RLC, ARC BAND-PASS COUPLED FILTERS

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ABSTRACT

The article describes design and the use of active band-pass coupled filters. These filters have better properties in comparison to properties of band-pass ladder filters. Active coupled filters are realized in this article with the use of synthetic inductor, frequency dependent negative resistor or impedance convertor. The article describes some potentialities of the use of SW programme for quick suggest and display of basic transfer functions and results of RLC and ARC coupled filters of the fourth and the sixth orders. This SW programme called „Coupled filters“ was realized in C++ Builder.

1. INTRODUCTION

The design of band-pass ladder filters brings certain problems in case of relatively narrow bandwidth, when the ratio of values of individual building elements is increasing. The main problem is to achieve the required quality factor of each element. The narrower relative bandwidth of band-pass means the higher needed quality factor Q of circuits, and the more qualitative elements L and C are necessary to be used for the realization of the filter, so that there will be no deformation of transfer functions. There are more difficulties in higher frequency when it is difficult to suppress the influence of undesirable elements, also with regard to the large spread of the value of the elements. It is also difficult to realize these filters. A big problem is during final setting of these filters. It can be said that the practical realization of band-pass filters with the narrow relative bandwidth is also a difficult problem. In most cases, it is necessary to optimize the designed filter and sometimes it is necessary to make some of additional modification for successful realization.

One of the possible solutions to the problems with the narrow band-pass is the use of coupled resonance circuits, which are characterized by relatively low sensitivity. The basic RLC circuit with capacitive or inductive structure can be seen on the figures 1 and 2. The band-pass filters which can be seen on the figures 1 and 2 must solve one particular problem – the capacity structure C_v creates high-pass and the inductive structure L_v creates low-pass instead of required band-pass transfer function. But if the bandwidth of band-pass is relatively small, approximately $B/f_0 < 0{,}1$, the character of the transfer function of the band-pass is dominating and the coupling element which is changing transfer to HP or LP, is sufficiently limited.

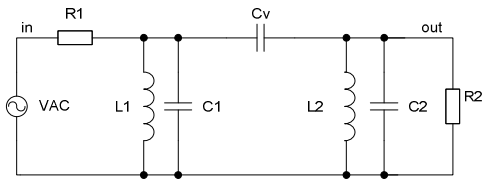

Figure 1: The capacitive coupled RLC filter.

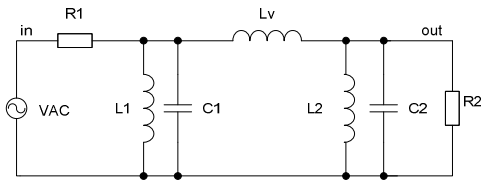

Figure 2: The inductive coupled RLC filter.

During the realization RLC filters for low frequency there are the most difficult problems with the quality, dimensions and price of the coils. That is the reason why RLC filters are replaced by ARC filters for the low frequency. Their basic principle is found by the substitution of the coil with help of insertion active element (OA, transistor) with two resistors and capacitors. So, it can be said that ARC circuits can make the use of the synthetic inductor or FDNR or circuits with GIC etc. Example of ARC filters using the synthetic inductor and FDNR are presented on the figures 3 and 4. The self replacement of passive coupled filters by the active coupled filters is not difficult. In the case of the capacitive or inductive coupling we replace only the passive inductors by the SI or FDNR, see figures 3 and 4.

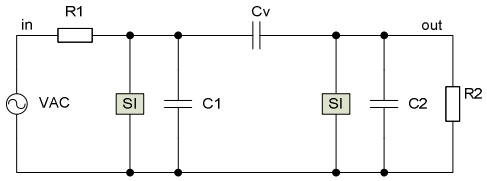

Figure 3: The capacitive coupled ARC filter with synthetic inductors – SI.

