Code Converters

BCD <-> GRAY
BCD <-> Excess 3
BCD -> seven segment display

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Binary to Gray Code - Introduction

Gray Code system is a binary number system in which every successive pair of numbers differs in only one bit. It is used in applications in which the normal sequence of binary numbers generated by the hardware may produce an error or ambiguity during the transition from one number to the next.

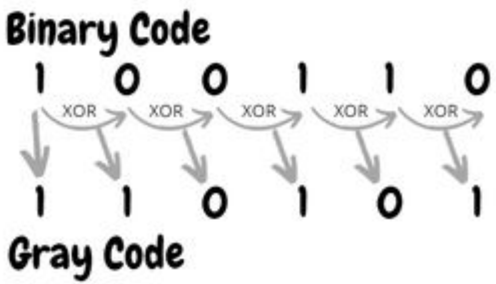
For example, the states of a system may change from 3(011) to 4(100) as- 011 — 001 — 101 — 100. Therefore there is a high chance of a wrong state being read while the system changes from the initial state to the final state.

This could have serious consequences for the machine using the information. The Gray code eliminates this problem since only one bit changes its value during any transition between two numbers

Binary to Gray Code - Manually

Binary to Gray conversion :

1. The Most Significant Bit (MSB) of the gray code is always equal to the MSB of the given binary code.
2. Other bits of the output gray code can be obtained by XORing binary code bit at that index and previous index.



Binary to Gray Code - Truth Table

Binary				Gray Code			
b_3	b_2	b_1	b_0	g_3	g_2	g_1	g_0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	1	1	0	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

Binary to Gray Code - K Maps for g0 - g3

K-map for – g0

b3,b2 \ b1,b0	00	01	11	10
00	0	1	0	1
01	0	1	0	1
11	0	1	0	1
10	0	1	0	1

K-map for – g1

b3,b2 \ b1,b0	00	01	11	10
00	0	0	1	1
01	1	1	0	0
11	1	1	0	0
10	0	0	1	1

K-map for – g2

b3,b2 \ b1,b0	00	01	11	10
00	0	0	0	0
01	1	1	1	1
11	0	0	0	0
10	1	1	1	1

K-map for – g3

b3,b2 \ b1,b0	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	1	1	1	1

Binary to Gray Code - Boolean expressions

$$g_0 = b_0 b_1' + b_1 b_0' = b_0 \oplus b_1$$

$$g_1 = b_2 b_1' + b_1 b_2' = b_1 \oplus b_2$$

$$g_2 = b_2 b_3' + b_3 b_2' = b_2 \oplus b_3$$

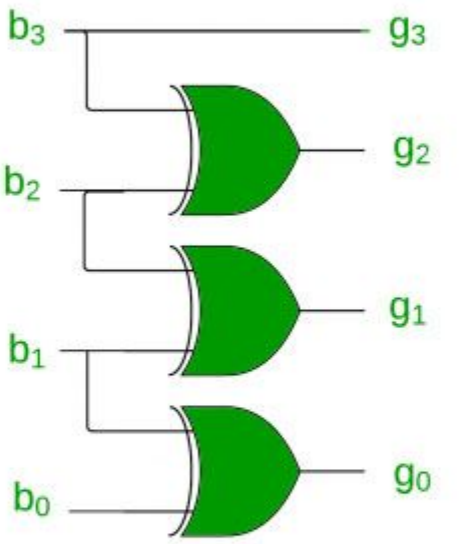
$$g_3 = b_3$$

Boolean expression for conversion of binary to gray code for n-bit :

