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# Design and Implementation of Code Converters using Memristor

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***ABSTRACT***
**This paper explores the utilization of memristor in digital circuits in replacement of general CMOS circuits. The basic idea is to improve the performance parameters of the circuit that include transistor count, power dissipation properties. In CMOS circuit presence of both NMOS and PMOS lead to increase in transistor count which indeed increases area. Thus, using a load along with NMOS circuit reduces the problem. In comparison memristor as load works efficiently as compared with resistor as load. Use of memristor lead to increase in density of transistors which may arise the drawback of increase in power dissipation. To overcome this issue, we adjust the values of Rin, Roff, Rinit of the memristor. This report discusses the simulation of code converters (Binary to gray, gray to binary, BCD to Excess-3, Excess-3 to BCD) using memristor. As code converters provide may applications including error correction in digital applications, protecting private information from spies it is considered for our analysis. We are using LT Spice software to perform the analysis. The performance parameters include power dissipation and transistor count in the circuit.**
***Keywords*: Code converters, CMOS, Memristors, Binary-Coded Decimal, Excess-3 code.**

## I.INTRODUCTION

Memristors are a relatively new type of circuit element that exhibit a property called memristance. [1] Memristors demonstrate a variety of unique properties that set them apart from standard passive circuit elements. The most notable of these is their non-volatile nature, which allows them to maintain resistance states even when powered off, making them excellent for long-term data storage. Memristors may also dynamically modify resistance dependent on the charge going through them, making them useful as programmable resistors in applications such as adaptive systems. Another important characteristic is their memory functionality, which allows them to store data in a non-volatile state, similar to resistive random-access memory (ReRAM)[2].

Furthermore, memristors run at low power levels, making them energy efficient, which is important for power-sensitive applications such as portable devices and IoT sensors. Furthermore, their high switching speeds allow for faster data processing and access, which improves memory and computer system performance. Memristors scalability allows them to be densely integrated, resulting in enhanced storage capacity and computing power in small designs[3].

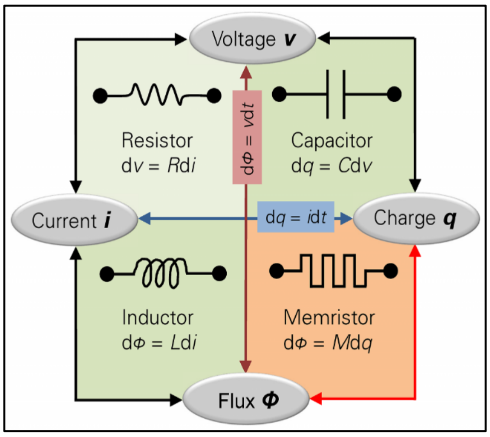


Fig. 1. Relation between passive devices

One potential application of memristors is as a load for CMOS circuits. In a typical CMOS circuit, the output stage is often composed of an inverter with a resistive load. This resistor sets the output voltage swing of the inverter and helps to determine its noise margins [4].
Replacing the resistive load with a memristor could offer several potential benefits. For example, the memristor's resistance could be programmed to vary depending on the input signal. This could be used to implement a form of analog memory or to create circuits with tunable gain [5]. However, there are also some challenges associated with using memristors as loads for CMOS circuits. One challenge is that memristors are still under development, and their characteristics can be somewhat variable. This can make it difficult to design circuits that are reliable

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and predictable [6]. Fig.1 depicts the relation of passive components.

Another challenge is that memristors are typically non-linear devices. This means that the relationship between their current and voltage is not a simple straight line. This non-linearity can make it difficult to analyze and design circuits that use memristors [7].

Despite these challenges, there is ongoing research into the use of memristors as loads for CMOS circuits. If these challenges can be overcome, memristors could offer a new way to design more versatile and functional CMOS circuits [8].

Code converters provide many applications in the digital world. They are used to design encoders as rotary encoders, which are used to convert shaft rotation into digital signals, error correction in data transmission systems [9], like digital television or cable TV, binary to Gray code conversion can help minimize errors They are also used in digital Potentiometers which are electronic components that mimic the behavior of a variable resistor.

