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A Novel Approach on MEMRISTOR and its Applications

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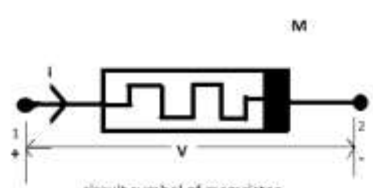
Abstract: - **A MEMRISTOR is a passive device which has two terminals, operating based on the principle of MEMRIS TANCE. Memristance (M) which is derived from flux (Φ) variation with respect to charge (q). When an electric charge flow through a MEMRISTOR, it have capable of remembering past history of the device for a long time. This result's gives MEMRISTOR acting like a non-volatile memory. MEMRISTOR basis concept was implemented in various areas like audio signal processing, image processing, logic imply, crossbar switch implementation, etc and HP MODEL MEMRISTOR, which is described briefly in this paper.**

***Key word*: memristance, non-volatile, flux, charge**

I. INTRODUCTION

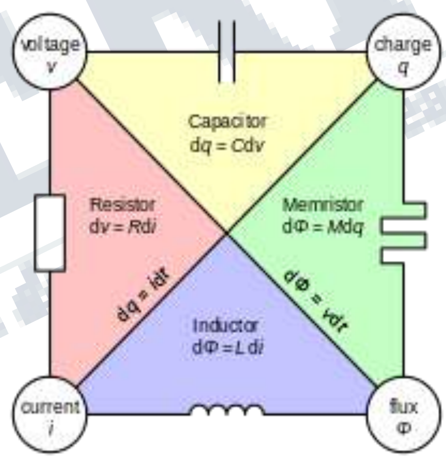
Still now we knew about only fundamental circuit element resistor, capacitor and inductor, MEMRISTOR was theoretically explained by Leon Chua in 1971. MEMRISTOR concept was based on the MEMRISTANCE which is defined as rate of change of flux with respect to charge per ohm. Which is also defined as the relationship between the time integral of the element's current and time integeral of the element's voltage?



circuit symbol of memristor

$$M(q(t)) = \frac{\mathrm{d}\Phi_m/\mathrm{d}t}{\mathrm{d}q/\mathrm{d}t} = \frac{V(t)}{I(t)}$$
$$V(t) = M(q(t))I(t)$$
$$M(q) = \frac{\mathrm{d}\Phi_m}{\mathrm{d}q}$$

Where q is the charge and Φ_m is the flux of the MEMRITANCE (M) unit (Wb/c). The relation chip between the various circuit elements shown in figure (2).



Historical Background: Memory resistor (MEMRISTOR) theoretical idea was initially given by circuit theorist Leonchua. As the electrical component relating electrical charge and magnetic flux linkage. Since chua was unable to find the memory resistance at that time, it remained conflicts for four decades. After fourty years MEMRISTOR described as a physical system by a researchers at HP lab in California, USA at 2008. They developed nano sized MEMRISTOR consisted of a Ti02 layer that was sandwiched between two platinum electrode. **MEMRISTOR anology**: MEMRISTOR is a pipe that changes diameter with the amount and direction of water that flows through it. If the water flows through this pipe in one directions, it expands(becoming less resistive). But, send the water in opposite directions and the pipe shrinks(becoming more resistive). Further, the MEMRISTOR remember it's diameter when water last

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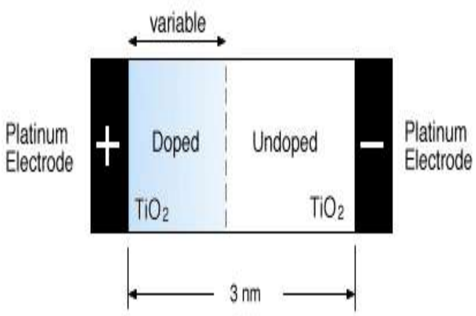
went through it. When turn off the flow and the diameter of the pipe ‘freezes’ until water is turned back on. That freezing properties suits MEMRISTORs brilliantly for computer memory. The ability to indefinitely stores resistance values means that a MEMRISTOR can be used as a non-volatile memory.

