

Non-Volatile Memory using Memristor

Major Project Report

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Bachelor of Technology

In

Electronics Engineering

Submitted By

Prayansh Shrivastava

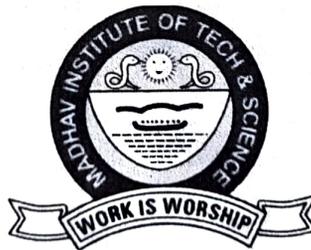
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UNDER THE SUPERVISION AND GUIDANCE OF

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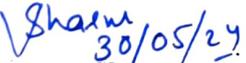
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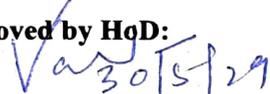
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ABSTRACT

Memories are integral parts of most of the digital devices and hence reducing power consumption of memory is very important in improving the system performance, efficiency and stability. The requirement in present scenario is low power devices. This paper proposes on Non-Volatile memory using Memristor. Memristor has an unique property to retain its previous state when power off.

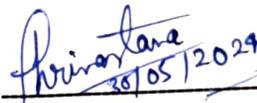
In this paper we used Tanner EDA as primary software tool to simulate 6T SRAM, memristor based memory cell etc.

Before 1971, all electronics depend on three fundamental circuit elements named Resistor, Capacitor and Inductor. In 1971, a new fundamental circuit element came called Memristor. Memristor is the combined form of Memory Resistor. Memristor has many applications including Non-volatile memory because it has a unique property of retain its previous state when power off.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude firstly to Dr. Vikas Mahor Sir (Assistant Professor, Department of Electronics, MITS Gwalior) for mentoring and supporting me in completing this project.

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ACRONYMS

Acronyms	Meaning
SRAM	Static Random Access Memory
DRAM	Dynamic Random Access Memory
NVRAM	Non-Volatile Random Access Memory
VTC	Voltage Transfer Characteristic
SNM	Static Noise Margin
WL	Word Line
NVM	Non-Volatile Memory
TWV	Tanner Waveform Viewer
VM	Volatile Memory
RRAM	Resistive Random Access Memory
PCRAM	Phase Change Random Access Memory
STT-MRAM	Spin-transfer torque magnetic random-access memory

NOMENCLATURE

Symbol/Name	Description
R	Resistor
C	Capacitor
L	Inductor
ϕ	Flux
V _r	Internal Voltage node right
V _l	Internal Voltage node left

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2. Steps for READ and WRITE of 6T SRAM

INTRODUCTION

Semiconductor Memories are an important part of many devices e.g. Computers, mobile phones, IoT based system, biomedical system, Satellites etc. There are basically two types of Semiconductor memory: Volatile Memory (VM) and Non-Volatile Memory (NVM).

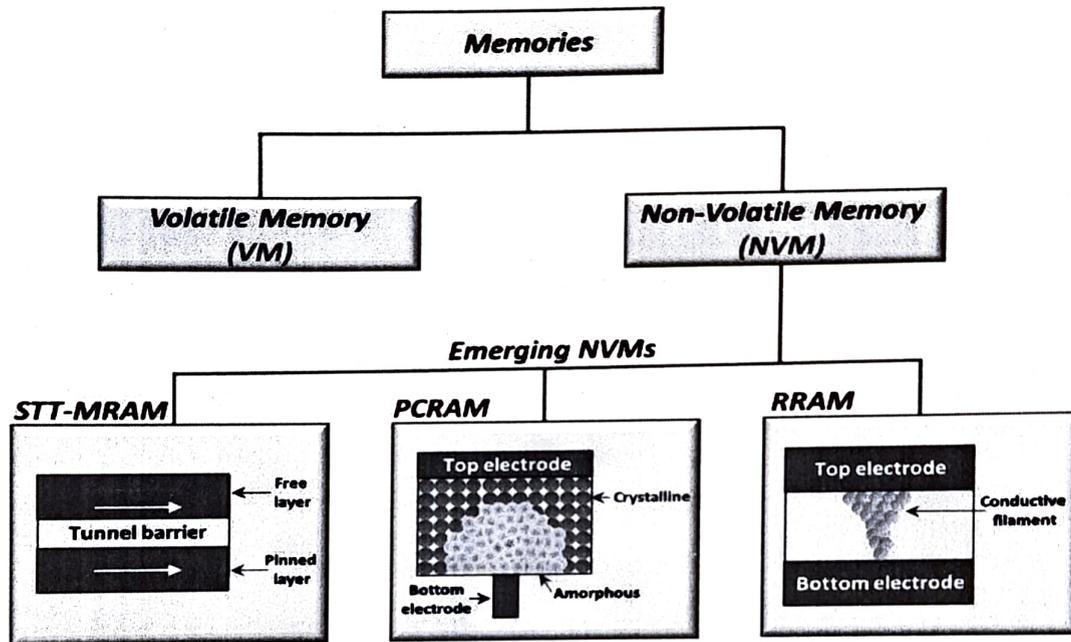


Figure 1: Classification of Memories

Volatile Memory (VM):