$G_n = B_n$

$G_{n-1} = B_n$ XOR B_{n-1}

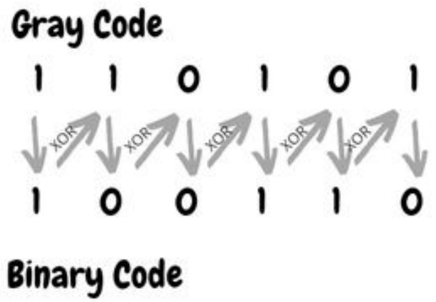
Binary to Gray Code - Digital Circuit



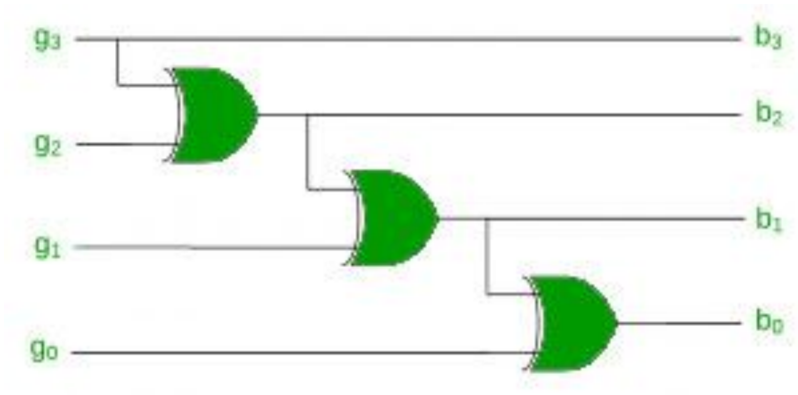
$$
\begin{aligned}
g_0 &= b_0 b_1' + b_1 b_0' = b_0 \oplus b_1 \\
g_1 &= b_2 b_1' + b_1 b_2' = b_1 \oplus b_2 \\
g_2 &= b_2 b_3' + b_3 b_2' = b_2 \oplus b_3 \\
g_3 &= b_3
\end{aligned}
$$

Gray to Binary Code - Manually

1. The Most Significant Bit (MSB) of the binary code is always equal to the MSB of the given gray code.
2. Other bits of the output binary code can be obtained by checking the gray code bit at that index. If the current gray code bit is 0, then copy the previous binary code bit, else copy the invert of the previous binary code bit.



Gray to Binary Code



Boolean expression for conversion of gray to binary code for n-bit :