II. IMPLEMENTATION OF MEMRISTORS:

❖ ***HP MEMRISTOR model***:

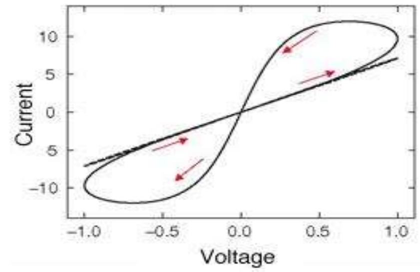
Electron photo of 17 titanium dioxide MEMRISTORs



R.Stanley Williams HP in 2008, HP MEMRISTORs was made up of two titanium oxide (Ti02) layer sandwiched between two platinum electrodes. One Tio2 layer, which is missing some oxygen molecules, is called the doped region (Ti02-x).The Oxygen makes this region conductive. Another layer Tio2 called undoped region. The two region size w and d-w. The total resistance of the device is composed of the two material resistances. When positive voltage is applied to the pt electrode near the doped region repels the oxygen vacancies in the Ti02-x, sending them into undopped region. so, increase in % conducting and decrease the overall resistance. When negative voltage is applied, it increases the overall resistance. When the device goes off, the oxygen vacancies do not move and the boundary between the two regions freezes. Thus the resistance retain its last value and this is why the device called a MEMRISTOR.

$$M(q)= R1+R2$$

Pinched hysteresis:



When enough charge has passed through the MEMRISTOR that ion can no longer move ,the device enter hysteresis. It ceases to integrate but rather keeps q at an upper bound and M is fixed thus acting as a constant resistor until current is *reversed.*

❖ ***Polymeric MEMRISTOR***:

In 2004, Krieger and Spitzer described dynamic doping of polymer and inorganic dielectric-like materials that improved the switching characteristics and retention required to create functioning nonvolatile memory cells. They used a passive layer between electrode and active thin films, which enhanced the extraction of ions from the electrode. It is possible to fast ion conductor as this passive layer, which allows a significant reduction of the ionic extraction field. In July 2008, Erokhin and Fontana claimed to have developed a polymeric MEMRISTOR before the more recently announced titanium dioxide MEMRISTOR In 2010, Alibart, Gamrat, Vuillaume et al. introduced a new hybrid organic device (the NOMFET: Nan particle Organic Memory Field Effect Transistor), which behaves as a MEMRISTOR and which exhibits the main behavior of a biological spiking synapse. This device, also called synapstor (synapse transistor), was used to demonstrate a neuro-inspired circuit (associative memory showing a pavlovian learning) In 2012, Crupi, Pradhan and Tozer described a proof of concept design to create neural synaptic memory circuits using organic ion-based MEMRISTORs. The synapse circuit demonstrated long term potentiation. learning as well as inactivity based forgetting. Using a grid of circuits, a pattern of light was stored and later recalled. This mimics the behavior of the V1 neurons in the primary visual cortex that act as spatiotemporal filters that process visual signals such as edges and moving lines.

❖ ***Layered MEMRISTOR***:

In 2014, Bessonov et al. reported a flexible memristive device comprising a Mo0x/MoS2 heterostructure sandwiched between silver electrodes on a plastic foil. The fabrication method is entirely based on printing and solution-processing technologies using two-dimensional

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layered transition metal dichalcogendies (TMDs). The MEMRISTORs are mechanically flexible optical transparent and produced at low cost. The memristive behaviour of switches was found to be accompanied by a prominent memcapacitive effect. High switching performance, demonstrated synaptic plasticity and sustainability to mechanical deformations promise to emulate the appealing characteristics of biological neural systems in novel computing technologies.

❖ ***FERROELECTRIC MEMRISTOR:***

The ferroelectric MEMRISTOR is based on a thin ferroelectric barrier sandwiched between two metallic electrodes. Switching the polarization of the ferroelectric material by applying a positive or negative voltage across the junction can lead to a two order of magnitude resistance variation: $R_{OFF} \gg R_{ON}$ (an effect called Tunnel Electro-Resistance). In general, the polarization does not switch abruptly. The reversal occurs gradually through the nucleation and growth of ferroelectric domains with opposite polarization. During this process, the resistance is neither R_{ON} or R_{OFF}, but in between. When the voltage is cycled, the ferroelectric domain configuration evolves, allowing a fine tuning of the resistance value. The ferroelectric MEMRISTOR's main advantages are that ferroelectric domain dynamics can be tuned, offering a way to engineer the MEMRISTOR response, and that the resistance variations are due to purely electronicphenomena, aiding device reliability, as no deep change to the material structure is involved.

