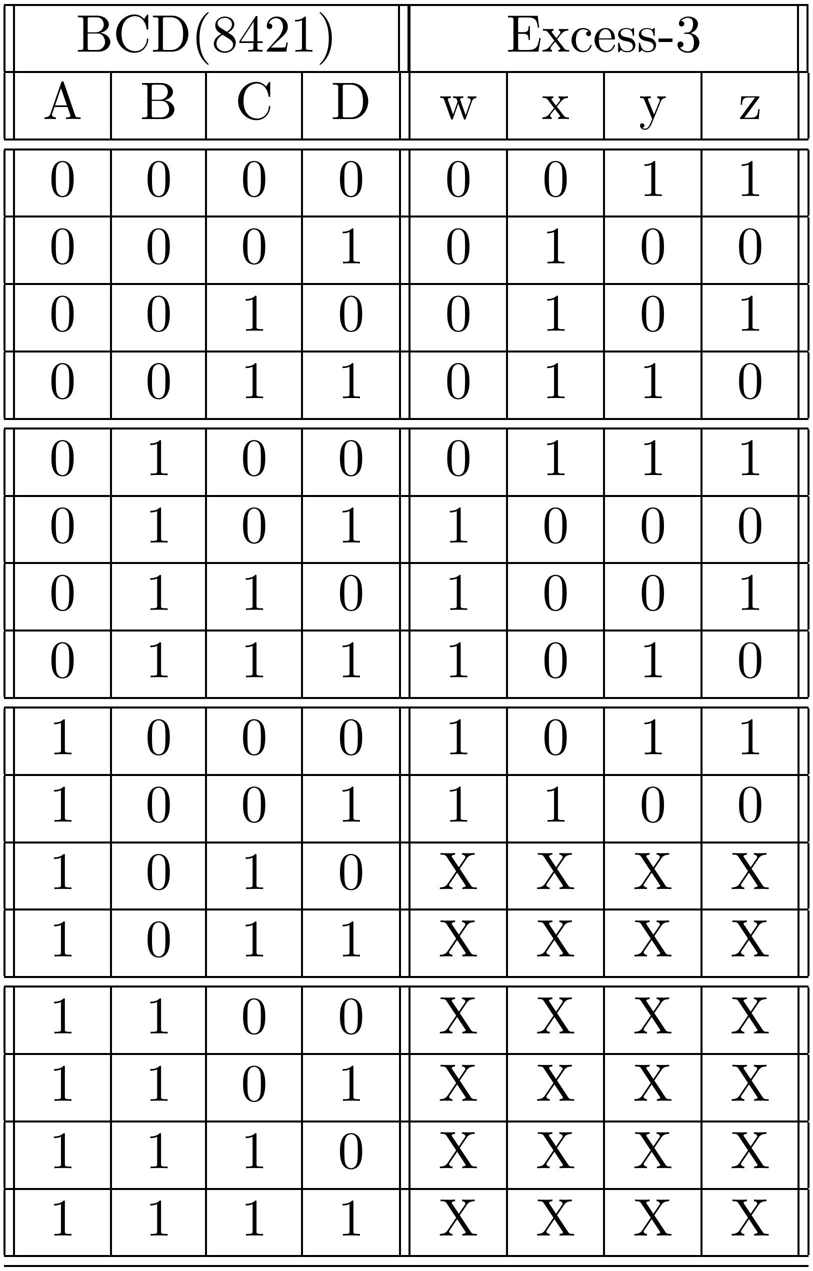
Digital Logic | Code Converters – BCD(8421) to/from Excess-3

Prerequisite – Number System and base conversions

Excess-3 binary code is a **unweighted self-complementary** BCD code.
Self-Complementary property means that the 1's complement of an excess-3 number is the excess-3 code of the 9's complement of the corresponding decimal number. This property is useful since a decimal number can be nines' complemented (for subtraction) as easily as a binary number can be ones' complemented; just by inverting all bits.
For example, the excess-3 code for 3(0011) is 0110 and to find the excess-3 code of the complement of 3, we just need to find the 1's complement of 0110 -> 1001, which is also the excess-3 code for the 9's complement of 3 -> (9-3) = 6.

