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Design and Implementing an Memristor in Basic Analog Circuits

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Abstract:- Memristor has been researched over the past decade as feasibility in memory devices, analog circuits, digital cirucits, artificial neuron, chaos and many more applications. Because of the lack of memristor as a off-shelf component, simulation has been tried to find the feasibility of memristor for the above mentioned applications. In this work, memristor SPICE model was added to the OrCAD-PSPICE 16.0 and the fingerprints of the memristor (i) Exhibited the hysteresis curve (ii) Both the current and voltage passing through the origin (iii) With increasing frequency the lobes of the hysteresis curve diminishes and exhibits an linear curve was verified. Next, basic analog circuits such as differentiator, integrator, Inverting and Non-inverting configuration replaced resistor with the memristor. And functionality of these analog circuits exhibited similar characteristics that of an conventional analog circuits with resistor.

Keywords: ORCAD PSPICE, Differentiator, Integrator, Memristor, Analog circuits

• INTRODUCTION

Leon Chua (1971) showed an relationship between charge and flux and named the circuit element as memristor. In other words, as charge integrals of current over time and flux integrals of time over voltage. [1-5]. Memristor is basically different compared to other basic circuit elements in a way that, memristor remembers the past depending on the last voltage applied to the memristor circuit element. This memory effect cannot be implemented by any resistor, capacitor and inductor circuit combination. Hence, memristor has been determined to be an fundamental circuit element[6-7]. Many circuits based on memristor such as chaotic circuits have been implemented[8-11].

The topology of these resistors, capacitor, inductor and memristor fundamental circuit components shall constute to be the basics for almost all of the electronic devices used in day-to-day life. This discovery has led to the brand new fundamental circuit element opened the door to a brand new type of electronics, which HP and its team of researchers discovered the switching Memristor in 2008 and implemented using a thin film of titanium dioxide[11]. In this work the design and analysis covers all the basic analog circuits. These basic analog circuits find varied application such as oscillators, active filters PLL and encrypting data. This paper utilizes the simulated Memristor device in a analog circuit. The Memristor was implemented in the OrCAD PSPICE[12,13] and switching condition was verified. OrCAD PSPICE 16.0 is used as simulation tool[14].

• SIMULATION CIRCUIT DIAGRAM

Integrator

Figure 1 performs the mathematical operation of integration with respect to time. Hence, this circuit performs an mathematical operation that the output voltage is proportional to the input voltage with respect to time. Here, the input resistor replaced by memristor which act as resistive switch in the circuit.

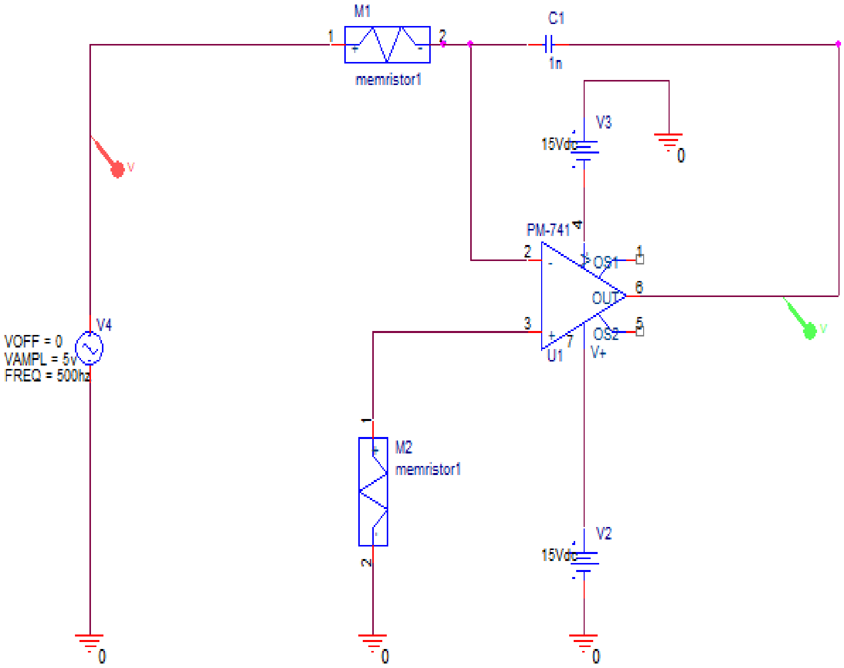

Figure 1: Integrator circuit diagram with input

The figure shows the current at the inverting terminal through the memrsitor(m_1) with the virtual ground.

