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A CAD Package for the Synthesis of Electric Circuits and Passive Filters*

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This paper presents a CAD package for the synthesis of single-port networks, two-port networks and passive filters. After the specifications are entered, the resulting electric network is graphically displayed on the screen. The most important feature in this program is the help function that provides complete information, step by step solution with explanations and numerical values for the given problem. This makes the program a powerful educational tool and distinguishes it from other CAD packages.

SUMMARY OF EDUCATIONAL INFORMATION

1. The paper discusses material for a course in: Circuit Synthesis.
2. Students of the following departments are taught in the course: Electrical Engineering.
3. Level of the courses: Graduate level.
4. Mode of presentation: Discussion Group.
5. Is the material presented in a regular or in an elective course: Elective Course.
6. Class hours required to cover the material: 45 Hours.
7. Student homework and revision hours required for the materials: 45 hours.
8. Description of the novel aspects presented in the paper: A menu-based CAD system presenting a step-by-step solution of a circuit synthesis problem with circuit drawings.
9. The standard text recommended for the course, in addition to authors' notes: See references [2] or [3] in the manuscript.
10. The material is/is not covered in the text. The discussion in the text is different in the following aspects: There is no major difference with the same material discussed in [2] or [3].

1. INTRODUCTION

THE synthesis of single-port networks, two-port networks and analog filters is a subject of great interest in several fields. This subject is taught in courses on the synthesis of electric circuits and used by many researchers and engineers for solving problems. A CAD package for the synthesis of the immittance of single-port RL, RC, and LC network using the Cauer and Foster forms is presented in [1]. This paper presents the extension of the package to the synthesis of a large variety of passive two-port networks and analog filters. In each case, the user selects the type of the circuit to synthesize using a menu-based system. The user is then asked to provide the necessary information for the synthesis on a different window for each type of entry. If the circuit is not theoretically realizable, a special message is sent to the user. A help menu provides the user with information about the use of this package as well as a general introduction to the synthesis of electric circuits. A help function provides the user with a detailed description about the method of synthesis used and the numerical calculations. In the case where the obtained network is too large to fit on to one screen, it is subdivided into pieces on different screens. These features make the package a powerful educational tool that may be used with a course on the synthesis of electric circuits. In order to illustrate this work, this paper is subdivided into three sections: section 2 deals with the synthesis of passive two-port networks, section 3 deals with the synthesis of passive filters, and section 4 provides a general description of the software. In each of these cases, general descriptions of the basic theory and the algorithms used in the program are given along with some design examples.

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2. THE SYNTHESIS OF TWO-PORT PASSIVE NETWORKS

This package contains several options for the synthesis of two-port networks. These options are considered based on the several possible ways of describing a two-port network. In each case the output consists of a graphical display of the synthesized circuit. A detailed description about the method of synthesis used and the numerical calculations may be obtained using a help function.

1. Open circuit impedance matrix synthesis of a two-port network. The input to the program consists of the open-circuit driving point impedances (z_{11}, z_{22}) and the transfer impedance ($z_m = z_{12} = z_{21}$). The Cauer's two-port synthesis method (partial fraction expansion) is used for the synthesis. As an example, Fig. 1(a) shows a circuit with z parameters to synthesize. Figure 1(b) shows the impedances in series at the input and output as well as the networks Q1 and Q2 corresponding to the poles $p = \pm j$ and $p = \infty$ of z_m, respectively. Figure 1(c) shows a window created by the help function containing a detailed description of the method and the solution obtained.

2. Short circuit admittance matrix synthesis of a two-port network. The input to the program consists of the short-circuit driving-point admittances (y_{11}, y_{22}) and the short-circuit transfer admittance ($y_m = y_{12} = y_{21}$). This problem is the dual of the previous one [2]. The Cauer's two-port synthesis method (partial fraction expansion) is used for the synthesis.

3. Transfer function synthesis of a singly loaded two-port LC network. The input to the program consists of the ratio $Z_T = V/I$, where I is the input current provided by an ideal source and V is the output voltage of the network loaded by a resistance of normalized value equal to 1. The circuit is synthesized in realizing z_{22} as a ladder network using the zero shifting technique. An example of this synthesis is shown in Fig. 2.

4. Transfer function synthesis of a doubly loaded two-port LC network. The input to the program consists of the ratio $Z_e = V/E$ where E is the voltage provided by a source of internal resistance R_i, and V is the output voltage of the network loaded by a resistance R_o. The values of the resistances R_i and R_o are also specified by the user. In this case, the Darlington method [2] is used in the synthesis.

