Lecture 14
Code Converter

Binary to Gray Code Converter

The Gray Code is unweighted and is not an arithmetic code: that is, there are no specific weights asssigned to the bit positions. The important feature of the Gray Code is that it exhibits only a single bit change from one code word to the next in sequence. This property is important in many applications, such as shaft position encoders, where error susceptibility increases with the number of bit changes between adjacent numbers in a sequence.

To convert a binary number to a Gray Code number,
the following rules apply.

1. The most significant digit (Left Most Bit) in the Gray Code is the
   same as the corresponding digit in the binary number.

2. Going from left to right, add each adjacent pair of binary digits to get
   the next Gray code digit, regradless carries.

**For instance** – Let us convert the binary number 1010 to Gray Code.

Step 1 – The left most Gray digit is the same as the left most binary

1   0   1   0   Binary

1   Gray

Step 2 – Add the left most binary digit to the adjacent one.

1 + 0   1   0   Binary

1   1   Gray

Step 3 – Add the next adjacent pair

1   0 + 1   0   Binary

1   1   1   Gray

Step 4 – Add the last adjacent pair

1   0   1 + 0   Binary

1   1   1   1   Gray

The conversion is now complete and the Gray Code is 1111.

Steps to design the converter

1. Design a converter by the following procedures:

a. Write down the truth table of both input and output bits of the converter.

b. Apply Karnaugh Map to look for the minimized logic expression for the output bits.

c. Implement the logic gates by using Circuit Maker.

Example:

For Binary to Gray Code Converter, binary bits are input and gray code bits are output. So first write the truth table for binary bits and gray code. Then k-map for the all bits of gray code, find the simplified expression for each bit of gray code. Then design the logical circuit.

Truth Table

| Decimal		Binary					Gray			
		A	B	C	D		Y_3	Y_2	Y_1	Y_0
0		0	0	0	0		0	0	0	0
1		0	0	0	1		0	0	0	1
2		0	0	1	0		0	0	1	1
3		0	0	1	1		0	0	1	0
4		0	1	0	0		0	1	1	0
5		0	1	0	1		0	1	1	1
6		0	1	1	0		0	1	0	1
7		0	1	1	1		0	1	0	0
8		1	0	0	0		1	1	0	0
9		1	0	0	1		1	1	0	1
10		1	0	1	0		1	1	1	1
11		1	0	1	1		1	1	1	0
12		1	1	0	0		1	0	1	0
13		1	1	0	1		1	0	1	1
14		1	1	1	0		1	0	0	1
15		1	1	1	1		1	0	0	0

K-Map for each bit of Gray code

For practical consideration code conversions are made for each bit.

(a) For Y_3, the Karnaugh map can draw as follow.

	$\overline{C}\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\overline{B}$	0	0	0	0
$\overline{A}B$	0	0	0	0
AB	1	1	1	1
$A\overline{B}$	1	1	1	1

(a)

By minimization, $Y_3 = A$

(b) For Y_2, the Karnaugh map can draw as follow.

	$\overline{C}\,\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\,\overline{B}$	0	0	0	0
$\overline{A}B$	1	1	1	1
AB	0	0	0	0
$A\overline{B}$	1	1	1	1

(b)

By minimization, $Y_2 = A \oplus B$

(c) For Y_1, the Karnaugh map can draw as follow.

	$\overline{C}\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\overline{B}$	0	0	1	1
$\overline{A}B$	1	1	0	0
AB	1	1	0	0
$A\overline{B}$	0	0	1	1

(a)

By minimization, $Y_1 = B \oplus C$

(d) For Y_0, the Karnaugh map can draw as follow.

	$\overline{C}\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\overline{B}$	0	1	0	1
$\overline{A}B$	0	1	0	1
AB	0	1	0	1
$A\overline{B}$	0	1	0	1

(b)