Volatile Memory is a type of Computer memory that requires continuous power to store data. These types of memory temporarily store data and when power off then it no longer remembers its previous state.

There are many types of Volatile Memory available in the market:

1. SRAM (Static Random Access Memory)
2. DRAM (Dynamic Random Access Memory)

Non-volatile Memory (NVM):

Non-volatile memory (NVM) has the capability to store information when power off. These days NVM is very popular because it does not require a continuous power supply. Due to this property of NVM, biomedical and healthcare devices are using this memory. There are many types of NVM available: RRAM, PCRAM, STT-MRAM etc.

MEMRISTOR

Origin of the Memristor:

Anyone with basic information in electrical engineering or electronics engineering knows that there are 4 fundamental electric circuit variables: Voltage v , Current i , Charge q , and Flux ϕ . Then it is clear that with these 4 parameters, there can be 6 possible combinations for relating them with each other. We have already completed understanding and control over 5 of these combinations in which 3 of them are passive elements and has two terminals, namely the resistor R , the capacitor C and the inductor L . Because these all 3 R , L and C are passive components, so they are not able to generate energy, they are the able/capable to store and dissipate energy.

The fundamental elements show the linear behavior between two electric circuit variables. The relationship between voltage and current i.e. V and I is defined by Resistor, similarly the relationship between voltage and charge i.e. V and q is defined by Capacitor and the relationship between current and flux i.e. q and ϕ is defined by an Inductor. The last two combinations are defined by Faraday's law. Faraday's law states that the current (I) is the time derivative of the charge (q), and the voltage (V) is the time derivative of the magnetic flux (ϕ), this figure shows the relationship between these all fundamental parameters.

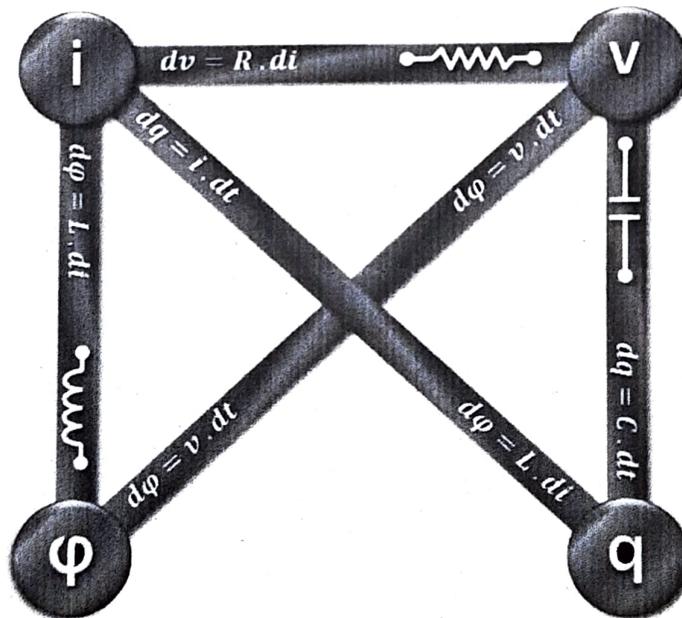


Figure 2: The relation between the fundamental circuit variables before Memristor

The Missing Link:

In 1971, Prof. L. Chua, a professor of EE from UC Berkeley compared this missing link with Aristotle's theory which shows the relationship between fundamental elements of nature. Based on this theory, and as shown in Fig., all matters consist of 4 fundamental elements, namely Water, Earth, Fire and Air. There are also 4 basic properties named moistness, dryness, coldness and hotness.

