NOTCH FILTER ON HIGHER FREQUENCY – STRUCTURE WIEN-ROBINSON

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ABSTRACT

This paper deals with analysis of active band rejection filter in higher frequency domain. Requirements expressions of used operation amplifiers parameters are derived with special concern on dimension of their transit frequency.

1 INTRODUCTION

Active RC filters are usually used in the low frequency area, where aren’t excessive demands on circuit elements (mainly amplifiers) setting. In studied frequency area (video signals) are active blocks used on the edge of their technological limitations. There are many emphatic parasitic features exhibited and they didn’t have to be previously respected.

2 ACTIVE WIEN-ROBINSON FILTER

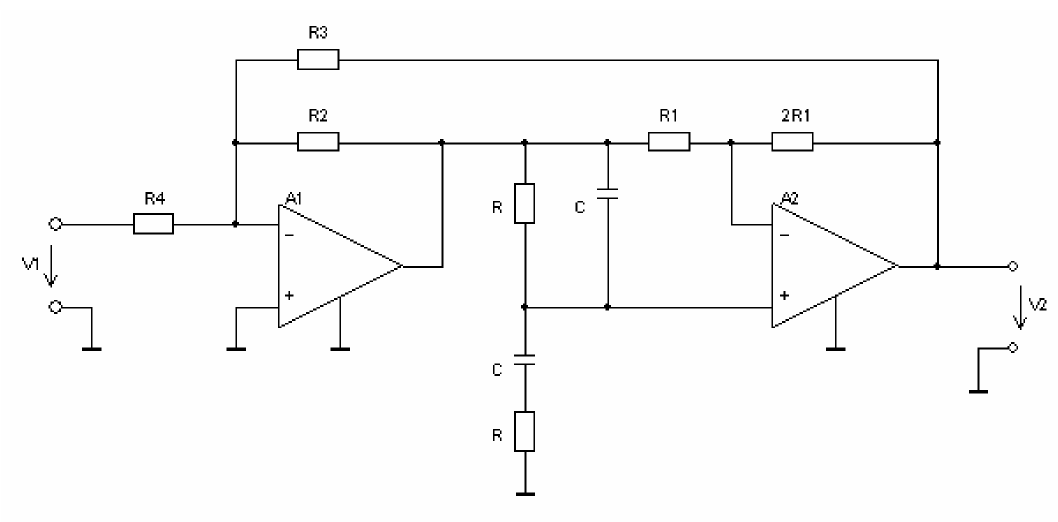

Fig. 1: *Circuit realization of Wien-Robinson filter*

From many types of active band-rejection filters with two operation amplifiers (opamps) which were tested [1], for this paper Wien-Robinson filter was chosen, because it has good properties in reflected area. This circuit [2] is based on passive band-rejection filter with differential output. The output voltage is the difference between the potential of a constant voltage divider and the output of a band-pass (Wien circuit) filter. To achieve higher values of selectivity, the passive version is connected into the feedback loop of an amplifier. Complete active circuit is shown on Fig. 1.

The program for symbolic analysis SNAP [5] was used for deduction of voltage transfer function of this circuit (Fig. 1). Its output (produced function) was formed according to common equation for description of second order band-rejection filter [3] whose form is

$$K(s) = \frac{K_0 (s^2 + \omega_P{}^2)}{s^2 + \frac{\omega_P}{Q_P} s + \omega_P{}^2} \tag{1}$$

Resultant equation for Wien-Robinson filter is

$$K(s) = -\frac{R_2 R_3}{R_4 (R_2 + R_3)} \cdot \frac{s^2 + \frac{1}{R^2 C^2}}{s^2 + \frac{3R_3}{R_2 + R_3} \cdot \frac{1}{RC} \cdot s + \frac{1}{R^2 C^2}} . \tag{2}$$

After comparison with (1) can be expressed separate parameters of filter.

