

ACTIVE BAND-PASS COUPLED FILTERS

Martin Friedl

Doctoral Degree Programme, FEEC BUT
E-mail: xfried02@stud.feec.vutbr.cz

Supervised by: Jiří Sedláček
E-mail: sedlacj@feec.vutbr.cz

ABSTRACT

The paper describes options replacement of classical ladder band-pass filters by the active coupled band-pass filters. The advantage of coupled filters is smaller spread of filter elements than in configurations of ladder filters. In comparison with a cascade synthesis method, this type of filters enables to reach smaller sensitivity of the filter element. Nevertheless, in the case of an active filter design, there are problems with active filter elements (active inductances and FDNR elements) which require relatively high quality factors and consequently, relatively high numbers of active elements (OAs). The paper deals with active coupled band-pass filters in which the lossy active elements are used. At the end of the paper the design and measurement of the realized active coupled band-pass filter with active inductance (synthetic inductor) are presented.

1. INTRODUCTION

The big technical problem appeared during implementation of RLC filters for low frequency range. There was problem with creation of inductors. This is the reason we replace passive filters - RLC by active filters - ARC. We replace an inductor by an active element. These components are the synthetic inductor (SI) and the frequency dependent negative resistor (FDNR). There are more options for design of active filters, but we will deal with the coupled active filters. Because this topology with relatively low sensitivity and concurrently small spread of filter element values are very suitable not only for direct realization of passive filters with lumped and distributed elements but also as RLC prototypes which are used as a basis of active filter realizations. The coupling of the RLC prototypes can be either inductive or capacitive. The self replacement of passive coupled filters by the active coupled filters is not difficult. In the case of the capacitive coupling we replace only the passive inductors by the synthetic inductors (Fig.1 and Fig.2).

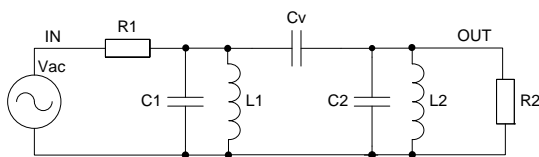


Figure 1: The capacitive coupled RLC filter.

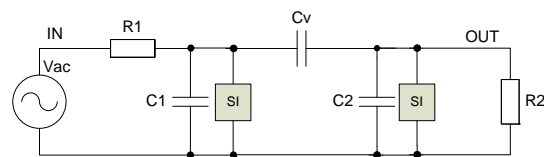


Figure 2: The capacitive coupled ARC filter with synthetic inductors.

In the case of the inductive coupling, the Bruton's transformation is used. Then the inductors are changed onto the resistors. The lossy components of circuit RLC are changed onto new lossy components – the capacitors. And the capacitors are changed onto the new synthetic components – FDNR (Fig.3 and Fig.4).

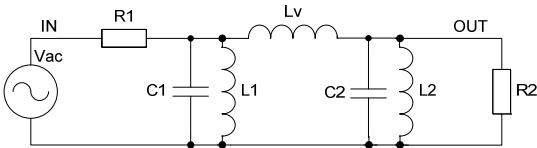


Figure 3: The inductive coupled RLC filter.

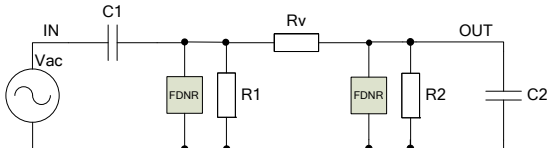


Figure 4: The resistive coupled ARC filter with frequency dependent negative resistor.

2. SYNTHETIC INDUCTOR

The first option replacement of the inductor is the use of synthetic inductors. The synthetic inductor replaces the inductor directly as a dipole, which has inductivity between definite terminals. The value of inductivity is a product of value of a functional component.

We can dispose the practical cases of implementation according to losses and relation to a ground node.

The easier circuits were realized by grounded lossy synthetic inductors (Fig.5). The losses inductance of these circuits had a low quality. That is why they were used in less exact applications.

