# Assignment # 3 Solutions

1) Design a combinational circuit that converts 4-bit binary code into 4-bit excess-3 code.

**This problem was solved in Class.**

2) Design a combinational circuit that converts 4-bit binary code into 4-bit gray code.

**Refer to quiz 3 for solutions**

3) Design a half-subtractor and a full subtractor circuit.

(a)

| x | y | B | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 0 |

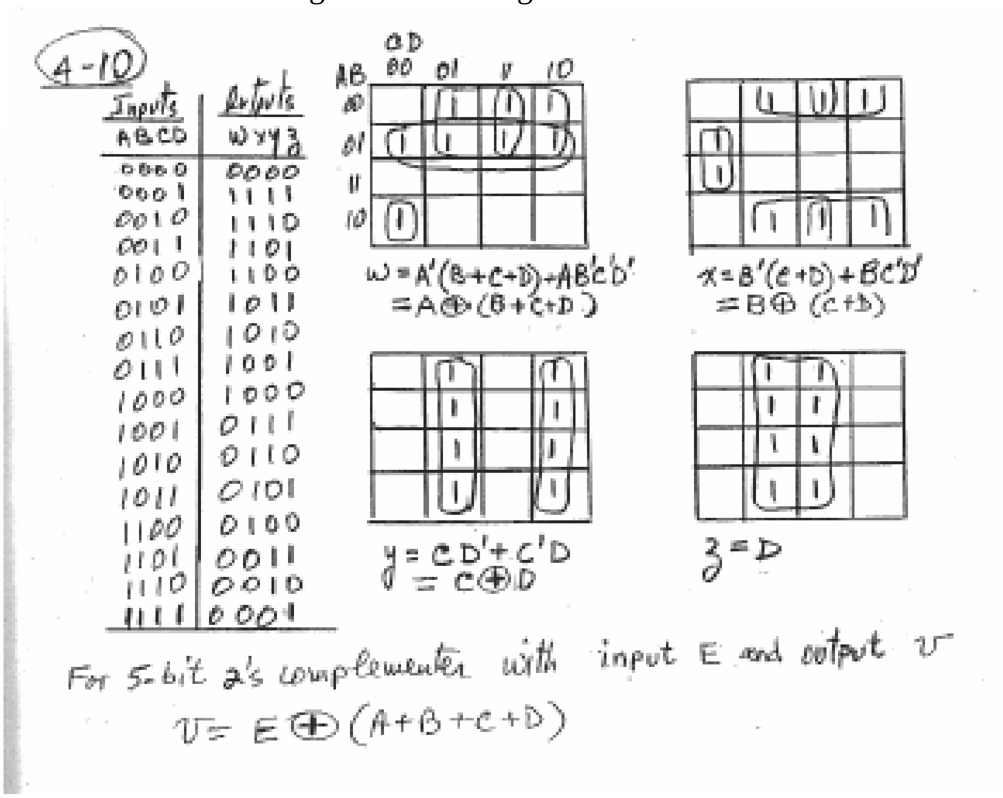
$$D = x'y + xy'$$
$$B = x'y$$

(b)

| x | y | z | B | D |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

$$D = x \oplus y \oplus z$$
$$B = x'y + x'z + yz$$

4) Design 4-bit combinational circuit 2's complementer. (The output generates the 2's complement of the input binary number) Show that the circuit can be constructed using exclusive-OR gates?



4-10

| Inputs ABCD | Outputs wxyz |
|---|---|
| 0000 | 0000 |
| 0001 | 1111 |
| 0010 | 1110 |
| 0011 | 1101 |
| 0100 | 1100 |
| 0101 | 1011 |
| 0110 | 1010 |
| 0111 | 1001 |
| 1000 | 1000 |
| 1001 | 0111 |
| 1010 | 0110 |
| 1011 | 0101 |
| 1100 | 0100 |
| 1101 | 0011 |
| 1110 | 0010 |
| 1111 | 0001 |