Frequency of rejection (mid-frequency) is given

$$\omega_0 \equiv \omega_N = \omega_P = \frac{1}{RC} , \tag{3}$$

$$f_0 = \frac{1}{2\pi \cdot RC} . \tag{4}$$

Rejection quality (selectivity) factor is

$$Q \equiv Q_P = \frac{1}{3} \cdot \left(1 + \frac{R_2}{R_3} \right) . \tag{5}$$

Gain in a passband is

$$K_0 = -\frac{R_2 R_3}{R_4 (R_2 + R_3)} = -\frac{R_2}{R_4} \cdot \frac{1}{3Q} . \tag{6}$$

3 ANALYSIS OF FEATURES OF FILTER

The greatest effect on degradation of features of active filters in higher frequency range has the ultimate rate of the transfer frequency f_T (finite bandwidth) of the used opamps. Deformation of the frequency characteristics $K(s)$ of circuits depends on decline of voltage gain $A(s)$ of amplifiers.

Aim of this testing [1] was description of requirements of filter on used operation amplifiers. In this paper the formulation of dependence of minimal required transit frequency

$f_{T\,MIN}$ on rejection quality (selectivity) Q is specified. For a disqualification of the effect of other nonideal features of amplifiers (especially finite input and nonzero output impedance), single-pole model [4] was employed. This model allows us independent setting of open-loop voltage gain A_0 and also of transit frequency f_T (through time constant of internal RC network).

For testing procedure the circuit simulator PSpice 9 [6] has been used. The filter was designed with certain set of parameters, in detail with mid-frequency $f_0 = 1$ MHz, rejection quality $Q = 10$ and passband gain $K_0 = -1$. The parameters of operational amplifier (A_0, f_T) were chosen in accordance with common available high-speed circuits [7] [8]. In analysis $A_0 = 10^3$ (60 dB) and $A_0 = 10^4$ (80 dB) were adjusted and f_T (order 10 – 100 MHz) was changed.

Frequency characteristics were tested for different values f_T, with the view of acquire their shapes. Then it is possible to composite a criterion for determination $f_{T\,MIN}$. The results are shown on the figure 2 below ($Q = 10$, $A_0 = 10^3$). There are two places of deformation appeared – overshoot K_{MAX} on $f < f_0$ (marked zone A) and fault of slope on $f > f_0$ (major effect) (zone B). Behavior in the area of rejection is a great advantage of this structure, because the attenuation is independent on f_T.

The analysis result shows the optimal standard for determining $f_{T\,MIN}$ – specific a tolerance zone ± 3 dB.

