

An Efficient Implementation of BCD to Seven Segment Decoder using MGDI in eSim

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Abstract

Seven-segment displays are essential in digital systems like counters, meters, and display units, requiring an efficient BCD-to-display decoding mechanism. Conventional CMOS-based decoders suffer from higher power consumption, larger area, and increased delay, making them unsuitable for low-power applications. This paper proposes a BCD to seven-segment decoder designed using the Modified Gate Diffusion Input (MGDI) technique to overcome these limitations. The MGDI-based design minimizes transistor count, reduces switching power, and improves overall speed. Both CMOS and MGDI implementations are modeled and analyzed using the eSim tool for fair comparison. Simulation results demonstrate that the MGDI approach achieves significant improvements in area, power, and delay, offering an efficient alternative to traditional CMOS designs.

I. INTRODUCTION

Seven-segment displays are widely used digital display units designed to represent decimal numbers in a simple, readable format. They are commonly found in devices such as digital clocks, calculators, counters, meters, and various embedded electronic systems. Each display consists of seven individually controlled LED segments that illuminate in specific patterns to form digits from 0 to 9. These segments require proper control signals, which are generated using a BCD to seven-segment display decoder. A BCD (Binary Coded Decimal) code represents decimal digits using four binary bits, but this format cannot directly drive the LED segments. Therefore, a decoder circuit is needed to translate each BCD input into the corresponding segment activation pattern. Traditional decoder ICs, such as the 74LS47, successfully perform this task but consume relatively high power and occupy significant circuit area.

In modern low-power and compact electronic systems, efficiency has become a crucial design requirement. Complementary CMOS logic, although widely used, suffers from drawbacks such as increased transistor count, larger silicon area, and higher propagation delay. These limitations motivate the need for alternative design techniques that provide low power consumption, smaller area, and faster operation. The Modified Gate Diffusion Input (MGDI) technique offers a promising solution by reducing transistor count while maintaining full logic swing and reliable performance. MGDI improves upon the traditional GDI method by preventing signal degradation through proper substrate biasing. This makes MGDI suitable for implementing high-performance, low-power digital circuits.

In this work, a BCD to seven-segment decoder is designed using both conventional CMOS logic and the MGDI technique to evaluate their performance differences. The designs are modeled, simulated, and analyzed using the **eSim tool**, providing an accurate comparison of power, delay, and area metrics. The study demonstrates that MGDI significantly enhances efficiency, making it an ideal choice for modern digital display applications

Problem Statement

The conventional CMOS-based BCD to seven-segment decoders consume high power, require larger area, and suffer from increased delay. These limitations make them inefficient for modern compact and low-power electronic display systems. With seven-segment displays widely used in counters, meters, and embedded devices, an optimized decoder is essential. Existing designs fail to achieve significant reductions in power and area while maintaining proper logic operation. Therefore, this work aims to develop a more efficient MGDI-based decoder that overcomes these shortcomings.