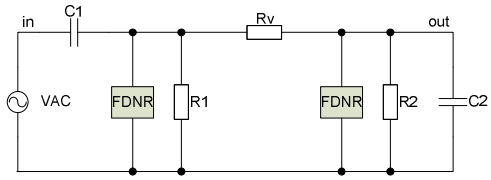

Figure 4: The inductive coupled ARC filter with frequency dependent negative resistor – FDNR.

2. SYNTHETIC INDUCTOR

Synthetic inductor lies in the direct simulation of the coil by the equivalent complicated circuit – dipole which includes one or more active elements and two or more resistors and the capacitors. This dipole on the input clamps exhibits the inductive reactance. The value of the equivalent inductance is based on product of values on the functional elements according to the relation $L = R_1 R_2 C$. The principle is shown on the figures 5 and 6 [1].

The practical examples of the realization can be divided into two potentialities – according to lossy and relation to the grounded. Much simpler circuits contain one OA and are realized by lossy grounded synthetic inductors. Lossless circuits usually contain two OAs and are more complicated. The individual connections are displayed on the pictures 5 and 6.

Input impedance of the grounded lossy synthetic inductor can be written as:

$$Z_{IN} = R + pL \tag{1}$$

Input impedance of the ideal grounded lossless synthetic inductor as:

$$Z_{IN} = pL \tag{2}$$

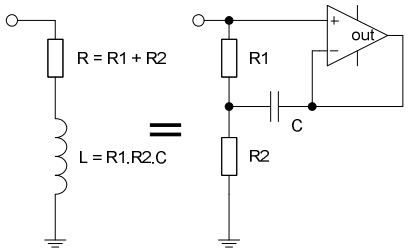

Figure 5: SI – The grounded lossy synthetic inductor.

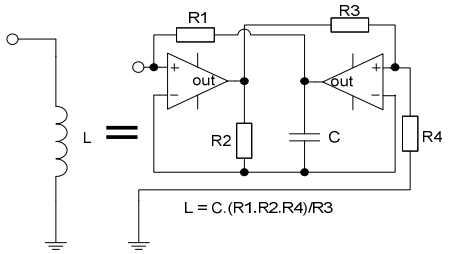

Figure 6: SI – The ideal grounded lossless synthetic inductor.

3. FREQUENCY DEPENDENT NEGATIVE RESISTOR

The realization of the structure of the filters with RCD elements is created by designing of the imitation of the synthetic element – FDNR. Admittance of this circuit is created by one resistor and two capacitors according to the relation $D = C_1 C_2 R$. The practical examples of the realization can be seen on the figures 7 and 8 [1]. If we want to use this circuit, it is necessary to use Brutton transformation.

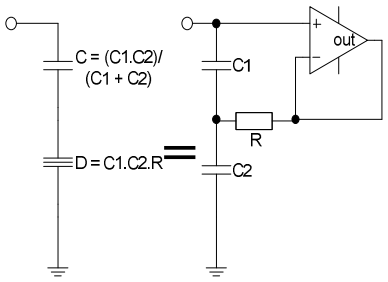

Figure 7: FDNR – The grounded lossy FDNR.

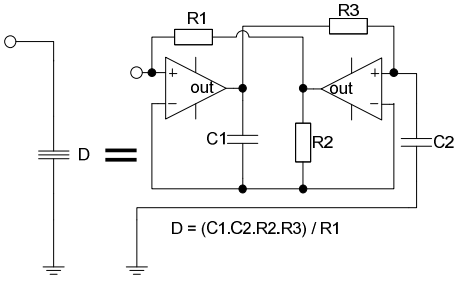

Figure 8: FDNR – The ideal grounded lossless FDNR.

