PROPERTIES AND COMPARISON OF AKERBERG-MOSSBERG AND KERWIN-HUELSMAN-NEWCOMB FILTERS

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ABSTRACT

The article describes design and properties of universal tuning filters of modified type Akerberg-Mossberg and type Kerwin-Huelsman-Newcomb with the help of use of the active modern elements. Both filters have good properties for digital tuning of resonant frequency f_0, Q-factor, constant K and frequency f_N. These universal filters are susceptible to obtain each transfer function as low-pass, high-pass, band-pass, band-reject, all-pass, low-pass notch and high-pass notch. The main purpose of the article was to create physical realization of one of these filters which embodies better properties during digital tuning of its individual parameters. This comparison of these filters was created due to the software SNAP and PSpice.

1. INTRODUCTION

In some cases, there are problems, which cannot be solved by common and standard types of filters. That is why we must solve universal filters individually, in majority of cases there are no clear solutions and often it is not possible to set unified processes of the design. Also during their designing, it is possible to use some findings from the solutions of standard filters. In the filter literature have been prescribed many connections of universal ARC circuits which enable to realize transfer function (1) in form of biquads [1]:

$$H(s) = K\frac{N(s)}{D(s)} = K\frac{b_2 s^2 + b_1 s + b_0}{a_2 s^2 + a_1 s + a_0} = K\frac{s^2 + s\omega_z / Q_z + \omega_z^2}{s^2 + s\omega_0 / Q_0 + \omega_0^2} \qquad (1)$$

From transfer function (1), with the help of the software SNAP it is possible to derive the formulas for f_0, f_N, Q, K_0 for both filters. Due to these formulas we can make a complete design of the filter, for frequency decades from 10Hz to 10MHz. On the basis of these designs, it is possible to simulate filters in the software PSpice, where the sensitive analyses will be made and possibilities of digital tuning and accuracy of basic parameters (f_0, Q, K_0) will be compared.

2. PROPERTIES OF UNIVERSAL FILTERS

The filters A-M and K-H-N are very often used in practice due to its large universal abilities. This chapter describes the derivation and optimalization of its parameters. These parameters functions for the design and following comparison of both filters. These filters can be seen on the figures 1 and 2 [1].

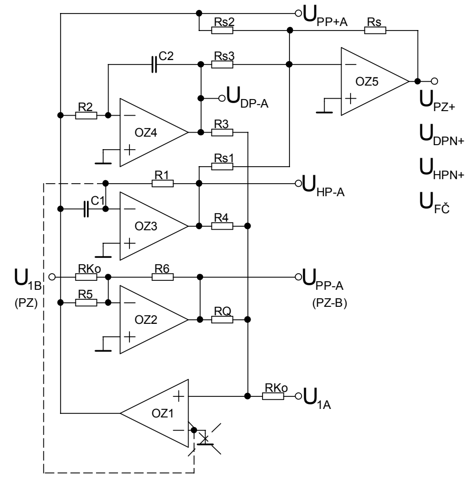

Figure 1: A-M biquad building (modification).

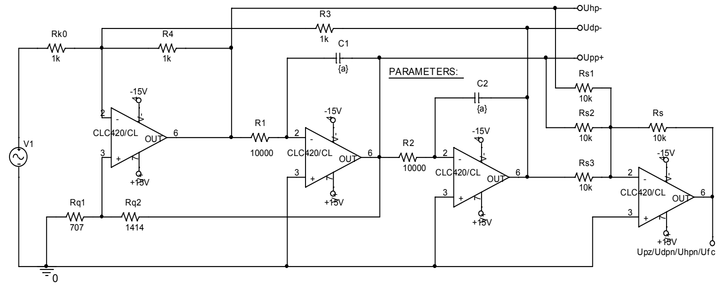

Figure 2: K-H-N biquad building.

