COMPUTER AIDED DESIGN AND SIMULATION OF FREQUENCY FILTERS

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INTRODUCTION

The complex design, simulation and optimization of frequency filters is great problem in general. Various ways are looked for to solve this. One way is the use of computers. This way can have more forms. In our contribution, the question of computer utilization as a powerful tool for designer will be discussed. The corresponding software is necessary for these purposes. We introduce program NAF for complex solution of design process of analogue filters.

ANALOGUE FILTER DESIGN AND OPTIMIZATION USING PERSONAL COMPUTER

The basic user knowledge of frequency filters is necessary for electronic engineering. Hitherto used forms of the filter design had a low effectiveness. It is determined by many factors. For example this area of the circuit theory has extensive width, it requires theoretic knowledge, it has many results of solutions and many forms of realisations, it has many problems with real properties of circuit elements etc. Therefore the design approaches were usually reduced to the design instructions without user's view and without deeper function understanding. The typical graduate of electronic engineering can't find effectively a optimum solution of frequency filters design problems.

The use of modern powerful personal computers brings quite new possibilities and approach to this area. Then we obtain many advantages:

- First of all the knowledge of the design algorithms are not needed to know. Therefore it is possible directlz turn attention to the user's and practical views of design.

- The problem of a filter requirement specification, selection, judging and comparing of approximations is very simple and clear. Possibility of the representing of all basic characteristics and responses is obvious.

- The simple understanding and verifying of second order filter properties and characteristics.

- The possibility of quick and simple comparison of different filter realizations for optimum user's choice.

- The possibility of analysis for the real filter properties verification (for example sensitivities, influence of loss ...)

These advantages make possible to reduce the contents of subject and reach a increase of quality and rapidity of this problem understanding. Necessary time to understand of these problems may be consequently shortened. The complex solution of filter design is also instructed.

To reach above mentioned goals, the software must fulfil some assumptions and requirements. First of all the program must contain all basic types of approximations (from maximally flat amplitude responses with good step responses to maximum steeples of transfer function). Further the transfer function coefficients of selected approximation must be able to be obtained and to be modified. Possibility of user's input of coefficients must be also accessible. The synthesis of LC ladder filters for various types of resistor terminating is supposed to include a simple solution of problems with even order filters. The possibility of special solutions (coupled circuits, Norton's transformation) and possibility of the element value modification can be used. The quick real analysis of the sensitivities and influence of losses is necessary for the verification of real filter properties.

The active RC filter synthesis with cascade realization is necessary for simple filters on low frequencies. In universities, this realization is very advisable for good object teaching of filter theory because the parameters of blocks are identical with transfer function parameters and the influence of block parameter values on result filter response is very clear. Possibility of the sensitivity analysis for parameter changes is necessary. The circuit synthesis of active filters is more complicated then LC ladder filter synthesis because more variants of solution are possible (for example we can use many various 2-nd order block circuits with one, two or more OA). We have two ways for the solution of this problem. First, the program offers a optimized solution (optimum block selection, optimum block gains). Second, the program offers various 2-nd order block circuits and enables to do a quick real circuit analysis for the optimum choosing. In both above mentioned ways the optimized circuit solution and element values of the offered blocks is necessary. The possibility of the correction of the GBW influence on the block parameters is also advantageous.

THE NAF PROGRAM PROPERTIES

The NAF program enables a fast and simple analogue filter study, a modeling of filter properties in frequency and time domain and a practice design. Friendly performed software allows a sufficient choice of type approximation (Bessel, transitive Bessel-Butterworth, Butterworth, Chebyshev, Inv. Chebyshev, Cauer) including possibility of the modification of offered approximation. The comparison of different type approximations and the obtaining of all frequency and time response plotting including a time response of user's real signal is also possible. The user's input of transfer function coefficients makes possible a study of the basic 2-nd order transfer function properties or the modeling of more complicated filters.