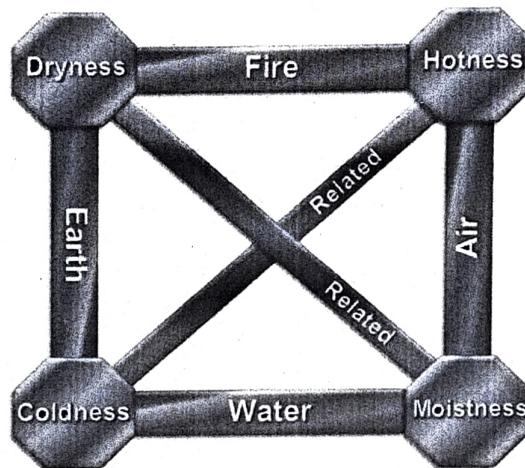


Figure 3: Theory of matter by Aristotle

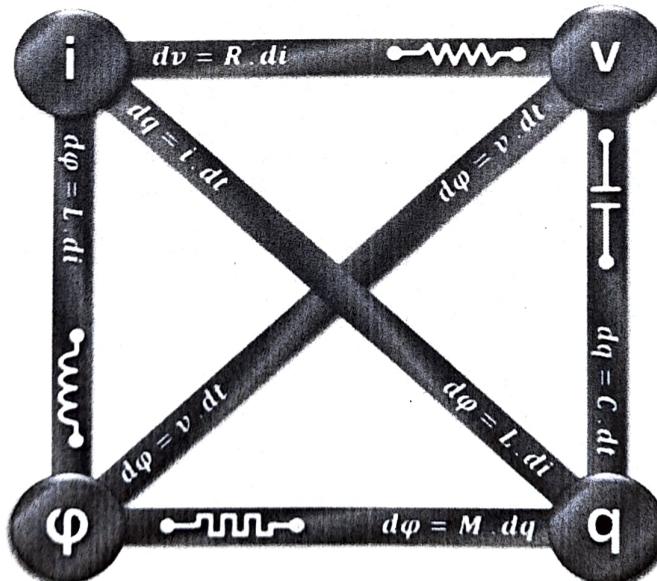


Figure 4: The relationship between the 4 circuit variables including Memristor

Memristor:

Memristor is a combined form of "Memory Resistor". Memristor is basically a two terminals device. It remembers the previous state or amount of charge flowing through it. Memristor cannot store energy because it is not an active element.

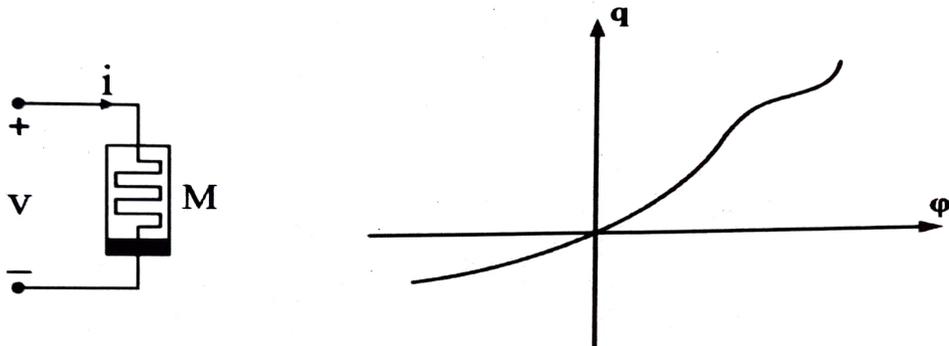


Figure 5: The symbol and curve of a memristor

Device	Equation	Unit
Resistor	$R = dV/dI$	Ohm
Capacitor	$C = dq/dV$	Farads
Inductor	$L = d\phi /dI$	Henrys
Memristor	$M = d\phi /dq$	Ohm

Table 1: Equations of all fundamental circuit elements

Memristance (M):

Memristance M is same as Resistance. Resistor has property called Resistance same as Memristor has property called Memristance. It is defined as the relationship between magnetic flux and charge. When the electrical charge flows through the memristor in one direction the resistance of the Memristor will increase and when the current flows in the other direction then the resistance of the Memristor will decrease. If power shuts down, it means stop providing power to the memristor then it will store whatever it has and if we will again provide power to the memristor it will start from previous state when there was no power.

6T SRAM

SRAM stands for 'Static Random Access Memory, it is a type of volatile memory. 6T means six transistors i.e. 2 PMOS and 4 NMOS. In 6T SRAM, 2 PMOS and 2 NMOS create 2 inverters which store 1 single bit. And the remaining 2 NMOS works as access transistors.

