Ex: Subtract 14 from 25 using 8 bit 1's EX: ADD -25 to +14

25	=	00011001	+14	= 00001110							
-45	=	11110001	-25	=+11100110							
+11		(1)00001010	-11	11110100							
	+1										
			No carr	y MSB $=1$							
	_	00001011		result=-ve=-11 ₁₀							
MSE	MSB is a 0 so result is +ve (binary)										

 $=+11_{10}$

Binary codes

Binary codes are codes which are represented in binary system with modification from the original ones.

□ Weighted Binary codes

 \Box Non Weighted Codes

Weighted binary codes are those which obey the positional weighting principles, each position of the number represents a specific weight. The binary counting sequence is an example.

Decimal	BCD 8421	Excess-3	84-2-1	2421	5211	Bi-Quinary 5043210		5	0	4	3	2	1	0
0	0000	0011	0000	0000	0000	0100001	0		Х					Х
1	0001	0100	0111	0001	0001	0100010	1		Х				Х	
2	0010	0101	0110	0010	0011	0100100	2		Х			Х		
3	0011	0110	0101	0011	0101	0101000	3		Х		Х			
4	0100	0111	0100	0100	0111	0110000	4		Х	Х				
5	0101	1000	1011	1011	1000	1000001	5	Х						Х
6	0110	1001	1010	1100	1010	1000010	6	Х					Х	
7	0111	1010	1001	1101	1100	1000100	7	Х				Х		
8	1000	1011	1000	1110	1110	1001000	8	Х			Х			
9	1001	1111	1111	1111	1111	1010000	9	Х		Х				

Reflective Code

A code is said to be reflective when code for 9 is complement for the code for 0, and

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so is for 8 and 1 codes, 7 and 2, 6 and 3, 5 and 4. Codes 2421, 5211, and excess-3 are reflective, whereas the 8421 code is not.

Sequential Codes

A code is said to be sequential when two subsequent codes, seen as numbers in binary representation, differ by one. This greatly aids mathematical manipulation of data. The 8421 and Excess-3 codes are sequential, whereas the 2421 and 5211 codes are not.

Non weighted codes

Non weighted codes are codes that are not positionally weighted. That is, each position within the binary number is not assigned a fixed value. Ex: Excess-3 code

Excess-3 Code

Excess-3 is a non weighted code used to express decimal numbers. The code derives its name from the fact that each binary code is the corresponding 8421 code plus 0011(3).

Gray Code

The gray code belongs to a class of codes called minimum change codes, in which only one bit in the code changes when moving from one code to the next. The Gray code is non-weighted code, as the position of bit does not contain any weight. The gray code is a reflective digital code which has the special property that any two subsequent numbers codes differ by only one bit. This is also called a unit-distance code. In digital Gray code has got a special place.

Decimal Number	Binary Code	Gray Code	Decimal Number	Binary Code	Gray Code
0	0000	0000	8	1000	1100
1	0001	0001	9	1001	1101
2	0010	0011	10	1010	1111
3	0011	0010	11	1011	1110
4	0100	0110	12	1100	1010
5	0101	0111	13	1101	1011
6	0110	0101	14	1110	1001
7	0111	0100	15	1111	1000

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Binary to Gray Conversion

□ Gray Code MSB is binary code MSB.

- □ Gray Code MSB-1 is the XOR of binary code MSB and MSB-1.
- □ MSB-2 bit of gray code is XOR of MSB-1 and MSB-2 bit of binary code.
- □ MSB-N bit of gray code is XOR of MSB-N-1 and MSB-N bit of binary code.

8421 BCD code (Natural BCD code):

Each decimal digit 0 through 9 is coded by a 4 bit binary no. called natural binary codes. Because of the 8,4,2,1 weights attached to it. It is a weighted code & also sequential . it is useful for mathematical operations. The advantage of this code is its case of conversion to & from decimal. It is less efficient than the pure binary, it require more bits.

Ex: $14 \rightarrow 1110$ in binary

But as 0001 0100 in 8421 ode.

The disadvantage of the BCD code is that , arithmetic operations are more complex than they are in pure binary . There are 6 illegal combinations 1010,1011,1100,1101,1110,1111 in these codes, they are not part of the 8421 BCD code system . The disadvantage of 8421 code is, the rules of binary addition 8421 no, but only to the individual 4 bit groups.

BCD Addition:

It is individually adding the corresponding digits of the decimal no,s expressed in 4 bit binary groups starting from the LSD. If there is no carry & the sum term is not an illegal code, no correction is needed. If there is a carry out of one group to the next group or if the sum term is an illegal code then $6_{10}(0100)$ is added to the sum term of that group & the resulting carry is added to the next group.

Ex: Perform decimal additions in 8421 code

(a)25	+13	
In BCD	25= 0010	0101
In BCD	+13 =+0001	0011

38 0011 1000 No carry, no illegal code .This is the corrected sum

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(b). 679.	.6 + 53	36.8											
679.6	=	0110)		0111		1001	.01	10 in	B	CD		
+536.8	=	+010)1		0011		0010	.1	000 i	in I	BCD		
1216.4	-	1011 +011	l 1 10	+	1010 0011		 0110 +0110	. 1 . +	110 0110)	i] a	llegal c dd 011	odes 0 to each
((1)000	1	(1)00	000	(1)0101	. (1)0	0100	1	pro	pagat	e carry	7
/	,		/			/		/					
	+1		4	-1		+1		+1					
(0001		00)10		0001		011	0.	•	0100)	
	1		2			1		6			4		

BCD Subtraction:

Performed by subtracting the digits of each 4 bit group of the subtrahend the digits from the corresponding 4- bit group of the minuend in binary starting from the LSD . if there is no borrow from the next group , then $6_{10}(0110)$ is subtracted from the difference term of this group.