The more complicated circuits implement ideal grounded lossless synthetic inductors. The circuit is usually called General Impedance Converter – GIC (Fig.6).

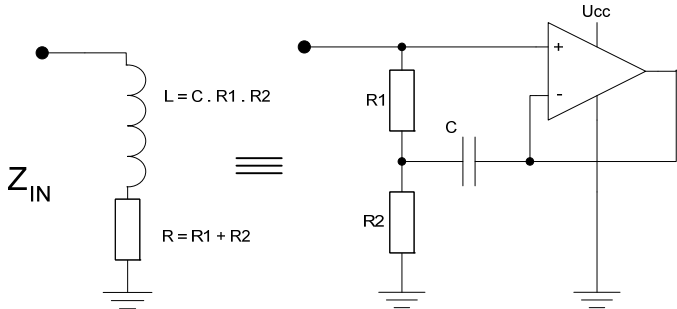


Figure 5: The grounded lossy synthetic inductor.

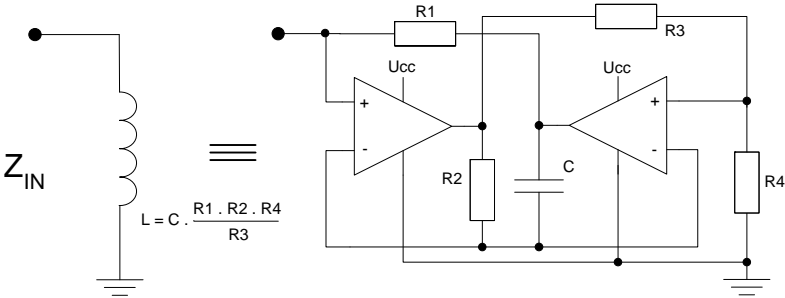


Figure 6: The ideal grounded lossless synthetic inductor.

Input impedance of the grounded lossy synthetic inductor (Fig.5) can be written as:

$$Z_{IN} = R + pL \quad (1)$$

and input impedance of the ideal grounded lossless synthetic inductor (Fig.6) as:

$$Z_{IN} = pL . \quad (2)$$

3. FREQUENCY DEPENDENT NEGATIVE RESISTOR

The second option replacement of inductor is the use of a frequency dependent negative resistor (FDNR). We use firstly Bruton's transformation on RLC filter. After using we will obtain a new RCD structure of filter. This structure has not an inductor, but it is made by the use of characteristic synthetic component FDNR with a parameter D [4].

In the same way as with the synthetic inductor we can dispose the practical cases of implementation according to losses and relation to a ground node. We can implement lossy grounded FDNR with a OA (Fig.7). The grounded lossless FDNR is performed by using two OAs (Fig.8).

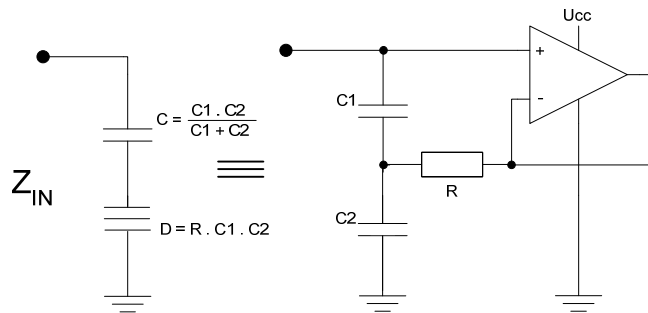


Figure 7: The grounded lossy FDNR.

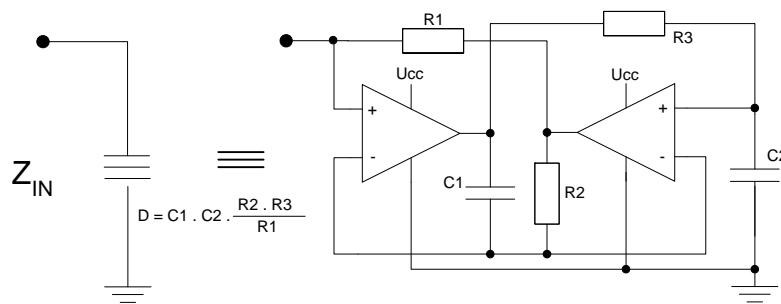


Figure 8: The ideal grounded lossless FDNR.