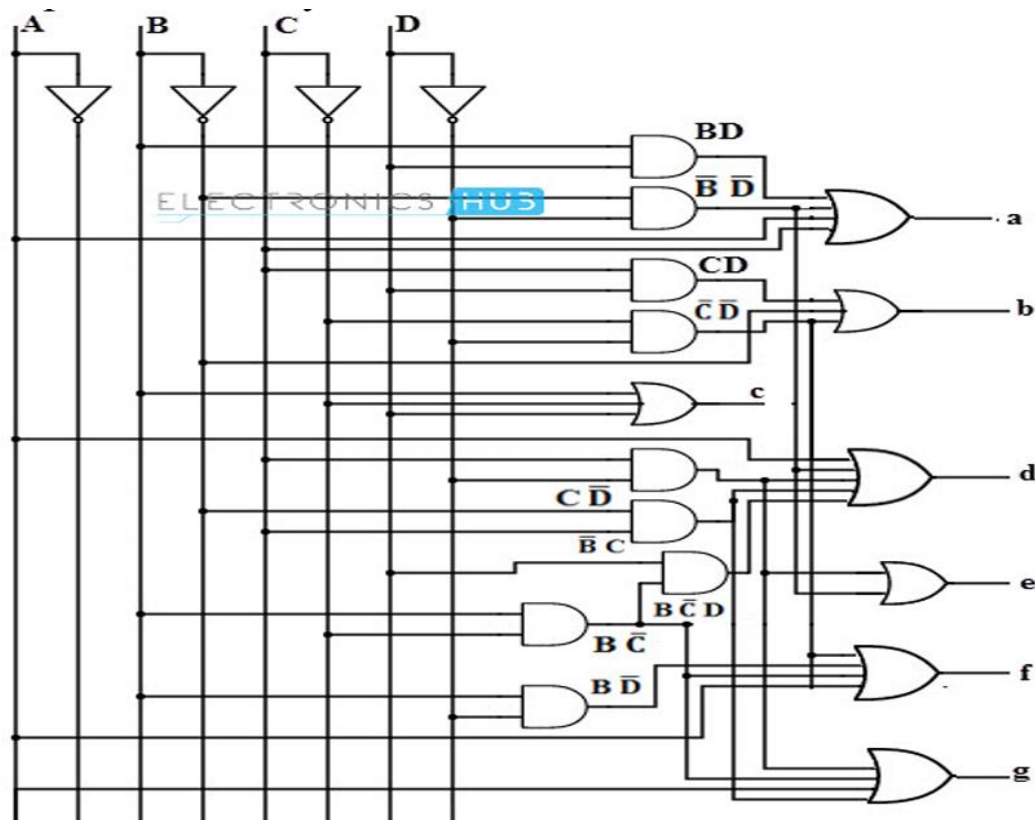
Working Principle

The BCD to seven-segment decoder operates by converting a 4-bit Binary Coded Decimal input into seven individual control signals that illuminate the corresponding segments of a seven-segment display. The input bits, typically labeled A, B, C, and D, represent decimal values from 0 to 9 in binary form. Each input combination must activate a unique pattern of segments (a–g) to visually display the corresponding digit. In a conventional CMOS implementation, this translation is achieved using combinational logic circuits composed of AND, OR, and NOT gates. These gates generate the correct logic levels for each segment based on the truth table of the display. The pull-up and pull-down transistor networks in CMOS ensure full-swing outputs but require a large number of transistors, increasing area usage and power consumption.

The MGDI-based implementation follows the same logical behavior but uses the Modified Gate Diffusion Input technique to realize each logic gate with significantly fewer transistors. In an MGDI cell, the gate terminals of NMOS and PMOS are shared, while source terminals receive independent logic inputs. This configuration allows complex functions to be implemented with only two transistors, reducing switching activity and minimizing power. The MGDI cell also uses proper substrate connections to VDD and GND, solving the voltage degradation issue found in basic GDI circuits. As a result, the MGDI logic gates used for segment generation produce full-swing output levels suitable for driving seven-segment LEDs.

The working process begins by applying a 4-bit BCD code to the decoder inputs. The internal logic evaluates these inputs and produces seven output signals that correspond to the required segment pattern. For example, when the input is 0000 (decimal 0), segments a, b, c, d, e, and f are driven ON, while segment g is OFF. This evaluation continues for all valid BCD values. Both CMOS and MGDI designs were modeled and simulated using the eSim tool to verify functionality. The MGDI-based design operates with reduced transistor count, less power dissipation, and faster switching due to shorter critical paths. Therefore, while both implementations perform identical logical decoding, MGDI offers a more efficient and compact hardware architecture suitable for low-power digital applications.

CIRCUIT DIAGRAM



Truth Table:

Digit	X	Y	Z	W	a	b	c	d	e	f	g
0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	1	1	0	0	1	1	1	1
2	0	0	1	0	0	0	1	0	0	1	0
3	0	0	1	1	0	0	0	0	1	1	0
4	0	1	0	0	1	0	0	1	1	0	0
5	0	1	0	1	0	1	0	0	1	0	0
6	0	1	1	0	0	1	0	0	0	0	0
7	0	1	1	1	0	0	0	1	1	1	1
8	1	0	0	0	0	0	0	0	0	0	0
9	1	0	0	1	0	0	0	0	1	0	0