Therefore, the current through the capacitor given by

Further, applying KCL at the inverting terminal

Substituting the terms of i_{m1} and i_c we get

Taking the integral we obtain

where 'V_o' the value of output voltage having integrated value of the input voltage. This integrator circuit has been employed in various circuits such as analog computers, analog -to- digital converters (ADC) and wave shaping circuits.

- SIMULATION CIRCUIT DIAGRAM OF THE DIFFERENTIATOR

Figure 2 shows the differentiating amplifier performs the mathematical operation of differentiation. Where the output signal becomes differentiated with respect to the applied input signal. This differentiator has been formed by the basic inverting amplifier an input resistor and a feedback capacitor into the feedback path.

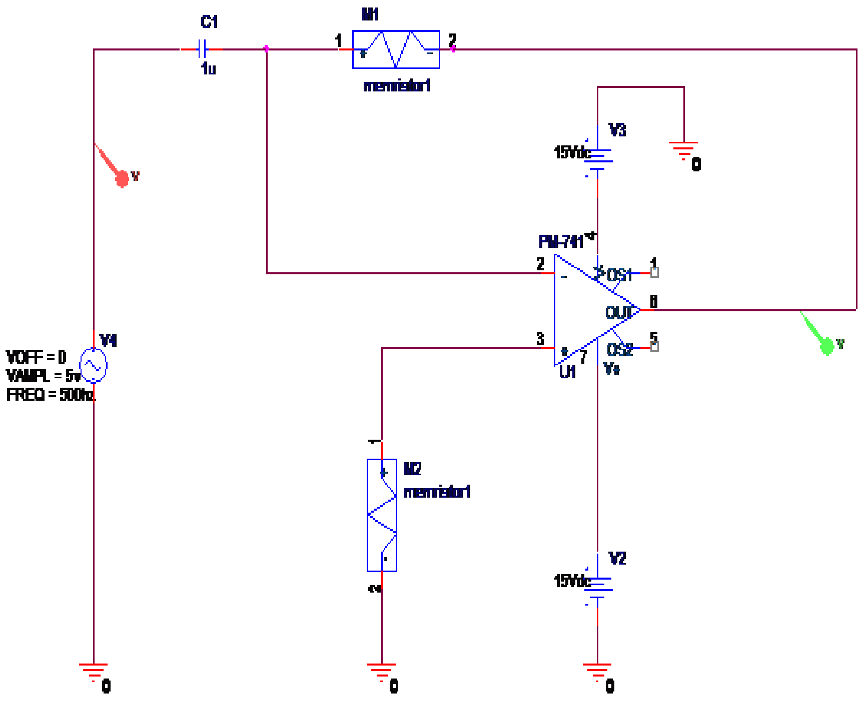

Figure 2: Differentiator circuit diagram with input

Figure 2 shows the inverting terminal current the current through the capacitor given by

And the current through the memristor(M_1) is

Furthermore, applying Kirchoff's Current Law into the inverting terminal input.

Therefore, the output voltage is

Thus the output voltage becomes inverted with input voltage *Vi* with respect to time and multiplied M_1C_1 times.

- **Simulation Circuit Diagram Of The Non-Inverting Amplifier**

Figure 3: Non-inverting amplifier circuit diagram with input.

Figure 3 shows the voltage at the non-inverting terminal

Let $V_1 = V_i$
Voltage gain defined as (A_V)=
Substituting the V_i in the above equation we obtain

Rearranging the above equation we get

Therefore, the output voltage
Hence, the output voltage shall be gain multiplied by input voltage with same polarity. Furthermore, the memristor M_2=0, an unity gain amplifier shall be obtained. And if the memristor M_1=0 gain of the amplifier shall approach infinity. However, practically these are determined by the open-loop differential gain(A_o).

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- **Simulation Circuit Diagram Of The Inverting AMPLIFIER**