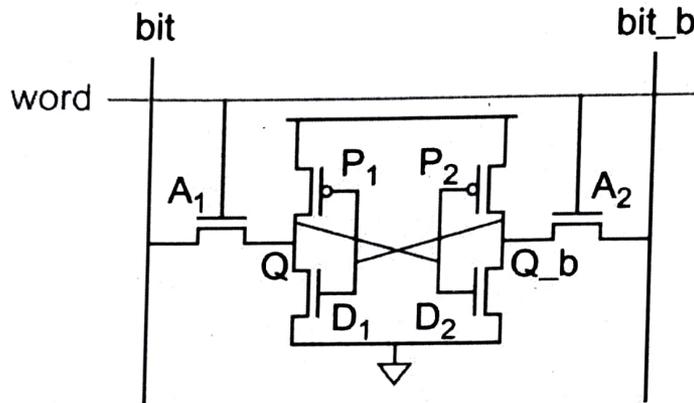


Figure 6: 6T SRAM Cell

Operation:

The two modes of operations of 6T SRAM cell, READ and WRITE, both the operation require different procedures to work. These steps are listed in table 2

READ:	WRITE:
<ol style="list-style-type: none"> 1. Charge both <i>bit</i> and <i>bit_b</i> HIGH 2. Let both <i>bit</i> and <i>bit_b</i> float 3. Raise the <i>word</i> line <p style="margin-top: 10px;"><i>Bit</i> will now contain the data value</p>	<ol style="list-style-type: none"> 1. Charge <i>bit</i> HIGH 2. Let <i>bit</i> float 3. Pull <i>bit_b</i> down to ground 4. Raise the <i>word</i> line <p style="margin-top: 10px;"><i>Q</i> will now contain a HIGH value (swap <i>bit</i> & <i>bit_b</i> to write a LOW value)</p>

Table 2: Steps for READ and WRITE Operation of 6T SRAM

Simulation of 6T SRAM:

There are some basic steps to simulate 6T SRAM using Tanner EDA -

1. Open S-edit tool and create a new library.
2. Create a new cell inside this new library.
3. Select some library from Tanner EDA e.g. Generic_250nm_devices, Misc, SPICE_Plot, SPICE_Sources etc.
4. Now start to create schematic using NMOS, PMOS, VDD, GND, Vbit etc components.
5. After creating schematic setup SPICE Simulation.
6. Save all the changes.
7. Now start Simulation.

Components:

PMOS - 2
NMOS - 4
V_bit - 3 (For input signal)
V_voltageprint - 5 (For output)
Vdd (2 Volt)
Gnd

S-edit:

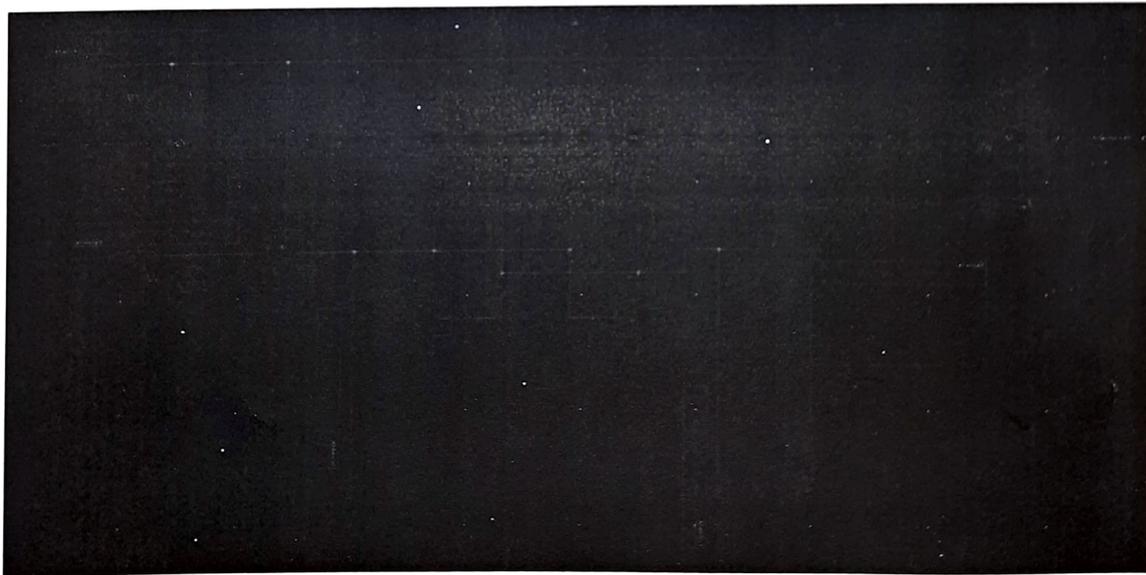


Figure 7: 6T SRAM schematic in S-edit (Tanner EDA)