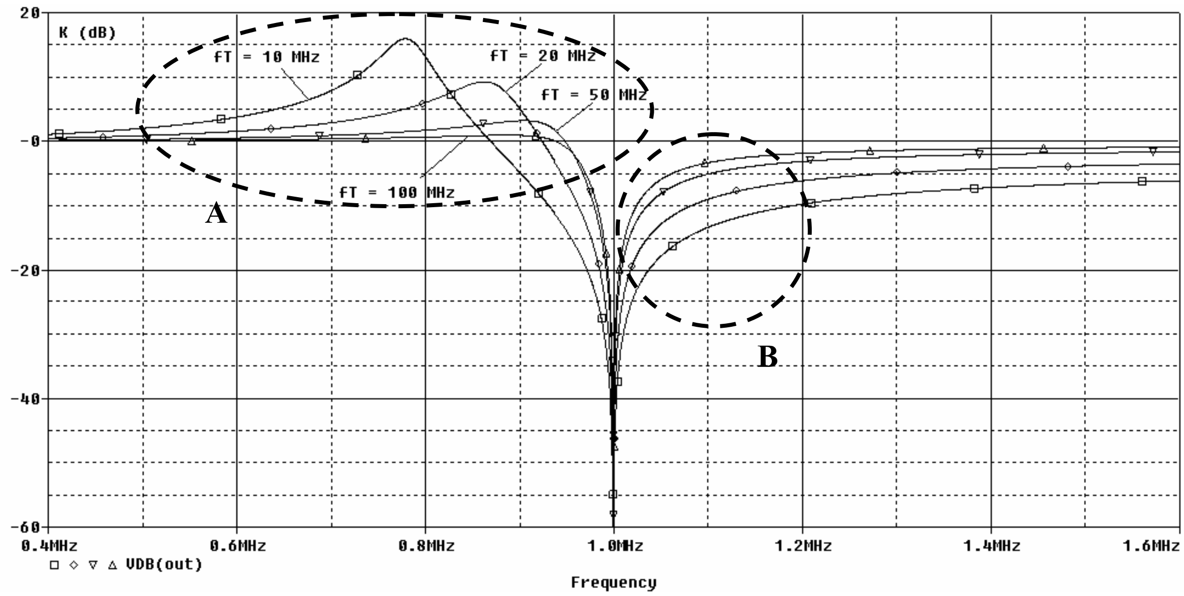

Fig. 2: *Frequency characteristics of Wien-Robinson filter for various values f_T*

In comparison with ideal filter, the measured gain curve must maintain within this region (see the figure 2). This can be expressed by means of following equation

$$f_T = f_{T\,MIN} \quad \Leftrightarrow \quad |K - K_{ID}| = 3\,dB \tag{7}$$

Practically, the frequency f_T has been traced (identically for both opamps) and the absolute value of error function has been plotted. Clearly, it is the difference between simulated and ideal process. I determined $f_{T\,MIN}$ in the points where the value of simulated function equals 3 dB. Several repeated analysis have been done for various values of the selectivity, namely $Q = 5, 10, 20, 30, 40, 50$ and 100.

For example, if designed filter has the selectivity factor $Q = 10$ and is considered an opamp with open loop gain $A_0 = 10^3$, then based on condition (7) following requirement on the amplifier has been stated: $f_{T\,MIN} = 96$ MHz. By comparison of frequency characteristics of mentioned filter $K(f)$ in this boundary state with ideal shape $K_{ID}(f)$ is showed below (Fig. 3). The determinant point is placed closely behind rejection – marked zone C on difference function.

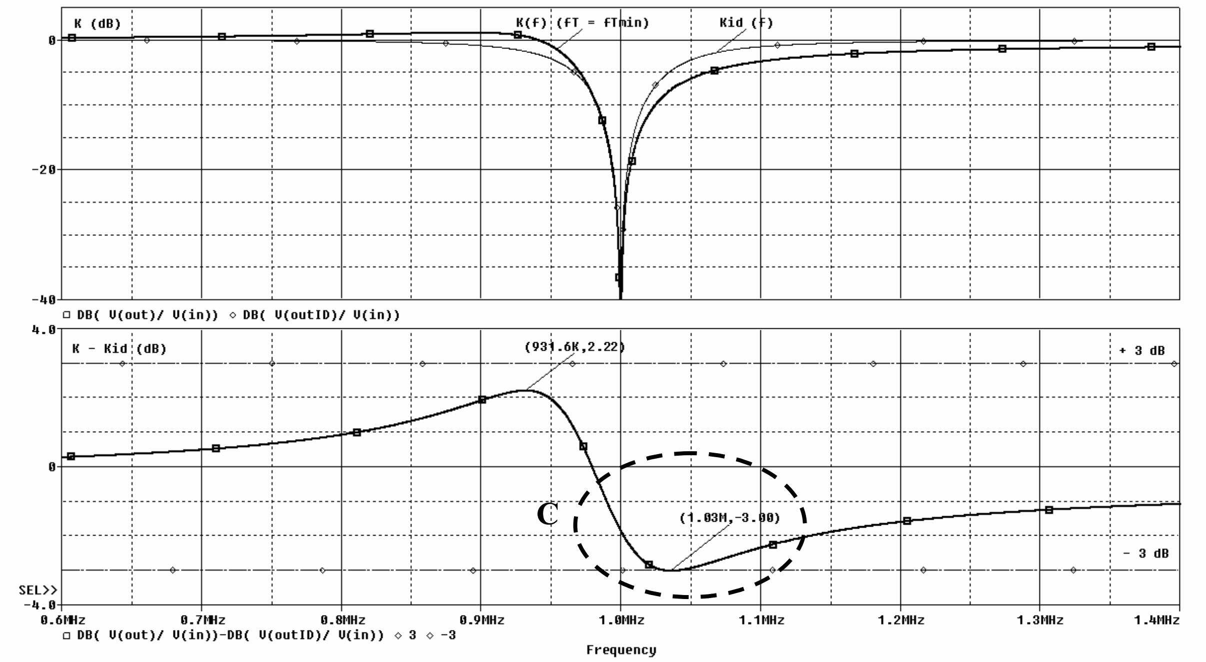

Fig. 3: *Frequency characteristics of Wien-Robinson filter for $f_T = f_{T\,MIN}$ – comparison of tested transfer function with ideal (upper) and comparison of difference function with toleration area (lower)*