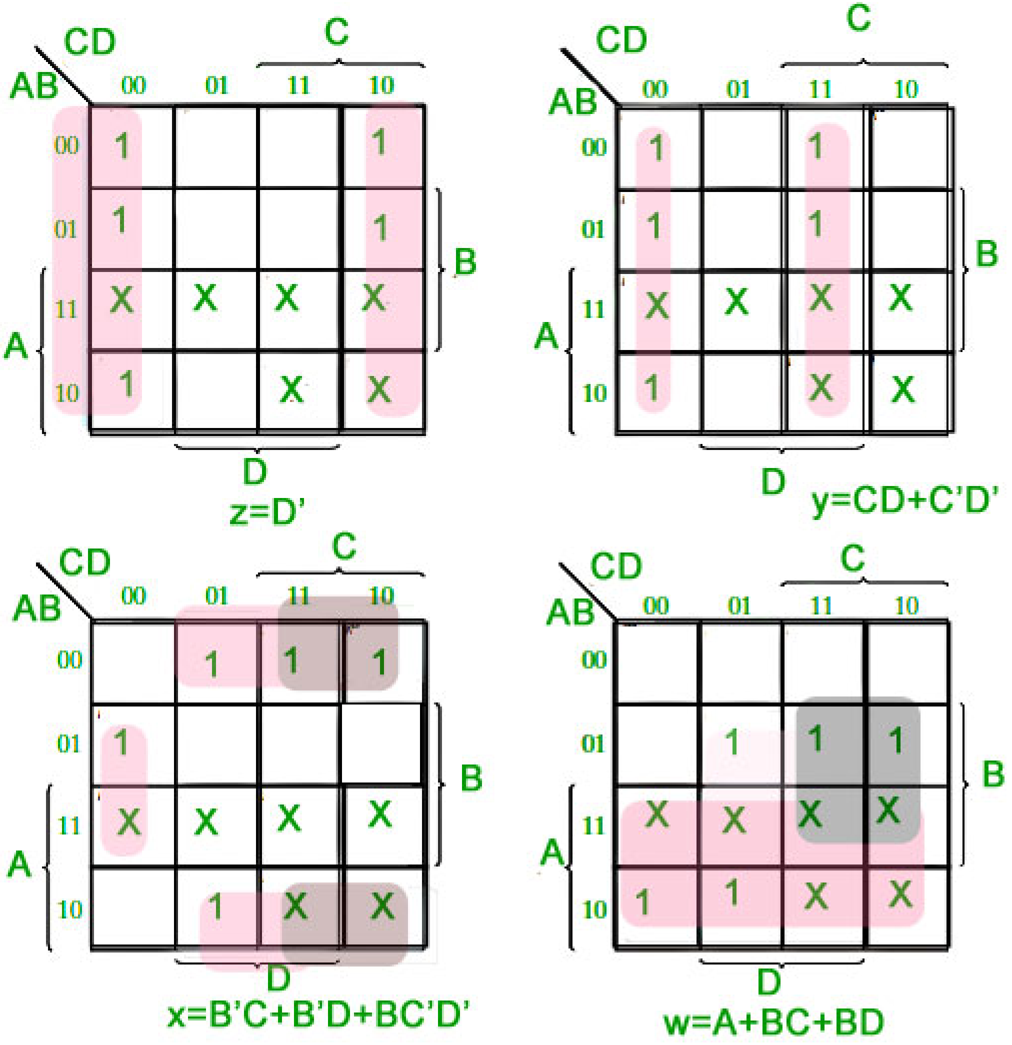
Converting BCD(8421) to Excess-3 –

As is clear by the name, a BCD digit can be converted to it's corresponding Excess-3 code by simply adding 3 to it.
Let $A,\ B,\ C,\ and\ D$ be the bits representing the binary numbers, where D is the LSB and 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.
The truth table for the conversion is given below. The X's mark don't care conditions.



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

To find the corresponding digital circuit, we will use the K-Map technique for each of the Excess-3 code bits as output with all of the bits of the BCD number as input.