Input impedance of the grounded lossy FDNR can be expressed as:

$$Z_{IN} = \frac{1}{pC} + \frac{1}{p^2 D} \tag{3}$$

Input impedance of the ideal grounded lossless FDNR as:

$$Z_{IN} = \frac{1}{p^2 D} \tag{4}$$

4. REALIZATION OF THE SW PROGRAMME

This SW programme called „Coupled filters“ was created with the help of C++ Builder. This software enables design and obtaining quick results and showing transfer functions for some band-pass of the coupled filters of the fourth to the sixth orders. The software enables to input these parameters: frequency f_0, input and output resistors R_1, R_2, coefficients a_1, a_2, a_3, bandwidth B, etc. Description of the programme:

- First part enables only the choice of input data which can be: f_0, Q, R_1, R_2 or coefficients a_1, a_2, a_3 and coefficient of Brutton transformation k_T, order of filters, types of filters etc.

- The second part includes RLC type band-pass coupled filters, on which we can verify basic calculations and simulations.
- Third part contains ARC filters with the use of SI, FDNR and GIC. There is possibility using another output of these filters.
- Fourth part enables only the display of the results for the sixth orders of the coupled band-pass filters with the help of FDNR, GIC, SI.

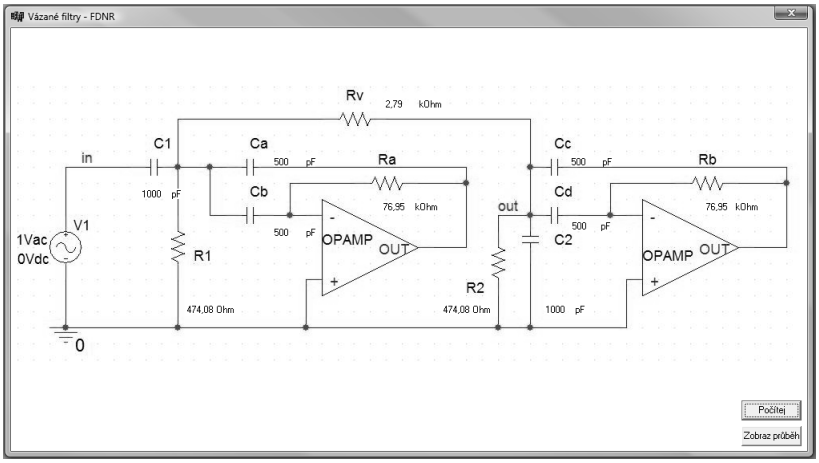

Figure 9: SW programme – ARC filter of 4th orders with FDNR.

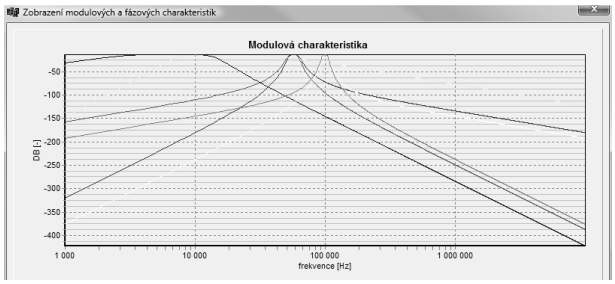

Figure 10: SW programme - transfer functions.

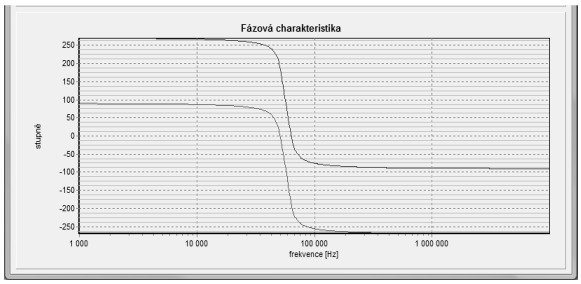

Figure 11: SW programme - phase functions.

The figure 9 displays a part of SW programme where there is ARC filter with the use of FDNR and his final values for certain input parameters and pictures 10 and 11 display final transfer functions.

5. MEASUREMENT OF THE CIRCUITS

After checking the possibilities of the SW programme, individual filters were designed, measured and their values were verified. Individual filters were designed on the frequency 57 kHz by bandwidth 11,7 kHz with Butterworth approximation. See the figure 12.