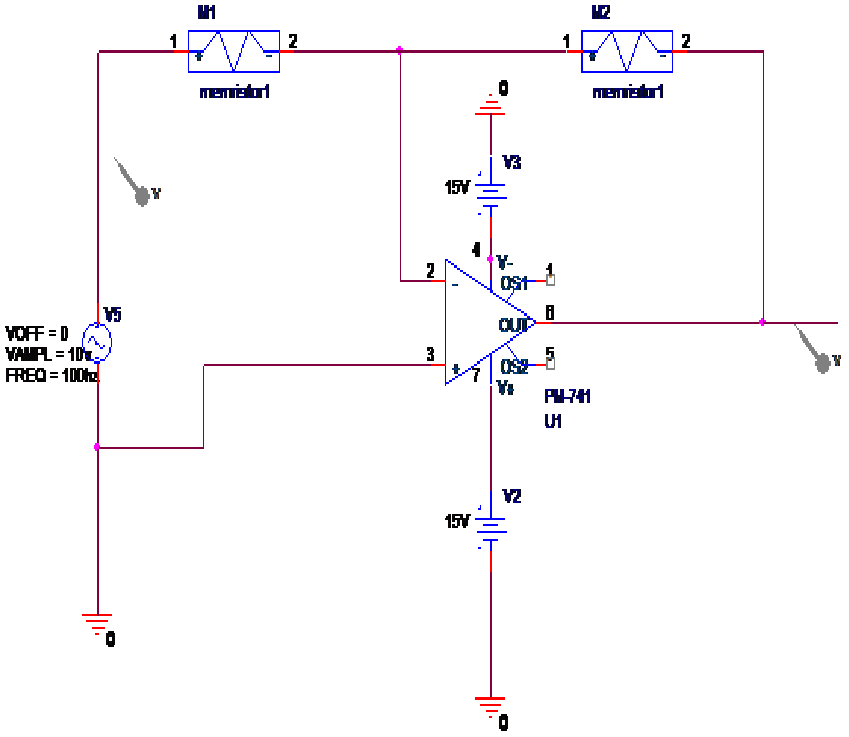

Figure 4: Inverting amplifier circuit diagram with input
Figure 4 shows the current at the inverting terminal input

Also at the virtual ground,
Therefore,

And as

Therefore the closed loop gain given as from the above equation

The above equation illustrates that the output signal voltage(V_o) gets inverted with respect to the input signal voltage(V_i). These inverting amplifier has many applications such as transresistance amplifier circuit. An current-to-voltage converter is an transresistance amplifier. For example, for low power applications, when an very small current generated by a photo-diode or photo-sensing device using this amplifier produces an usable output voltage which is proportional to the input current.

- **Simulation results**

The ORCAD Pspice version 16.0 has been used for simulation[8].

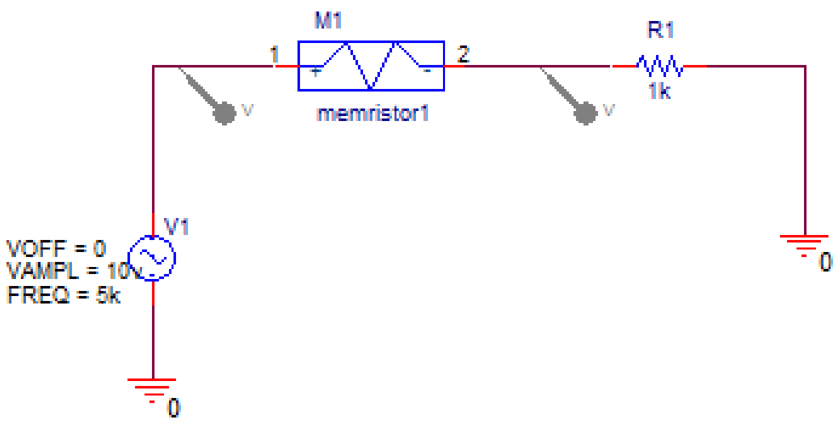

Figure 5: Simulation circuit of Ideal Memristor

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Figure 5 shows the circuit connection for simulating the ideal memristor characteristcs