To satisfy all its applications they should work faster and efficient. In digital world where circuits are designed using MOS or FIN's require efficient techniques such that they perform well in further applications. Building entire circuit using transistors can rise the problem of increase in number of transistors thus leading to increase in area and power dissipations[10]. To reduce the transistor count we opt the method of used loaded transistor methods. Using resistor as load can solve the problem of area but will not help in solving the problem of power dissipation. So, it is better to use other load which works in the similar way of resistor in the application but much more in efficiency. Thus, here arises the use of memristor for the load in transistor circuits. It is observed the improvement in performance parameters of the memristor circuits than the previous circuits[11-12].

A mathematical description of a memristor used to describe how they behave in electronic circuits is called a memristor model. Memristors, which stand for "memory resistors," are a type of passive electronic component that have an interesting characteristic: the amount of electric charge that has gone through them in the past affects how much of their electrical resistance changes[13-14]. A memristor's resistance may be remembered depending on previous inputs of voltage or current, according to a phenomenon termed the memory effect.

The "pinched hysteresis loop" model, first put out by Leon Chua in 1971, is one of the foundational models in this field. This model describes the current-voltage characteristics of a memristor with a pinched hysteresis loop, which resembles the letter "pinched" between two linear segments.

The Joglekar resistance-switch memristor model is one of the widely used models to describe the behavior of memristors, particularly those based on the principle of resistance switching. This model was proposed by [4]. It describes the behavior of memristor through a set of equations that capture its resistance dynamics based on the applied voltage and the internal state variables.

The model is described in Fig.2 is quite well in [5], In the model, there is a window function:

$$f(x)=1-(2x-1)^{2p}$$

Joglekar model enables the simulation and analysis of memristor circuits using the resistance-switching mechanism.

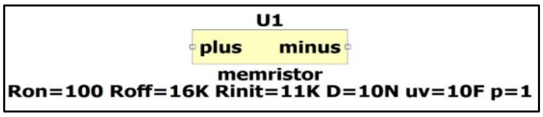


Fig. 2. Designed Memristor model

## II. LITERATURE SURVEY

Explores the use of memristors in combinational circuit design. It's probable that the study stresses the benefits of memristors, such their non-volatility, low power consumption, and reconfigurability, and explores methods for incorporating them into combinational circuits like AND, OR, and XOR gates. It illustrates how memristors add to increased efficiency and flexibility in circuit design by providing analysis of their performance in terms of speed, power consumption, and scalability. It may also provide predictions about potential uses and lines of inquiry for memristor-based circuit design in the future, such reconfigurable logic and neuromorphic computing [1].

Investigates the use of memristors in combinational and sequential logic components of digital logic circuits. It illustrates how to create digital logic circuits with memristors, including arithmetic units, shift registers, and flip-flops, and it offers insights into the process. Additionally, it shows how efficient these circuits are in comparison to conventional CMOS designs. To further demonstrate memristors' benefits in terms of space, power, and performance metrics—and to underscore their potential for energy-efficient and high-performance computing—the article may additionally provide analytical or simulation findings [2].

[3] Discusses the use of memristors to facilitate logic operations in digital circuits, such as AND, OR, and NOT. It highlights memristor advantages such as non-volatility and reconfigurability, as well as experimental data that show the feasibility and prospective benefits of memristor-aided logic circuits in terms of area efficiency and power consumption. The study discusses how memristors help to create new computing paradigms and allow new functions in digital systems, paving the way for next-generation computing architecture.

[4] Offers an overview of the burgeoning topic of memristor-based logic design, which includes logic gates and circuits. It reviews the current status of memristor-based logic design, including hybrid CMOS-memristor circuits and memristor crossbar arrays, and provides fresh techniques or methodologies for creating energy-efficient and high-performance logic circuits with memristors. The research focuses on how memristors provide compact, reconfigurable, and adaptable circuit topologies, giving circuit designers additional opportunity to optimize and customize digital systems.

[5] Investigates the efficiency advantages of memristor-based analogue circuits, including voltage-controlled oscillators and analog-to-digital converters. It includes analysis or simulation data that show how these circuits are more efficient in terms of

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linearity, bandwidth, and power consumption than typical analogue circuits.. [8] A simulation study of memristor-based digital logic circuits is presented, including discussions of the design and simulation approaches employed, as well as simulation results proving the circuits' functionality and performance is high.