$w = A'(B+C+D) + AB'C'D' = A \oplus (B+C+D)$

$x = B'(C+D) + BC'D' = B \oplus (C+D)$

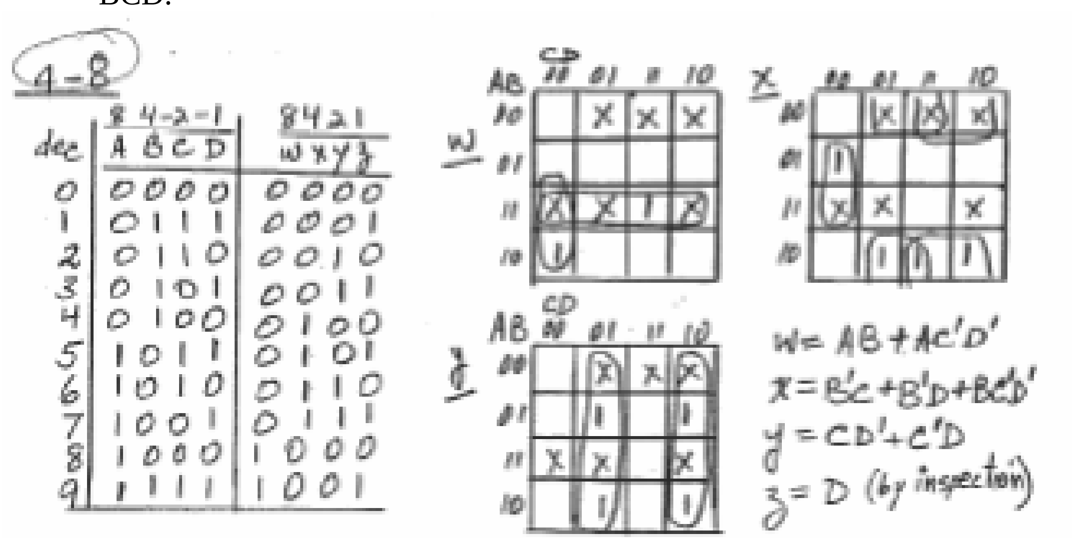
$y = CD' + C'D = C \oplus D$

$z = D$

For 5-bit 2's complementer with input E and output v

$v = E \oplus (A+B+C+D)$

5) Design a code converter that converts a decimal digit from 8, 4,-2,-1 code to BCD.



4-8

| dec | 8 4 -2 -1 ABCD | 8421 wxyz |
|---|---|---|
| 0 | 0000 | 0000 |
| 1 | 0111 | 0001 |
| 2 | 0110 | 0010 |
| 3 | 0101 | 0011 |
| 4 | 0100 | 0100 |
| 5 | 1011 | 0101 |
| 6 | 1010 | 0110 |
| 7 | 1001 | 0111 |
| 8 | 1000 | 1000 |
| 9 | 1111 | 1001 |

$w = AB + AC'D'$

$x = B'C + B'D + BC'D'$

$y = CD' + C'D$

$z = D$ (by inspection)

6) Design a combinational circuit that converts a 4-bit Gray code to a 4-bit binary number. Implement the circuit with exclusive-OR gates.

4-7

| ABCD | wxyz |
|---|---|
| 0000 | 0000 |
| 0001 | 0001 |
| 0011 | 0010 |
| 0010 | 0011 |
| 0110 | 0100 |
| 0111 | 0101 |
| 0101 | 0110 |
| 0100 | 0111 |
| 1100 | 1000 |
| 1101 | 1001 |
| 1111 | 1010 |
| 1110 | 1011 |
| 1010 | 1100 |
| 1011 | 1101 |
| 1001 | 1110 |
| 1000 | 1111 |

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 |

$w = A$

| | | | | |
|---|---|---|---|---|
| | | | | |
| | 1 | 1 | 1 | 1 |
| | | | | |
| | 1 | 1 | 1 | 1 |

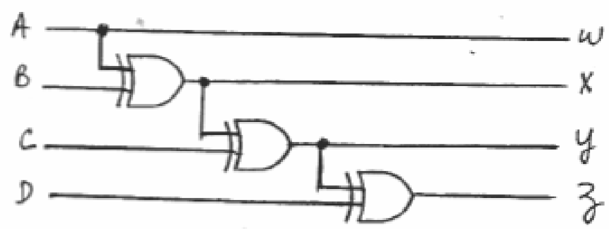
$x = AB' + A'B = A \oplus B$

| | | | | |
|---|---|---|---|---|
| | | | 1 | 1 |
| | 1 | 1 | | |
| | | | 1 | 1 |
| | 1 | 1 | | |