For LC ladder realisation, the program has a synthesis for arbitrary termination ($R_1 = R_2$, $R_1 \neq R_2$, $R_1 = 0$, $R_1 = \infty$, $R_2 = 0$, $R_2 = \infty$) for all approximations (including, for example, transient Bessel-Butterworth approximation). This solution is optimized to value ratio minimisation. Therefore the program offers a solution for Inverse Chebyshev approximation and for some examples of Cauer approximation, which is not presented, for example, in Saal's catalogue. The simple selection and comparison of the T and P mode and the synthesis of filters with modified transfer function is also possible. The program also offers a quasipolynomial solution with coupled resonant circuits for narrow band-pass filter. The consecutive analysis inclusive analysis of loss influence or sensitivities enables to the user to obtain knowledge of real properties and comparison of solved filters. The possibility of

element value modification is able to use for next modification or modeling of practical tuning etc.

The ARC cascade realization is also optimized (block solution for maximally dynamic range), the optimized circuits for block realization are also chosen by the program. Optimized basic capacitor values are solved automatically and program enables the user to change capacitor values. The program also enables to select a GBW of user's OA with automatic correction of this influence. The sensitivity characteristics for the block parameter changes can also be obtained.

Beside these basic possibilities, the program allows the user to plot all basic frequency and time responses (amplitude, phase, group delay, step response) with automatic scaling or user axis ranges. The saving of the responses, their simultaneous displaying with topical response for comparison, reading of accurate values by cursor line are also possible. Further the program enables the diagrams of all designed filters, output to printer, saving of the approximation or circuit data files etc. Program has a single menu-driven operation, one help line for all menu offers or selected help.

EXAMPLES OF DESIGNING AND OPTIMIZATION BY NAF PROGRAM

The understanding and knowledge of the 2-nd order filter properties is necessary for the beginning of filter design. The program enables the solution of this problem by input of block coefficients and displaying of corresponding frequency and time responses. The higher order filter design needs a understanding of various approximations responses. The program offers a simple and object table for input of amplitude response specification for the band-pass filter. Further the program enables drawing of selected types characteristics with fully automatically scaling. The response can be saved and redisplayed with other response for comparison. This is the way how to determine optimum specifications to signal filtering and how to select optimum type of approximation in practice .

Second step of filter design is a problem of filter synthesis and realization. First of all the choosing of LC ladder filter terminating is necessary. The program enables a double-sided or one-sided terminating for any source and load resistor value. The circuit diagrams of T and P mode of synthesized filter are displayed for the comparison and selection. For the design of the even order filters and some types of approximations, the knowledge of the possibility of first and second frequency transformations is necessary. The program gives three kinds of circuit realisations for these filter orders. We can compare their properties by consecutive analysis.

Two realizations of narrow-band filters are offered. We can investigate quickly result element values for both cases using NAF program. For the coupled circuits realization we obtain approximately 1000 times smaller element value ratio than that for basic realisation. The good understanding of real properties needs a possibility to verify the influence of element value changes on the transfer function responses. In this way, we can obtain maximum admissible element value tolerances.

For the active RC filters the program gives optimized circuits. The program optimizes a circuit also for the maximum dynamic range. It is very problematic, first of all, for band-pass filters with Cauer and inverse Chebyshev approximations. We can verify it by responses to block outputs. The necessary GBW values for minimum influence of block OAs are also given. In addition, the program offers a possibility of compensation of the lower GBW value influence. The change of the basic capacitor values with automatic element value recalculating

is able. For the practice design, we must know sensitivities of the result amplitude response to the block parameter changes. The program enables a simple verification of the basic block parameter value changes. By this method we can illustrate, for example, a greater influence of resonance frequency change than quality factor change influence.

Except these typical filter design problems, the NAF program can be used for solution of the many other problems as the modeling of the phase influence of crossovers etc.

CONCLUSIONS

The filter design using personal computers with proper program makes a considerable change of the contents of subject and it enables to reach higher quality and rapidity of solution of these problems. Needed time to understanding of the problems may be consequently shortened. The design with computers leads to the complex which is near a real practice. Above discussed form of design with personal computers enables computer experiments. That is also the way to obtain a higher designer's activity and to stimulate further self-education.

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