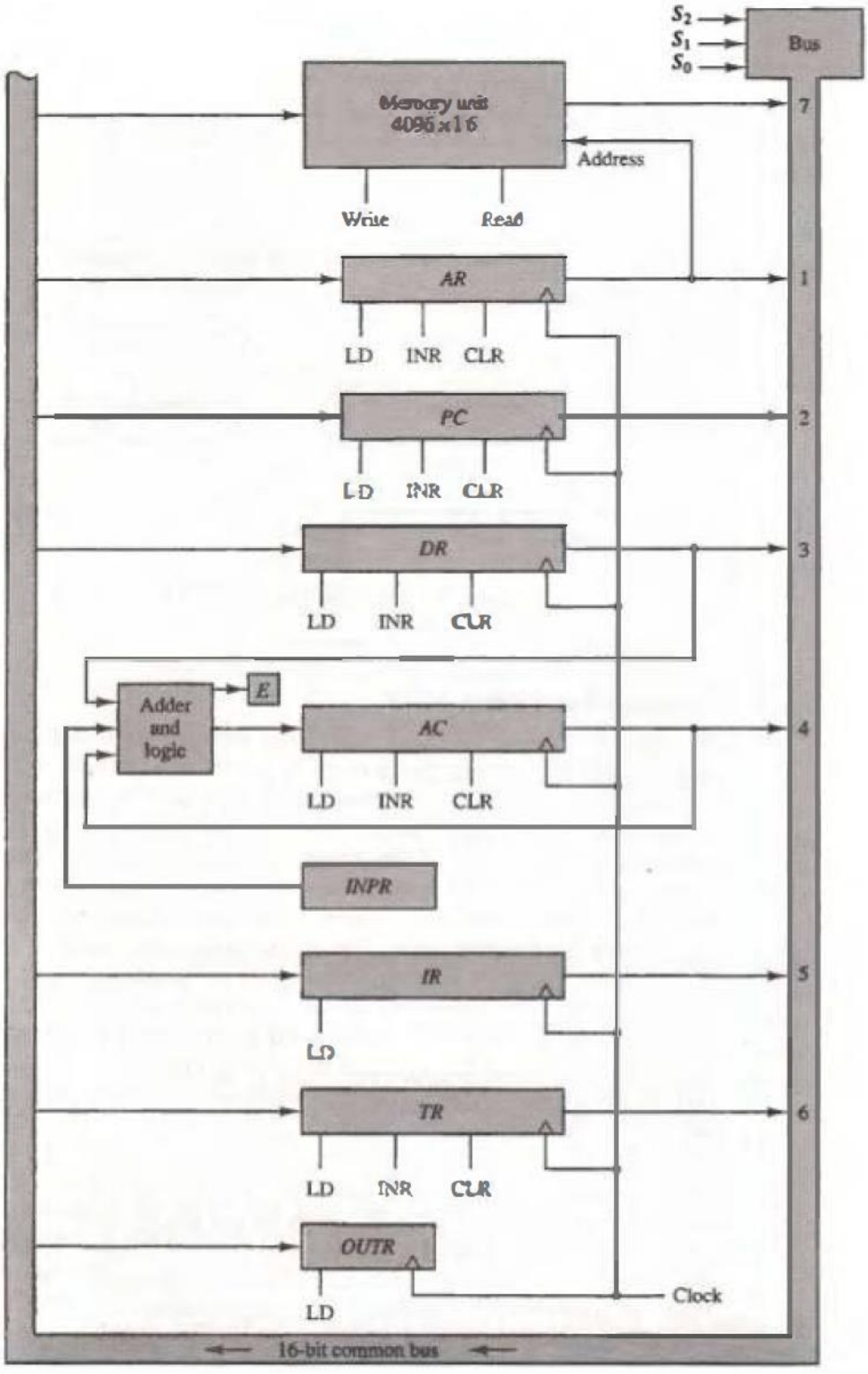


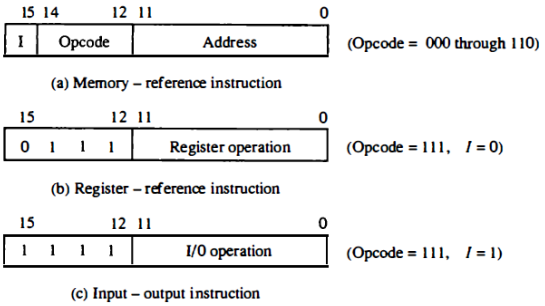
Figure 5-4 Basic computer registers connected to a common bus.

Instruction Set Completeness

1. Arithmetic, logical, and shift instructions
2. Instructions for moving information to and from memory and processor registers
3. Program control instructions together with instructions that check status conditions
4. Input and output instructions

Basic Computer Instruction Format

Figure 5-5 Basic computer instruction formats.



