Gray Code Vs Binary

Absolute encoders are available in many output types, a common choice is SSI and BISS, less common now is parallel output, though they have a common theme that the structure of the output is represented in Binary, Gray, or Binary coded Decimal (BCD).

In a base-2 number system, only two digits are used: 0 and 1. For this reason, it is the base of data processing in computing and electronic systems where 0 and 1 can be represented, electronically, as states “off” and “on”.

Binary code represents the information through the base-2 number system. It is very efficient but has a disadvantage from the point of view of the measuring equipment: more than one digit at a time often changes in consecutive positions. Because of the variations caused by gate delays, line impedances, etc. transitions do not occur simultaneously, and this could result in erroneous readings and therefore lead to significant measuring errors.

Consider, for instance, the following sequence: From position 1 to 2 (decimal), the last two digits both change in the binary representation (0 → 1; 1 → 0). The same happens from position 3 to 4, where the last three digits all change (0 → 1; 1 → 0; 1 → 0). During operation, a sensing error of the detection elements could result in a positioning command error. For instance, let’s suppose the following wrong sequence: 0001 → 0011 → 0010 (position 1 → 3 → 2 instead of 1 → 2 → 3).

Decimal	0	1	2	3	4	5	6	7	8	9	10
Binary (4 digits)	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010
Gray (4 Digits)	0000	0001	0011	0010	0110	0111	0101	0100	1100	1101	1111

Figure 1, conversion table

The motion controller would command position 1, then position 3, and then a reverse motion to position 2.

Protections exist in the encoders to prevent such errors and ensure consecutive position values are always transmitted.

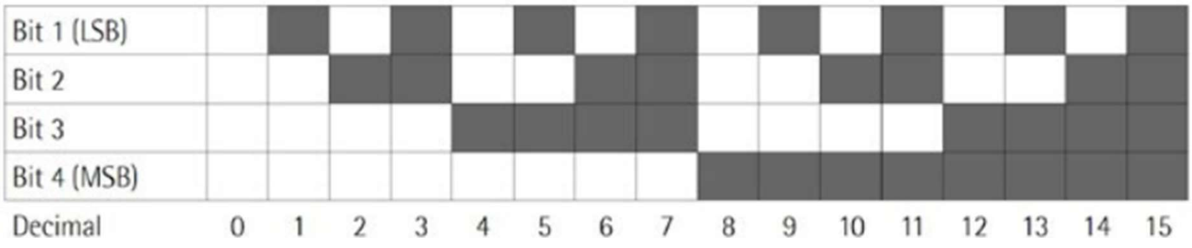

Figure 2. Binary code 4-bit representation (high logic level is represented in black)

Gray code, patented by Bell Laboratories researcher Frank Gray in 1947 (Lucal 1957), and similar to Binary code, represents the information through the base-2 number system; but in Gray Code the binary strings are ordered so that two successive values differ in only one bit (table 3). This property is preserved even at the transition from the last to the first position of the sequence, provided that the number of information (namely, the resolution) is a power of 2 (otherwise, we must exploit the property of the so-called ”Shifted Gray” code or “Gray Excess” code, see the section “Shifted Gray code or Gray Excess code” hereafter).

Gray code is considered a safer method than binary code because any sequence where more than one bit at a time changes can be easily and immediately detected by the control unit. The maximum error is always the value of the LSB.

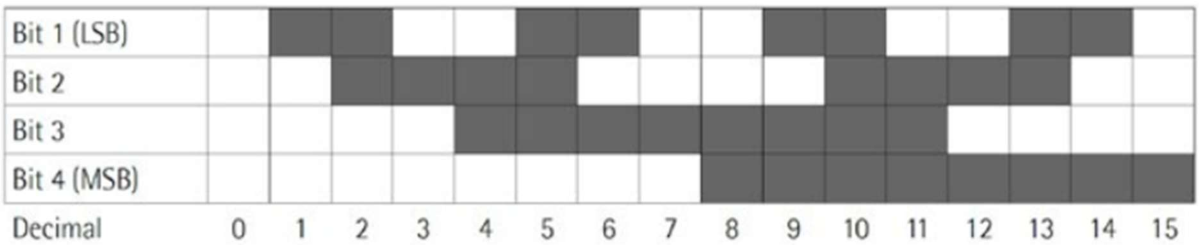

Figure 3. Gray code 4-bit representation (high logic level is represented in black)

BCD code (binary-coded decimal) represents the decimal numbers using for each digit the corresponding 4-bit binary value. This means that only binary numbers from 0 to 9 are used. For instance: decimal number 123 is represented as: 0001 0010 0011 (1111011 in binary code). The main advantage of BCD code is its straight relation with decimal code which allows to easily convert the binary numbers into decimal numbers and vice versa. On the other hand, it requires more memory. BCD code is more and more rarely used, in particular in outdated electronics and spare parts now.

References

Harold M. Lucal. (December 1959). Arithmetic Operations for Digital Computers Using a Modified Reflected Binary Code* *Available at* https://ieeexplore.ieee.org/document/5222057 *Pages 445-458. Accessed 08.04.2024*

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