By minimization, $Y_0 = C \oplus D$

Binary Input

A   B   C   D

Y_3 Y_2 Y_1 Y_0
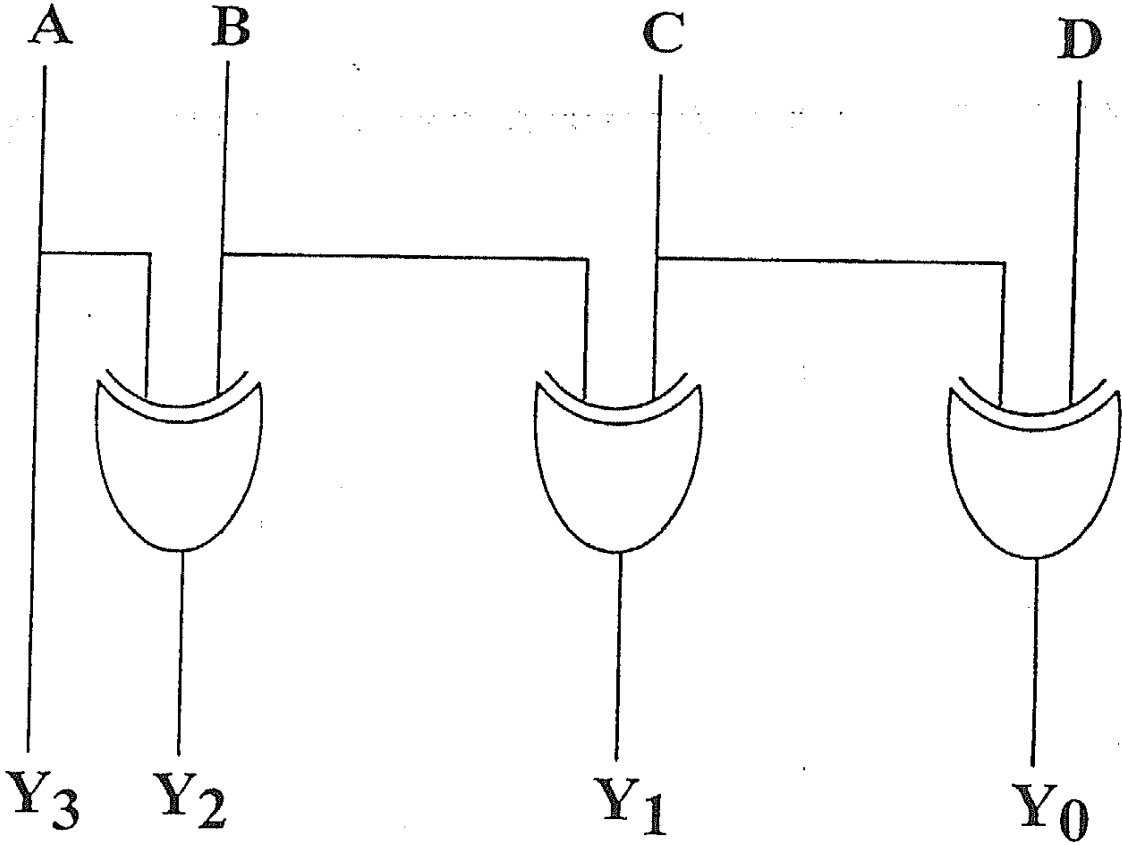
Gray Code Output
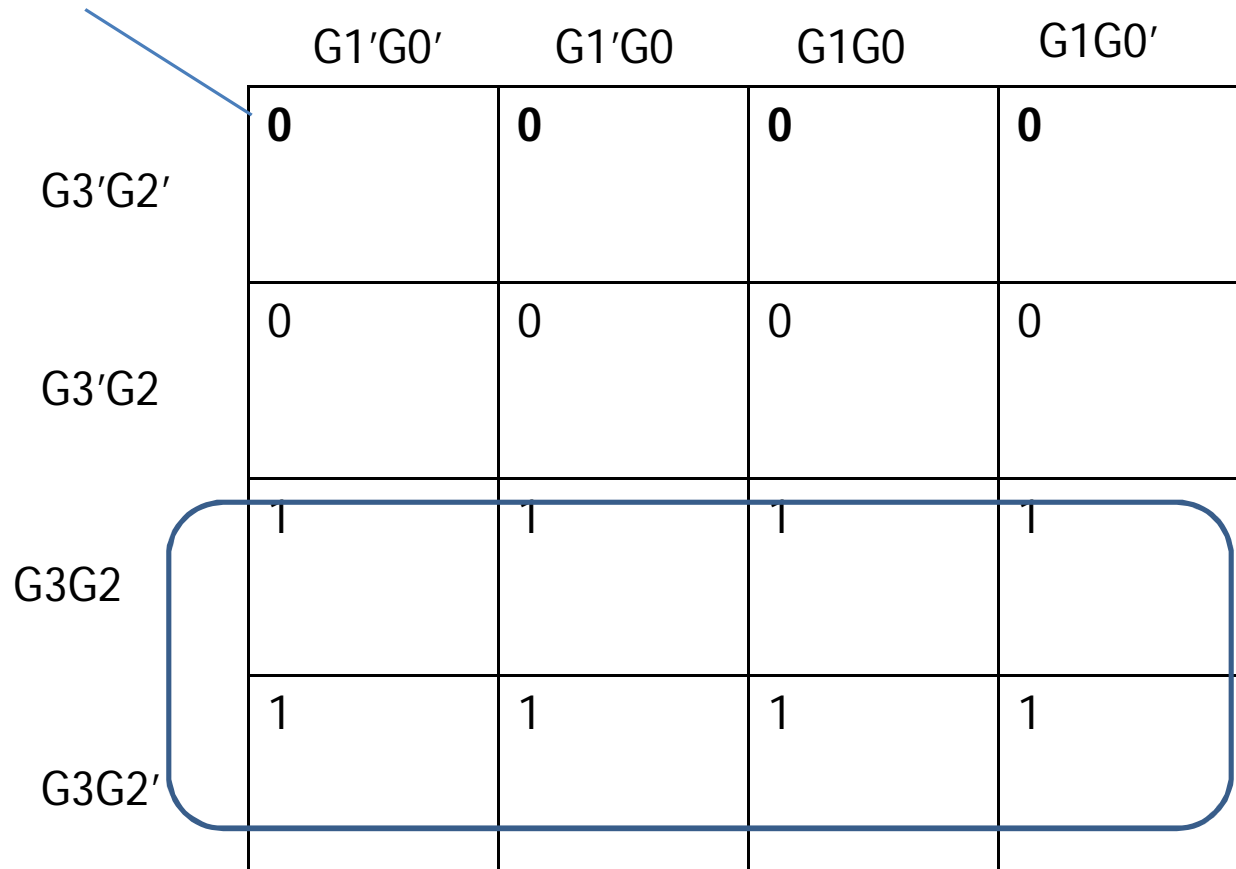
Figure 3.1 Binary-to-Gray Code