First, we will define the denominator D(s) for both filters:

$$D(s) = s^2 + s\frac{R_a}{R_Q RC} + \frac{1}{C^2R^2} \tag{2}$$

$$D(s) = s^2 + s\frac{R_{Q1}\left(R_3R_4 + R_3R_{K0} + R_4R_{K0}\right)}{R_1R_3R_{K0}\left(R_{Q1} + R_{Q2}\right)C_1} + \frac{1}{C^2R^2} \tag{3}$$

In the case of optimized A-M circuits are circuit elements chosen according equations:

$$C_1 = C_2 = C; \qquad R_1 = R_2 = R; \qquad R_3 = R_4 = R_5 = R_6 = R_a \tag{4}$$

And similarly for optimized K-H-N circuit:

$$C_1 = C_2 = C; \qquad R_1 = R_2 = R; \qquad R_3 = R_4 = R_a \tag{5}$$

Then we can determine Q-factor for both filters:

$$Q_{A-M} = \frac{R_Q}{R_a} \tag{6}$$

$$Q_{K-H-N} = \frac{R_{Q1} + R_{Q2}}{R_a + 2R_{K0}} \tag{7}$$

Other parameters of K-H-N circuit as well as A-M circuits then can be given by the same Eqs. (8) - (12), constant K is determined using ratio of resistors $K = R_a / R_{K0}$. Thus the resonant frequency f_0 can be expressed as $f_0 = 1/(2\pi RC)$.

The numerators N(s) from Eq. (1) are given for different types of filter transfers by next expressions:

$$N_{LP}(s) = \omega_0^2 \tag{8}$$

$$N_{HP}(s) = -s^2 \tag{9}$$

$$N_{BP}(s) = s\omega_0 \tag{10}$$

$$N_{BR}(s) = R_S\left(s^2\frac{R_S}{R_{S1}} + \frac{R_S\omega_z}{R_{S3}}\right) \tag{11}$$

$$N_{AP}(s) = R_S\left(s^2\frac{1}{R_{S1}} - s\frac{\omega_0}{R_{S2}} + \frac{\omega_0^2}{R_{S3}}\right) \tag{12}$$

When we look at the comparison of Q-factor in the formula (6) – (7), we can say that the filter A-M enables much easier setting of Q-factor than the filter H-K-N. The second advantage of above presented modification of A-M circuit is in wider and more accurate usable frequency range than K-H-N filter. See the figures 3 and 4.

3. SIMULATING AND COMPARISON OF BOTH FILTERS

Simulations of both filters can be seen on the following figures 3 and 4. With the help of these simulations there is possibility to compare these properties of both filters, mainly f_0 and Q. After creating of individual simulations it can be said that both filters are able to set resonant frequency f_0 very well but about 1MHz are some problems with the Q-factor. If we want Q-factor bigger than 5, we can see some problems with the deformation of the transfer function about frequency 800 kHz and higher. These deformations are caused by the fact that both filters are not able to hold required parameters for the Q-factor. To see the situation on the example, filter A-M for the required value Q=20 has about f_0=1MHz another Q=28 and K-H-N has Q=48. The problem is probably caused by inappropriate type OAs when we require f_T about 1 GHz.

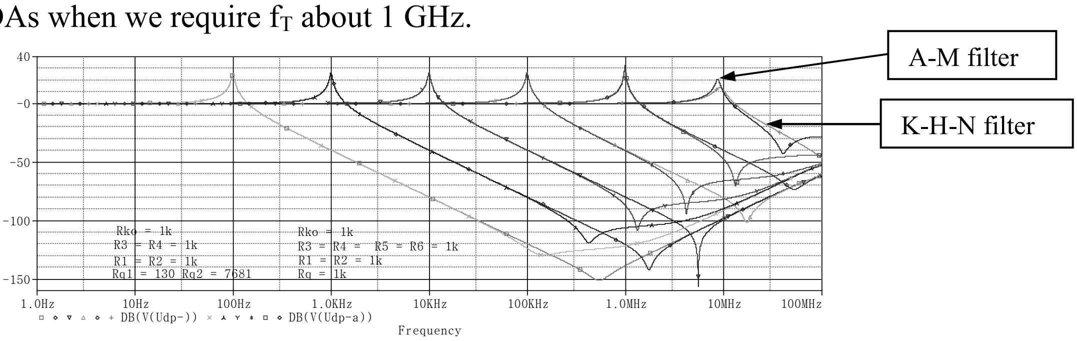

Figure 3: Comparison of A-M and K-H-N filters, low-pass Q=20, K=1.

