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Design of Reversible Logic Gates for Digital Applications

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Abstract - **Recent applications of quantum computing is the design and evaluations on the reversible logic technology. The digital systems widely utilize the code conversion technology in enhancing the data security and also minimize the required hardware. This nano-metric technology is high prolific in digital systems as it minimize the power consumption in logic circuits. This paper proposes the reversible logic design for such a code conversion including the binary to gray code, gray to binary code, BCD to excess 3 codes, excess 3 to BCD code.**

Keywords : **Quantum computing, Reversible logic gates, Digital systems**

I. Introduction

The challenging aspect in the modern digital circuit design is the reduction of power consumption. The irreversible hardware computation, regardless of its realization technique, results in energy dissipation due to the information loss [1]. Reversible logic circuits have theoretically zero internal power dissipation because they do not lose information. Bennett in his work showed that in order to avoid the power loss, the energy dissipation in a circuit is built using reversible logic gates [2]. A circuit is reversible if the input vector is recovered in unique fashion from the output vector and there is a one-to-one correspondence between its input and output assignments. In other words the outputs are uniquely determined from the input and also the inputs are recovered from the outputs [4-8]. This paper presents design of reversible code converters that includes the reversible binary to gray code converter, reversible gray to binary converter, reversible BCD to excess 3 code converter, reversible excess3 to BCD code converter.

II. Design of Reversible Logic Circuit

Reversible logic has received significant attention in recent years including applications in various research areas such as low power CMOS design, optical computing, quantum computing, bioinformatics, thermodynamic technology, DNA computing and nanotechnology. It is not possible to construct quantum circuits without reversible logic gates. Synthesis of reversible logic circuits is significantly more complicated than traditional irreversible logic circuits because in a reversible logic circuit the use fan-out and feedback is not allowed [4]. The performance of the reversible circuit is determined by the number of unused outputs present in the reversible logic circuit, the total number of reversible logic gates used, the maximum number of unit delay gates in the path of propagation and the number of input in order to get the required function.

Consider an (m X m) reversible represented as IV=(A,B,C,....) OV = (P,Q,R,....) where IV and OV are input and output vectors respectively. The different types reversible logic gates available are as shown in Table 1. The design of the reversible logic circuit is quite challenging with the usage on the number of gates in the design. The building blocks are to be reversible, making it essential the the design of the reversible code converters. In the digital domain, data or information is represented by a combination of 0's and 1's. A code is basically the pattern of these 0's and 1's that are used to represent the data. Code converters are a class of combinational digital circuits that are usedfoir the conversion of a particular type of code in to another type. Some of the most prominently used codes in digital systems are the binary sequence, the Binary Coded Decimal

(BCD), the excess-3 code, the gray code, ASCII code etc. Like any combinational digital circuit, a code converter isimplemented with the use of a circuitry of AND, OR and NOT gates [9-14]. Conversion of code between binary to gray and BCD to excess-3, reversible binary to gray and gray to binary code converter is presented in the following section.

III. Design Of Building Block

A. Binary to Gray Code Converters

Binary to Gray code converters used to reduce switching activity by achieving single bit transition between logical sequences. If Input vector is I(D,C,B,A) then the output vector O(Z,Y,X,W). The circuit is constructed with the help of Feynman Gate (FG) gate [7] and the functional truth table is shown in Table II. Figure 1 and Figure 2 shows the circuit diagram of reversible binary to gray code converter and gray to binary code converter respectively.