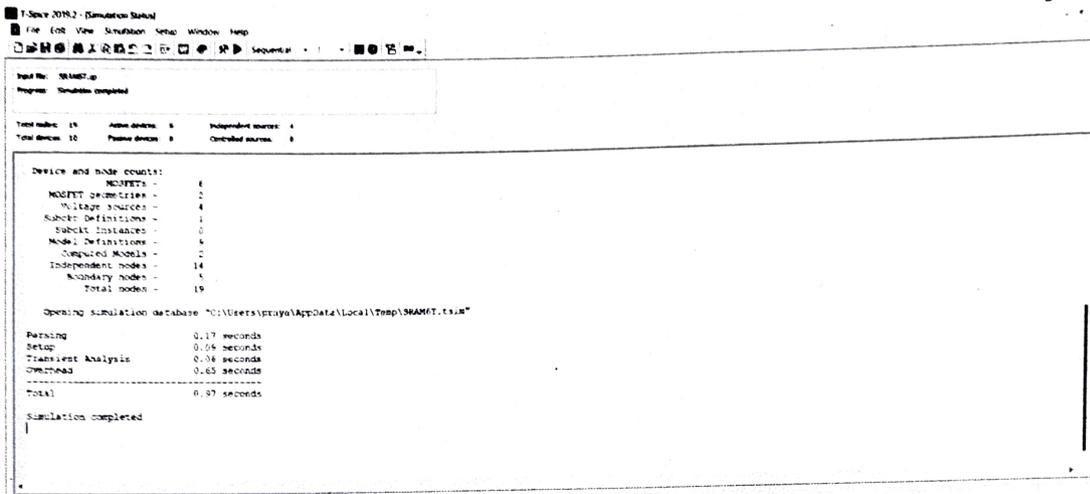


Figure 8: Simulation result of 6T SRAM in T-Spice

Tanner Waveform Viewer:

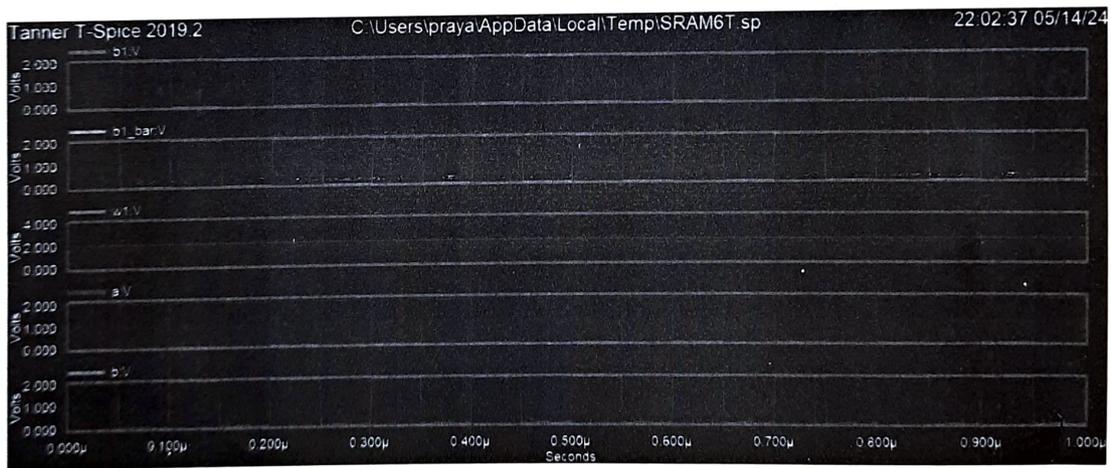


Figure 9: 6T SRAM Input and Output waveforms in Tanner Waveform Viewer (TWV)

NOISE MARGIN

The Noise Margin in SRAM Cell shows the Stability of cell. There are three types of SNM in SRAM Cell because SRAM has three types of operation i.e. Hold, Read and Write.