B n = G n

B n-1 = B n XOR G n-1 = G n XOR G n-1

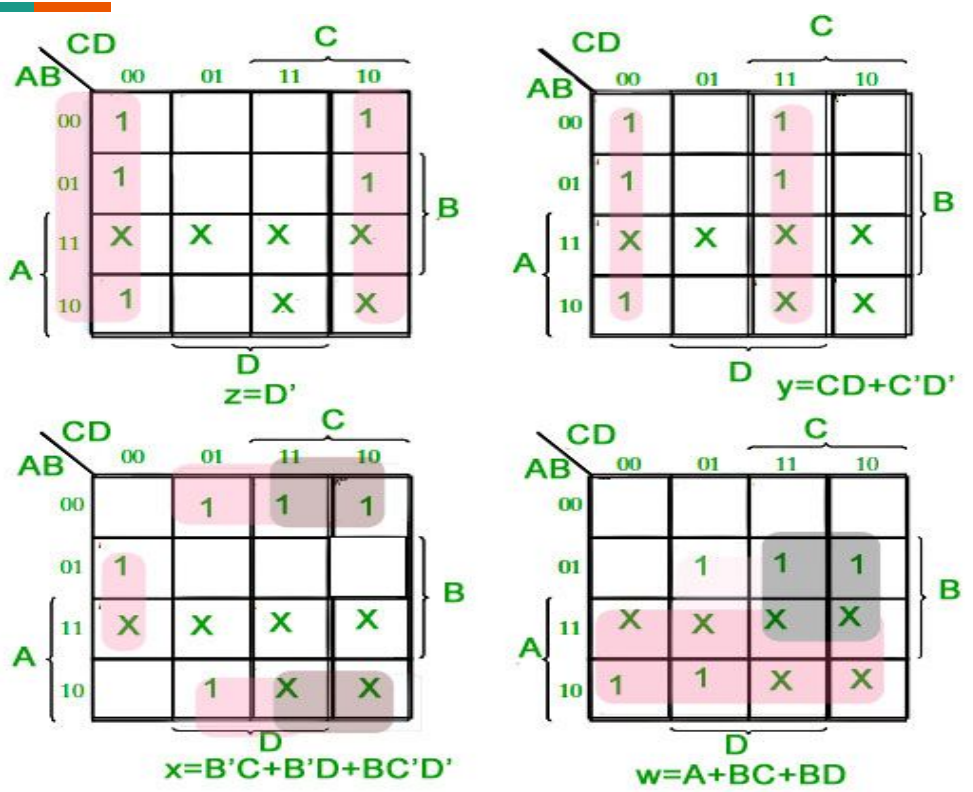
BCD to excess 3 - Truth Table

As is clear by the name, a BCD digit can be converted to its corresponding Excess-3 code by simply adding 3 to it. Since we have only 10 digits(0 to 9) in decimal, we don't care about the rest and marked them with a cross(X)

BCD(8421)				Excess-3			
A	B	C	D	w	x	y	z
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0
1	0	1	0	X	X	X	X
1	0	1	1	X	X	X	X
1	1	0	0	X	X	X	X
1	1	0	1	X	X	X	X
1	1	1	0	X	X	X	X
1	1	1	1	X	X	X	X

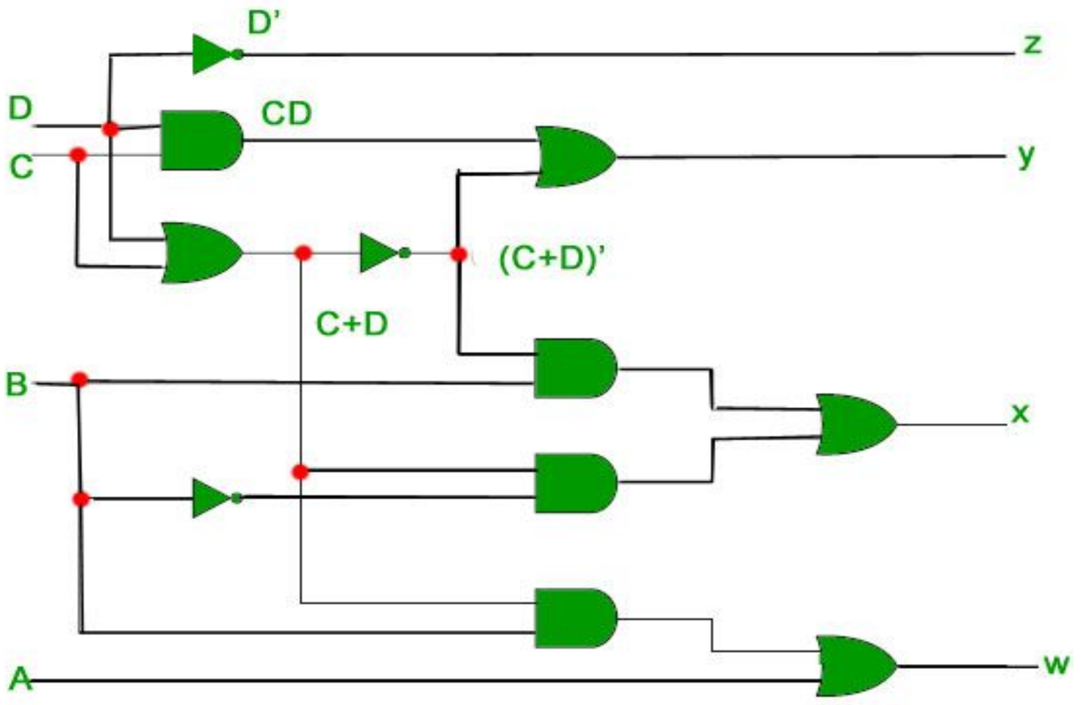
In Truth Table:
Let A, B, C and D be the bits representing the binary numbers, where D is the LSB and is the A is the MSB, and Let W,X,Y and Z be the bits representing the gray code of the binary numbers, where Z is the LSB and W is the MSB

