Weighted Binary codes.-
Weighted binary codes obey the positional weighting principles. Each position of a number represents a specific weight. In a weighted binary code, the bits are multiplied by the weights indicated; the sum of these weighted bits gives the equivalent decimal digit. The code 8421, 2421, 5421 and 5411 are weighted codes.

Non weighted codes:-
Non weighted codes are codes that are not positionally weighted. This means that each position within a binary number is not assigned a fixed value. Excess-3 codes and Gray codes are examples of Non weighted codes.

Reflective codes:-
A code is said to be reflective when the code for 9 is the complement of code for 0, 8 for 1, 7 for 2, 6 for 3 and 5 for 4. The 2421, 5211 and Ex-3 codes are reflective codes.

Sequential codes:- A code can be said to be sequential when each succeeding code is one binary number greater than its preceding code. 8421 and Ex-3 codes are sequential codes.

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Binary Coded Decimal (BCD):-

BCD is a combination of four binary digits that represent decimal numbers. The BCD no. has 4 bits that represents decimal digits from 0 to 9. To express any decimal no. in BCD each decimal digit should be replaced by appropriate four bit code.

for ex. BCD code of decimal no. 874 is,

	8	7	4
BCD →	1000	0111	0100

Hence $(874)_{10} = (1000\ 0111\ 0100)_{BCD}$

BCD addition:-

The rule of addition for BCD no. are -

i) Add the two no. using the rules for binary addition

ii) If a four-bit sum is equal or less than 9, it is a valid BCD no.

iii) If a four bit sum is greater than 9, or a carry out is generated, it is an invalid result. Add 6 $(0110)_2$ to the 4-bit sum in order to skip the six invalid states and return the code to BCD. If a carry generated add this to the next 4-bit group.

Q 1. Add BCD no - 1001 and 0100

```
      1001
    + 0100
    ------
      1101  → Invalid BCD no.        9
    + 0110  → Add 6                 +4
    ------                          ----
0001  0011  → Valid BCD no.         (13)10
```

$\underbrace{0001}_{1}\ \underbrace{0011}_{3}$

2. Add BCD no. 00011001 and 0001 0100

```
      0001 1001
    + 0001 0100
    -----------
      0010 1101 → Right gr. is Invalid
         + 0110 → Add 6                19
    -----------                       +14
      0011 0011                       ----
                                      (33)10
```

$\underbrace{0011}_{3}\ \underbrace{0011}_{3}$

BCD Subtraction:-

The Method in BCD Subtraction is the addition of the 9's complement of the Subtrahend to the Minuend.

ex- Subtract 748 from 983 by 9'C Com Method

9's complement of 748 = 999 − 748 = 251

```
        983
      + 251
      -----
EAC ← (1) 234
          1 → End Around carry (EAC)
      -----
        235
```

```
  983
- 748
-----
(235)10
```

Excess-3 code -

The excess-3 represents a decimal no. in binary form as a no greater than 3.

An ex-3 code is obtained by adding 3 to a decimal no.

ex- Convert $(643)_{16}$ to its Ex-3 code

Decimal no.	6	4	3
Add 3 to each bit	+3	+3	+3
sum	9	7	6

Convert the above sum into BCD code

9 7 6

↓ ↓ ↓

BCD ⇒ 1001 0111 0110

Ex-3 for $(643)_{10}$ is 1001 0111 0110

Gray Codes-

In Gray code only one bit in the code group changes when moving from one step to next. The Gray code is reflective code which has a property of containing two adjacent code no. that differ by only one bit. Therefore it is also called a unit distance code.

Decimal no.	Binary code	Gray code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

Conversion of binary no. to gray code -

i) Ist bit (MSB) of the gray code is the same as the first bit of binary no.

ii) The IInd bit of Gray code is equal the Ex-OR of the first and second bit of binary no.

iii) The IIIrd bit of Gray code is equal to the Ex-OR of second and third bit of binary no. and so on.

ex - Convert $[10110]_2$ to its gray code.

b_4	b_3	b_2	b_1	b_0
1	0	1	1	0

$G_4 = b_4 = 1$

$G_3 = b_4 \oplus b_3 = 1 \oplus 0 = 1$

$G_2 = b_3 \oplus b_2 = 0 \oplus 1 = 1$

$G_1 = b_2 \oplus b_1 = 1 \oplus 1 = 0$

$G_0 = b_1 \oplus b_0 = 1 \oplus 0 = 1$

So the Gray code is 11101

conversion from gray code to binary code:-

i) The first binary bit (MSB) is the same of that of the first Gray code bit.

ii) The second bit of binary code is equal to the Ex-OR of first binary bit and second gray code bit and so one.

ex - convert [110101] gray code to its binary code.

$$G_5 \quad G_4 \quad G_3 \quad G_2 \quad G_1 \quad G_0$$
$$1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1$$

$b_5 = G_5 = 1$

$b_4 = b_5 \oplus G_4 = 1 \oplus 1 = 0$

$b_3 = b_4 \oplus G_3 = 0 \oplus 0 = 0$

$b_2 = b_3 \oplus G_2 = 0 \oplus 1 = 1$

$b_1 = b_2 \oplus G_1 = 1 \oplus 0 = 1$

$b_0 = b_1 \oplus G_0 = 1 \oplus 1 = 0$

$[110101]_G = (100110)_2$

ASCII Code :-

A standardized code that has been widely accepted by the industry the ASCII code American standards code for Information Interchange used in most Micro computers. This represents a character with 7 bits

EBCDIC code -

Another alphanumeric code used in IBM equipment is the EBCDIC or Extended Binary coded Decimal Information code. It uses 8 bits for each character and a ninth bit for parity.