Gray to Binary Converter

Truth Table

Dec	G3	G2	G1	G0	B3	B2	B1	B0
0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1
3	0	0	1	1	0	0	1	0
2	0	0	1	0	0	0	1	1
6	0	1	1	0	0	1	0	0
7	0	1	1	1	0	1	0	1
5	0	1	0	1	0	1	1	0
4	0	1	0	0	0	1	1	1
12	1	1	0	0	1	0	0	0
13	1	1	0	1	1	0	0	1
15	1	1	1	1	1	0	1	0
14	1	1	1	0	1	0	1	1
10	1	0	1	0	1	1	0	0
11	1	0	1	1	1	1	0	1
9	1	0	0	1	1	1	1	0

K MAP For B3

	G1′G0′	G1′G0	G1G0	G1G0′
G3′G2′	**0**	**0**	**0**	**0**
G3′G2	0	0	0	0
G3G2	1	1	1	1
G3G2′	1	1	1	1

B3 = G3

K MAP For B2

	G1′G0′	G1′G0	G1G0	G1G0′
G3′G2′	**0**	**0**	**0**	**0**
G3′G2	1	1	1	1
G3G2	0	0	0	0
G3G2′	1	1	1	1
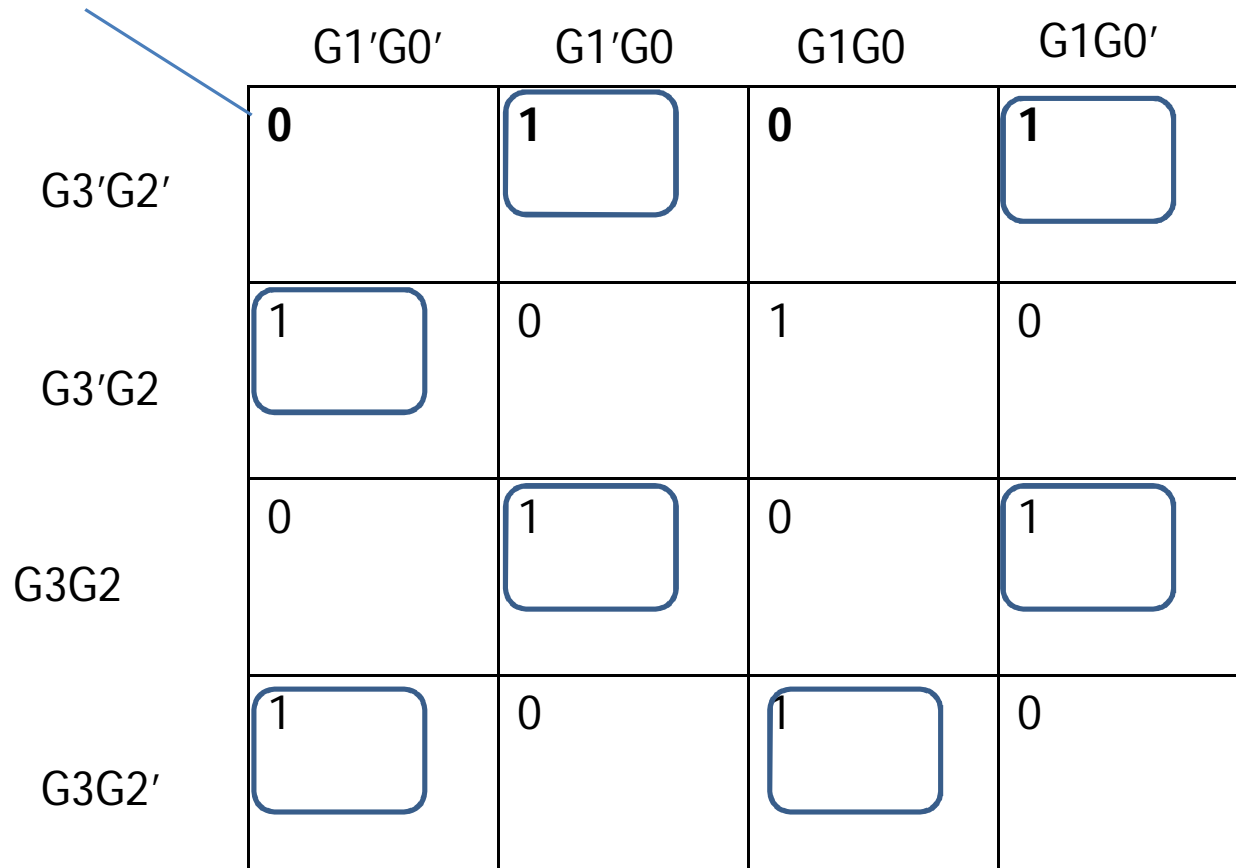
$$B1 = G3 \oplus G2 \oplus G1$$

K MAP For B1

	G1′G0′	G1′G0	G1G0	G1G0′
G3′G2′	**0**	**0**	1	1
G3′G2	1	1	0	0
G3G2	0	0	1	1
G3G2′	1	1	0	0

$$B1 = G3 \oplus G2 \oplus G1$$

K MAP For B0

	G1′G0′	G1′G0	G1G0	G1G0′
G3′G2′	**0**	**1**	**0**	**1**
G3′G2	1	0	1	0
G3G2	0	1	0	1
G3G2′	1	0	1	0

$$B0 = G3 \oplus G2 \oplus G1 \oplus G0$$

B3 ——————————————————— G3

B2 ———⊐ XOR ⊐——— G2

B1 ———⊐ XOR ⊐——— G1

B0 ———⊐ XOR ⊐——— G0
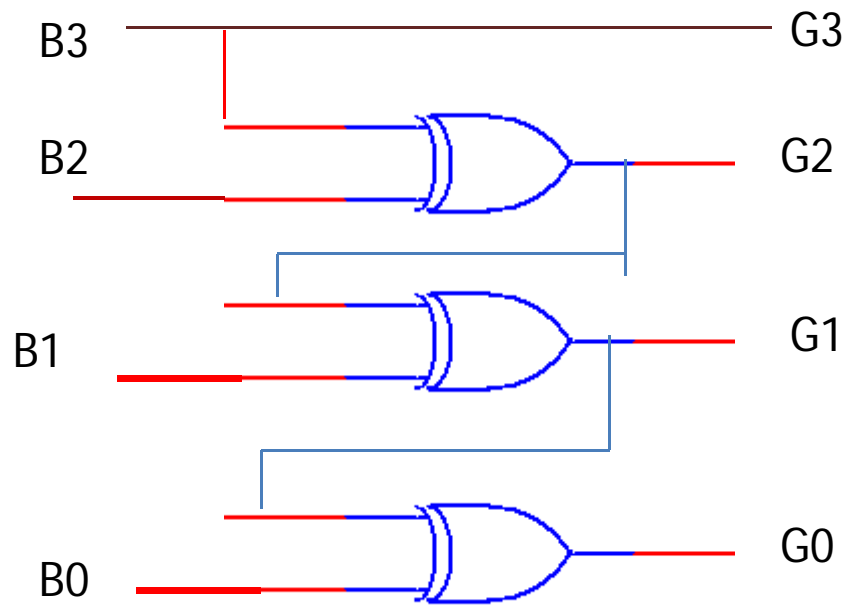
Assignment-14

Design the Converter for
1. Binary to BCD
2. BCD to Gray
3. BCD to Binary
4. BCD to Excess