Table I Existing Reversible Logic Gates

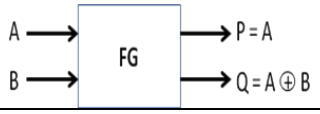
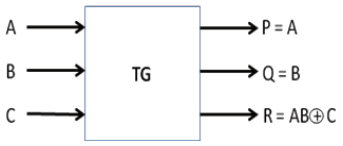
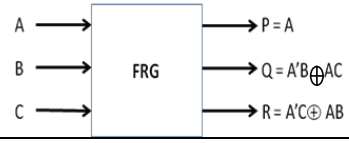
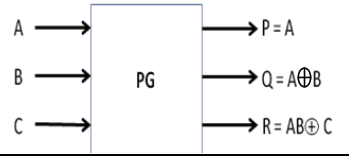
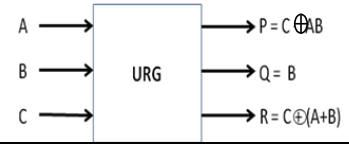
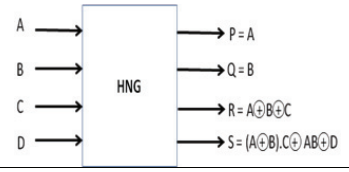
Type	Schematic Representation	Inputs	Outputs
Feynman gate		A,B	P , Q P = A; Q = A⊕ B
Toffoli gate		A,B,C	P ,Q , R P = A; Q = B; R = AB ⊕ C
Fredkin gate		A,B,C	P ,Q , R P = A; Q = A'B ⊕ AC R = A'C ⊕ AB
Peres gate		A,B,C	P ,Q , R P = A; Q = A ⊕B; R = AB ⊕ C
URG gate		A,B,C	P ,Q , R P = C ⊕ AB Q = B; R =C ⊕(A+B)
HNG gate		A,B,C,D	P,Q,R,S P = A; Q = B; R = A⊕B⊕C S = (A⊕ B)C⊕AB⊕ D

Table II Truth table of FG gate

A	B	P	Q
0	0	0	0
0	1	0	1
1	0	1	1
1	1	1	0

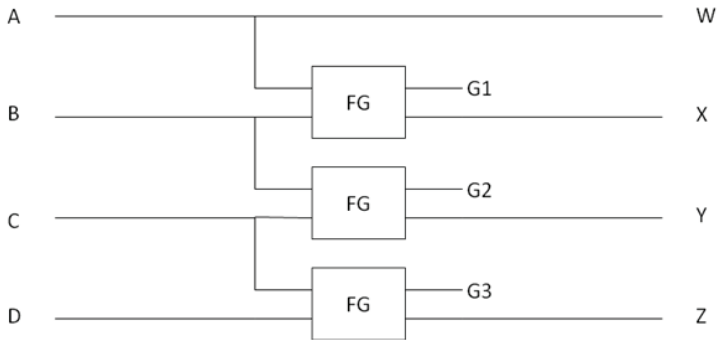


Fig.1 Circuit diagram of Reversible Binary to Gray Code Converter

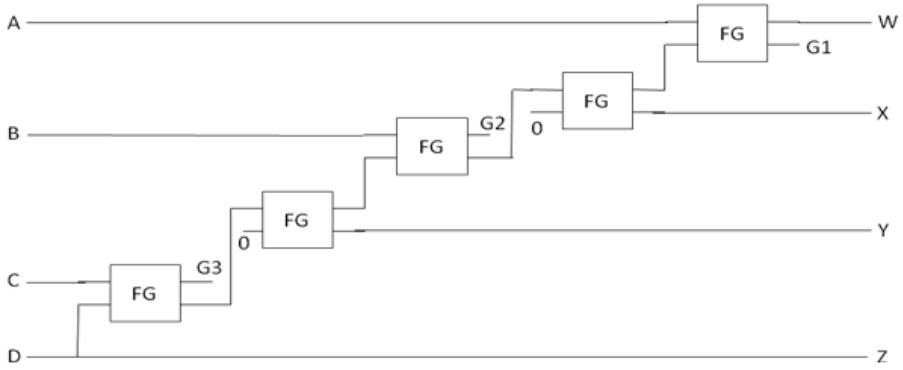


Fig.2 Circuit diagram of Reversible Gray to Binary Code Converter

Table III Truth Table of URG Gate

A	B	C	P	Q	R
0	0	0	0	0	0
0	0	1	1	0	1
0	1	0	0	1	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	1	1	1
1	1	1	0	1	0

B. Reversible BCD to Excess-3 code and Excess-3 to BCD code converter

The BCD to excess-3 code converter used in arithmetic circuits is to reduce the hardware complexity. The circuit is constructed with the help of two reversible gates Feynman Gate (FG) and Universal Reversible Gate (URG) [9] with the functional truth table of URG as in Table III. The circuit configuration of the reversible BCD to excess-3 and excess-3 to BCD are shown in Figure 3 and Figure 4 respectively. The proposed reversible code converter is better efficient than the conventional code converters.