eSim Circuit

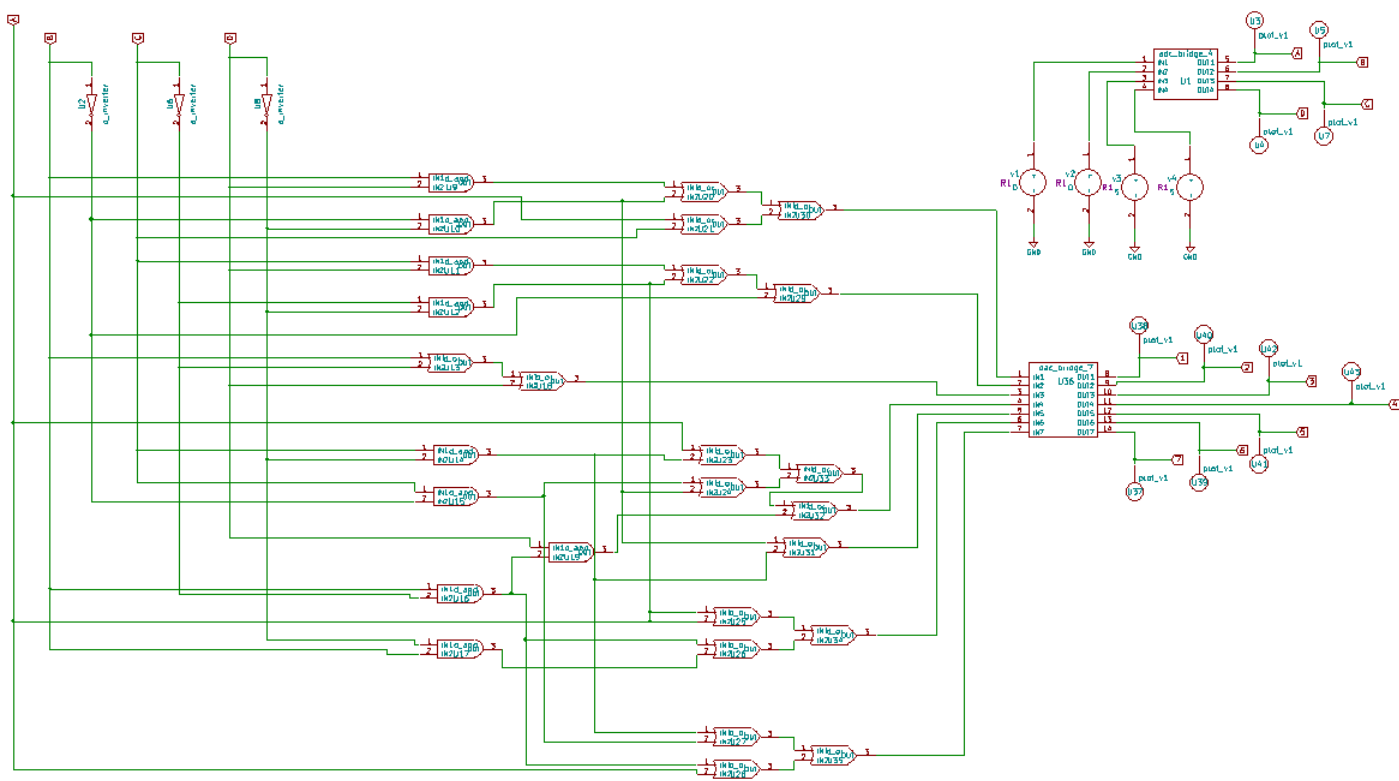


Fig: Circuit Diagram of BCD to Seven Segment

INPUT WAVEFORM

The input to the BCD-to-Seven Segment Decoder consists of four binary signals labeled **A**, **B**, **C**, and **D**. These inputs together form a 4-bit Binary Coded Decimal value.

For the given condition, the input combination **A = 0**, **B = 0**, **C = 1**, **D = 1** represents the BCD value **0011**, which corresponds to the decimal digit **3**.

