

# Memristor Based Adders

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**Abstract** – Currently memristors are being researched to offer logic and memory functions. Recently, ultra dense resistive memory arrays built from various two terminal semiconductor or insulator thin film devices have been demonstrated. This paper presents memristor-based designs of commonly used (ripple carry, conditional sum and parallel prefix) adders. The latency and area of these adders are compared.

## I. INTRODUCTION

Memristors were first hypothesized by Leon Chua [1] in 1971 where he described the theoretical basis for the passive two terminal circuit device. The resistance of this device depends on its voltage history. Thus the memristor behaves like a conventional resistor while storing some past information. The relationship between the magnetic flux ' $\phi$ ' and the charge ' $q$ ' is provided by the memristance ' $M$ ' as

$$d(\phi) = M(q) d(q). \quad (1)$$

Memristors form the fourth fundamental basic circuit element along with resistors, inductors and capacitors. In 2008, researchers at HP labs realized memristors in nano scale titanium dioxide cross-point switches and concluded that including memristors and memristive systems in integrated circuits has the potential to significantly extend circuit functionality as long as the dynamic nature of such devices is understood and properly used [2].

This paper examines the usage of memristors to design several types of adders. In this paper the latency and the area for the designs using memristors has been studied and comparisons are made among the ripple carry, conditional sum and parallel prefix adders. Section II gives an overview of the past research done in the memristor physics and the ways in which memristors can be used to implement arithmetic units. Section III describes the use of the 'material implication' operation implemented with memristors to realize fundamental Boolean logic functions. In Sections IV, V and VI, the material implication technique is used to create ripple carry, conditional sum and parallel prefix adders. Section VII offers conclusions.

## II. RELATED WORK

Arithmetic operations can be performed using memristors as 1) a switch 2) an analog memory, and 3) interconnect.

In memristor switch based logic, the memristor is programmed to be either in a conducting state (ON) or a non-conducting state (OFF). Control and sensing logic can

be made with memristor cross bar arrays due to the switching property as suggested by Mouttet [3]. The use of memristors as analog memories for arithmetic computing was presented in [4]. The third implementation involves a memristor and complementary metal oxide semiconductor (CMOS) hybrid, where the memristor is used as programmable interconnects for the CMOS logic. Reference [5] reported the implementation of the first memristor-CMOS hybrid circuit.

Reference [6] introduces the use of memristors for basic arithmetic operations like addition and multiplication. It shows that the overhead in terms of operational delay and programming complexity for the control, sensing and setting logic is high. They provide an analysis of ripple carry adders that are constructed by building the basic gates using material implication. A detailed explanation of the design of gates using material implication is given in Section III.

## III. LOGIC OPERATIONS VIA MATERIAL IMPLICATION

The memristive switch approach can be used to realize fundamental Boolean operations using material implication. Reference [7] demonstrated this. The basic implication gate/latch circuit is shown in Fig. 1.

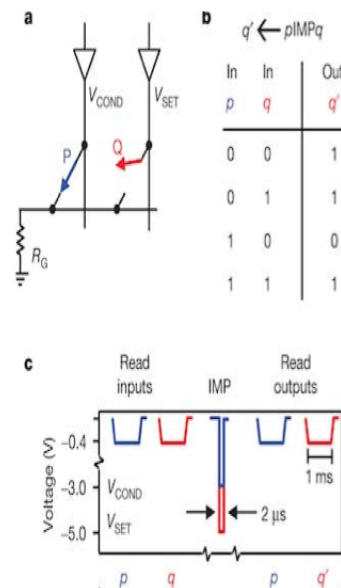


Fig. 1. a) Basic Implication circuit, b) Truth table for the IMP operation, and c) Voltages applied.