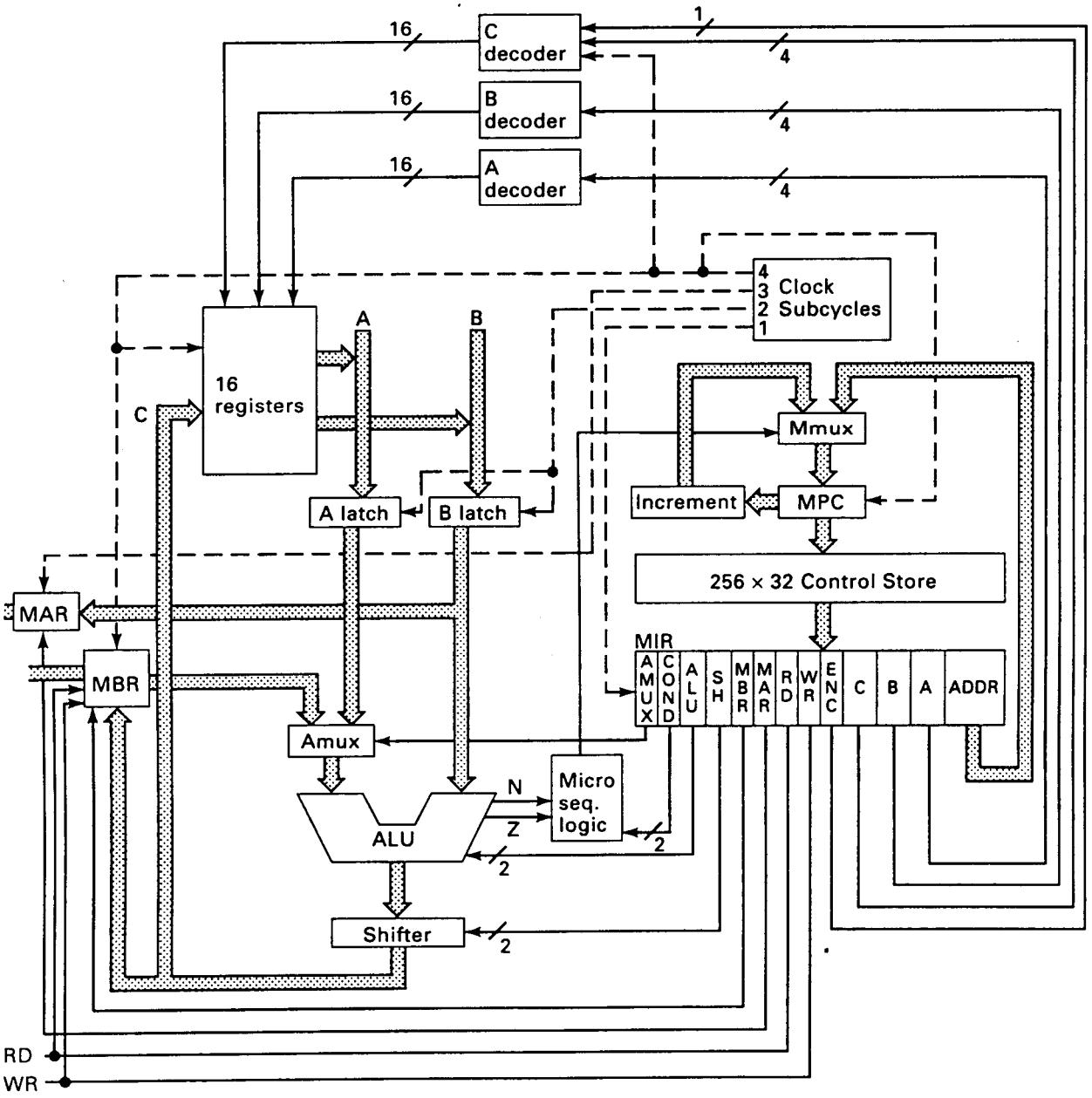