5. Transfer function synthesis of a doubly loaded two-port RC or RL network. The input to the program consists of the ratio $Z_n = V/E$ or $Z_n = V/I$ where E is the voltage, I is the current provided by a source of internal resistance R_i, and V is the output voltage of the network loaded by a resistance R_o. The values of the resistances R_i and R_o are also specified by the user. The circuit is synthesized in realizing z_{11} as a ladder network using the zero shifting technique. An example of this synthesis is shown in Fig. 3.

In each case, the user uses the menu to select the type of synthesis required. Each type of input is done on a window opened by the program for this purpose as shown on various examples. An immittance parser is used to read the value of a function in the s-domain which allows the detection of typing mistakes and provides the user with flexibility in data entry. The synthesized circuit is graphically displayed with a scale automatically adjusted by the program to allow the use of output screen with maximum efficiency. Detailed theoretical background related to each synthesis method used can be found in many textbooks [2, 3].

3. THE SYNTHESIS OF PASSIVE FILTERS

In this package, synthesis of analog passive LC filters with an ideal input current source is also possible. In this case, the user uses the menu to specify the type of synthesis (Chebyshev and Butterworth filters are now available in the menu) and the type of filter (low-pass, high-pass, band-pass or band-stop). The input to the program consists of the filter characteristics such as cut-off frequencies, attenuation, load resistance and the ripple (in the case of Chebyshev filters). The synthesis is done using filter transformations and in realizing z_{22} as a ladder network using the zero shifting technique [2]. An example of filter synthesis is shown in Fig. 4. The input and output have the same characteristics as in section 2.

4. SOFTWARE DESCRIPTION

The software contains many modules. The main module is the data interpretation module. This module is used to read and analyze the data provided by the user. It is responsible for deciding the type of data needed for a given synthesis and recognizes illegal data. This module also contains an immittance parser that recognizes legal expressions of the rational fractions. According to the type of synthesis required, this module calls one of the following modules:

1. The one-port networks synthesis module.
2. The two-port networks matrix synthesis module.
3. The transfer function synthesis module.
4. The passive LC filters synthesis module.

Each of these modules uses a graphical design module: this module receives information about the network and its components and provides circuit schematics drawings using an elaborate scale.

To show the abilities of the program, its commands are given in Fig. 5. The program is written in Pascal Programming Language. It runs on a PC XT or a compatible under DOS operating system.