$y = A'B'C + A'BC' + ABC + AB'C'$
$= A'(B \oplus C) + A(B \oplus C)'$
$= A \oplus B \oplus C$
$= x \oplus C$

| | | | | |
|---|---|---|---|---|
| | | 1 | | 1 |
| | 1 | | 1 | |
| | | 1 | | 1 |
| | 1 | | 1 | |

$z = A \oplus B \oplus C \oplus D$
$= y \oplus D$

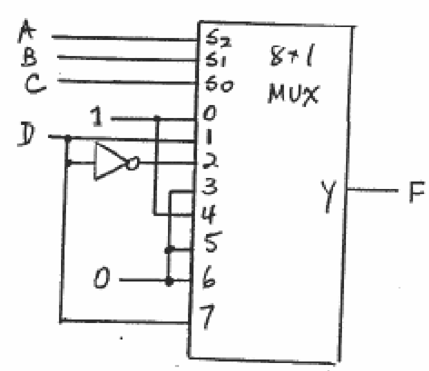



7) Implement the following Boolean function with a multiplexer

$$F(A,B,C,D) = \sum m(0,1,3,4,8,9,15)$$

4-32

| ABCD | F | |
|---|---|---|
| 0000 | 1 | F=1 |
| 0001 | 1 | |
| 0010 | 0 | F=D |
| 0011 | 1 | |
| 0100 | 1 | F=D' |
| 0101 | 0 | |
| 0110 | 0 | F=0 |
| 0111 | 0 | |
| 1000 | 1 | F=1 |
| 1001 | 1 | |
| 1010 | 0 | F=0 |
| 1011 | 0 | |
| 1100 | 0 | F=0 |
| 1101 | 0 | |
| 1110 | 0 | F=D |
| 1111 | 1 | |



8) An $8 \times 1$ multiplexer has inputs A, B, and C connected to the selection inputs $S_2$, $S_1$, and $S_0$, respectively. The data inputs $I_0$ through $I_7$, are as follows: $I_1 = I_2 = I_7 = 0$; $I_3 = I_5 = 1$; $I_0 = I_4 = D$; and $I_6 = D'$. Determine the Boolean function that the multiplexer implements.

4-34

| | ABCD | F |
|---|---|---|
| $I_3=1$ | 0110 | 1 |
| | 0111 | 1 |
| $I_5=1$ | 1010 | 1 |
| | 1011 | 1 |
| $I_0=D$ | 0000 | 0 |
| | 0001 | 1 |
| $I_4=D$ | 1000 | 0 |
| | 1001 | 1 |

| | ABCD | F |
|---|---|---|
| $I_6=D'$ | 1100 | 1 |
| | 1101 | 0 |

other six minterms $= 0$ since $I_1 = I_2 = I_7 = 0$

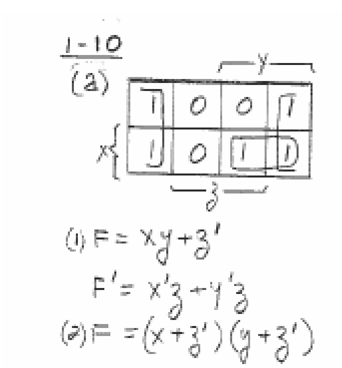
$F(A,B,C,D) = \Sigma(1,6,7,9,10,11,12)$

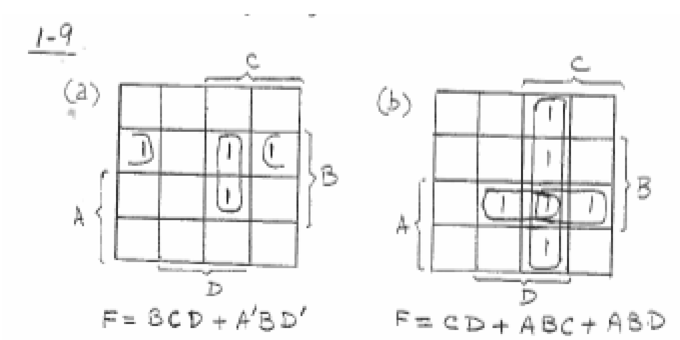
From the textbook "Computer Systems Architecture, 3rd Edition by Morris Mano.