Basic Computer Instructions

TABLE 5-2 Basic Computer Instructions

Symbol	Hexadecimal code $I = 0$	Hexadecimal code $I = 1$	Description
AND	0xxx	8xxx	AND memory word to AC
ADD	1xxx	9xxx	Add memory word to AC
LDA	2xxx	Axxx	Load memory word to AC
STA	3xxx	Bxxx	Store content of AC in memory
BUN	4xxx	Cxxx	Branch unconditionally
BSA	5xxx	Dxxx	Branch and save return address
ISZ	6xxx	Exxx	Increment and skip if zero
CLA	7800		Clear AC
CLE	7400		Clear E
CMA	7200		Complement AC
CME	7100		Complement E
CIR	7080		Circulate right AC and E
CIL	7040		Circulate left AC and E
INC	7020		Increment AC
SPA	7010		Skip next instruction if AC positive
SNA	7008		Skip next instruction if AC negative
SZA	7004		Skip next instruction if AC zero
SZE	7002		Skip next instruction if E is 0
HLT	7001		Halt computer
INP	F800		Input character to AC
OUT	F400		Output character from AC
SKI	F200		Skip on input flag
SKO	F100		Skip on output flag
ION	F080		Interrupt on
IOF	F040		Interrupt off

Programming the Basic Computer

Consider the simple BASIC statement

$$N = I + J + K$$

Suppose we wished to program this statement in machine language and to initialize I, J, and K to 2, 3, and 4, respectively. This is shown in Figure 11.13a. The program starts in location 101 (hexadecimal). Memory is reserved for the four variables starting at location 201. The program consists of four instructions:

1. Load the contents of location 201 into the AC.
2. Add the contents of location 202 to the AC.
3. Add the contents of location 203 to the AC.
4. Store the contents of the AC in location 204.

This is clearly a tedious and very error-prone process.

Address	Contents			
101	0010	0010	101	2201
102	0001	0010	102	1202
103	0001	0010	103	1203
104	0011	0010	104	3204
201	0000	0000	201	0002
202	0000	0000	202	0003
203	0000	0000	203	0004
204	0000	0000	204	0000

(a) Binary program

Address	Contents
101	2201
102	1202
103	1203
104	3204
201	0002
202	0003
203	0004
204	0000

(b) Hexadecimal program

Address	Contents
101	2201
102	1202
103	1203
104	3204
201	0002
202	0003
203	0004
204	0000

(b) Hexadecimal program

Label	Operation	Operand
FORMUL	LDA	I
	ADD	J
	ADD	K
	STA	N
I	DATA	2
J	DATA	3
K	DATA	4
N	DATA	0

(d) Assembly program

Another Example

TABLE 6-2 Binary Program to Add Two Numbers

Location	Instruction code
0	0010 0000 0000 0100
1	0001 0000 0000 0101
10	0011 0000 0000 0110
11	0111 0000 0000 0001
100	0000 0000 0101 0011
101	1111 1111 1110 1001
110	0000 0000 0000 0000

TABLE 6-3 Hexadecimal Program to Add Two Numbers

Location	Instruction
000	2004
001	1005
002	3006
003	7001
004	0053
005	FFE9
006	0000

TABLE 6-4 Program with Symbolic Operation Codes

Location	Instruction	Comments
000	LDA 004	Load first operand into *AC*
001	ADD 005	Add second operand to *AC*
002	STA 006	Store sum in location 006
003	HLT	Halt computer
004	0053	First operand
005	FFE9	Second operand (negative)
006	0000	Store sum here

TABLE 6-5 Assembly Language Program to Add Two Numbers

```
        ORG 0       /Origin of program is location 0
        LDA A       /Load operand from location A
        ADD B       /Add operand from location B
        STA C       /Store sum in location C
        HLT         /Halt computer
A,      DEC 83      /Decimal operand
B,      DEC -23     /Decimal operand
C,      DEC 0       /Sum stored in location C
        END         /End of symbolic program
```

TABLE 6-6 Fortran Program to Add Two Numbers

```
INTEGER A, B, C
DATA A,83  B,-23
C = A + B
END
```

Assembly language program to Subtract Two Numbers

TABLE 6-8 Assembly Language Program to Subtract Two Numbers

```
        ORG 100      /Origin of program is location 100
        LDA SUB      /Load subtrahend to AC
        CMA          /Complement AC
        INC          /Increment AC
        ADD MIN      /Add minuend to AC
        STA DIF      /Store difference
        HLT          /Halt computer
MIN,    DEC 83       /Minuend
SUB,    DEC -23      /Subtrahend
DIF,    HEX 0        /Difference stored here
        END          /End of symbolic program
```

Translation to Binary

TABLE 6-9 Listing of Translated Program of Table 6-8

Hexadecimal code			
Location	Content	Symbolic program	
			ORG 100
100	2107		LDA SUB
101	7200		CMA
102	7020		INC
103	1106		ADD MIN
104	3108		STA DIF
105	7001		HLT
106	0053	MIN,	DEC 83
107	FFE9	SUB,	DEC -23
108	0000	DIF,	HEX 0
			END

Can you explore the above instruction set (25 instructions listed above) and see what are the other assembly programs you can write?

Then you can also explore the instructions (ISA) of your chosen processor?