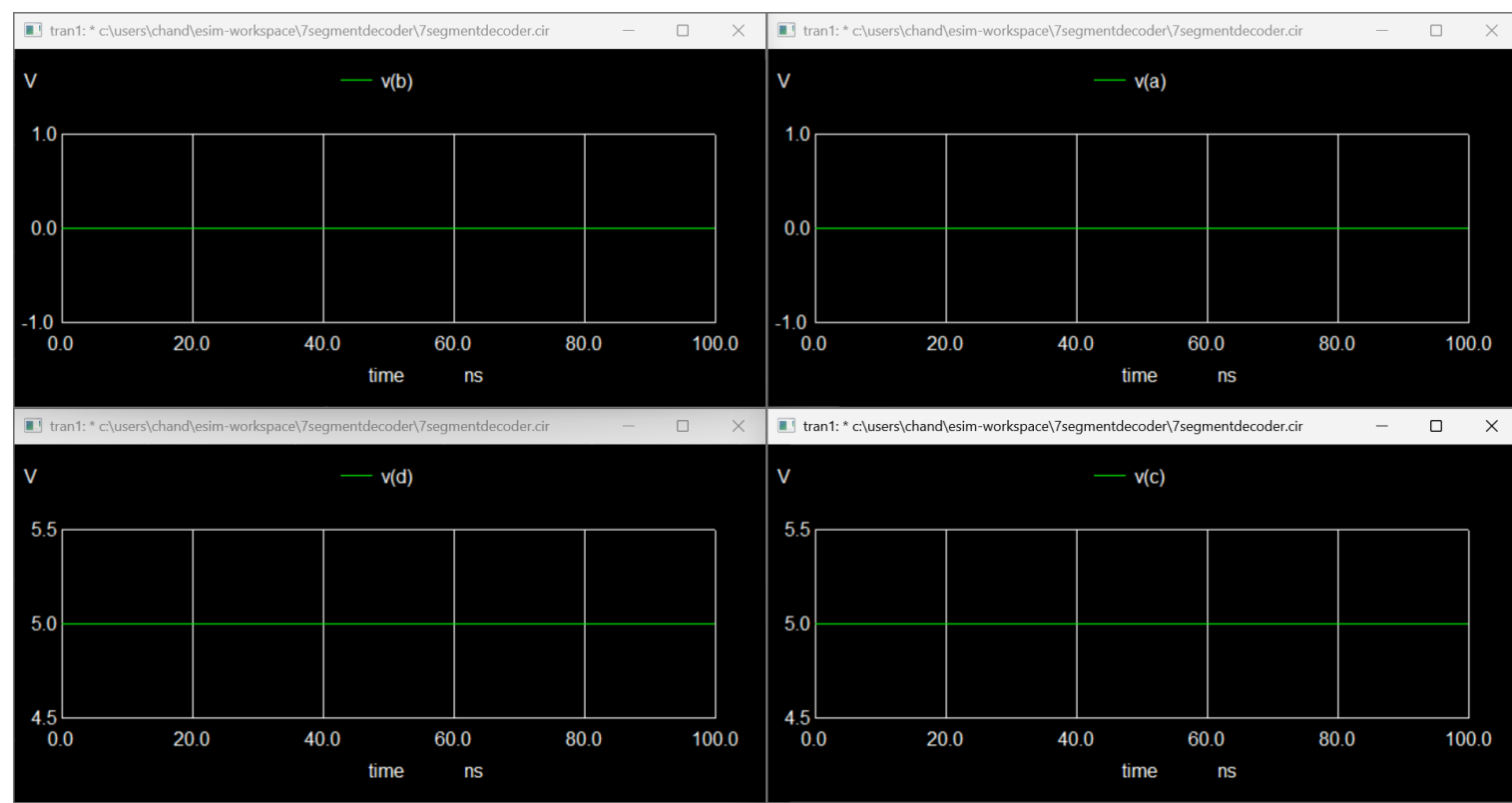