BCD to excess 3 - Digital Circuit (1)



$$w = A + BC + BD$$
$$x = B'C + B'D + BC'D'$$
$$y = CD + C'D'$$
$$z = D'$$

BCD to excess 3 - Digital Circuit (2)



$$w = A + BC + BD$$
$$x = B'C + B'D + BC'D'$$
$$y = CD + C'D'$$
$$z = D'$$

Excess 3 to BCD - Truth Table

Excess-3				BCD			
w	x	y	z	A	B	C	D
0	0	0	0	X	X	X	X
0	0	0	1	X	X	X	X
0	0	1	0	X	X	X	X
0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	1
0	1	0	1	0	0	1	0
0	1	1	0	0	0	1	1
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
1	0	1	0	0	1	1	1
1	0	1	1	1	0	0	0
1	1	0	0	1	0	0	1
1	1	0	1	X	X	X	X
1	1	1	0	X	X	X	X
1	1	1	1	X	X	X	X

Excess 3 to BCD - Digital Circuit (1)

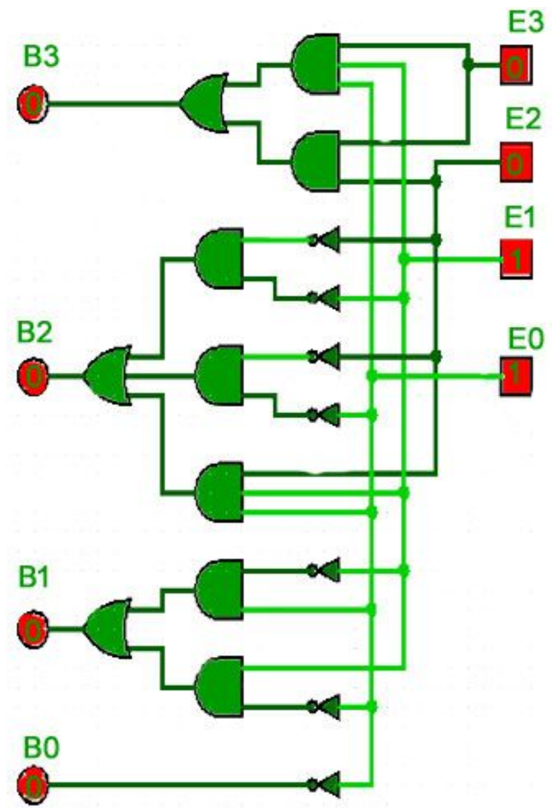
wx \ yz	00	01	11	10
00	X	X	0	X
01	1	0	0	1
11	1	X	X	X
10	1	0	0	1