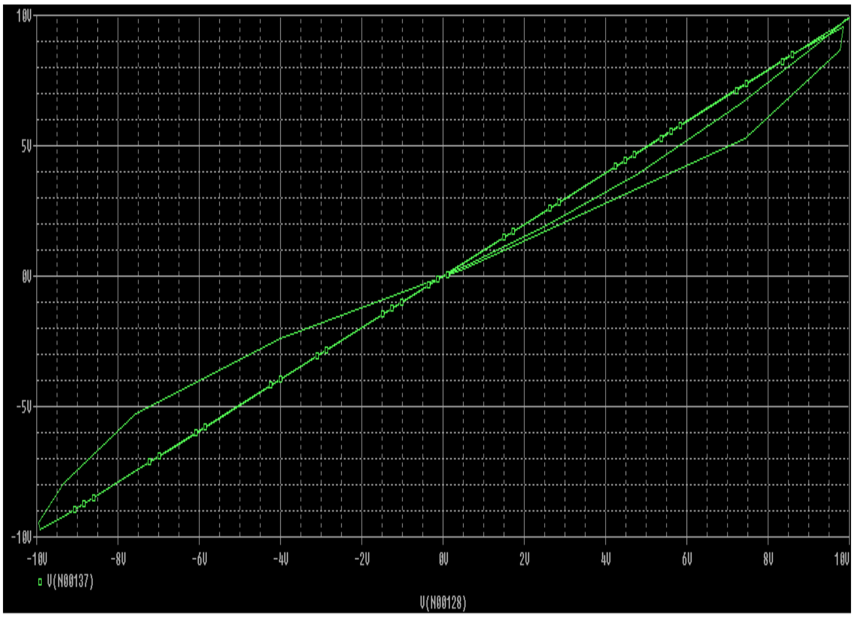

Figure 6: Hysteresis Waveform of Memristor

Figure 6 shows the results obtained from the simulation of Memristor. Which indicates the finger prints of the memristor such as pinched hysteresis curve passing through origin and with increasing frequency the lobes of the hysteresis curve diminishes and exhibiting an linear curve were also verified.

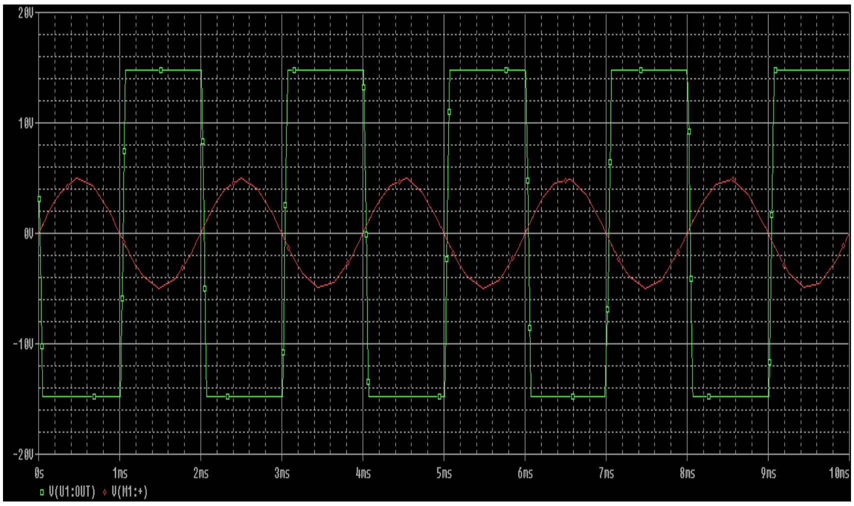

Figure 7: Simulation Output Of The Integrator

Figure 7 shown the output of integrator. The sine wave is applied to the integrator circuit. when input is zero output raises to the saturation level, when input raises the output saturation voltage remains constant.

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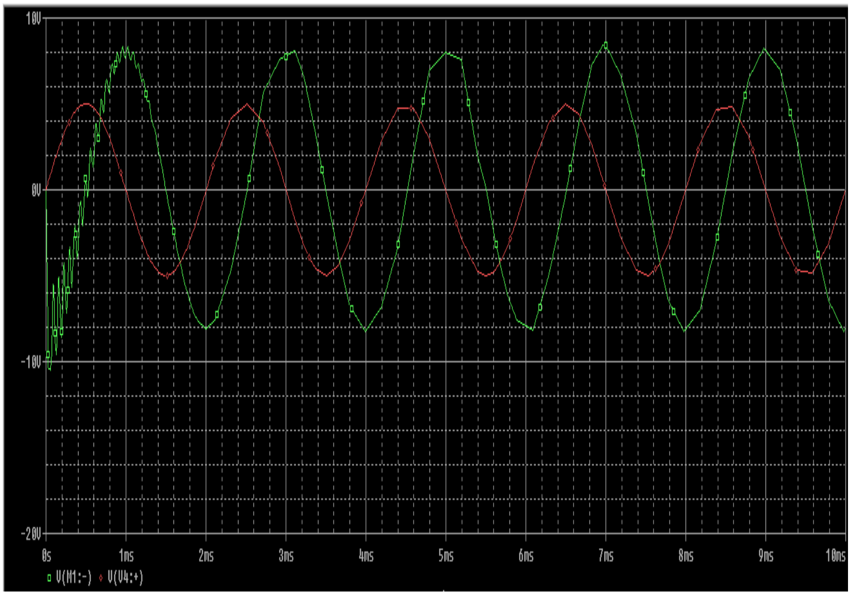

Figure 8: Simulation Output Of The Differentiator

Figure 8 shows the output of the differentiator. when input is applied to the capacitor, capacitor current moves through the feedback memristor producing voltage drop across it. Therefore, when the input waveform applied as a sine wave and output will be cosine waveform.

