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Design of N- Bit Gray Counter Using Verilog

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***Abstract*— Gray counters hold a pivotal role in various technological domains, including digital signal processing, telecommunications, and control systems. The primary objectives of this paper encompass a thorough exploration of Gray code theory, the logical design of an N-bit Gray counter, and its practical realization using digital logic gates. The initial phase involves an extensive study of Gray code, elucidating its significance in mitigating glitches and easing transitions within digital systems. Subsequently, the paper outlines the step-by- step process of designing an N-bit Gray counter, from the development of a comprehensive truth table to the synthesis of logical equations through Karnaugh mapping. The "Design N-Bit Gray Counter" provides a comprehensive understanding of Gray counters, from theory to practical implementation, emphasizing their applications in digital systems. Finally, design can be synthesized and implemented using Verilog with the help of Xilinx Vivado Software.**

***Key Words* — Gray Counter, Xilinx Vivado, Verilog.**

I. Introduction

The heart of this paper lies in the development of an N-bit Gray counter—a counter that utilizes Gray code as its counting sequence rather than conventional binary code. Gray counters find applications in numerous fields, ranging from digital signal processing and telecommunications to robotics and error detection systems. The primary objective here is to harness VLSI techniques to design, simulate, and eventually fabricate an N-bit Gray counter circuit.

What we now call "Gray code" was invented by Frank Gray. It was described in a patent that was awarded in 1953, however, the work was performed much earlier, the patent being applied for in 1947. Gray was a researcher at Bell Telephone Laboratories; during the 1930s and 1940s he was awarded numerous patents for work related to television1. According to Heath [Hea72] the code was first, in fact, used by Baudot for telegraphy in the 1870s, though it is only since the advent of computers that the code has become widely known.

The term "Gray code" is sometimes used to refer to any single-distance code, that is, one in which adjacent code words (perhaps representing integers differing by 1) differ by 1 in one-digit position only. Gray introduced what we would now call the canonical binary single-distance code, though he mentioned that other binary single-distance codes could be obtained by permuting the columns and rotating the rows of the code table. The codes of Gray, and natural extensions to bases other than binary, are only a very small subset of all single-distance codes. In this report we will use the term "the Gray code" to refer to the code of Gray and "single- distance" to refer to the more general case; we will be concerned mainly with properties of the Gray code. In this Paper initially we will simulate the design using Verilog and after that we will synthesis the design.

II. Literature Survey

[Bar81] Barr, K. G.: "A decimal Gray code"; Wireless World, Vol. 87, No. 1542, pp. 86-87, March 1981.

The algorithms and circuits involving Gray-codes are of particular interest because they are so simple and surprising. The simple Gray code offers a dense counting sequence that is not very useful for humans but has the potential of being more "natural" for machines.

However, when it comes to practical and long-lasting use of the codes it does turn out Gray code does not offer significant advantage over conventional representation. Indeed, Gray encoding usually gives rise to more complexity. Be that as it may, Gray code continues to turn up in diverse areas, some of which are listed in the bibliography that follow.

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Carla Savage, ' A surve y of combinatorial Gray codes,'-SIAM Rev., Vol. 39, No.4, pp 605-629, D ecember 1997.

The term combinatorial Gray code was introduced in 1980 to refer to any method for generating combinatorial objects so that successive objects differ in some prespecified, small way. This notion generalizes the classical binary reflected Gray code scheme for listing n -bit binary numbers so that successive numbers differ in exactly one bit position as well as work in the 1960s and 1970s on minimal change listings for other combinatorial families including permutations and combinations The area of combinatorial Gray codes was popularized by Herbert Wilf in his invited address at the SIAM Conference on Discrete Mathematics in 1988 and his subsequent SIAM monograph Combinatorial Algorithms: An Update , 1989 in which he posed some open problems and variations on the theme. This resulted in much recent activity in the area, and most of the problems posed by Wilf are now solved. In this paper, we survey the area of combinatorial Gray codes, describe recent results, variations, and trends. and highlight some open problems.

Alan, A., Bertossi, Alessandro, Mei., 2004, "Time and Work Optimal Simulation of Basic Reconfigurable Meshes on Hypercubes," J. of Parallel and Distributed Computing, Vol. 64(1), pp.173 - 180.