Corresponding minimized Boolean expressions for Excess-3 code bits –

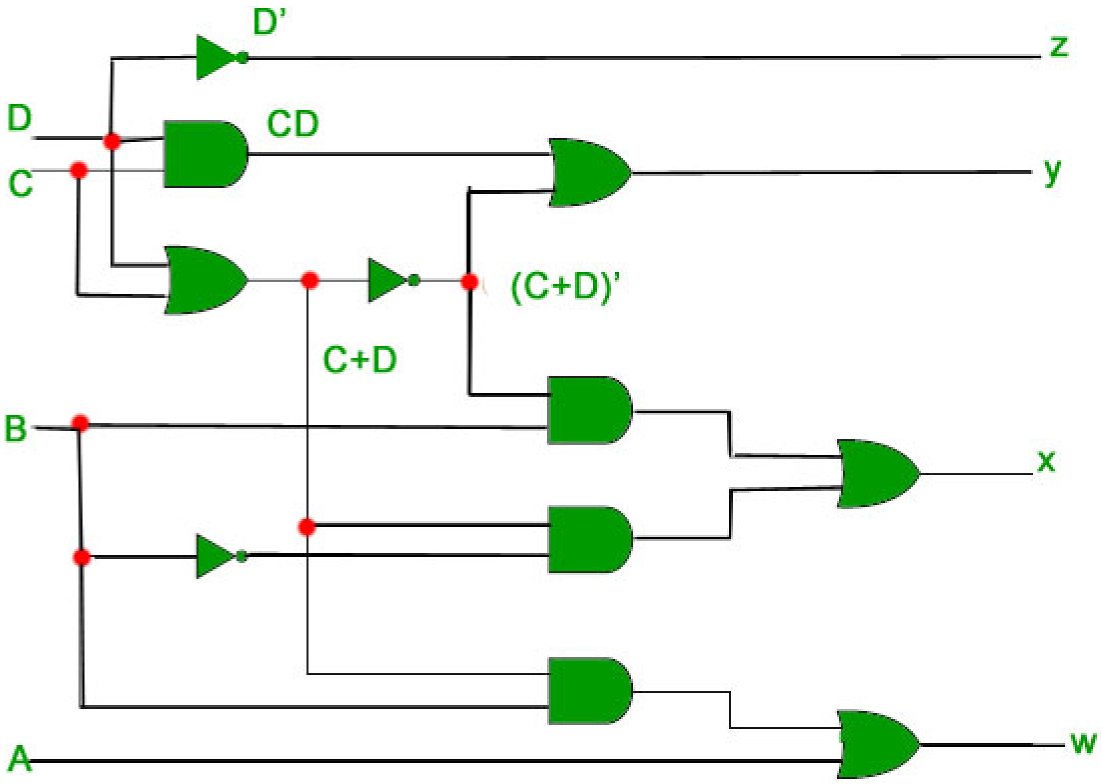
$$w = A + BC + BD$$

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

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

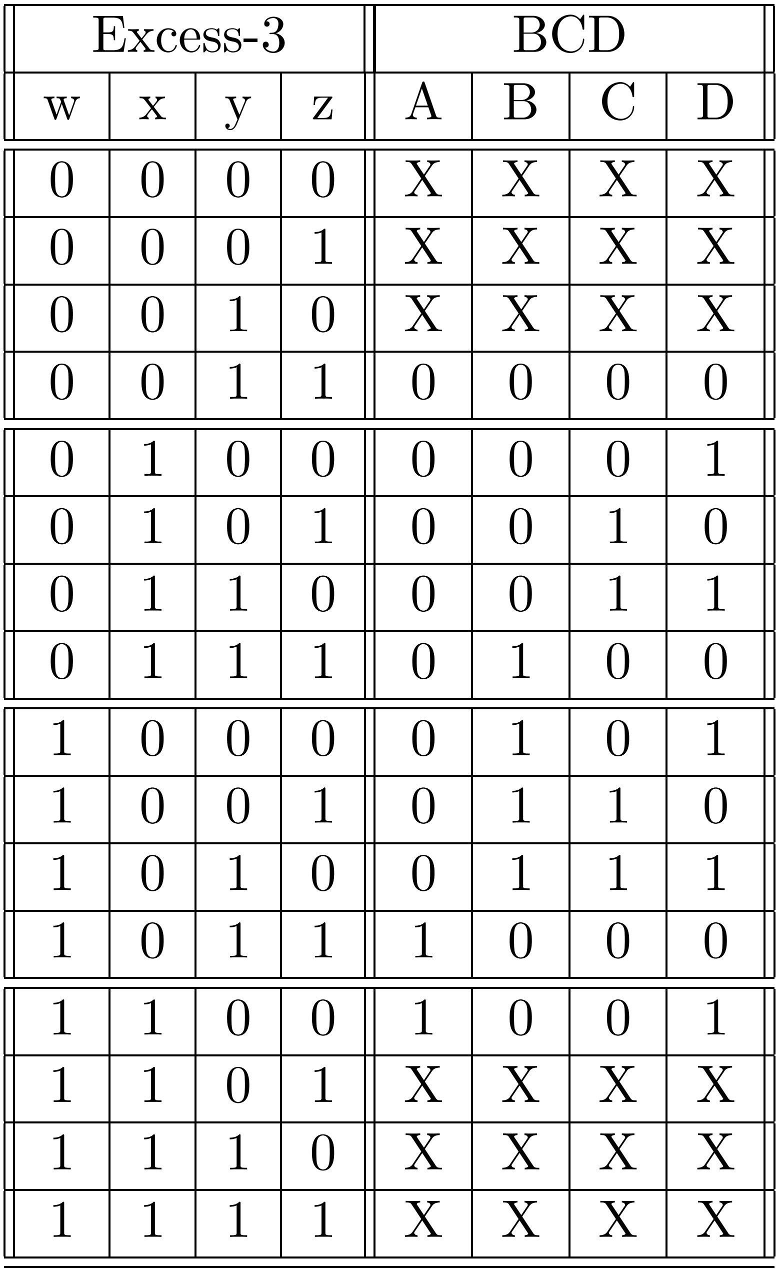
$$z = D'$$

The corresponding digital circuit-



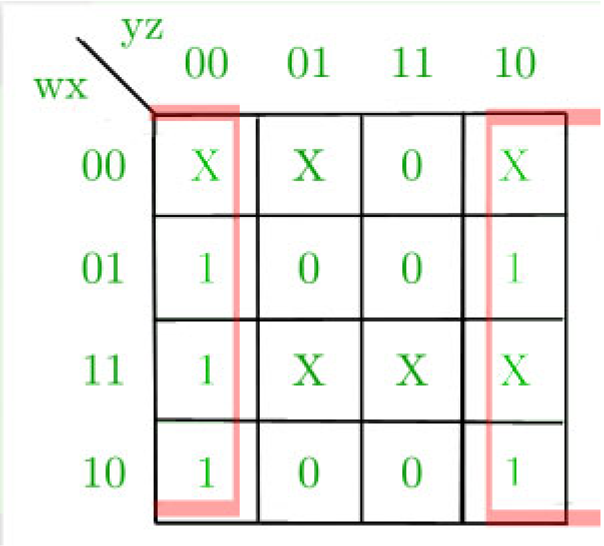
Converting Excess-3 to BCD(8421) –

Excess-3 code can be converted back to BCD in the same manner.
Let $A,\ B,\ C,\ and\ D$ be the bits representing the binary numbers, where D is the LSB and 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.