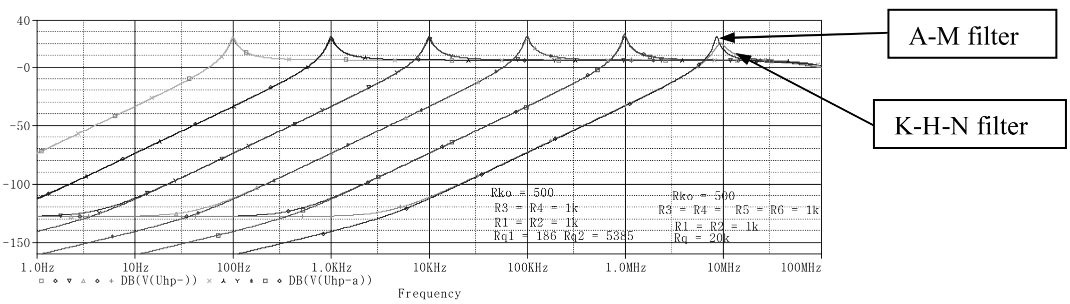

Figure 4: Comparison of A-M and K-H-N filters, high-pass Q=10, K=6.

Figures 5 and 6 present comparison of both filters with Q=10 and using of ideal OA and real OA of type CLC420. It is obvious that the filter A-M has smaller relative deviation then K-H-N filter.

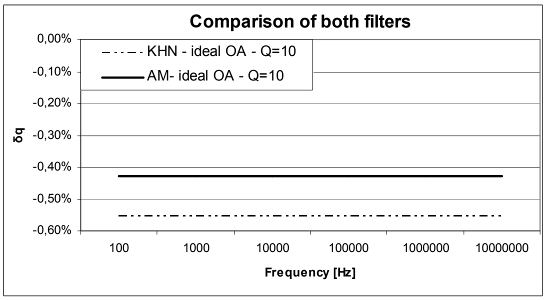

Figure 5: Comparison of A-M and K-H-N filters for ideal OA.

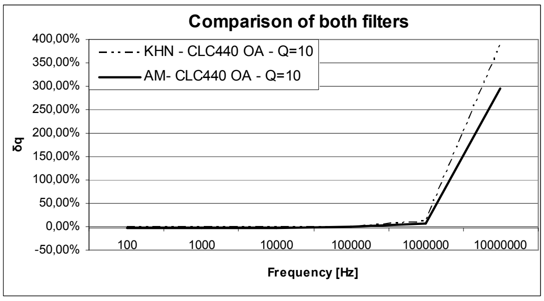

Figure 6: Comparison of A-M and K-H-N filters for real OA type of CLC440.

4. FINAL REALIZATION OF THE FILTER

It is obvious that there is overall connection of modified A-M filter on the figure 1. If we want to make use of digital tuning for this filter, we have to replace resistors R_1 and R_2 by the digital potentiometer, and capacitors C_1 and C_2 by the multiplexers. The multiplexers, digital potentiometer and other electronical elements are tuned by the microprocessor ATMEGA 32. Individual requirements from the user are set with the help of a keyboard and these commands are displayed on LCD display. The complex tuning can be seen on the figure 7. By the extension of this connection it is possible to tune other parameters as f_N and K_0.

