Proposal for Memristors in Signal Processing

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Abstract. Recently researchers at Hewlett-Packard have announced the discovery of a new material having resistance switching characteristics and which has been characterized as a fourth fundamental circuit component called the “memristor”[1]. It is proposed to combine such memristors with operational amplifier circuitry and fixed resistor elements so as to form a programmable signal processor capable of selective transmission and multiplexing of multiple signals for applications in communications and programmable drive waveform control.

Description of Device

While the recent revelation by Hewlett-Packard of bi-layer titanium oxide as a candidate material for the “missing memristor” initially speculated by Leon Chua [2] is an interesting and important development, it is not entirely unprecedented. Similar resistance variability effects in thin film oxides have been studied using perovskite [3] and similar materials. However, this research has mostly been limited to applications in non-volatile memory in which the switching resistance acts to store binary data in the form of high or low resistance states. Such materials may also have use in signal processing and control applications.

Fig. 1 illustrates an idealized approximation for the behavior of memristance material in which an applied voltage greater than some positive threshold voltage V_{L1} initiates a memristance region exhibiting variation from a high resistance level R_H to a low resistance level R_L as voltage is increased. Similarly, resistance may be converted from a low level back to a high level by a reversed polarity voltage in the region between $-V_{L2}$ and $-V_{H2}$. In the small signal region between $-V_{L2}$ and V_{L1} the material is either at a high or low resistance level depending on the history of voltage application to the material.

Fig. 2 illustrates an array of memristors M_1-M_4 having inputs connected to fixed resistors R_1-R_4 and outputs connected to a common inverting input of an operational amplifier having a feedback resistance R_F. Operational amplifiers in such a configuration exhibit the well known effect of summing the input signals based on a weighting determined by a ratio of the feedback resistance and the input resistances. However, the inclusion of memristors allows controllability in selecting which signals to sum and, if tuned within the memristance region, the weighting values of each input signal may also be adjusted. By using harmonic sinusoidal signals or step

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signals with relative time delays as the voltage signal inputs this circuit configuration may be used for programmable waveform generation useful for automatic control systems. Programmable signal mixing and modulation may also be facilitated using this configuration by switching memristor values during communication applications such as frequency hopping.

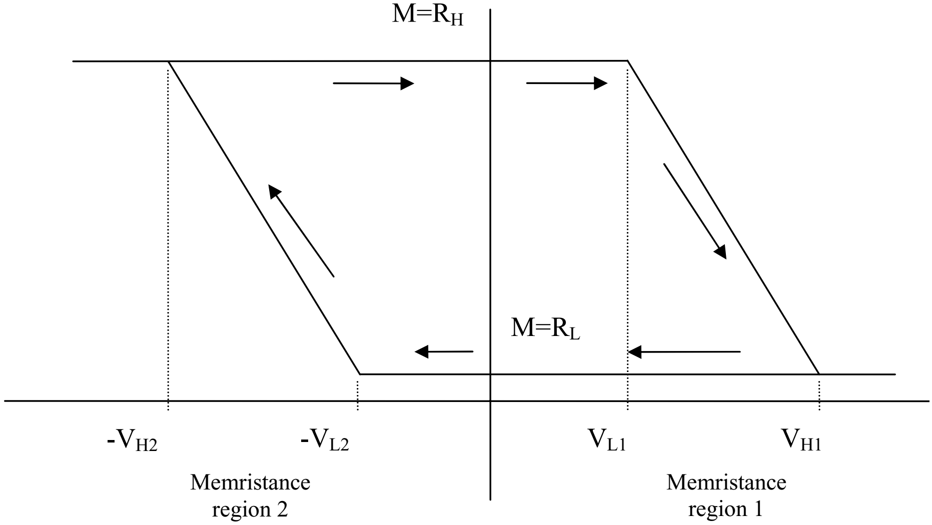
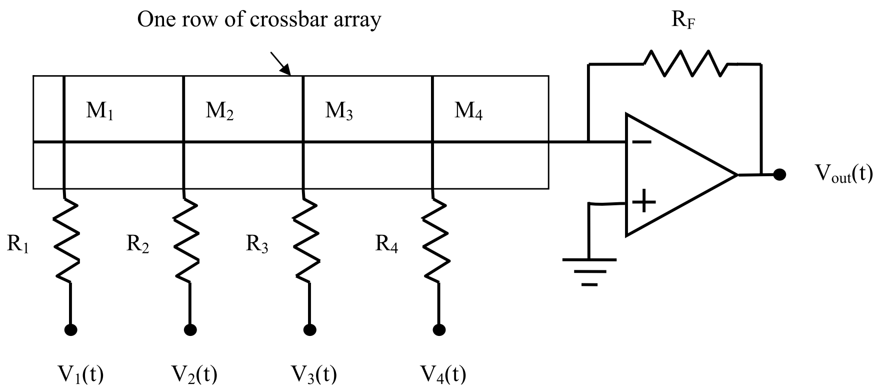


Fig. 1. Idealized hysteresis model of resistance vs. voltage for memristance switch



$V_{out}(t) = -\sum_i V_i(t) * R_F /(R_i + M_i)$ $M_i = R_H$ or R_L for $-V_{L2} < V_i(t) < V_{L1}$

By setting the fixed resistors $R_F << R_H$ and $R_i = R_F - R_L$ the output signal may be approximated by:

$V_{out}(t) \cong -\sum_i V_i(t) * \delta(M_i)$, $0 \le \delta(M_i) \le 1$ depending on the memristance states.

Fig. 2. Summing amplifier configured with memristance elements

References

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