The truth table for the conversion is given below. The X's mark don't care conditions.



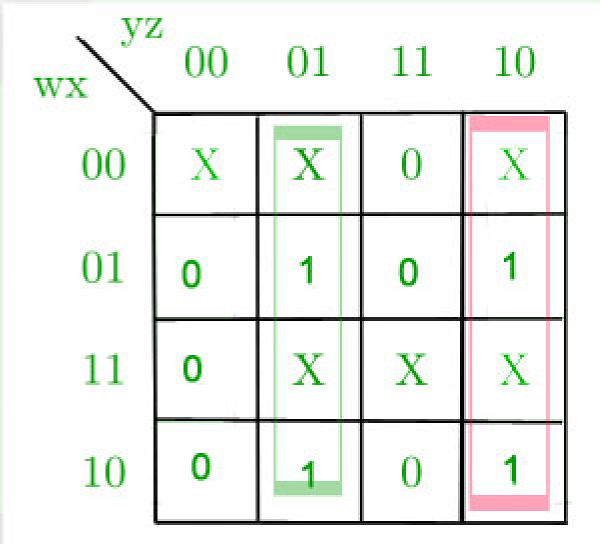
Excess-3				BCD			
w	x	y	z	A	B	C	D
0	0	0	0	X	X	X	X
0	0	0	1	X	X	X	X
0	0	1	0	X	X	X	X
0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	1
0	1	0	1	0	0	1	0
0	1	1	0	0	0	1	1
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
1	0	1	0	0	1	1	1
1	0	1	1	1	0	0	0
1	1	0	0	1	0	0	1
1	1	0	1	X	X	X	X
1	1	1	0	X	X	X	X
1	1	1	1	X	X	X	X

K-Map for D-



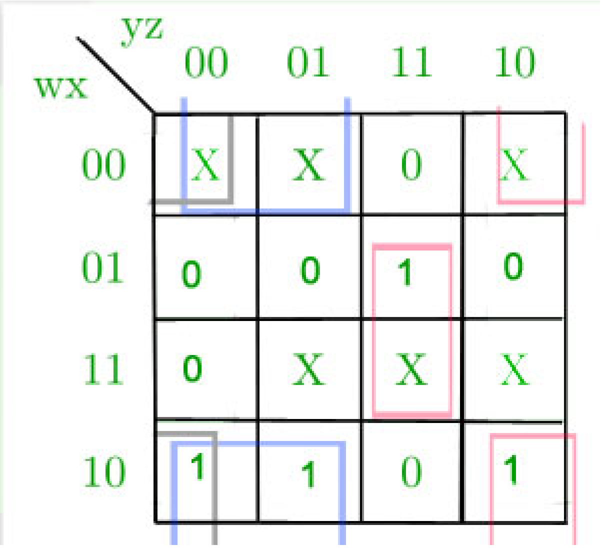
wx \ yz	00	01	11	10
00	X	X	0	X
01	1	0	0	1
11	1	X	X	X
10	1	0	0	1