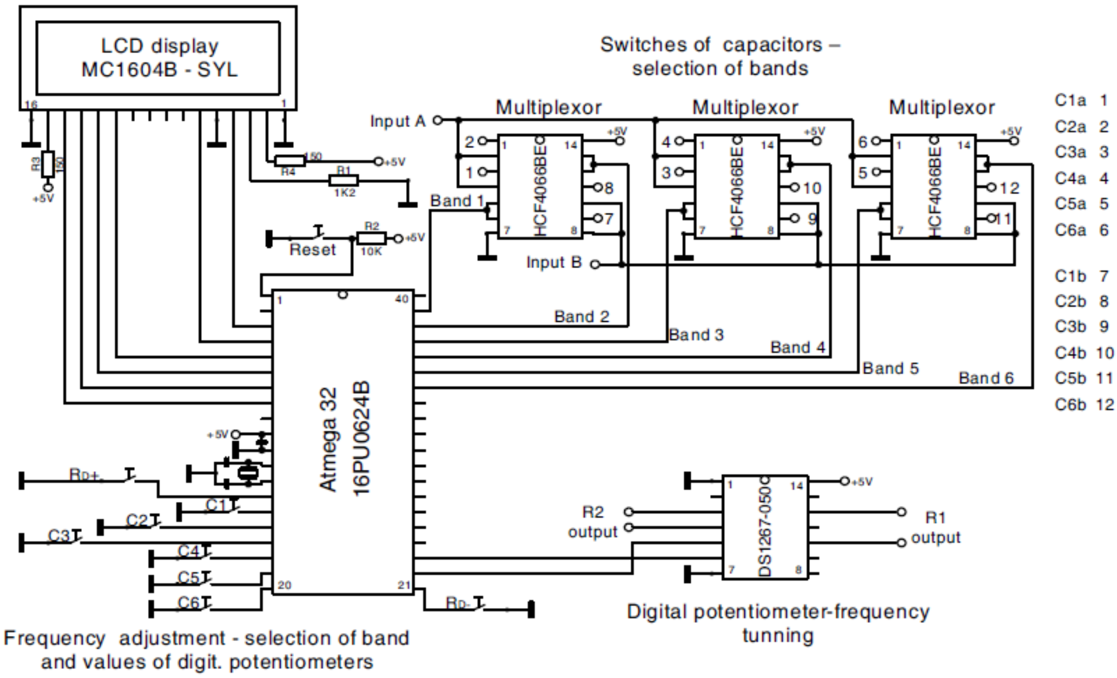

Figure 7: Main part of microprocessor control of the universal adaptive filter.

5. MEASURING OF THE A-M FILTER

This universal biquad block is enable to fulfil many special requirements on tuning of filter parameters or adaptive switch able filter options. The filter has a lot of output transfer function which can be used in wide band from 10Hz to 10MHz with digital tuning of parameters Q-factor, transmission constant K_0, frequency f_0. The example of measurement of the low-pass of the A-M can be seen on the pictures 8 and 9.

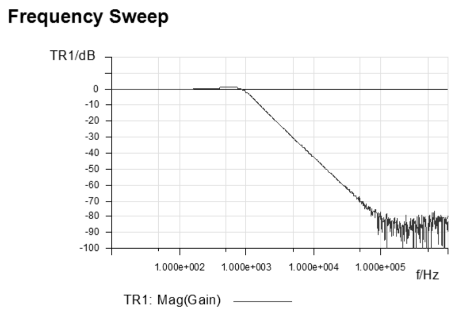

Figure 8: Transfer function of the filter A-M for LP: Q=1, K=1 and f_0=1kHz.

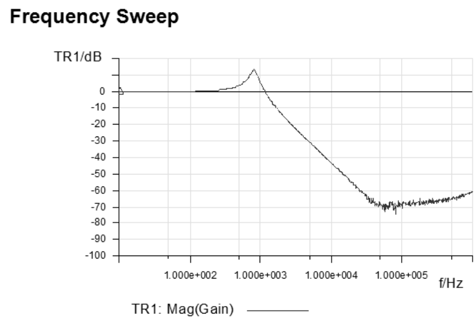

Figure 9: Transfer function of the filter A-M for LP: Q=5, K=1 and f_0=1kHz.

6. CONCLUSION

This article presents some basic information about properties of modified A-M filter and K-H-N filter. This article was divided into three parts. First part describes properties of A-M and K-H-N filters. These properties could be gained by the software SNAP which helped me with the creating of basic formulas of both filters. Second part compares these two types of filters in terms of individual simulations. By the help of these simulations, it was possible to create graphs which show relative deviation of the filters for resonant frequency f_0 and Q-factor. At the end, it can be said that A-M filter has better properties for both resonant frequency f_0 and Q-factor than K-H-N. A-M filter has much easier tuning Q-factor only with the help of resistor R_q. The whole design of filter was created for the frequency band from 10Hz do 10MHz using digital potentiometer. Switching of capacitors C_1, C_2 and also choice of frequency decade was realized with the help of multiplexer. For the realization of the filter, OAs CLC420 were used, it enables working on the resonant frequency around 1MHz. Next increasing of the frequency leads to the deformation of the transfer functions. The following step will be creating of the filter enabling realization up to 10th orders with the use of D/A convertor.

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