***CARBON NANOTUBE MEMRISTOR*:** In 2013, Ageev, Blinov et al. reported observing MEMRISTOR effect in structure based on vertically aligned carbon nanotubes studying bundles of CNT by scanning tunneling microscope.

SPINTRONIC MEMRISTOR: Chen and Wang, researchers at disk-drive manufacturer Seagate technology described three examples of possible magnetic MEMRISTORs. In one device resistance occurs when the spin of electrons in one section of the device points in a different direction from those in another section, creating a "domain wall", a boundary between the two sections. The Electrons flowing into the device have a certain spin, which alters the device's magnetization state. Changing the magnetization, in turn, moves the domain wall and changes the resistance. The work's significance led to an interview by IEEE spectrum. A first experimental proof of the spintronic MEMRISTOR based on domain wall motion by spin currents in a magnetic tunnel junction was given in 2011.

PROPERTIES OF MEMRISTOR: Listed below are some of the most characteristic and important features for MEMRISTORs: • An ac element, not dc .• No storage of energy. • Two-point terminal circuit element. • Pinched hysteresis loop in the i-v plane .• Positive or negative differential resistance .• Nonlinear q-φ curve.•Low-frequency property and frequency-dependent memristance.• Typically only apparent at small scales.

FEATURES OF MEMRISTORS:

- ❖ MEMRISTORs can be designed to be virtually immune to radiation. They are not affected by magnetism and the bottom line.
- ❖ MEMRISTOR can be scaled down less than 10nm and also read and write time is smaller.
- ❖ Non-volatile semiconductor memory.
- ❖ Unique properties, theoretically, one could restart a computer immediately without the need for reloading data.
- ❖ Current memory are mainly binary and can store only ones and zeros, where as MEMRISTORs have multilevel states, which means a single MEMRISTOR unit can replace many binary transistors and realize higher density memory.
- ❖ MEMRISTOR can also implement analog storage besides binary and multilevel information memory.
- ❖ MEMRISTOR with continuously variable resistance can be used as analog memory to remember the sampled signal directly, providing greater storage capability, small circuit size, high memory performance and shorter processing time.
- ❖ Memory resistor working based on the physical history.
- ❖ Disconnecting the memory resistor from external voltage, the current stop flowing, the boundary stop moving, and the element remember its resistance for theoretically arbitrarily long time.
- ❖ MEMRISTOR may be applied is that of non-volatile random access memory. Memory does not require continuous power draw and consumes little physical area.
- ❖ For digital memory applications, one bit of information can be stored using a single MEMRISTOR. This is done by changing resistance value.
- ❖ DC voltages are used to set the resistance of a MEMRISTOR element. In order to read stored data AC signal are utilized. So that stored data is not disturbed.
- ❖ MEMRISTOR can be used as associative memories.
- ❖ Introduction of non volatile memory into the main memory or cache architecture can be an effective

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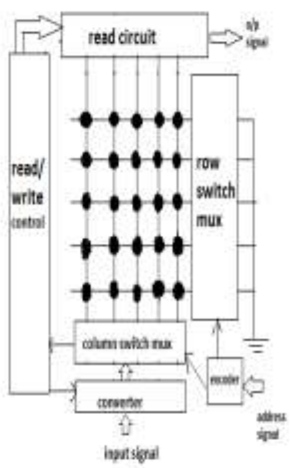
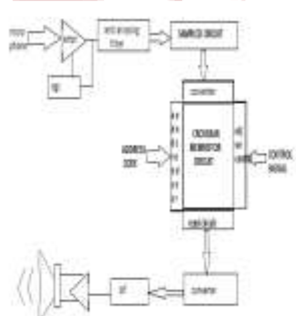
means to decrease booting time and energy consumption.

