DESIGN OF OSCILLATION-BASED TEST STRUCTURES FOR ACTIVE RC FILTERS

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Abstract

We apply the oscillation-based test strategy [1] to test active RC filters. We develop general guidelines for the design of the oscillation-based test structures and describe in more details the resonator active filter (biquad filter) configuration. It can be shown that some of the derived structures are achieved by simple circuit modification while for the more general case additional feedback loop network is required.

The sinusoidal steady-state frequency response characteristics of a filter are related to pole and zero locations. In principle, one can assess if given filter conforms the required specifications by establishing its pole and zero positions. In practice, some means must be provided to put the filter circuit into oscillation at the frequency of the pole and the frequency is measured by an electronic counter. Possible faulty components manifested in the changes of the oscillation frequency are thus detected.

High order filters are mostly constructed by cascaded filter stages. In this paper we focus our discussion on testing filter stages which realize a second-order voltage transfer function.

The expressions representing the general form of the second-order voltage transfer function have the following general form

$$\frac{V_2(s)}{V_1(s)} = \frac{N(s)}{s^2 + \frac{\omega_n}{Q}s + {\omega_n}^2}$$

Hereby, $N(s)$ is a polynomial of the order ≤ 2, depending on the type of the filter (e.g., low-pass, high-pass, band-pass), ω_n is the undamped frequency of the pole, and Q is the quality factor.

The positions of poles in the complex frequency plane are given by $p_{1,2} = -\frac{\omega_n}{2Q} \pm j\frac{\omega_n}{2Q}\sqrt{4Q^2-1}$. In order to put the network into oscillation with constant amplitude the poles must be placed on the $j\omega$ axis. Consequently, if $\frac{\omega_n}{2Q} = 0$ the network will oscillate with the resonant frequency ω_n. This condition is satisfied when the quality is sufficiently high (ideally infinitive). Both ω_n and Q are functions of the elements of the network. In order to keep the frequency of pole unaltered the quality should be increased only by changing the values of the components which do not affect the change of the frequency.

To illustrate the approach, we give an example of the oscillation-based test structure for the resonator active filter shown in Fig.1. The denominator of its transfer function is given by $s^2 + \frac{1}{R_1C_1}s + \frac{R_6}{R_2R_3R_5C_1C_2}$. The frequency of the pole and quality factor are given by $\omega_n = \sqrt{\frac{R_6}{R_2R_3R_5C_1C_2}}$ and $\frac{1}{Q} = \frac{1}{R_1}\sqrt{\frac{R_2R_3C_2}{C_1}}$. The condition for oscillation $\frac{1}{Q} \to 0$ without affecting ω_n will be satisfied if $R_1 \to \infty$. As a result, the switch S_1 is introduced to disconnect R_1 during the test mode.

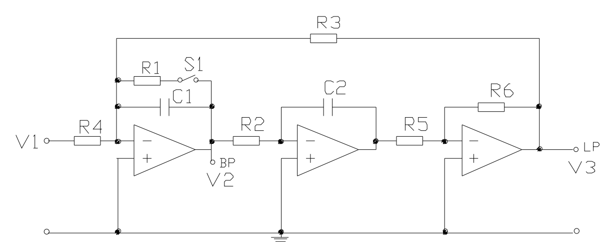

Figure 1: A resonator active filter (with switch S_1 OFF in the test mode

Oscillation-based test structures for other active RC filters and experimental results are described in [2].

[1] K.Arabi, B.Kaminska, *Oscillation-test strategy for analog and mixed-signal integrated circuits*, Proc. 14th VLSI Test Symp. 1996, pp. 476-482.
[2] M.Santo Zarnik, et al., *Design of oscillation-based test structures* IJS Tech.Report 7479, 1996.

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