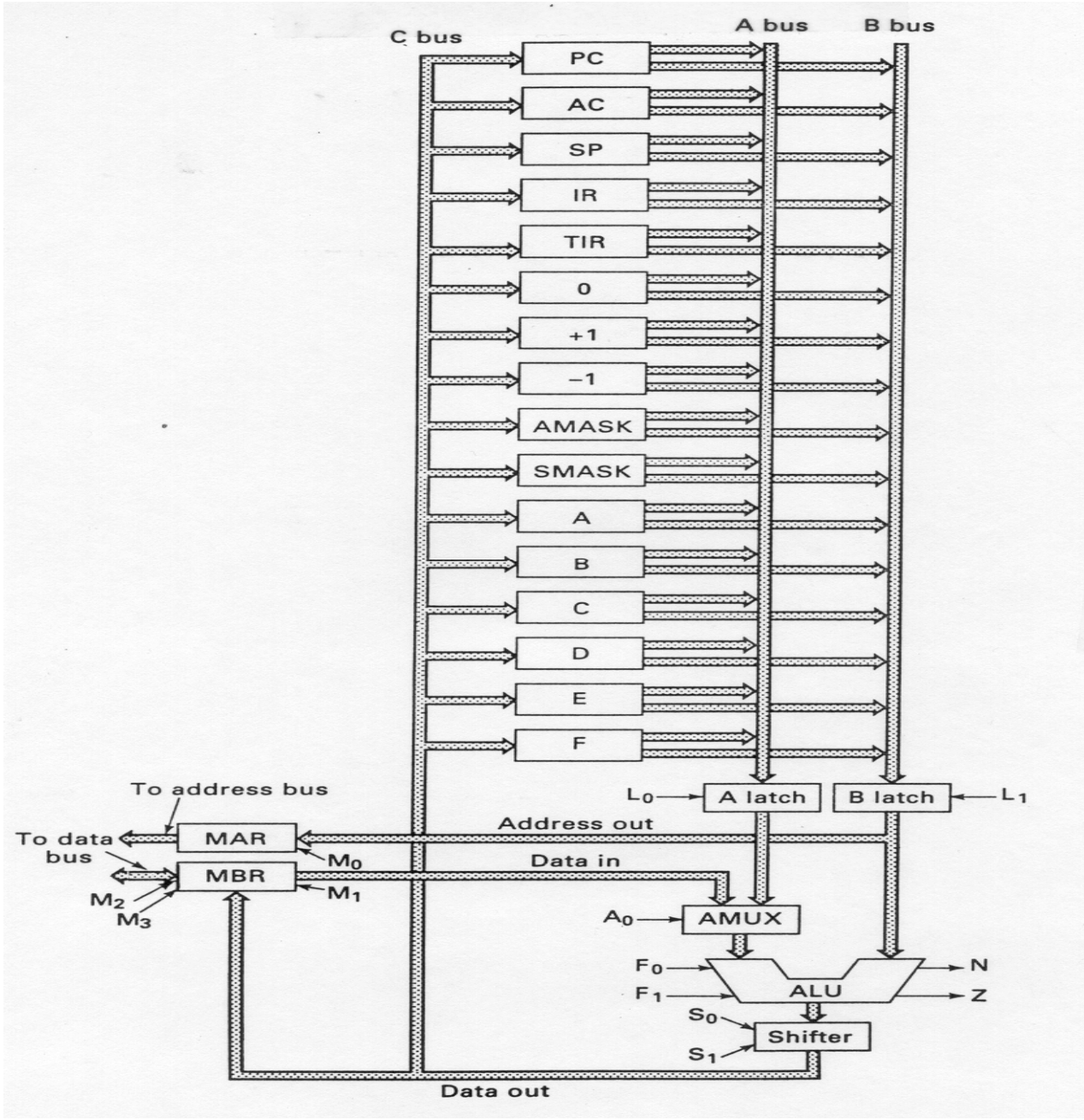