Hamming code :- (Error correcting code)

Hamming developed a system that provides a methodical way to detect and correct the errors. The Hamming distance betⁿ two codes is defined as the ~~word~~ number of bits changed from one code to another.

The 7-bit Hamming (7,4) code word $h_1 h_2 h_3 h_4 h_5 h_6 h_7$ associated with a 4-bit binary no. $b_3 b_2 b_1 b_0$:-

$$h_1 = b_3 \oplus b_2 \oplus b_2 \qquad h_3 = b_3$$
$$h_2 = b_3 \oplus b_1 \oplus b_0 \qquad h_5 = b_2$$
$$h_4 = b_2 \oplus b_1 \oplus b_0 \qquad h_6 = b_1$$
$$h_7 = b_0$$

To decode a hamming code check for odd parity over the bit fields in which even parity was previously established for ex. a single bit error is indicated by a non zero parity word c_4, c_2, c_1 where

$$c_1 = h_1 \oplus h_3 \oplus h_5 \oplus h_7$$
$$c_2 = h_2 \oplus h_3 \oplus h_6 \oplus h_7$$
$$c_4 = h_4 \oplus h_5 \oplus h_6 \oplus h_7$$

If $c_4 c_2 c_1 = 000$ then there is no error.

If $c_4 c_2 c_1 = 101$ then in bit 5 error i.e. bit 5 has to be complemented.

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Hamming code Example.

Encode data 0101 in a 7 bit even Parity Hamming code.

Given $b_3 b_2 b_1 b_0 = 0101$

$h_1 = b_3 \oplus b_2 \oplus b_3 = 0 \oplus 1 \oplus 1 = 0$ $\quad h_3 = b_3 =$

$h_2 = b_3 \oplus b_1 \oplus b_0 = 0 \oplus 0 \oplus 1 = 1$ $\quad h_5 = b_2 = 1$

$h_4 = b_2 \oplus b_1 \oplus b_0 = 1 \oplus 0 \oplus 1 = 0$ $\quad h_6 = b_1 = 0$

$h_7 = b_0 = 1$

h_1	h_2	h_3	h_4	h_5	h_6	h_7
0	1	0	0	1	0	1

Tabulation Method :-

For logic expression with more than 4 variable the visualisation of adjacent cells and the drawing of the K map become more difficult. The tabulation Method or Quine-Mc cluskey method can be employed in such cases. This method employes a systematic, step by step Procedure to Produce a simplified standard form of expressions for a function with any no of variables. The steps to be followed in Tabulation method are :-

step 1 - A set of all Prime implicants of the function must be obtained

step 2 - From the set of all prime implicants a set of essential implicants must be determined by Preparing a Prime implicant chart

step 3 - The minterms which are not covered by the essential implicants are taken into consideration and a min cover is obtained from the remaining Prime implicants.

Ex – Find the SOP for the Boolean expression F = Σ (1,2,3,7,8,9,10,11,14,15) using Tabulation Method

Binary representation of Minterms

minterms	Variables			
	A	B	C	D
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
14	1	1	1	0
15	1	1	1	1

Group of minterms for different no of 1's

No. of 1's	Min	Variables			
		A	B	C	D
1	1 ✓	0	0	0	1
	2 ✓	0	0	1	0
	8 ✓	1	0	0	0
2	3 ✓	0	0	1	1
	9 ✓	1	0	0	1
	10 ✓	1	0	1	0
3	7 ✓	0	1	1	1
	11 ✓	1	0	1	1
	14 ✓	1	1	1	0
4	15 ✓	1	1	1	1

2-cell combination Table

combination	A	B	C	D
1,3 ✓	0	0	-	1
1,9 ✓	-	0	0	1
2,3 ✓	0	0	1	-
2,10 ✓	-	0	1	0
8,9 ✓	1	0	0	-
8,10 ✓	1	0	-	0
3,7 ✓	0	-	1	1
3,11 ✓	-	0	1	1
9,11 ✓	1	0	-	1
10,11 ✓	1	0	1	-
10,14 ✓	1	-	1	0
7,15 ✓	-	1	1	1
11,15 ✓	1	-	1	1
14,15 ✓	1	1	1	-

From the 2-cell combination one variable and a- ~~com~~ hee in the same Position can form 4-cell combination

4-cell combination Table

combination	A	B	C	D
1,3,9,11	-	0	-	0
2,3,10,11	-	0	1	-
8,9,10,11	1	0	-	-
3,7,11,15	-	-	1	1
10,11,14,15	1	-	1	-

Ans. Prime Implicant Table

Prime Impli	Minterms 1	2	3	7	8	9	10	11	14	15
1,3,9,11)	X		X			X		X		
2,3,10,11)		X	X				X	X		
8,9,10,11)					X	X	X	X		
3,7,11,15)			X	X				X		X
10,11,14,15)							X	X	X	X
	✓	✓		✓	✓				✓	

The colums having one cross mark the corresponding essential PI. The sum of all PI give the minimal SOP form.

$$F = \overline{B}D + \overline{B}\cdot C + A\overline{B} + CD + AC$$