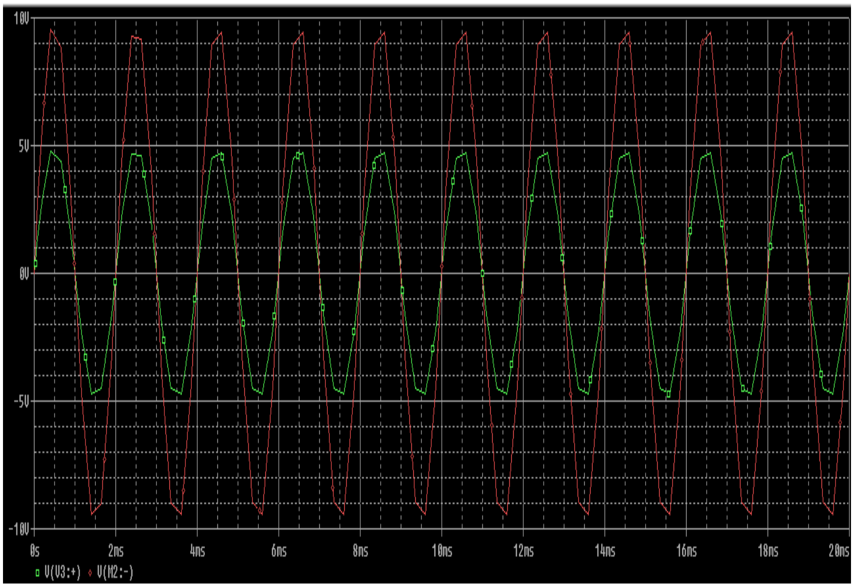

Figure 9: Simulation Result Of The Non Inverting Amplifier

Figure 9 shows the output of the non inverting amplifier. When an input voltage is applied through non-inverting terminal of the opamp, the two memristor provide voltage divider in the circuit. Hence, when the input applied voltage to the positive terminal of the opamp. And the output terminal is fed back to the negative terminal of the opamp through an resistive divider formed by m1 and m2(Figure 3) has the same phase that of the applied input voltage.

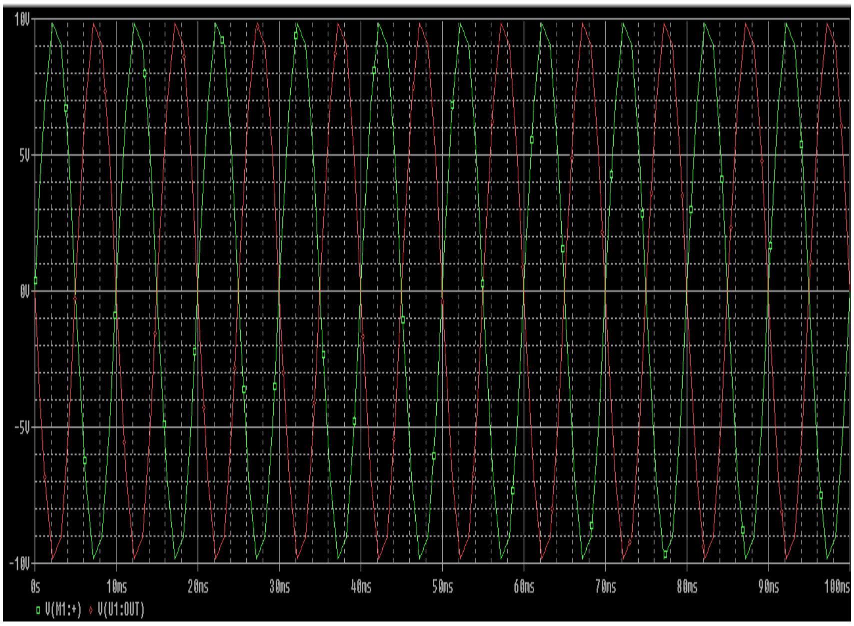

Figure 10: Simulation Output Of The Inverting Amplifier

The input voltage is applied to one terminal of the memristor which is connected to the negative terminal of the opamp. The positive terminal is grounded with the output terminal is connected to the negative terminal with a memristor(Figure 4). Figure 10 shows the simulation result of the inverting amplifier. The output signal is inverted with respect to the input signal applied to the inverting terminal of the amplifier.

• CONCLUSION

The Memristor can be classified as such a discovery which can revolutionize the future of the Electronics Industry. Memristor modelling has been studied and the implementation of memristor in pspice and the characteristics of memristor also obtained. Design and simulation of basic analog circuits using memristor has been implemented.

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