wx \ yz	00	01	11	10
00	X	X	0	X
01	0	1	0	1
11	0	X	X	X
10	0	1	0	1

wx \ yz	00	01	11	10
00	X	X	0	X
01	0	0	1	0
11	0	X	X	X
10	1	1	0	1

wx \ yz	00	01	11	10
00	X	X	0	X
01	0	0	0	0
11	1	X	X	X
10	0	0	1	0

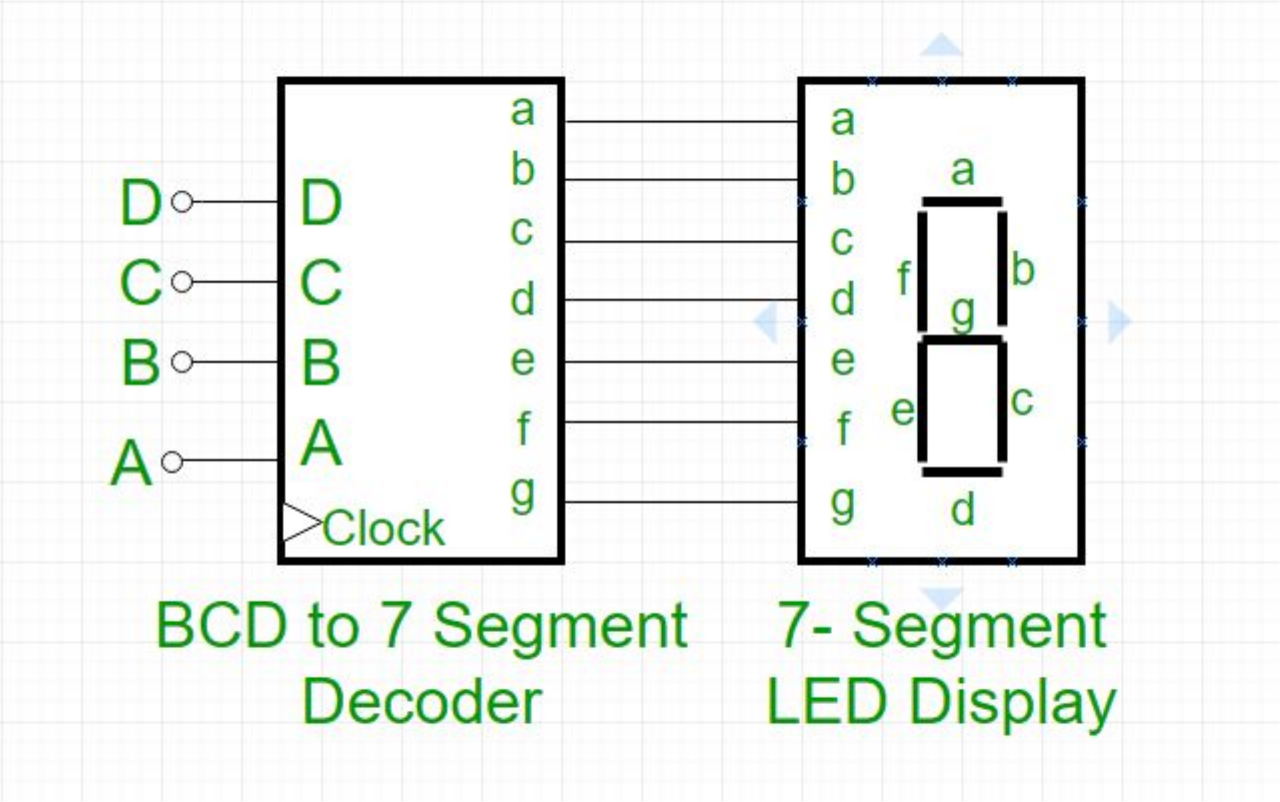
Excess 3 to BCD - Digital Circuit (2)



Here E3, E2, E1 and E0 correspond to w,x,y,z and B3,B2,B1,B0 correspond to A,B,C and D

$$A = wx + wyz$$
$$B = x'y' + x'z' + xyz$$
$$C = y'z + yz'$$
$$D = z'$$

BCD to 7 segment display



BCD to 7 segment display - Truth Table

A	B	C	D	a	b	c	d	e	f	g
0	0	0	0	1	1	1	1	1	1	0
0	0	0	1	0	1	1	0	0	0	0
0	0	1	0	1	1	0	1	1	0	1
0	0	1	1	1	1	1	1	0	0	1
0	1	0	0	0	1	1	0	0	1	1
0	1	0	1	1	0	1	1	0	1	1
0	1	1	0	1	0	1	1	1	1	1
0	1	1	1	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1	1	1	1
1	0	0	1	1	1	1	1	0	1	1