The results of testing (dependencies $f_{T\,MIN} = f(Q)$) are summarized in following table 1 and figure 4.

Q (-)	5	10	20	30	40	50	100	A_0 (-)
$f_{T\,MIN}$ (MHz)	49	96	203	336	510	777	> 1000	1,00E+03
	47	90	176	264	353	443	900	1,00E+04

Tab. 1: *Requirements of Wien-Robinson filter to transit frequency*

Graphical expression (Fig. 4) shows, that the rising of function $f_{T\,MIN} = f(Q)$ is by $A_0 = 10^4$ approximately linear. Based on this finding can be write equation for estimation of requirements:

$$f_{T\,MIN} \approx 9 \cdot Q \quad [MHz, -] \tag{8}$$

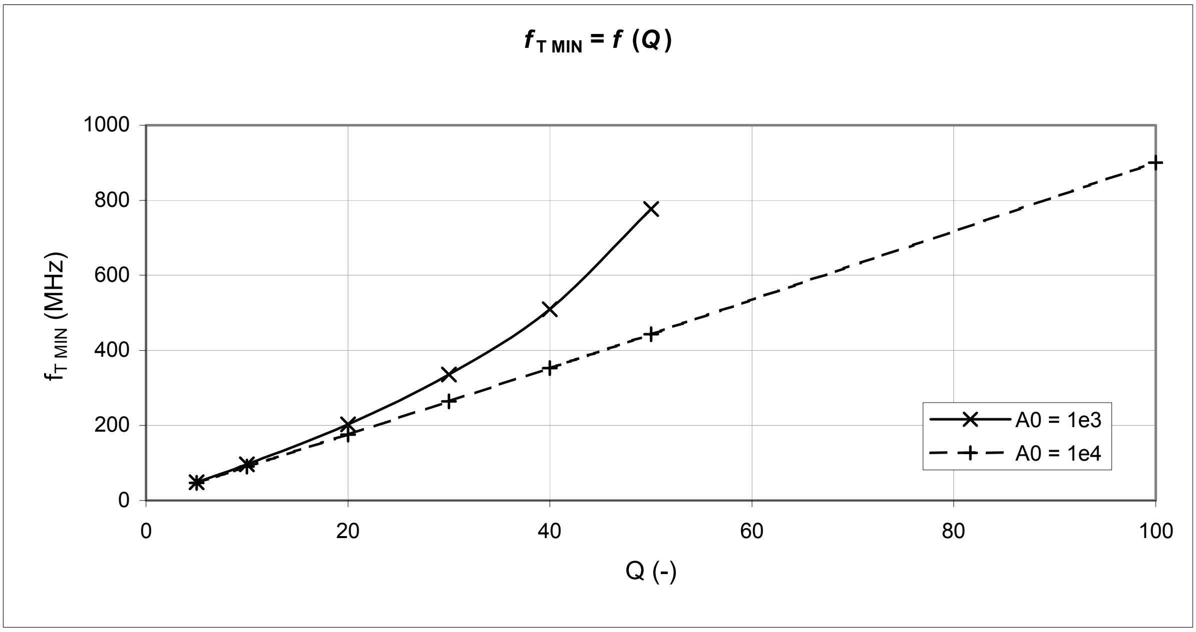

Fig. 4: *Dependence of transit frequency on selectivity*

4 CONCLUSION

Based on obtained results it can be stated that in special cases (f_0 = 1 MHz), this filter is useful for practical experimental measuring. Frequency requirements on the opamps are satisfied by many commercially available products in high-speed category [7] [8]. Testing of effects of input and output impedance of opamps [1] also validates this statement.

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