Solve the following problems:

From chapter 1, pages 38 - 39

1-10 (a), 1-9 (a, b)

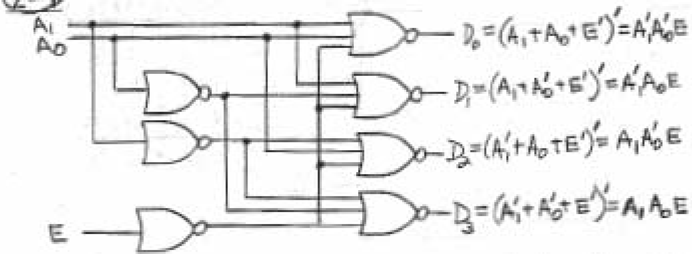


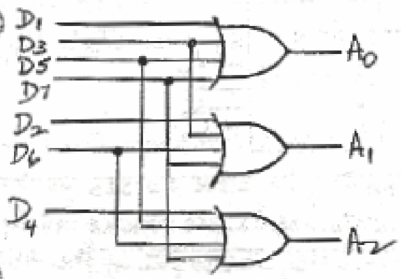
From chapter 2, pages 64 - 65

2-4, 2-6, 2-7, 2-8

2-4



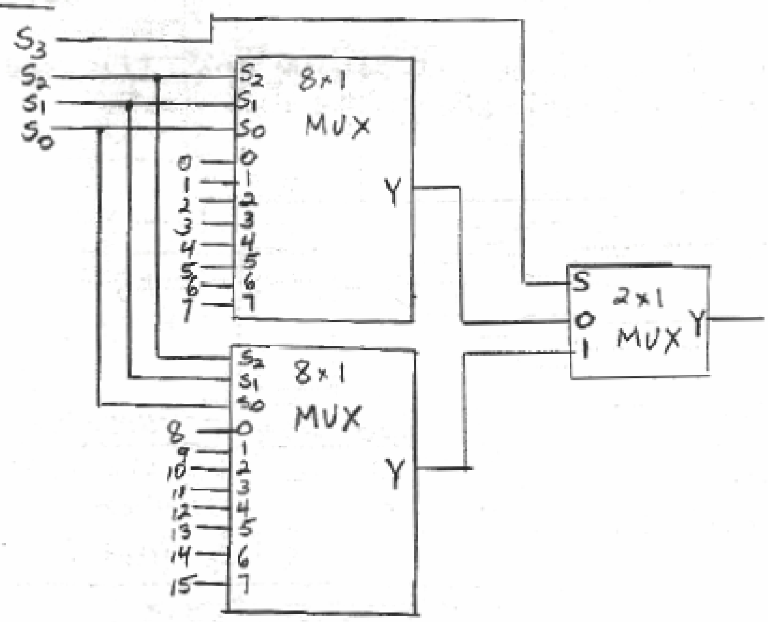

2-6



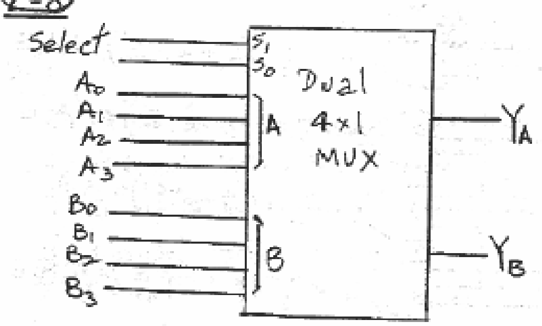

If all inputs equal 0 or if only $D_0=1$: the outputs $A_2A_1A_0=000$

Needs one more output to recognize the all zeros input condition.

2-7




2-8




| $S_1$ $S_0$ | $Y_A$ $Y_B$ |
|---|---|
| 0 0 | $A_0$ $B_0$ |
| 0 1 | $A_1$ $B_1$ |
| 1 0 | $A_2$ $B_2$ |
| 1 1 | $A_3$ $B_3$ |

Function table

From chapter 4, pages 120 – 121

4-12,

| M | A | | B | Sum | $C_4$ | |
|---|---|---|---|---|---|---|
| 0 | 0111 | + | 0110 | 1101 | 0 | 7+6 = 13 |
| 0 | 1000 | + | 1001 | 0001 | 1 | 8+9 = 16+1 |
| 1 | 1100 | − | 1000 | 0100 | 1 | 12−8 = 4 |
| 1 | 0101 | − | 1010 | 1011 | 0 | 5−10 = −5 (in 2's comp.) |
| 1 | 0000 | − | 0001 | 1111 | 0 | 0−1 = −1 (in 2's comp.) |

4-13

A−1 = A + 2's complement of 1 = A + 1111