This paper presents a constant slow-down, optimal and locally normal simulation for basic reconfigurable meshes on hypercubes, if the log-time delay model for broadcasting is assumed. Such a simulation algorithm is based on: (i) an O(log B) time algorithm for the segmented scan problem on a (2n−1)-node toroidal X tree,where B is the size of the longest segment; this algorithm is time optimal; (ii) a constant slow-down optimal and locally normal simulation algorithm for basic reconfigurable meshes on the mesh of toroidal X-trees; and (iii) a constant slow- down optimal simulation of locally normal algorithms for meshes of toroidal X- trees on the hypercube.

III. METHODOLOGY AND IMPLEMENTATION

Block Diagram

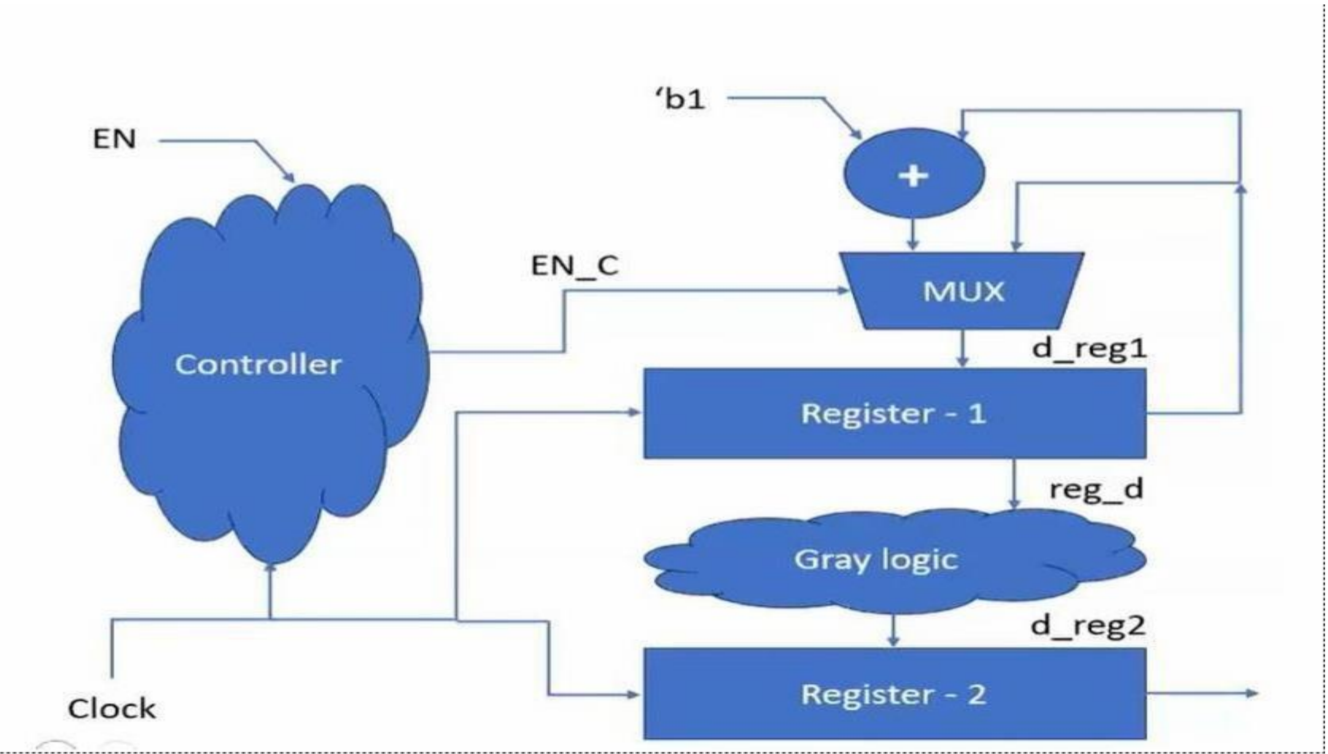

Fig 1: Block Diagram of Proposed System

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The N-bit Gray counter block diagram comprises essential components for precise counting in Gray code. Central to its operation is the N-bit Gray Code Generation Logic, which determines the next Gray code value based on the current one, minimizing bit transitions. The N-bit Register stores the Gray code as the current count, with each flip-flop representing a bit. A Clock Input synchronizes the counter, Control Inputs offer versatility, and Output Signals convey the Gray code count and related information. Timing and Control Logic ensure synchronization, and Optional Outputs may serve specific purposes. Together, these components create a circuit that counts accurately in Gray code with controlled transitions.