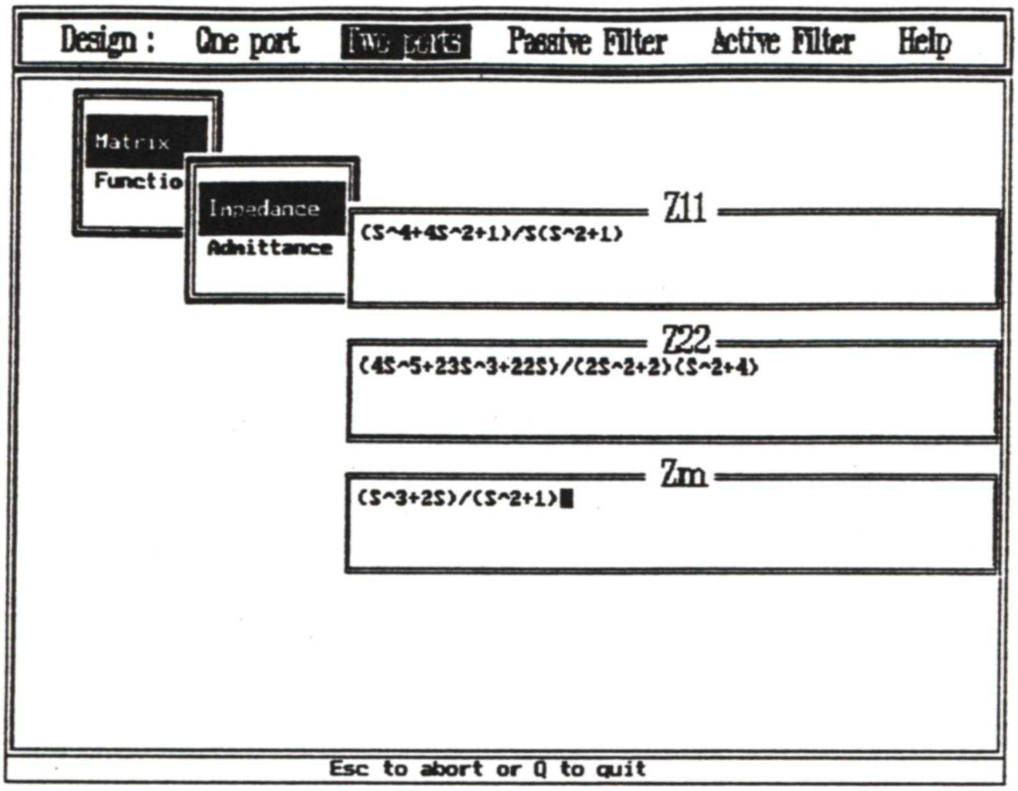
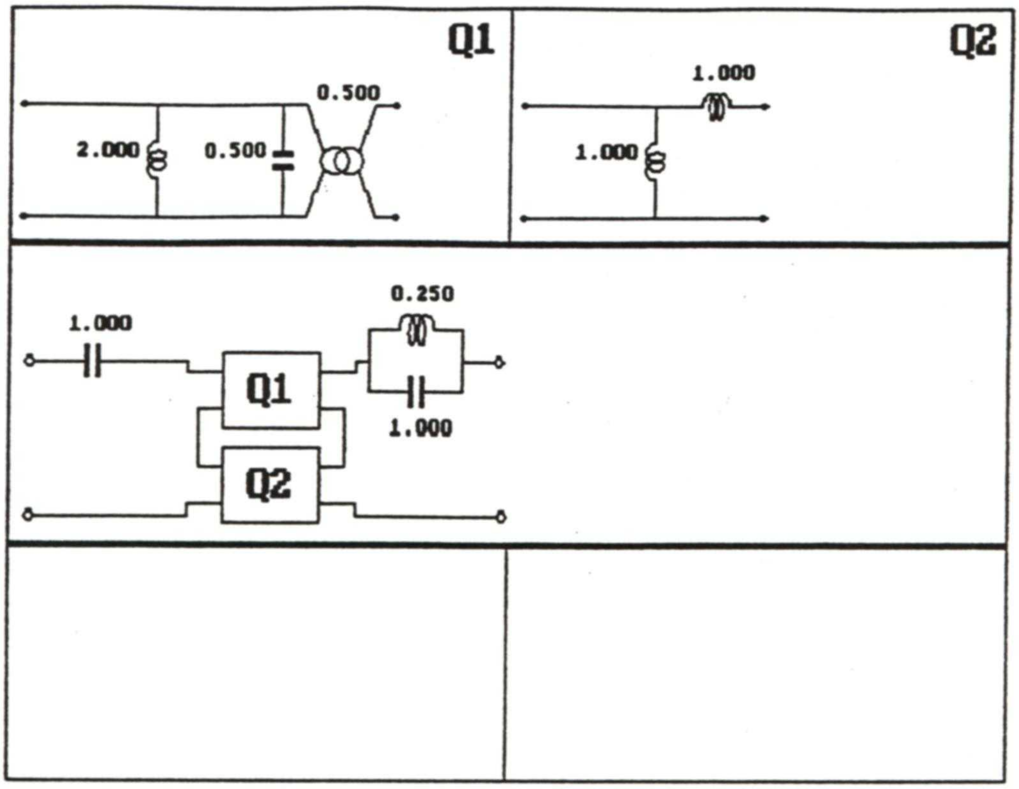
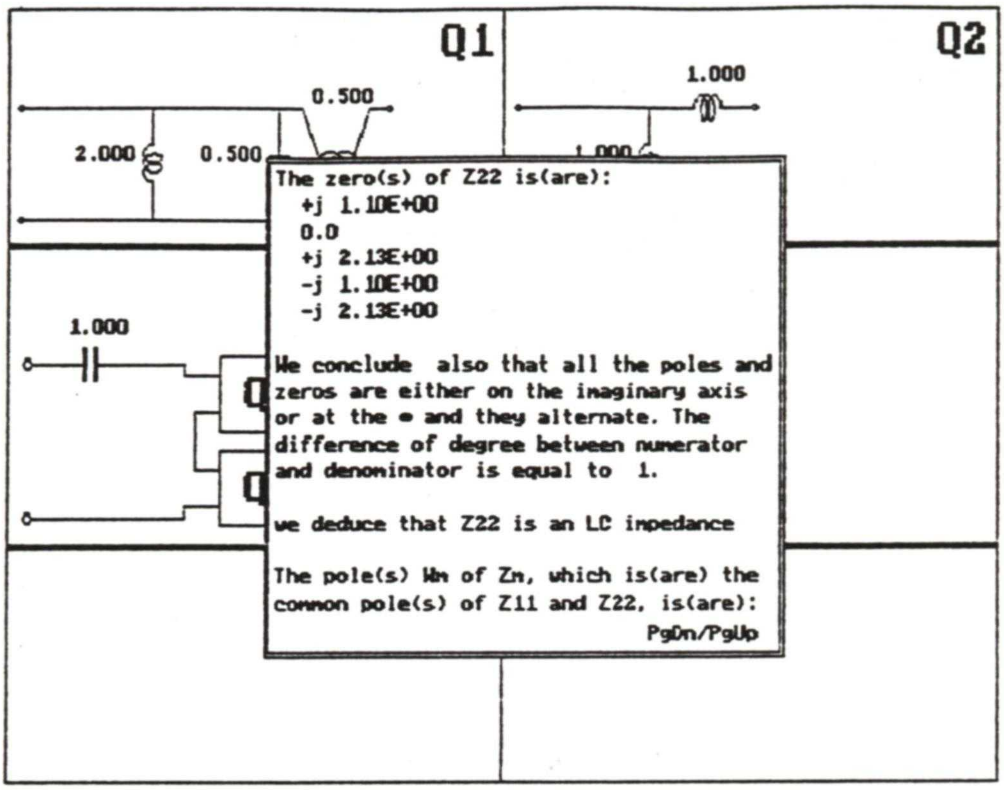


