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Gray Codes, Natural Binary Codes, and Conversions

What is Gray Code?

Gray Code is a form of binary that uses a different method of incrementing from one number to the next. With Gray Code, only one bit changes state from one position to another. This feature allows a system designer to perform some error checking (i.e. if more than one bit changes, the data must be incorrect). Table 1 illustrates the difference between Natural Binary and Gray Code.

Gray Code		Natural Binary	
0000	0	0000	0
0001	1	0001	1
0011	2	0010	2
0010	3	0011	3

Table 1

Why use Gray Code?

Gray Code is the most popular Absolute encoder output type because its use prevents certain data errors that can occur with Natural Binary during state changes. For example, in a highly capacitive circuit (or sluggish system response), a Natural Binary state change from 0011 to 0100 could cause the counter/PLC to see 0111. This sort of error is not possible with Gray Code, so the data is more reliable. In Table 2, note that even from position 7 to 8, Gray Code only changes one bit state.

Gray Code				Position	Binary			
2^3	2^2	2^1	2^0		2^3	2^2	2^1	2^0
0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	1
0	0	1	1	2	0	0	1	0
0	0	1	0	3	0	0	1	1
0	1	1	0	4	0	1	0	0
0	1	1	1	5	0	1	0	1
0	1	0	1	6	0	1	1	0
0	1	0	0	7	0	1	1	1
1	1	0	0	8	1	0	0	0
1	1	0	1	9	1	0	0	1
1	1	1	1	10	1	0	1	0
1	1	1	0	11	1	0	1	1
1	0	1	0	12	1	1	0	0
1	0	1	1	13	1	1	0	1
1	0	0	1	14	1	1	1	0
1	0	0	0	15	1	1	1	1

Table 2

How do I convert the Gray Code to Natural Binary?

On paper, the process is easy:

1) Write the Gray Code and copy the left most bit under itself.
2) Add the copied bit to the next Gray Code bit to the right, drop all carries, and write result next to the copied digit from step 1. Remember, 0+0=0, 0+1=1, 1+0=1, 1+1=0.
3) Repeat step 2 until completed. See Table 3.

1	1	0	1	1	Gray Code
1					Natural Binary
1	1	0	1	1	Gray Code
1	0				Natural Binary
1	1	0	1	1	Gray Code
1	0	0			Natural Binary
1	1	0	1	1	Gray Code
1	0	0	1		Natural Binary
1	1	0	1	1	Gray Code
1	0	0	1	0	Natural Binary

Table 3

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Gray Codes, Natural Binary Codes, and Conversions Cont.

How about using software to convert Gray Code?

Again the process is very straightforward. One way to convert Gray Code to binary is by means of a short software routine, such as the following for a 10-bit encoder:
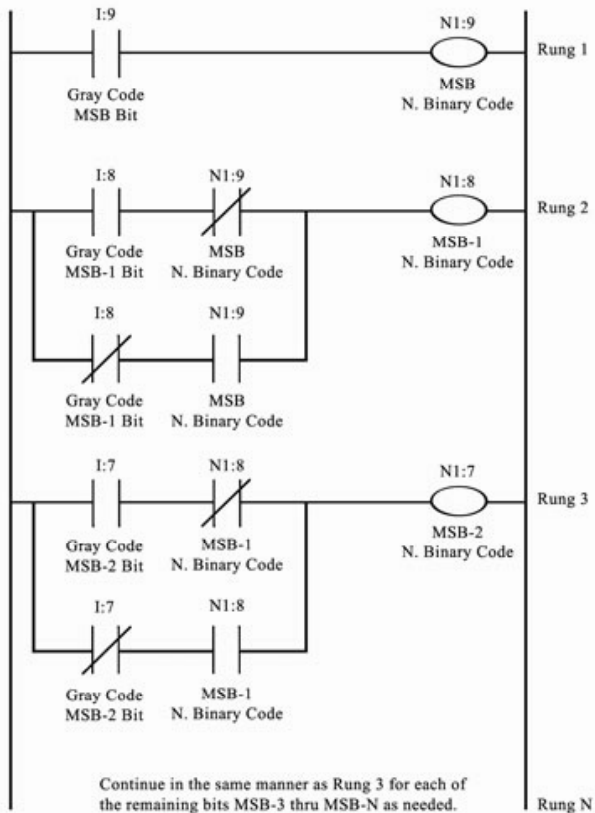
```
BEGIN:
        set B0 through B9 = 1
        B9 = G9
  IF B9 = G8 THEN B8 = 0
  IF B8 = G7 THEN B7 = 0
  IF B7 = G6 THEN B6 = 0
  IF B6 = G5 THEN B5 = 0
  IF B5 = G4 THEN B4 = 0
  IF B4 = G3 THEN B3 = 0
  IF B3 = G2 THEN B2 = 0
  IF B2 = G1 THEN B1 = 0
  IF B1 = G0 THEN B0 = 0
DONE
```

Can I convert Gray Code to Natural Binary in PLC ladder logic?

Sure, and again, it's very simple. Here are the first few rungs starting with the MSB (most significant bit, or left most Gray Code bit shown in the Table 3 on previous page.

Notice that Rungs 2 and 3 are simply exclusive-OR circuits. The outputs of each of these Rungs will make up the Natural Binary code for all N bits. The PLC then converts this code into an integer for use elsewhere in the PLC program.

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