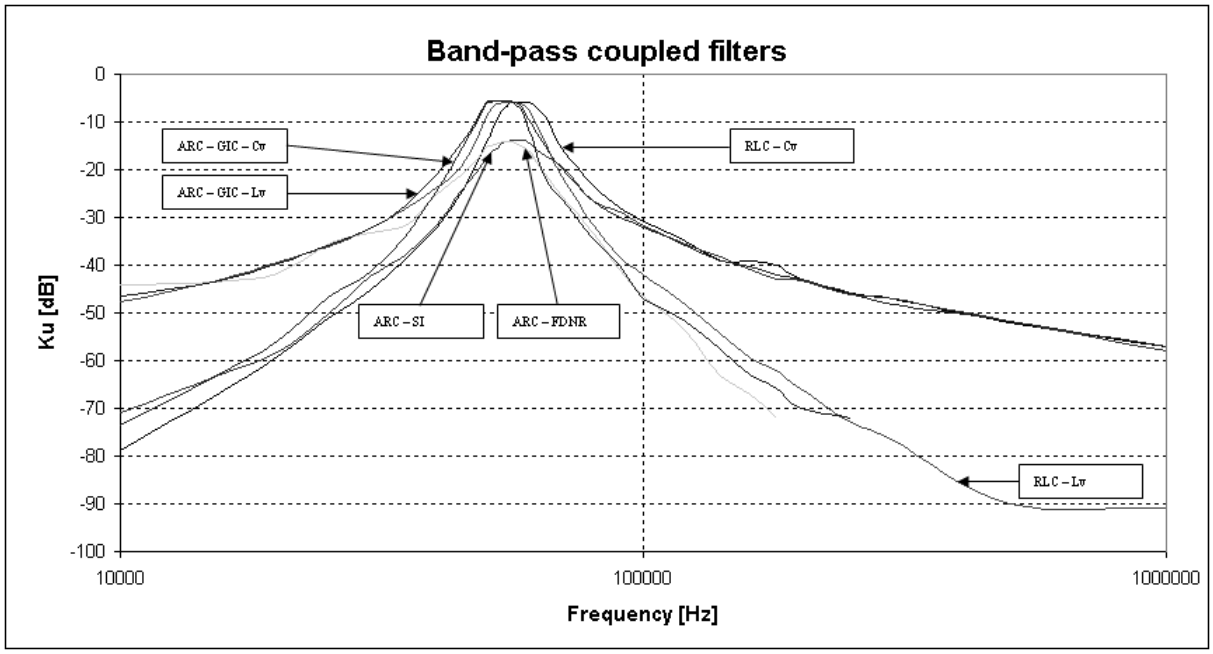

Figure 12: Measurement of band-pass coupled filters.

6. CONCLUSION

This article deals with the design of active coupled band-pass filters, which are used very often in practical use due to their better qualities than filters with ladder structure. RLC ladder filters embodies much bigger spread of elements than coupled filters. This spread of elements will display in decreasing of bandwidth. This article also aimed to show possibilities of the replacement of the coil in RLC coupled filters by individual blocks SI, FDNR and GIC. In physical realization of RLC and ARC coupled filters using blocks SI, FDNR and GIC, there are obvious signs of lossy. That is why during choice of suitable block it must be considered whether to use grounded lossy block SI and FDNR or grounded lossless blocks GIC or others. Circuits SI and FDNR embodies lossy approximately 15 dB in contrast to coupled RLC and ARC filters when using GIC block. ARC filters with the use of these blocks can be used up to 1MHz. It depends on the used OAs and capacitors. For individual designs of RLC and ARC coupled filters, it can be used also above mentioned SW programme enabling design, result and display of values and transfer characteristic depending on input values. A design of band-pass coupled filters is the same as well as for a low-pass filter or a high-pass filter.

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