Functional Flow

1. **Controller:**

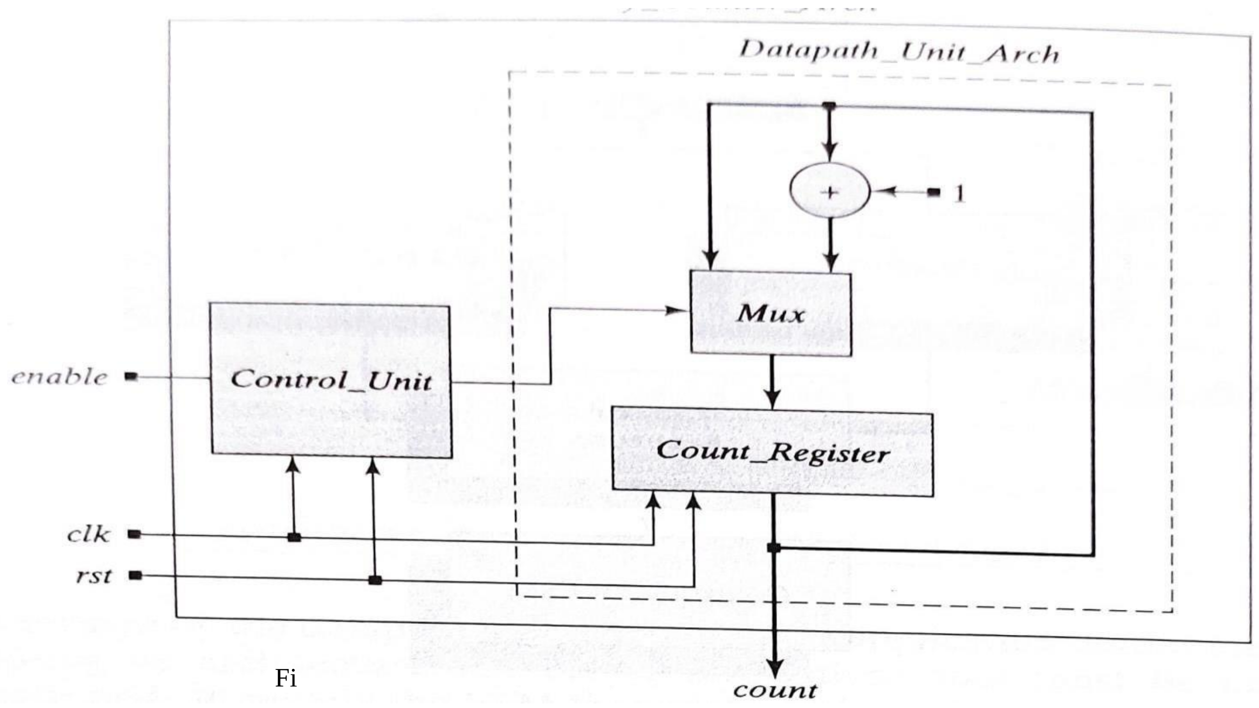

Fig 2: Controller

In the specific design of an N-bit Gray code counter, a dedicated controller is typically not a standard component because Gray code counters are relatively straightforward sequential circuits. Instead, the focus is primarily on designing the counter itself. The primary components of this counter include N flip-flops, which represent the state of the counter, following the Gray code sequence, and combinatorial logic to compute the next state based on the current state. The objective is to ensure that only one bit changes at a time to maintain the Gray code sequence, which simplifies the design compared to more complex counter types.

Additionally, output logic is implemented to generate the N-bit Gray code output corresponding to the current state. While controllers are often used in more complex digital systems to manage various functions and processes, Gray code counters are relatively self-contained and rely on sequential logic, making them more straightforward in terms of design and implementation.

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2. Data Path:

The data path plays a pivotal role in ensuring the counter operates correctly by processing data and making it available for further computation or output. For an N-bit Gray code counter, the data path consists of N flip-flops, each representing a bit of the counter's state. These flip-flops store and update the Gray code values as the counter counts up or down. Additionally, an N-bit adder may be included to increment or decrement the counter's value, ensuring it adheres to the Gray code sequence.