Fig. 1. Synthesis of a network with a given Z-matrix. (a) The input screen.



(b) The obtained network.



(c) A detailed description of the method and calculations provided by the help function

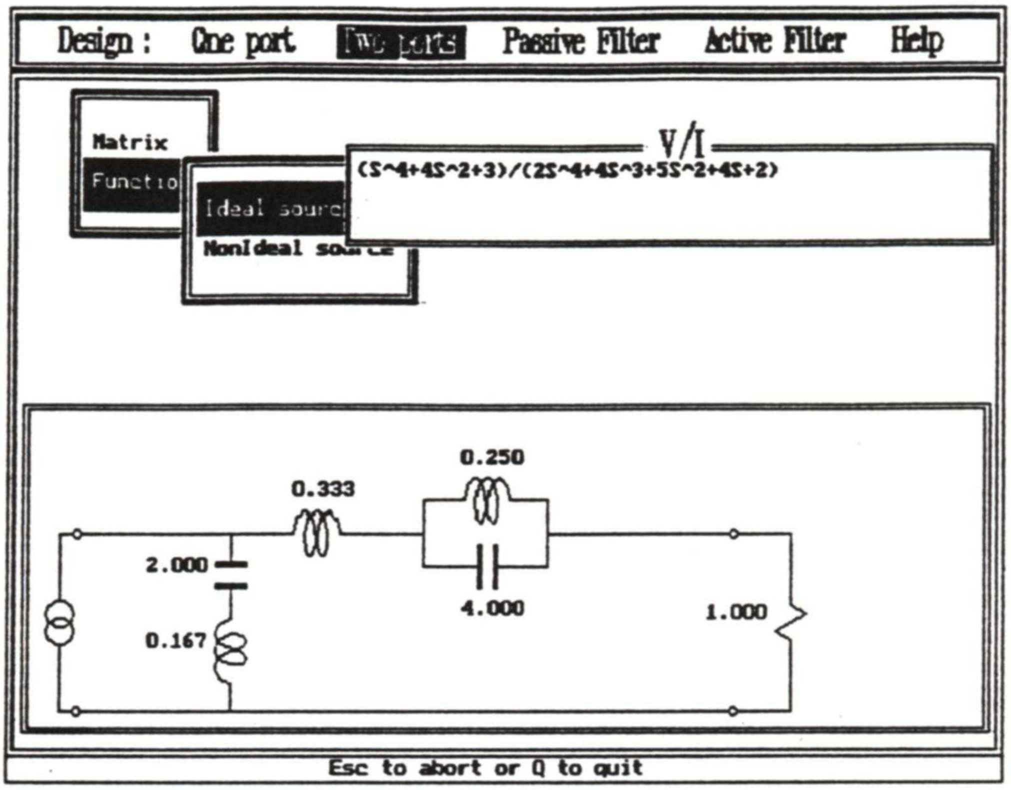


Fig. 2. Synthesis of an LC network with ideal input source when the ratio V/I is given