C decoder
B decoder
A decoder
16
1
4
Clock
Subcycles
16 registers
A
B
C
A latch
B latch
Mmux
Increment
MPC
256 x 32 Control Store
MIR
AMUX
COND
ALU
SH
MBR
MAR
RD
WR
ENC
C
B
A
ADDR
MAR
MBR
Amux
ALU
N
Z
Micro seq. logic
Shifter
RD
WR


C bus
A bus
B bus
PC
AC
SP
IR
TIR
0
+1
−1
AMASK
SMASK
A
B
C
D
E
F
To address bus
To data bus
MAR
MBR
M0
M1
M2
M3
L0
A latch
B latch
L1
Address out
Data in
A0
AMUX
F0
F1
ALU
N
Z
S0
S1
Shifter
Data out

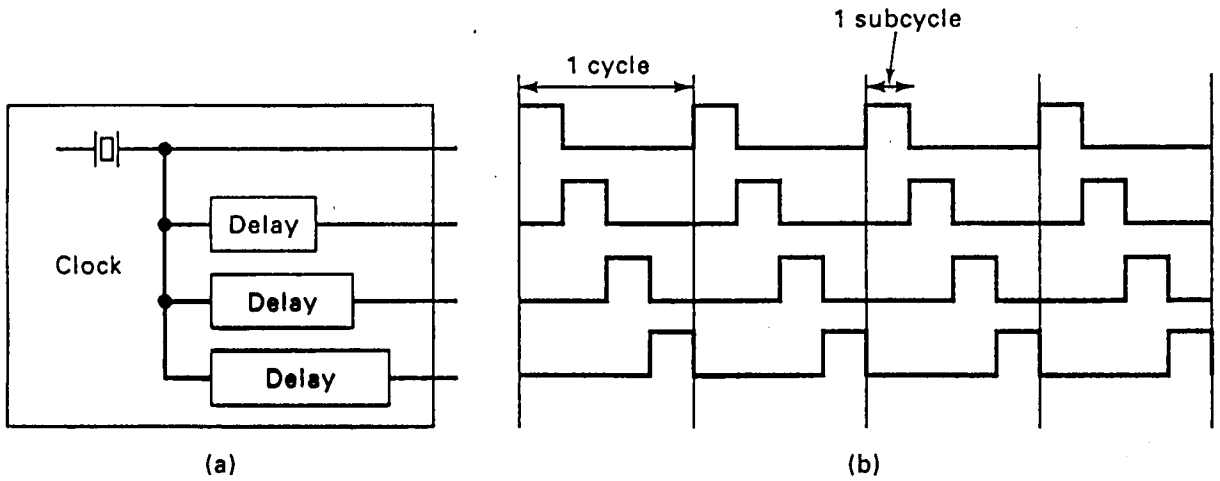
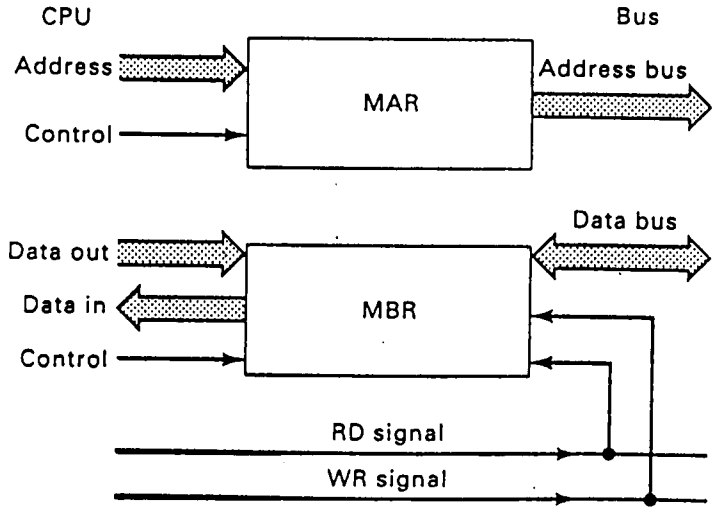


Fig. 4-5. (a) A clock with four outputs. (b) The output timing diagram.



AMUX — controls left ALU input: 0 = A latch, 1 = MBR

ALU — ALU function: 0 = A + B, 1 = A AND B, 2 = A, 3 = $\overline{A}$

SH — shifter function: 0 = no shift, 1 = right, 2 = left

MBR — loads MBR from shifter: 0 = don't load MBR, 1 = load MBR

MAR — loads MAR from B latch: 0 = don't load MAR, 1 = load MAR

RD — requests memory read: 0 = no read, 1 = load MBR from memory

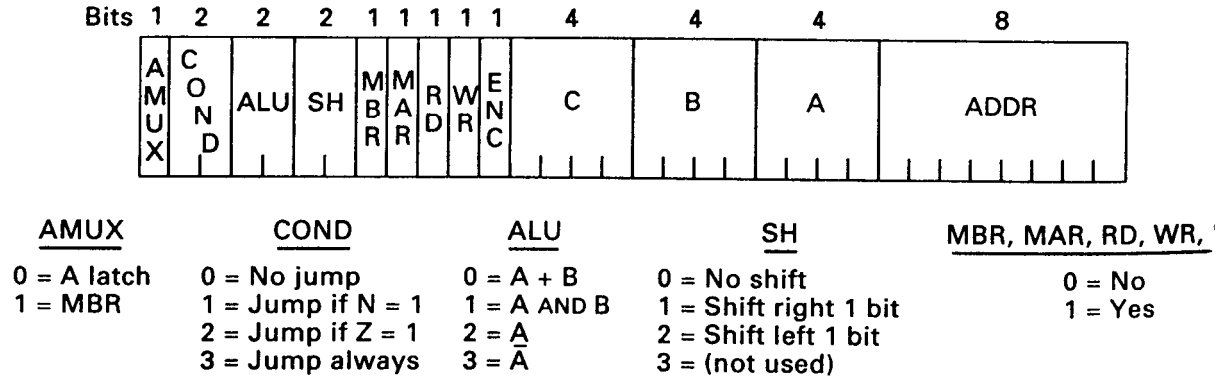
WR — requests memory write: 0 = no write, 1 = write MBR to memory

ENC — controls storing into scratchpad: 0 = don't store, 1 = store

C — selects register for storing into if ENC = 1: 0 = PC, 1 = AC, etc.