Input impedance of the grounded lossy FDNR (Fig.7) can be expressed as:

$$Z_{IN} = \frac{1}{pC} + \frac{1}{p^2D} \quad (4)$$

and input impedance of the ideal grounded lossless synthetic inductor (Fig.8) as:

$$Z_{IN} = \frac{1}{p^2 D} . \quad (5)$$

4. THE DESIGN AND MEASUREMENT OF A BAND-PASS FILTER

The design and measurement of the active coupled filter (band-pass) with lossy synthetic inductors will be described in this part. The circuit of the filter is designed for frequency $f_0 = 57$ kHz and with the bandwidth $B = 5,7$ kHz. Firstly, the values of components were calculated for an ideal RLC coupled band-pass filter (Fig.9) and passive inductors were replaced by synthetic inductors [1]. Then we did optimization of the component values so that all components were from E12 or E24 series. The final circuit of the band-pass filter is on the Fig.10. An output of the filter is taken from an output OA because there is a higher value of voltage. However there is a little, but in practise negligible deformation of transfer.

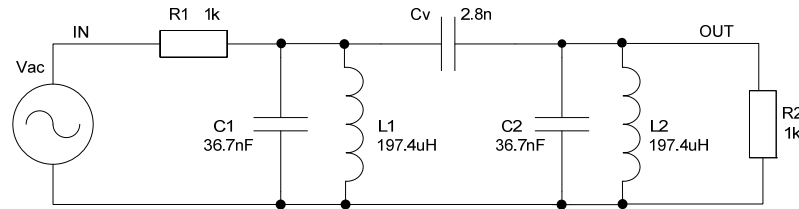


Figure 9: The ideal RLC coupled band-pass filter.

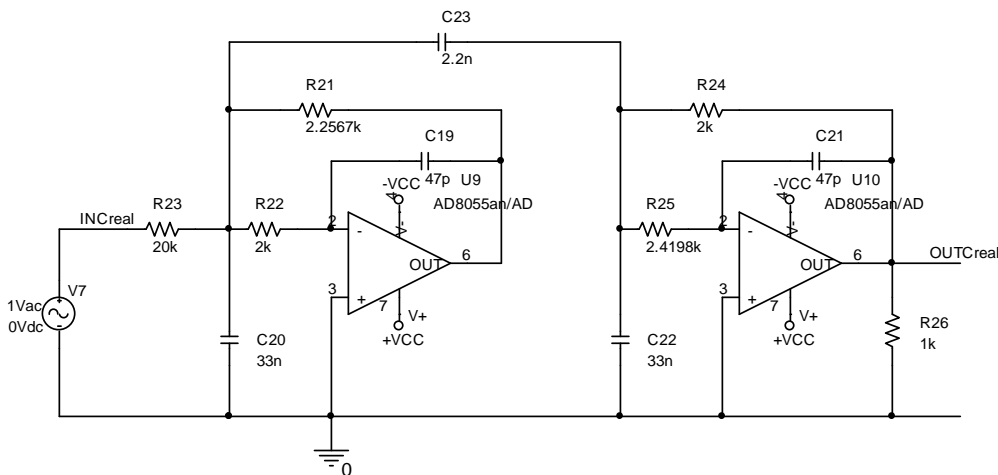


Figure 10: The active coupled band-pass filter with the synthetic inductors.

The final transfer characteristic of the realized band-pass filter is on the Fig.11. We can see that the measurement is nearly as ideal transfer of the designed filter. These parameters were verified by using PC modeling in Orcad. The smaller deviations are caused by some parasitic capacities.