(a)38-15

In BCD	38 = 0011	1000
In BCD	-15 = -0001	0101

23 0010 0011 No borrow, so correct difference.

.(b) 206.7-147.8

206.7 =	0010 0000	0110 .	0111	in BCD
-147.8 =	-0001 0100	0111 .	0110	in BCD
58.9	0000 1011	1110 .	1111	borrows are present
-0110	-0110.	-0110	subtract 0110	_
	0101	1000 .	1001	

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BCD Subtraction using 9's & 10's compliment methods:

Form the 9's & 10's compliment of the decimal subtrahend & encode that no. in the 8421 code . the resulting BCD no.s are then added.

305.5 - 168.8EX: 305.5 =305.5 -168.8= +83.19's comp of -168.8 (1)136.6+1end around carry corrected difference 136.7 305.5_{10} = 0011 0000 0101 0101 9's comp of ¹68.8 in BCD $+831.1_{10} =$ +10000011 0001 0001 0011 0110. 1011 is illegal code +10110110 add 0110 +0110(1)00010011 0110 . 0110 +1End around carry 0001 0011 0110 . 0111 = 136.7

Excess three(xs-3)code:

It is a non-weighted BCD code .Each binary codeword is the corresponding 8421 codeword plus 0011(3).It is a sequential code & therefore , can be used for arithmetic operations..It is a self-complementing code.s o the subtraction by the method of compliment addition is more direct in xs-3 code than that in 8421 code. The xs-3 code has six invalid states 0000,0010,1101,1110,1111.. It has interesting properties when used in addition & subtraction.

Excess-3 Addition:

Add the xs-3 no.s by adding the 4 bit groups in each column starting from the LSD. If there is no carry starting from the addition of any of the 4-bit groups, subtract 0011 from the sum term of those groups (because when 2 decimal digits are added in xs-3 & there is no carry, result in xs-6). If there is a carry out, add 0011 to the sum term of those groups (because when there is a carry, the invalid states are skipped and the result is normal binary).

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EX:	37	0110	1010	
	+28	+0101	1011	
				-
	65	1011	(1)0101 carry	y generated
		$^{+1}$ <=		propagate carry
		1100	0101	add 0011 to correct 0101 &
		-0011	+0011	subtract 0011 to correct 1100
		1001	1000	=6510

Excess -3 (XS-3) Subtraction:

Subtract the xs-3 no.s by subtracting each 4 bit group of the subtrahend from the corresponding 4 bit group of the minuend starting form the LSD .if there is no borrow from the next 4-bit group add 0011 to the difference term of such groups (because when decimal digits are subtracted in xs-3 & there is no borrow, result is normal binary). I f there is a borrow, subtract 0011 from the differenceterm(b coz taking a borrow is equivalent to adding six invalid states, result is in xs-6)

Ex: 267-175

267 = 0101 1001 1010 -175= -0100 1010 1000

> 0000 1111 0010 +0011 -0011 +0011

 $0011 \ 1100 \ +0011 \ =92_{10}$

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Xs-3 subtraction using 9's & 10's compliment methods:

Subtraction is performed by the 9's compliment or 10's compliment Ex:687-348 The subtrahend (348) xs -3 code & its compliment are:

	9's comp of 348 = 651 Xs-3 code of 348 = 0110 0111 1011 1's comp of 348 in xs-3 = 1001 1000 0100 Xs=3 code of 348 in xs=3 = 1001 1000 0100										
	687 -348	\rightarrow	687 +651 9	's compl of 348							
_	339		(1)338 +1 	end around carry corrected di	fference in decimal						
	1001 +1001		1011 1000	687 in xs-3 1's comp 348 in xs-3							
+1	_(1)0	010(1)0 +1)011	1110 carry gen	erated propagate carry						
(1)001		0010	1110	- - " +1	end around carry						
	0011 +0011		0011 +0011 	1111 +0011 addi	(correct 1111 by sub0011 and correct both groups of 0011 by ng 0011)						
	0110		0110	- 1100	corrected diff in $xs-3 = 330_{10}$						

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The Gray code (reflective –code):

Gray code is a non-weighted code & is not suitable for arithmetic operations. It is not a BCD code . It is a cyclic code because successive code words in this code differ in one bit position only i.e, it is a unit distance code.Popular of the unit distance code.It is also a reflective code i.e,both reflective & unit distance. The n least significant bits for 2^n through 2^{n+1} -1 are the mirror images of thosr for 0 through 2^n -1.An N bit gray code can be obtained by reflecting an N-1 bit code about an axis at the end of the code, & putting the MSB of 0 above the axis & the MSB of 1 below the axis.

		Gra	y (Code							
1 bit 2		2 bit		3 bit		4 bit		Decimal		4 bit binary	
0		00		000		0000		0		0000	
1		01		001		0001		1		0001	
		11		011		0011		2		0010	
		10		010		0010		3		0011	
				110		0110		4		0100	
				111		0111		5		0101	
				101		0101		6		0110	
				110		0100		7		0111	
					1	100	8		1	000	
					1	101	9)	1	001	
					1	111	1	0	1	010	
					1	110	1	1	1	011	
					1	010	1	2	1	100	
					1	011	1	3	1	101	
					1	001	1	4	1	110	
					1	000	1	5	1	.111	

Reflection of gray codes: