Gray code

Gray code

- **Gray code or reflected binary code:**
  - It is a type of binary coding system where two successive values differ in only one bit.
  - Example: 7 =$(0111)_2 = (0100)_{Gray}$ and 8 = $(1000)_2$ = $(1100)_{Gray}$
    - 7 and 8 are two successive values
    - Transition from 7 to 8: 0100 to 1100 only one bit changes
    - Transition from 7 to 8 in natural binary requires to change 4 bits

Gray code

- **Gray code or reflected binary code:**
- It is widely used in various applications especially where errors in data transmission can occur, as it minimizes the chance of multiple bit errors.

✓ **Example 1**: Send the sequence 5 → 6 → 7 using Gray code

Decimal	Binary	Gray Code
5	0101	**0111**
6	0110	**0101**
7	0111	**0100**

✓ The transmitter sends the sequence:

- 0111 (Gray code for 5)
- 0101 (Gray code for 6)
- 0100 (Gray code for 7)

Gray code

- **Gray code or reflected binary code:**

Example 1:

- ✓ The receiver receives: 0111 → 0101 → 0100

1. Compare Consecutive Gray Code Values:
   - 0111 → 0101: 1-bit change (Valid).
   - 0101 → 0100: 1-bit change (Valid).
2. Convert Gray Code Back to Binary: If no errors are detected, the receiver converts the Gray code back to binary. 0101 → 0110 → 0111 (5 →6 →7)

Gray code

➢ **Gray code or reflected binary code:**

Example 1: Suppose noise corrupts the second value (0101) into 1101.

✓ The receiver receives: 0111 → 1101 → 0100

1. Compare Consecutive Gray Code Values:

   - 0111 → 1101 : 2-bit change (Invalid, **error detected**).

2. The receiver flags an error, may request retransmission or discard the data.

Decimal	Binary	Gray
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

Two successive values differ in only one bit.

Gray code

➢ **Gray code or reflected binary code:**

Example 2: Gray Code in a Digital State Machine

✓ Design a state machine to represent a 4-state sequential process using Gray code

- State A: 000, State B: 001, State C: 011, D:010

✓ Using Gray code ensures that transitions between states involve only one bit change:

- A → B: Only the last bit changes (000 → 001).
- B → C: Only the second bit changes (001 → 011).
- C → D: Only the third bit changes (011 → 010).
- D → A: Only the second bit changes (010 → 000).

✓ Only One bit changes between states. This avoid errors during state transitions.

Gray code

- **Convert Binary code to Gray Code:**
  - ✓ Let B be a number written in pure natural binary on m bits

$$B_{(2)} = B_m \ldots\ldots B_3 B_2 B_1 B_0; B_m \text{ is the most significant bit (MSB)}$$

  - ✓ G is the Gray code equivalent of the number B also written on m bits

$$G_{(Gray)} = G_m \ldots\ldots G_3 G_2 G_1 G_0$$

Gray code

- **Convert Binary code to Gray Code:**

- ✓ To convert a binary number to Gray code, follow these steps:

1. The first bit of the Gray code is the same as the first bit of the binary number.

$$G_m = B_m$$

2. Each subsequent bit in the Gray code is found by performing an XOR (Exclusively-OR) operation between the current binary bit and the previous binary bit.

If $B_m = B_{m-1}$ then $G_{m-1} = 0$

If $B_m \neq B_{m-1}$ then $G_{m-1} = 1$

Gray code

- **Convert Binary code to Gray Code:**

- **Example**: Convert 0110 (6 in decimal) to Gray code
- B = 0110 = $B_3B_2B_1B_0$

  1. G_3= B_3

  2. The second step :

$$B_3 \neq B_2 \text{ then } G_2 = 1$$

$$B_2 = B_1 \text{ then } G_1 = 0$$

$$B_1 \neq B_0 \text{ then } G_0 = 1$$

- **G= 0101**

Gray code

- **Convert Gray Code to Binary Code:**

  - Let G be a number written in Gray code on m bits

$$G_{(Gray)} = G_m \ldots\ldots G_3 G_2 G_1 G_0,\ G_m \text{ is the most significant bit (MSB)}$$

  - B is the equivalent in pure or natural binary code of the number G, B also written on m bits.

$$B_{(2)} = B_m \ldots\ldots B_3 B_2 B_1 B_0$$

Gray code

- **Convert Gray Code to Binary Code :**

- To convert a binary number to Gray code, follow these steps:

  1. The first bit of the Gray code is the same as the first bit of the binary number.

$$B_m = G_m$$

  2. Now we compare the pairs:

If $G_{m-1} = B_m$ then $B_{m-1} = 0$

If $G_{m-1} \neq B_m$ then $B_{m-1} = 1$

Gray code

- **Convert Gray Code to Binary Code :**

- **Example**: Convert 0100 to Binary code

- G = 0100 =$G_3 G_2 G_1 G_0$

    1. G_3= B_3 $= 0$

    2. The second step :

$G_2 \neq B_3$ then B_2 = 1

$G_1 \neq B_2$ then B_1 = 1

$G_0 \neq B_1$ then B_0 = 1

- **B= 0111**