1. Hold Static Noise Margin:

These are some following steps to determining HSNM-

1. Connecting b1 and b1_bar to Vdd.
2. Connecting WL to Gnd.
3. Plotting both VTCs of the inverter 1 and inverter 2 on the same graph.
4. Finding the maximum square SRAM that can fit into VTC lobe.
5. The SNM is the side of the maximum square.

2. Read Static Noise Margin:

These are some following steps to determining RSNM-

1. Connect b1 and b1_bar to Vdd.
2. Connecting WL to Vdd.
3. Using graphical method, the SNM is the side of the maximum square.

3. Write Static Noise Margin:

These are some following steps to determining WSNM-

1. Connecting b1 to Gnd and b1_bar to Vdd.
2. Connecting WL to Vdd.
3. Using graphical method, the SNM is the side of the maximum square.

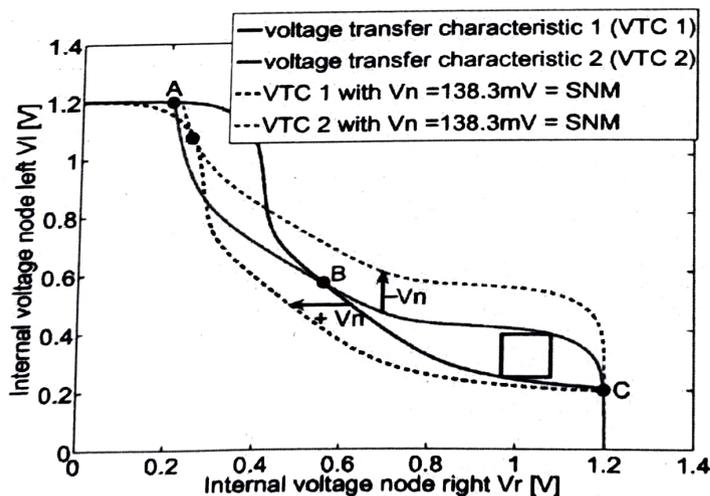


Figure 10: Static Noise Margin Curve of 6T SRAM

MEMORY USING MEMRISTOR

Memristor has a unique property to retain its previous state when no supply is available. Due to this property, we use memristor for Non-Volatile Memory. Memristor is also smaller in size than PMOS and NMOS and consumes less power than PMOS and NMOS.

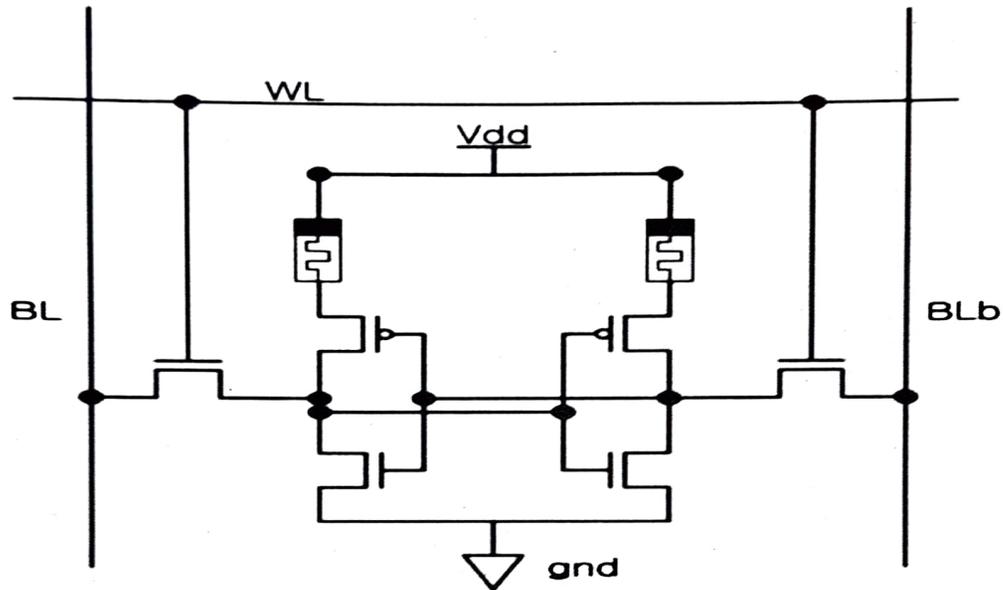


Figure 11: Memristor based memory Cell

Advantage of Memristor:

1. It consumes less power than MOSFET.
2. It generates less heat.
3. It is very small and scalable.
4. It is nonvolatile.

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