- MEMRISTOR suitable for memory cell and switching circuit which can be used argument of traditional cmos gates.
- Ferro electric MEMRISTOR can store data as an intermediate value rather than binary ‘1&0’

APPLICATIONS OF MEMRISTOR:

Analog audio signal storage:





Analog audio signal storage based on the previous work, we propose an audio record/play system with an analog memristive crossbar array memory to explore the application of MEMRISTOR memory on analog audio storage. Analog memristive crossbar array memoryThe combination of MEMRISTOR and nano-wire crossbar interconnection technology has absorbed great interest from researchers. Millions of MEMRISTOR interconnects can be realized in a microscopic space formation of a memristive crossbar array. A memristive crossbar array memory for analog information storage is proposed as illustrated in above Figure. It contains a 6×6 crossbar array with with MEMRISTORs located at the cross points (denoted by circles), i.e., the two terminals of the MEMRISTOR connect the row and column lines, respectively. The column and row switch multiplexers (mux) are used to address the target MEMRISTOR in the control of the address encoder output. A converter is employed to convert the input signal into a proper current for input to the MEMRISTOR array under the read/write control signal. The read circuit is in charge of measuring the voltage across the target MEMRISTOR. When information is sent to the converter (including the amplifier circuit and signal generator), the converter changes the information into a proper current signal with amplitude in a certain range to make sure the MEMRISTOR works normally. This current signal is input to the target MEMRISTOR to set it to the required resistance state. This is the write operation, and in this case, the write-control-signal is eff ective. If the read-control-signal is active, the signal generator in the converter generates a read-current with the pattern determined in advance. The read-current flows through the selected MEMRISTOR and the resulting voltage is measured by the read circuit.

SUMMING AMPLIFIER WITH MEMRISTOR:

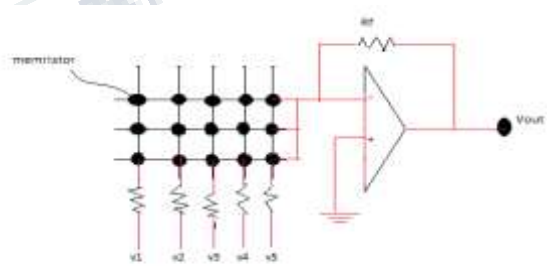


IMAGE PROCESSING:

A common operation involved in image recognition and other image processing techniques is that of edge detection. Edge detection identifies where large changes in a digital image occur, such as the outline of an object. However, edge detection is notoriously computationally intensive. One application of MEMRISTORs identified by is that of performing edge detection using a memristance grid. An example of this operation can be seen below in Figure . The light intensity of the original photo is applied as voltages to points on a

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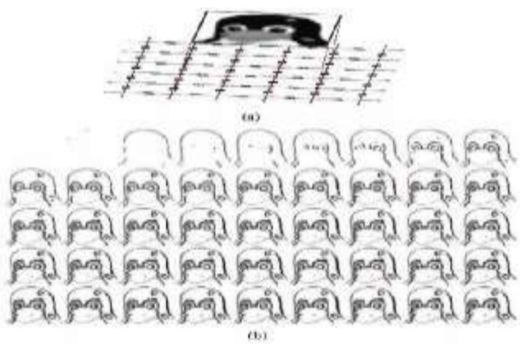
grid of MEMRISTORs (a). The resulting changes in resistance across the grid over time are then shown in the frames in (b). Thus, after the system has been allowed to settle, the edge detected image can be recovered by measuring the resistance of each element in the grid .



What Memristive applications are on the horizon, and how close are they to reality? We look at a survey of MEMRISTOR applications and technology, starting from what the first devices will look like, and where they might go. This reference page will be updated as advances in each of the areas are made.

NON-VOLATILE MEMORY APPLICATIONS: MEMRISTORs can retain memory states, and data, in power-off modes. Non-volatile random access memory, or NVRAM, is pretty much the first to-market MEMRISTOR application we'll be seeing. There are already 3nm MEMRISTOR in fabrication now. Crossbar latch memory developed by Hewlett Packard is reportedly currently about one-tenth the speed of DRAM. The fab prototypes resistance is read with alternating current, so that the stored value remains unaffected. Rosy colored industry analysts state there is industry concurrence that these flash memory or solid state drives competitors could start showing up in the consumer market within 2 years.

