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# Revisit to RC Linear Circuit Theory

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This paper discusses two RC linear circuits. (i) The first one is the spatial and temporal response of *spatially shift-variant* (non-uniform) networks with positive and negative resistors. Response of general spatially shift-variant networks whose resistor components are different from each other is investigated. This study is motivated by the vision chip in [1] whose network consists of positive and negative resistors with parasitic capacitors; we previously found there that when the negative resistance effect becomes large, the resistor network becomes unstable [2]. We also showed that both spatial and temporal network behaviors have some relationships even for the shift-variant network [3]. In this paper, we have further investigated their relationships and obtained the following conjecture from extensive simulations: *"The network is temporally unstable if there is a node where the input current is injected and its node voltage as the spatial impulse response is negative. However even if there is NOT such a node, there are some networks which are temporally unstable".* (ii) The second one is a relaxation digital-to-analog converter (ReDAC) configuration with positive and negative polarity output with a simple RC high pass filter (HPF) [4]. Its digital input is provided in two's complement format, to which the proposed ReDAC configuration directly matches. The proposed ReDAC with HPF is an extension of the conventional ReDAC using a simple RC low-pass filter (LPF) which generates an analog output with only positive polarity. We remark that the RC linear circuit theory is considered as a mature research area, but still there are challenging problems.

**References**

[1] H. Kobayashi, J. et. al., "An Active Resistor Network for Gaussian Filtering of Images", *IEEE Journal of Solid-State Circuits*, vol.26, no.5, pp.738-748 (May 1991).

[2] H. Kobayashi, et. al., "Two-Dimensional Spatio-Temporal Response of Analog Image Processing Neural Networks", *IEEE Trans. Neural Networks*, vol.6, no.5, pp.1148-1164 (May 1995).

[3] M. Chiba, et. al., "Spatial and Temporal Dynamics of Non-Uniform Active Resistor Networks", *IEEE 16th International Conference on Solid-State and Integrated Circuit Technology*, (Oct. 2022).

[4] L. Nengvang, et. al., "Relaxation DAC with Positive and Negative Polarity Output using High-Pass Filter", IEICE Electronics Express (Advance online publication: Jan. 2023).