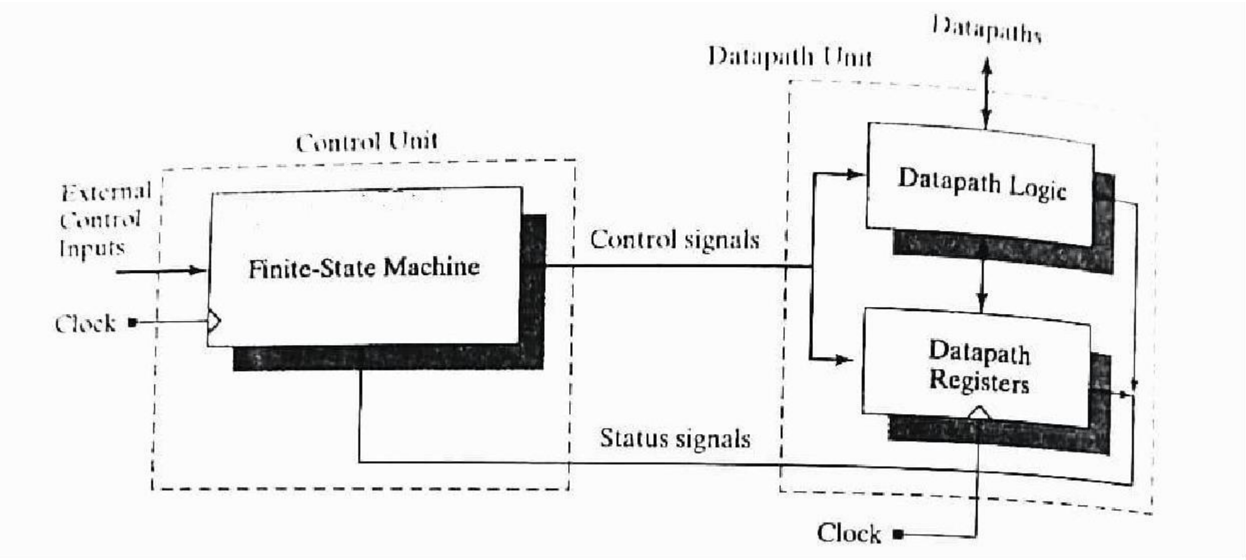

Fig 3: Data Path

A proposed solution for N-bit Gray code counters involves customizable, parameterized designs that allow for efficient power management and advanced features. Implementing a modular approach with configurable options enables adaptability to various applications and simplifies integration. Additionally, utilizing modern synthesis tools and design methodologies can optimize performance while meeting specific design constraints, enhancing versatility and scalability.