## III.PROPOSED CODE CONVERTERS IMPLEMENTATION

### A. BINARY TO GRAY code converter:

In a binary to Gray code converter, a fundamental operation involves determining the Gray code bits based on the binary input bits. The converter receives a binary input consisting of multiple binary digits, representing a numerical value in binary format. Conversion: The converter processes the binary input and generates the corresponding Gray code output, where each digit is transformed according to the rules of Gray code conversion. Memristor-based logic gates and circuits are employed to perform the conversion operation. These circuits are configured to implement the necessary logical transformations to convert binary input to Gray code output. Result is depicted in Table.1

Table.1 : Binary to Gray Truth Table

| BINARY | | | | GRAY CODE | | | |
|---|---|---|---|---|---|---|---|
| b3 | b2 | b1 | b0 | g3 | g2 | g1 | g0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |

### B. GRAY TO BINARY:

In a Gray code to binary converter, combining specific Gray code bits to generate binary outputs is a key operation. The converter receives a Gray code input consisting of multiple digits, representing a numerical value in Gray code format. The converter processes the Gray code input and generates the corresponding binary code output, where each digit is transformed according to the rules of Gray code to binary code conversion. Memristors can be configured in arrays to serve as OR gates. By controlling the resistance states of these

[11] investigates the use of memristors in digital circuit design to minimise power dissipation. It presents design techniques and experimental findings that show power reductions in terms of both dynamic and static power .

Table.2 : Gray to Binary Truth Table

memristors, the OR gate array logically combines Gray code bits to produce corresponding binary outputs which shown in Table.2.

| GRAY CODE | | | | BINARY | | | |
|---|---|---|---|---|---|---|---|
| g3 | g2 | g1 | g0 | b3 | b2 | b1 | b0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |

### C .BCD TO EXCESS-3:

They are essential components in digital systems where data needs to be transformed from BCD format to Excess-3 code format. The Excess-3 code is a non-weighted code used to represent decimal digits, where each digit is represented by adding 3 to its corresponding BCD code. The converter processes the BCD input and generates the corresponding Excess-3 code output, where each digit is incremented by 3 compared to its BCD equivalent. Memristor-based logic gates are used to perform the conversion operation. These logic gates are configured to implement the required arithmetic operations to add 3 to each BCD digit.

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Table.3 : BCD to Excess-3 Truth Table

| BCD | | | | Excess-3 | | | |
|---|---|---|---|---|---|---|---|
| A | B | C | C | w | x | y | z |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 | X | X | X | X |
| 1 | 0 | 1 | 1 | X | X | X | X |
| 1 | 1 | 0 | 0 | X | X | X | X |
| 1 | 1 | 0 | 1 | X | X | X | X |
| 1 | 1 | 1 | 0 | X | X | X | X |
| 1 | 1 | 1 | 1 | X | X | X | X |

## D. EXCESS-3 TO BCD:

The converters are crucial components in digital systems where data needs to be transformed from Excess-3 code format to BCD format. The Excess-3 code is a non-weighted code used to represent decimal digits by adding 3 to their corresponding BCD code. The converter processes the Excess-3 input and generates the corresponding BCD output, which is shown in Table.4 where each digit is decremented by 3 to obtain its BCD equivalent. Implementation Using Memristors: These gates are configured to implement the necessary arithmetic operations to subtract 3 from each Excess-3 digit.

Table.4 : Excess-3 to BCD Truth Table

| Excess-3 | | | | BCD | | | |
|---|---|---|---|---|---|---|---|
| w | x | y | z | A | B | C | D |
| 0 | 0 | 0 | 0 | X | X | X | X |
| 0 | 0 | 0 | 1 | X | X | X | X |
| 0 | 0 | 1 | 0 | X | X | X | X |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 1 | X | X | X | X |
| 1 | 1 | 1 | 0 | X | X | X | X |
| 1 | 1 | 1 | 1 | X | X | X | X |

## IV. RESULTS AND DISCUSSION

The works is carried out as follows. Simulated all the code converters using Memristor technology, implemented using LT-Spice tool. The design and corresponding simulated results are provided below with tables providing their performance analysis. Fig 3,4,5,6,7,8,9,10 figures shows the implementation and output waveforms of the converters.