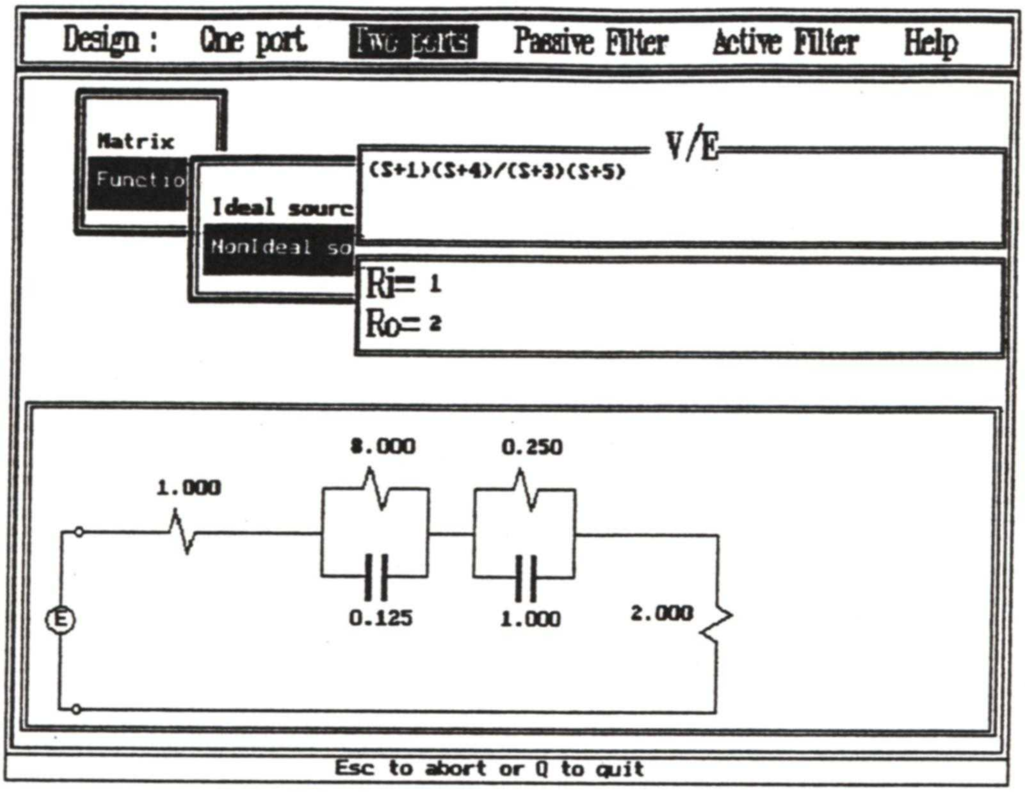


Fig. 3. Synthesis of an RC network with nonideal input source when the ratio V/E is given