IV. IMPLEMENTATION RESULTS

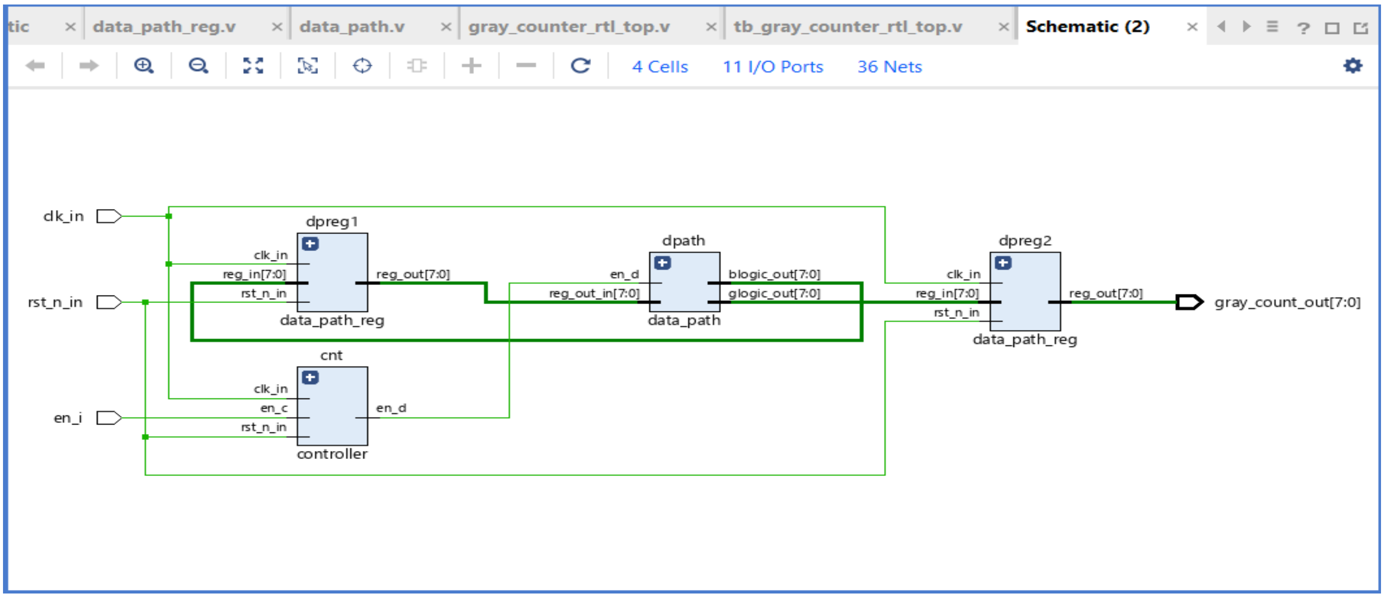

Fig 4: RTL SCHEMATIC OF N-BIT GRAY COUNTER

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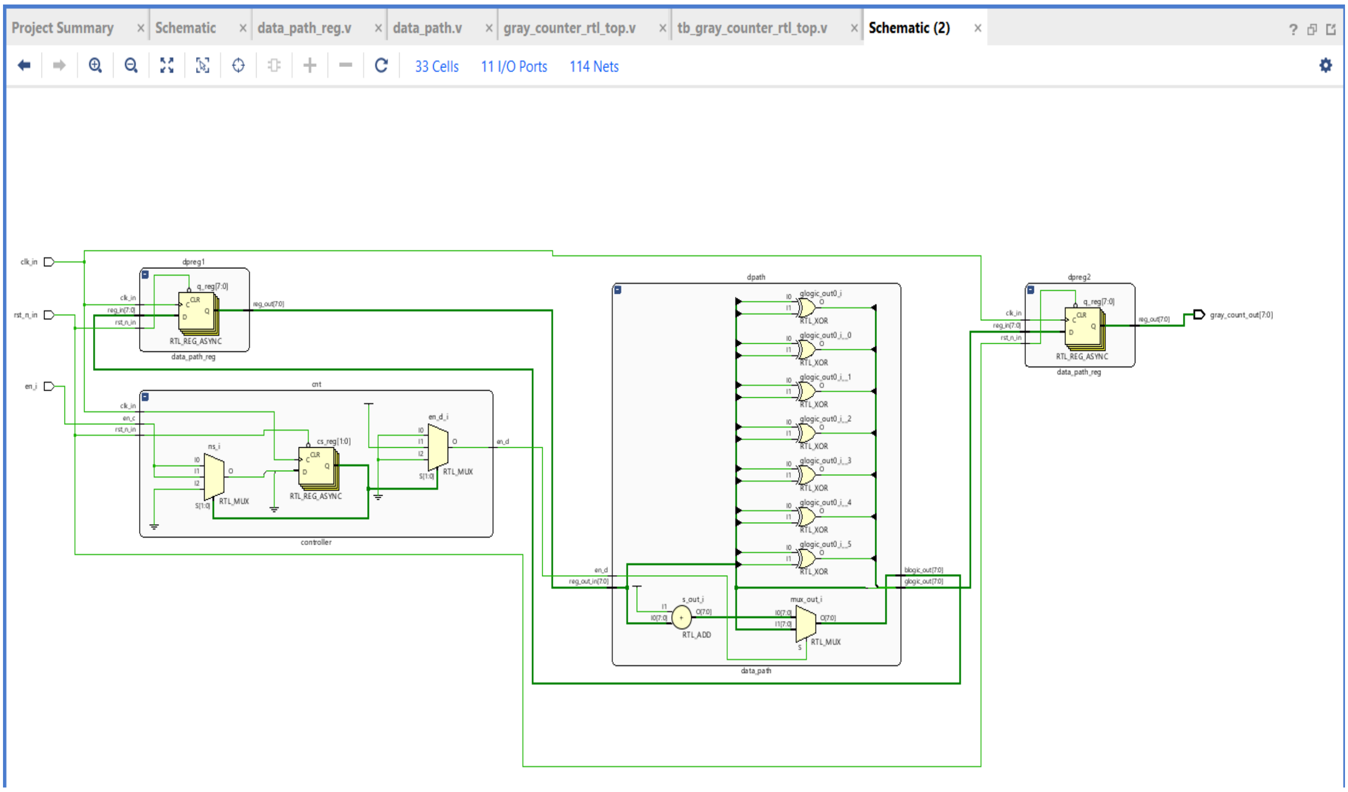