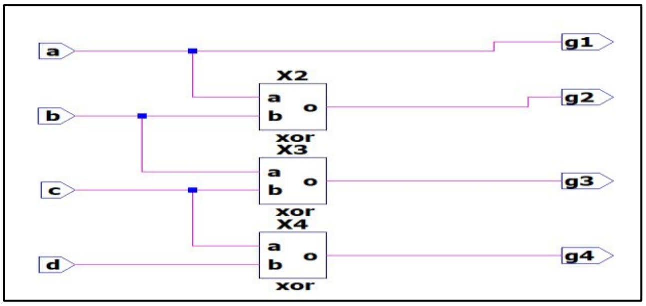


Fig.3 Implementation of Binary to Gray converter

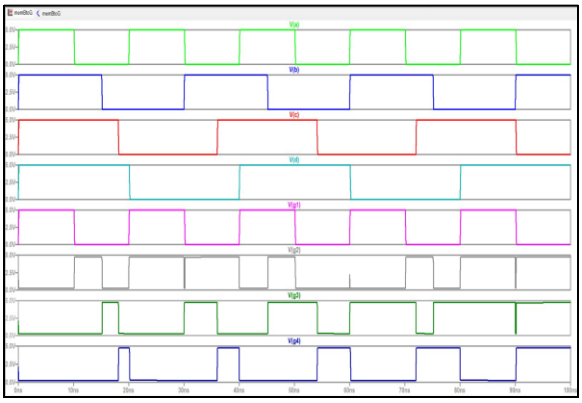

Fig.4 Output waveform of Binary to Gray converter

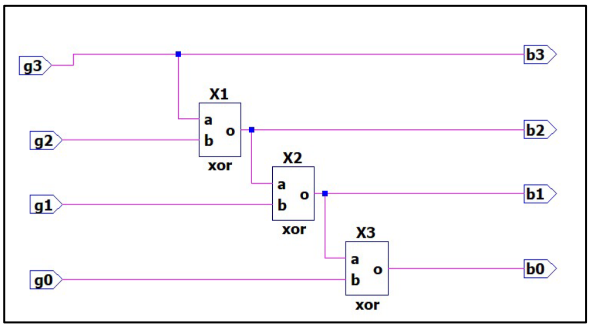


Fig.5 Implementation of Gray to Binary converter

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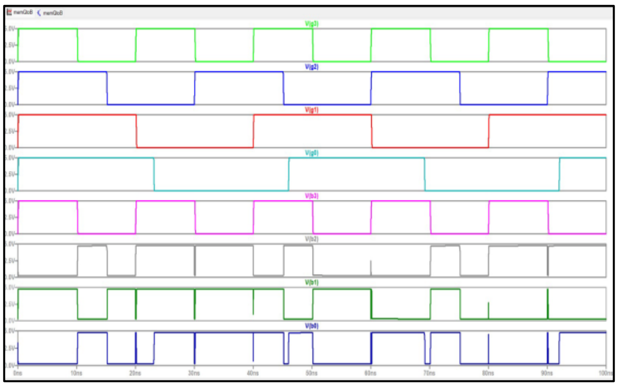