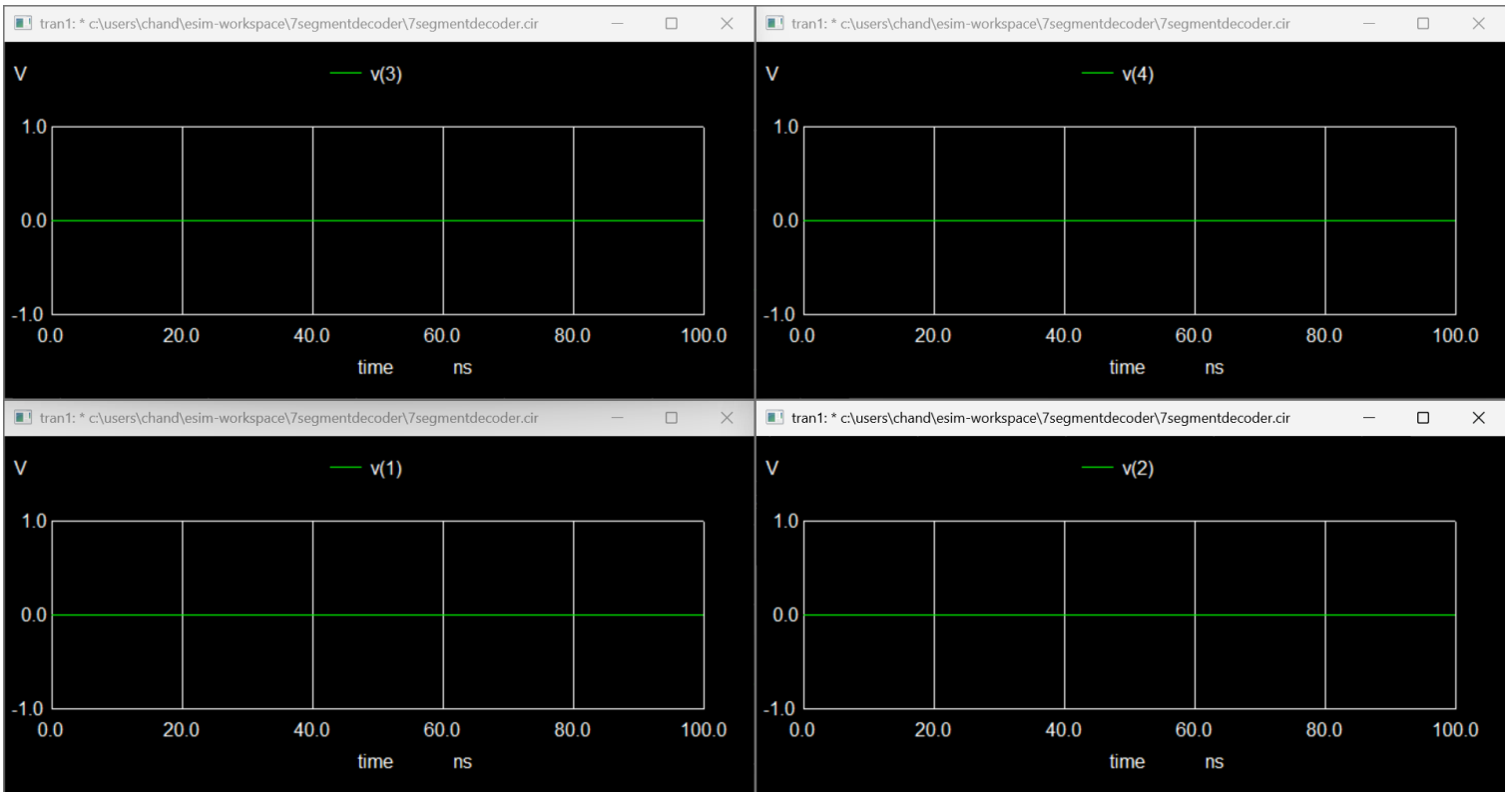