LOW-POWER AND REMOTE SENSING APPLICATIONS: Coupled with me capacitors and me inductors, the complementary circuits to the MEMRISTOR which allow for the storage of charge, MEMRISTORs can possibly allow for nano-scale low power memory and distributed state storage, as a further extension of NVRAM capabilities. These are currently all hypothetical in terms of time to market.

CROSSBAR LATCHES AS TRANSISTOR REPLACEMENTS OR AUGMENTORS: The hungry power consumption of transistors has been a barrier to both miniaturization and microprocessor controller development. Solid-state MEMRISTORs can be combined into devices called crossbar latches, which could replace transistors in future computers, taking up a much smaller area. There are difficulties in this area though, although the benefits these could bring are focusing a lot of money in their development. So perhaps the "where theres a will, or a dollar, theres a way" adage will get these developed. Unless a competition war amongst industry giants becomes one of those patent showdowns, where companies buy out technological advances to bury them. Remember 3G? Well, someone bought out 4G back in 2004, before 3G even came to market, and has been sitting on it ever since. And have profited greatly.

Analog computation and circuit Applications: There was a track of electrical/mathematic engineering which was largely abandoned to stasis in the 1960s, as digital mathematics and computers rose to dominance. Analog computations embodied a whole area of research which, unfortunately, were not as scalable, reproducible, or dependable as digital solutions. However, there still exist some very important areas of engineering and modeling problems which require extremely complex and difficult workarounds to synthesize digitally: in part, because they map economically onto analog models. The early work of Norbert Wiener has already started to be revisited, after the analog/digital split between him and John vonNeumann. Analog was great, but required management for scalability beyond what even the extremely complex initial digital vaccum tube computers could provide. MEMRISTOR applications will now allow us to revisit a lot of the analog science that was abandoned in the mid 1960's.

CIRCUITS WHICH MIMIC NEUROMORPHIC AND BIOLOGICAL SYSTEMS:

This is a very large area of research, in part because a large part of the analog science detailed above has to do with advances in cognitive psychology, artificial intelligence modeling, machine learning and recent neurology advances. The ability to map peoples brain activities under MRI, CAT, and EEG scans is leading to a treasure trove of information about how our brains work. But *modeling a brain using ratiocinated mathematics is like using linear algebra to model calculus*. Simple electronic circuits based on an LC network and MEMRISTORs have been built, and used recently to model experiments on adaptive behavior of unicellular organisms. The experiments show that the electronic circuit, subjected to a train of periodic pulses, learns and anticipates the next pulse to come, similar to the behavior of the slime mold physarum polycephalum periodic timing as it is subjected to periodic changes of environment. The recent MEMRISTOR cat brain is also getting a lot of

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mention. These types of learning circuits find applications anywhere from pattern recognition to Neural Networks. No more neural pattern algorythm training on stock market data for the pop-sci investor: now, you can grow your own neural network! Just add two drops of MEMRISTOR. Not anywhere close to reality, FYI, even in the 30 years range, but very realistic in terms of helping advance the science itself, if not the consumer market for intelligent brains-in-a-jar.

PROGRAMMABLE LOGIC AND SIGNAL PROCESSING and a variety of Control System MEMRISTOR patents are out there, waiting for the microchips to fall where they may. The memristive applications in these areas will remain relatively the same, because it will only be a change in the underlying physical architecture, allowing their capabilities to expand, however, to the point where their applications will most likely be unrecognizable as related.

CONCLUSION:

MEMRISTOR used for various applications available. So here we have a fundamentally new device that promises a dramatically new form of fast, inexpensive, low power, universal, and long lasting nonvolatile memory. MEMRISTORs require less energy, faster than flash memory, and contain far more data per area than any other present memory. MEMRISTOR technology should replace not only hard drives, but DRAM and Flash drives as well. Imagine turning on your computer and, like turning on a light switch, it instantly displays all the information you had on it when it was last turned off. No more boot up time. No more moving parts. RAM would not be needed. Backup memory could be made automatically and quicker and easier than Apple's "Time Machine." Computers, laptops, cell phones, and iPods could be made much smaller with much larger memories. MEMRISTOR currently not available in market but it's projects coming soon before 2018.

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