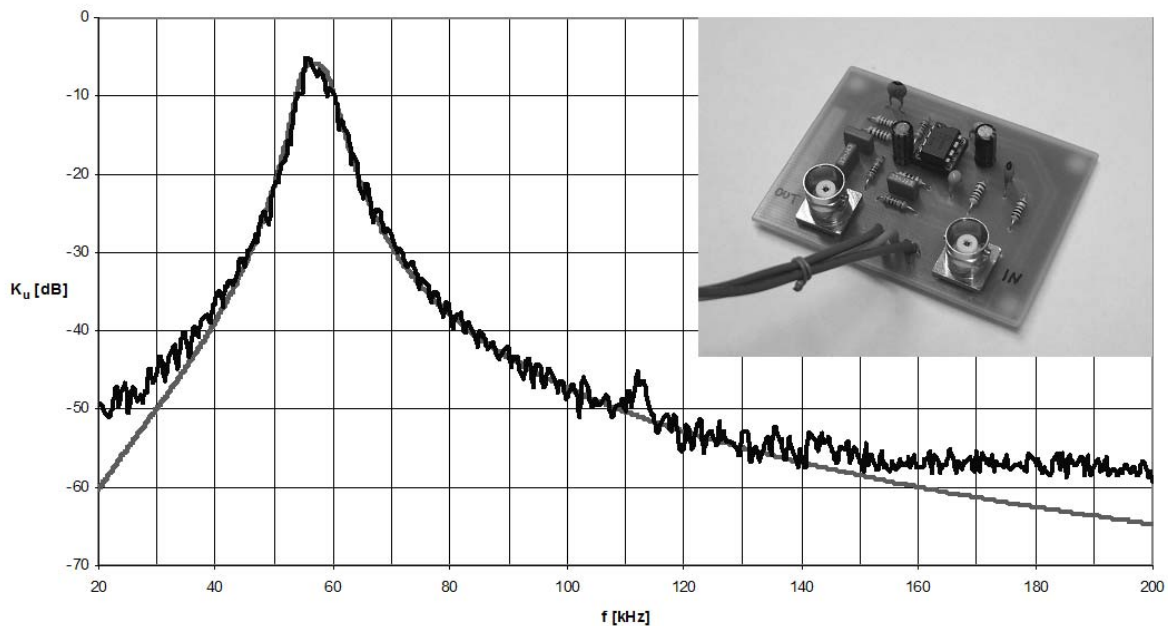


Figure 11: The design and measurement of the band-pass filter.

5. CONCLUSION

In this paper two possibilities from many ways of replacement inductor in band-pass filters were presented, they are the synthetic inductor and the FDNR element. The one example of design of BP filter and his transfer characterization was showed here. A design of a filter is the same easy as well as for a low-pass filter or a high-pass filter. The prescribed design of the active coupled lossy BP filter with synthetic inductors was designed for required frequency $f = 57 \text{ kHz}$. However a highest frequency of the filter can reach about 1 MHz. It depends on used components - primarily in the used OAs and capacitors. The designed coupled structure of the band-pass filter was realized, because exhibits better properties with comparison to the cascade structure.

REFERENCES

- [1] Sedláček, J., Hájek, K.: *Kmitočtové filtry*, Praha: BEN – technická literatura, 2002, 535 stran, ISBN 80-7300-023-7
- [2] Dostál, T.: *Elektrické filtry*, Brno: Vysoké učení technické v Brně, 2004, 136 stran, ISBN 80-214-2561-X
- [3] Gajdošík L.: Využití obecného impedančního konvertoru ve studentských laboratorních úlohách, *STO-9 Seminář teorie obvodů*, Vojenská akademie, Brno, září 2005, ISBN 80-7231-011-9
- [4] Bruton LT.: *RC-Active Circuits Theory and Design*, Prentice-Hall, Inc.: Englewood Cliffs, New Jersey, 1980, ISBN 0-13-753467-1