K-Map for C-



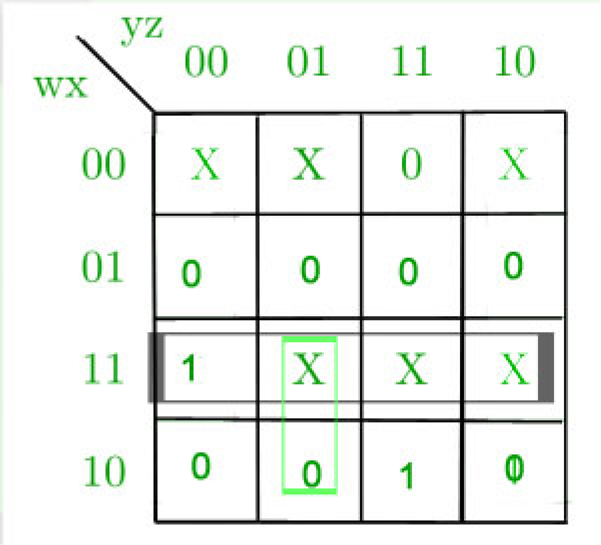
wx \ yz	00	01	11	10
00	X	X	0	X
01	0	1	0	1
11	0	X	X	X
10	0	1	0	1

K-Map for B-



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

K-Map for A-



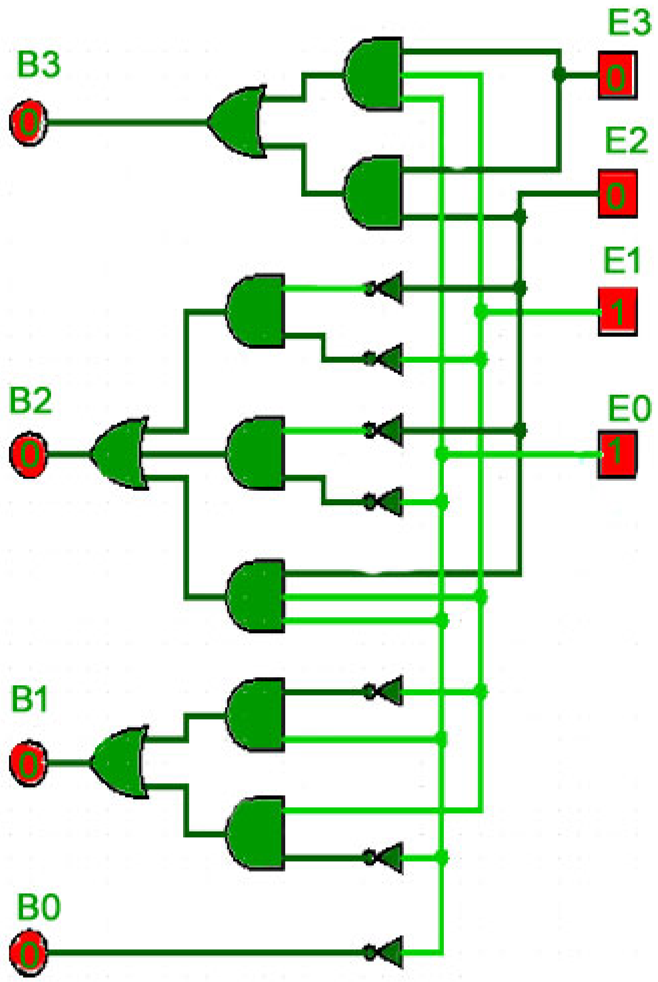
wx \ yz	00	01	11	10
00	X	X	0	X
01	0	0	0	0
11	1	X	X	X
10	0	0	1	0

Corresponding minimized boolean expressions for Excess-3 code bits –

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

The corresponding digital circuit –

Here $E_3,\ E_2,\ E_1,\ and\ E_0$ correspond to $w,\ x,\ y,\ and\ z$ and $B_3,\ B_2,\ B_1,\ and\ B_0$ correspond to $A,\ B,\ C,\ and\ D$.



References-

Digital Design, 5th edition by Morris Mano and Michael Ciletti
Excess-3 – Wikipedia

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Shoikot • a month ago

In Converting BCD(8421) to Excess-3:
K-Map for X is worng... IN 0110 there will be no 1.

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Mithlesh Upadhyay Mod ➦ Shoikot • a month ago

Thanks for pointing out, corrected.

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