Fig.6 Output waveform of Gray to Binary converter

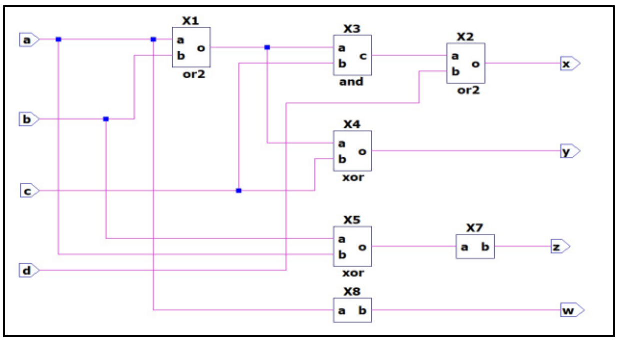


Fig.7 Implementation of BCD to Excess-3 converter

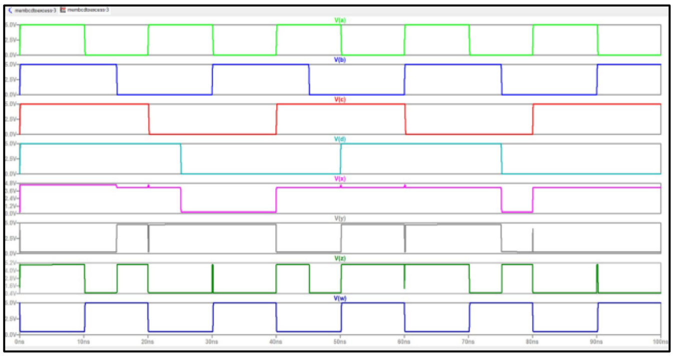

Fig.8 Output waveform of BCD to Excess-3 converter

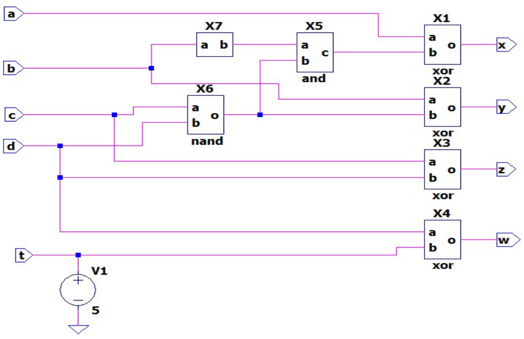


Fig.9 Implementation of Excess-3 to BCD converter

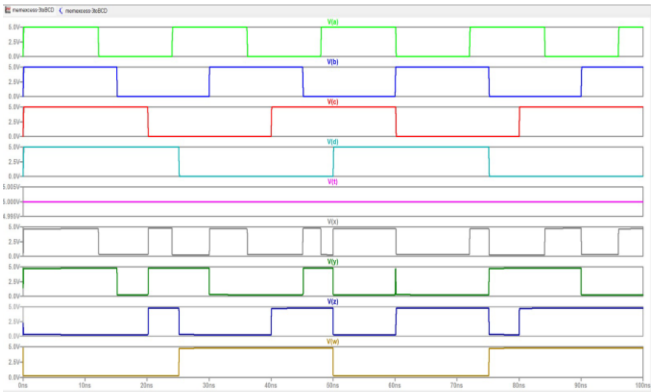

Fig.10 Output waveform of Excess-3 to BCD converter

Table.5: Binary to Gray

| Parameters | CMOS | Memristor |
|---|---|---|
| No of transistors | 48 | 24 |
| Power dissipation | 8.68 fW | 5.64 fW |

Table.6: Gray to Binary

| Parameters | CMOS | Memristor |
|---|---|---|
| No of transistors | 48 | 24 |
| Power dissipation | 8.68 fW | 3.84 fW |

Table.7: BCD to Excess-3

| Parameters | CMOS | Memristor |
|---|---|---|
| No of transistors | 59 | 29 |
| Power dissipation | 639.1 microW | 1fW |

Table.8: Ecxess-3 to BCD

| Parameters | CMOS | Memristor |
|---|---|---|
| No of transistors | 76 | 38 |
| Power dissipation | 746.7pW | 80.42 fW |

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The above table.5,6,7,8 is the comparison of Power Dissipation and Transistor count between CMOS and Memristor technology. Transistor count has been reduced by 50% and power Dissipation has been reduced by 52.12% with designed memristor logic.

## V. CONCLUSION

"Design and Implementation of Code Converters Using Memristor" is a significant achievement in the field of electrical engineering, with promising results. The successful design and simulation of all four code converters represents a significant step forward in using memristor technology for digital circuit applications. Notably, a significant reduction in transistor count, resulting in more effective use of area resources is observed. Furthermore, the comparison of CMOS and memristor-based implementations reveals considerable reductions in power dissipation, implying the possibility of large energy savings in the applications

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