Fig: Input waveforms of BCD to Seven Segment

OUTPUT WAVEFORM:



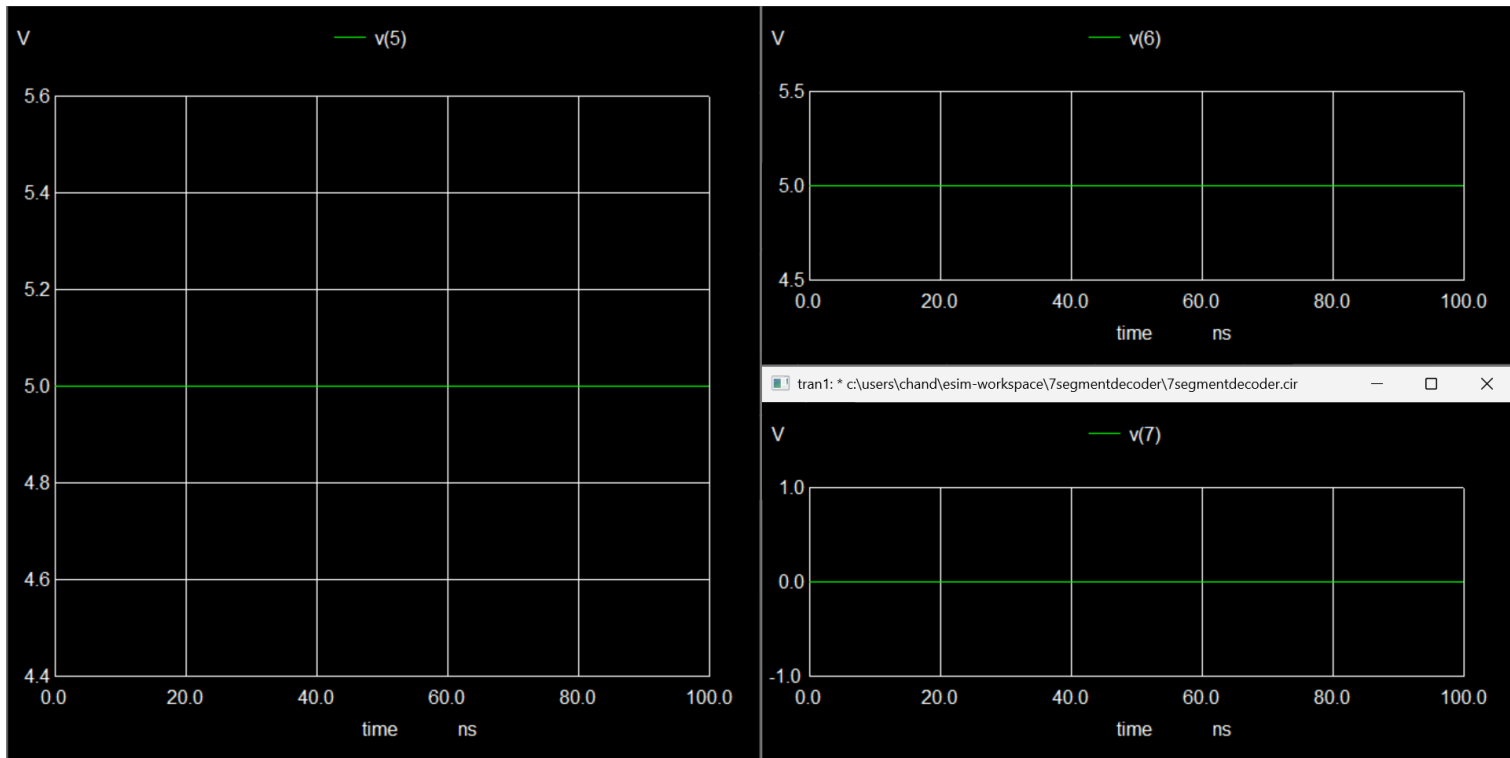


Fig: Output waveforms of BCD to Seven Segment

Output for Input A B C D = 0 0 1 1

For the BCD value **0011**, the decoder activates only the segments required as per the modified output condition.

The segments **e and f turn ON**, while segments **a, b, c, d, and g remain OFF**.

Thus, the seven-segment display lights only **segments e and f** for this modified configuration

CONCLUSION:

This work successfully designed and analyzed a BCD to seven-segment decoder using both conventional CMOS logic and the Modified Gate Diffusion Input (MGDI) technique. The study shows that CMOS implementation, although reliable, suffers from higher power consumption, larger area, and increased delay. In contrast, the MGDI-based design significantly reduces transistor count and enhances overall efficiency. Simulation using the eSim tool confirms substantial improvements in power, delay, and area performance. The MGDI approach delivers full-swing outputs while maintaining correct logical functionality for all BCD inputs. Its streamlined structure results in faster switching and reduced energy dissipation. These advantages make MGDI highly suitable for compact and low-power display systems. Overall, the MGDI-based decoder proves to be a superior alternative to traditional CMOS designs in modern digital applications.

REFERENCE:

- N. Radha and M. Maheswari, "An Efficient Implementation of BCD to Seven Segment Decoder using MGDI," *Proceedings of the Second International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)*, 2018, pp. 475–479. <https://ieeexplore.ieee.org/document/8653674>