Fig 5: Gate Level Netlist of N- bit Gray Code Counter

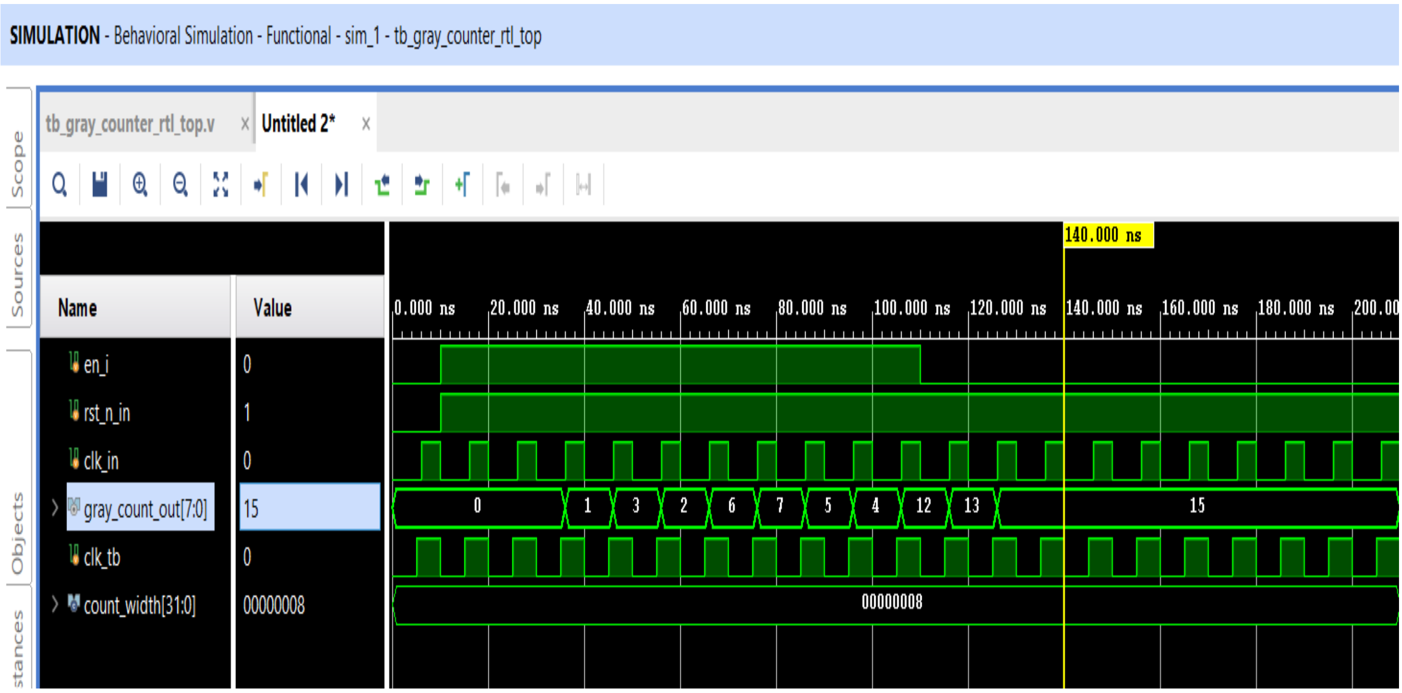

Fig 6: Simulation Result of N- bit Gray Code Counter

V. CONCLUSION & FUTURE SCOPE

It involves arranging n flip-flops in a cascade and utilizing XOR gates to compute the inputs for each flip-flop. The resulting counter produces a Gray code sequence, where adjacent values differ by only one bit, making it valuable for applications requiring minimal transition errors. A well-executed design ensures precise counting and is a crucial component in various digital systems, contributing to error detection, rotary encoders, and other applications where Gray code is advantageous. Careful consideration of timing, logic, and connections is essential to create a reliable n-bit Gray counter.

The future scope for n-bit Gray counters is promising, with applications spanning a wide range of technological fields. These counters are poised to play a pivotal role in communication systems by aiding in error detection and correction during data transmission. They are also set to advance digital signal processing, particularly in image and audio processing, as well as in cryptography, where Gray counters can contribute to efficient signal manipulation. In the realm of robotics and automation, Gray counters will continue to be instrumental in achieving precise position sensing, motion control, and encoder feedback, enhancing the capabilities of robots and autonomous systems.

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