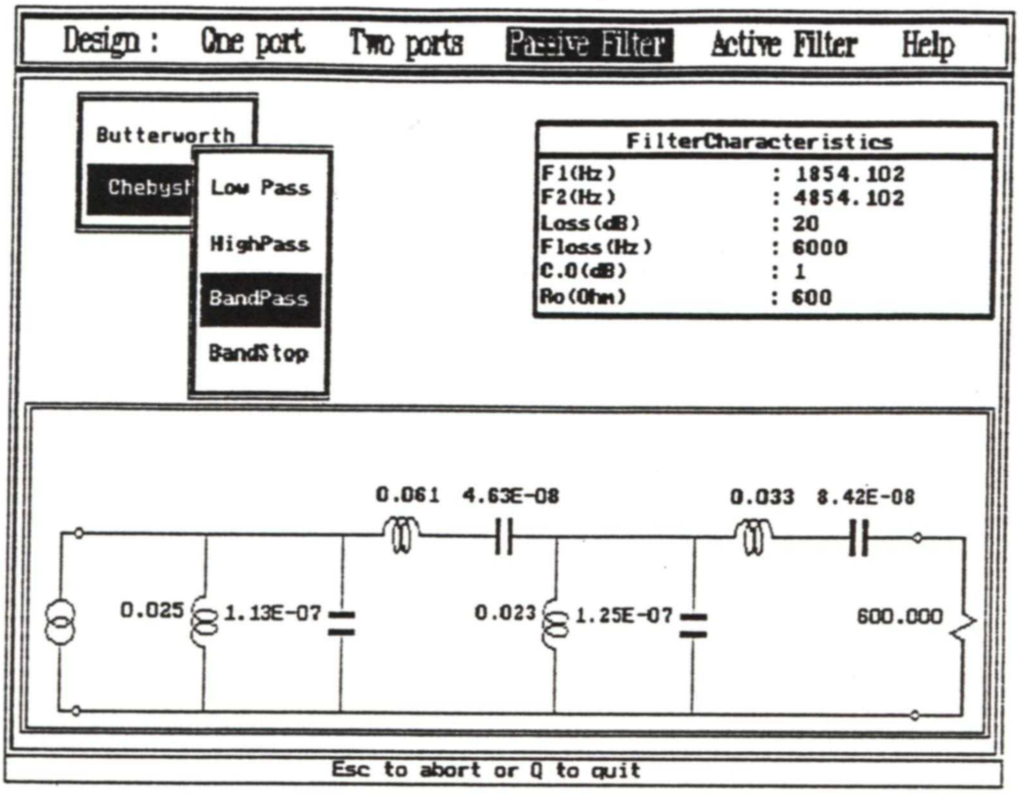


Fig. 4. Synthesis of a Chebyshev band-pass filter

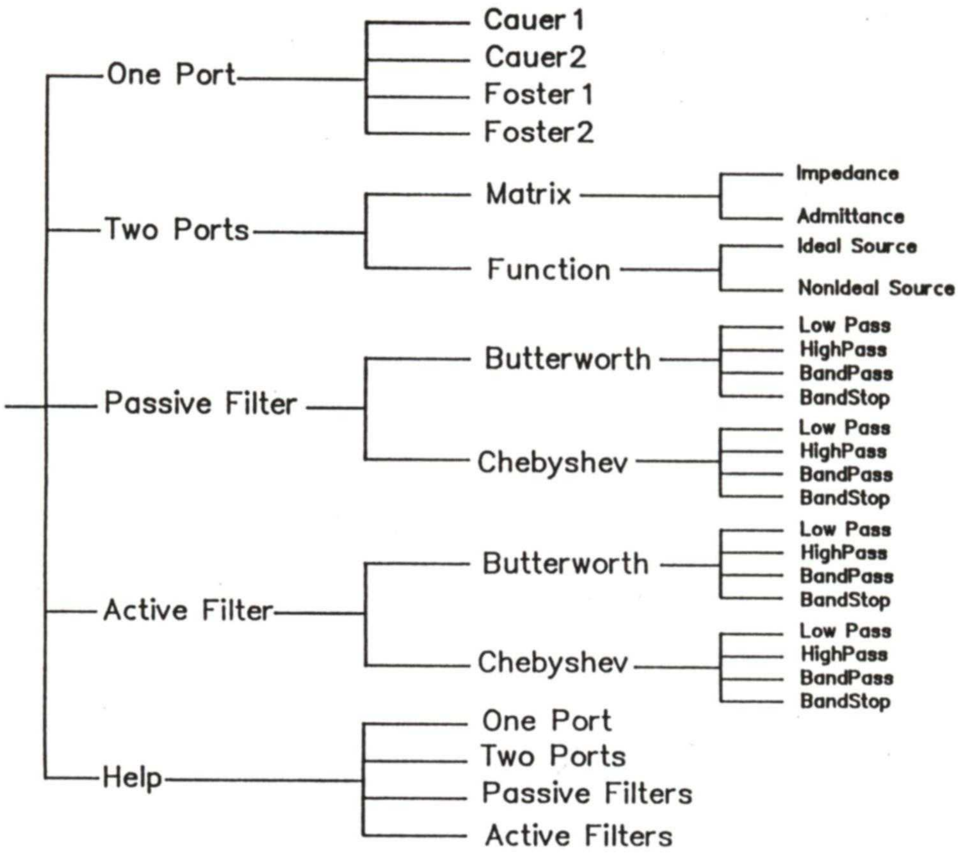


Fig. 5. Program commands

5. CONCLUSIONS

This package is proven to be effective and user-friendly. It is modular, which allows addition of other options. The most important feature in this program is the help function that provides complete information and numerical values for the solution obtained, which makes it a powerful educational tool and distinguishes it from other CAD tools. Work is in progress to implement other types of filters for synthesis as well as some other available methods for synthesis of active filters.

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