Evaluation of the proposed circuit is compared and evaluated as in Table IV. The representation of logical function are namely a = XOR logic; b = buffer; c = NOT logic; d = OR logic; e = AND logic. For example if

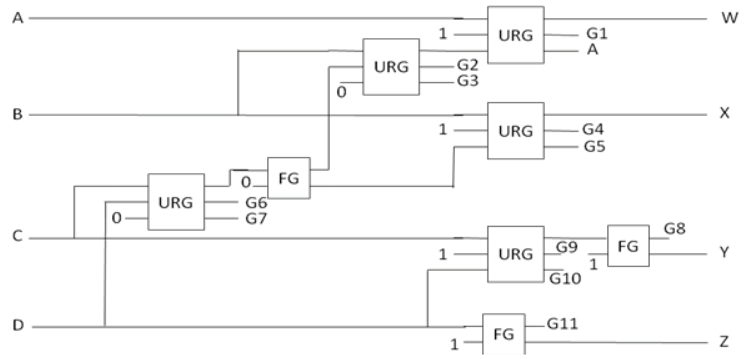


Fig. 3 Circuit diagram of Reversible BCD to Excess-3 code converter

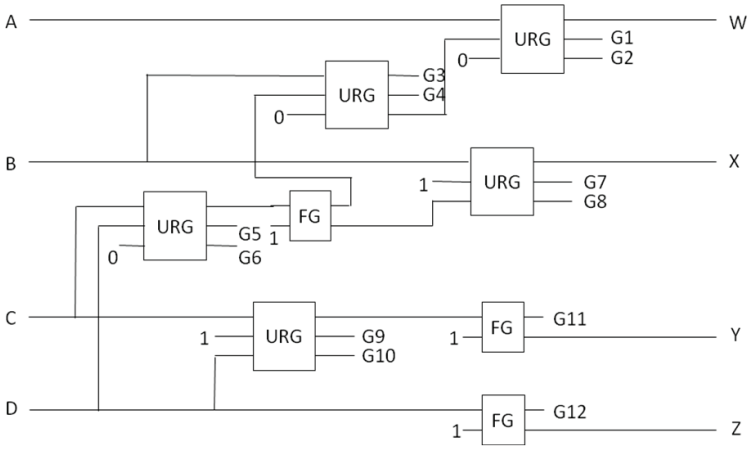


Fig. 4.Circuit diagram of Reversible Excess-3 to BCD code converter

Table IV Comparative Result of Different Reversible Logic Circuits

Reversible Code Converters	Number of Gate Numbers	Number of Garbage	Number of Constants	Total logical Calculation
Binary to Gray	3	3	0	3a
Gray to Binary	5	3	2	3a+2b
BCD to Excess-3	8	12	8	3a+1b+2c+1d+1e
Excess-3 to BCD	8	12	8	2a+3c+1d+2e

T = (2a+3d) then the circuit involves two numbers of XOR logical operation and three numbers of OR logical operations.

IV. Conclusions

This paper has introduced and proposed reversible logic gates and reversible circuits for realizing different code converters like BCD to Excess-3, Excess-3 to BCD, Binary to Gray and Gray to Binary using reversible logic gates. The proposed design leads to the reduction of power consumption compared with conventional logic circuits, the design proposed is implemented with FG and URG gates only in near future with the invent of new RLG the power consumption may reduced to little more greater extent, not only that there will be a chance of implementing different logic circuits using reversible logic gates and which intern helps to increase the energy efficiency to a greater extent.

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