B — selects B bus source: 0 = PC, 1 = AC, etc.

A — selects A bus source: 0 = PC, 1 = AC, etc.



```
 0: mar := pc ; rd ;                                  {main loop}
 1: pc := pc + 1; rd ;                                {increment pc}
 2: ir := mbr ; if n then goto 28;                    {save, decode mbr}
 3: tir := lshift (ir + ir ); if n then goto 19;
 4: tir := lshift (tir ); if n then goto 11;          {000x or 001x?}
 5: alu := tir ; if n then goto 9;                    {0000 or 0001?}

 6: mar := ir ; rd ;                                  {0000 = LODD}
 7: rd ;
 8: ac := mbr ; goto 0;

 9: mar := ir ; mbr := ac ; wr ;                      {0001 = STOD}
10: wr ; goto 0;

11: alu := tir ; if n then goto 15;                   {0010 or 0011?}

12: mar := ir ; rd ;                                  {0010 = ADDD}
13: rd ;
14: ac := mbr + ac ; goto 0;

15: mar := ir ; rd ;                                  {0011 = SUBD}
16: ac := ac + 1; rd ;                                {Note: x - y = x + 1 + not y}
17: a := inv (mbr );
18: ac := ac + a ; goto 0;

19: tir := lshift (tir ); if n then goto 25;          {010x or 011x?}
20: alu := tir ; if n then goto 23;                   {0100 or 0101?}

21: alu := ac ; if n then goto 0;                     {0100 = JPOS}
22: pc := band (ir , amask ); goto 0;                 {perform the jump}

23: alu := ac ; if z then goto 22;                    {0101 = JZER}
24: goto 0;                                           {jump failed}

25: alu := tir ; if n then goto 27;.                  {0110 or 0111?}
26: pc := band (ir , amask ); goto 0;                 {0110 = JUMP}

27: ac := band (ir , amask ); goto 0;                 {0111 = LOCO}

28: tir := lshift (ir + ir ); if n then goto 40;      {10xx or 11xx?}
29: tir := lshift (tir ); if n then goto 35;          {100x or 101x?}
30: alu := tir ; if n then goto 33;                   {1000 or 1001?}

31: a := ir + sp ;                                    {1000 = LODL}
32: mar := a ; rd ; goto 7;

33: a := ir + sp ;                                    {1001 = STOL}
34: mar := a ; mbr := ac ; wr ; goto 10;

35: alu := tir ; if n then goto 38;                   {1010 or 1011?}

36: a := ir + sp ;                                    {1010 = ADDL}
37: mar := a ; rd ; goto 13;

38: a := ir + sp ;                                    {1011 = SUBL}
39: mar := a ; rd ; goto 16;
```

```
40: tir := lshift (tir ); if n then goto 46;          {110x or 111x?}
41: alu := tir ; if n then goto 44;                   {1100 or 1101?}

42: alu := ac ; if n then goto 22;                    {1100 = JNEG}
43: goto 0;

44: alu := ac ; if z then goto 0;                     {1101 = JNZE}
45: pc := band (ir , amask ); goto 0;

46: tir := lshift (tir ); if n then goto 50;

47: sp := sp + (−1);                                  {1110 = CALL}
48: mar := sp ; mbr := pc ; wr ;
49: pc := band (ir , amask ); wr ; goto 0;

50: tir := lshift (tir ); if n then goto 65;          {1111, examine addr}
51: tir := lshift (tir ); if n then goto 59;
52: alu := tir ; if n then goto 56;

53: mar := ac ; rd ;                                  {1111000 = PSHI}
54: sp := sp + (−1); rd ;
55: mar := sp ; wr ; goto 10;

56: mar :=sp ; sp := sp + 1; rd ;                     {1111001 = POPI}
57: rd ;
58: mar := ac ; wr ; goto 10;

59: alu := tir ; if n then goto 62;

60: sp := sp + (−1);                                  {1111010 = PUSH}
61: mar := sp ; mbr := ac ; wr ; goto 10;

62: mar := sp ; sp := sp + 1; rd ;                    {1111011 = POP}
63: rd ;
64: ac := mbr ; goto 0;

65: tir := lshift (tir ); if n then goto 73;
66: alu := tir ; if n then goto 70;

67: mar := sp ; sp := sp + 1; rd ;                    {1111100 = RETN}
68: rd ;
69: pc := mbr ; goto 0;

70: a := ac ;                                         {1111101 = SWAP}
71: ac := sp ;
72: sp := a ; goto 0;

73: alu := tir ; if n then goto 76;

74: a := band (ir , smask );                          {1111110 = INSP}
75: sp := sp + a ; goto 0;

76: a := band (ir , smask );                          {1111111 = DESP}
77: a := inv (a );
78: a := a + 1; goto 75;
```