

*Personal Computer
Circuit Design
Tools*



FILTERMASTER PROFESSIONAL USER'S GUIDE

© copyright **Omicron** licensed by Intusoft 1992
P.O.Box 710
San Pedro, Ca. 90733-0710
Tel. (310) 833-0710
Fax (310) 833-9658

intusoft provides this manual "as is" without warranty of any kind, either expressed or implied, including but not limited to the implied warranties of merchantability and fitness for a particular purpose.

This publication could contain technical inaccuracies or typographical errors. Changes are periodically made to the information herein; these changes will be incorporated in new editions of this publication.

Copyright

OMICRON, 1992. All Rights Reserved. No part of this publication may be reproduced, transmitted, transcribed, stored in a retrieval system, or translated into any language in any form by any means without written permission of OMICRON.



Epson is a registered trademark of Epson Inc. Hercules Graphics Card is a trademark of Hercules Computer Technology. HP is a trademark of the Hewlett-Packard Corp. IBM is a registered trademark of International Business Machines Corporation. Microsoft Word and MS are registered trademarks of Microsoft Corp. FILTERMASTER, FILTERMASTER PROFESSIONAL, AFil, AnaLAB, DPA-1000 and PE/L are trademarks of OMICRON electronic. Touchstone is a registered trademark of EESof Inc. WordStar is a registered trademark of the MicroPro International Corporation.

All company/product names are trademarks/registered trademarks of their respective owners.

Printed in the U.S.A.

Table Of Contents

Chapter 1 Introduction

- 7 Structure Of The Manual
- 8 Typefaces
- 9 Installing FilterMaster Professional
- 10 Starting FilterMaster Professional
- 12 Quitting FilterMaster Professional

Chapter 2 Program Introduction

- 13 Features
- 15 Program Structure
- 16 Program Support

Chapter 3 Tutorial

- 17 Tutorial
- 18 Starting The Program
- 19 Specifying The Filter
- 25 Designing The Circuit
- 26 Analyzing Circuits

TABLE OF CONTENTS

Chapter 4 Operating Instructions

29	Selecting Menu Options
29	Selecting Options Using The Keyboard
30	Selecting Options Using The Mouse
31	Dialog Fields
31	Entering Data In Fields
32	Entering Filenames
34	On-Line Help Text
34	Output
36	Graphic Output
36	Program Setup

Chapter 5 Program Functions

39	Specifications
40	Standard Approximations
44	General Amplitude Approximations
45	SPECIFICATION Menu (for general amplitude approx.)
51	OPTIMIZATION Menu
58	STOPBAND SPECIFICATION Menu
60	TRANSMISSIONZERO INPUT Menu
61	Example 1: Lowpass Filter
66	Example 2: Bandpass Filter
71	Circuit Design
72	PASSIVE DESIGN menu
73	OUTPUT CIRCUIT Menu
74	SPICE Menu
75	TOUCHSTONE Menu
76	Input Circuit menu
77	TERMINATION Menu
78	Accuracy Menu
79	Manipulation And Analysis Menu
81	Dual Circuit Menu
81	Change Values Menu
82	Norton's Transformation Menu
84	Pi-To-Tee Conversion Menu
85	Exchange Two-Ports Menu
85	Split Two-Ports Menu

86	Example: Bandpass Filter
97	Analysis
98	Circuit Analysis Menu
101	Polynomial Analysis Menu
101	Property menu
101	Representation Menu
102	Transfer menu
103	Graph_Load Menu
105	Example: Elliptic Bandpass
112	Graphics
113	X-Y Menu
115	X-Y Parameters Menu
116	X(Y)-Scale Menu
117	Output Graphic Menu
118	Printer Options Menu
120	X-Y Marker Menu
121	Macros
124	Example: Keystroke Macros

Chapter 6 **IsSPICE Interface**

133	FilterMaster Output to IsSpice
133	Stand-alone Netlist
136	Subcircuit Netlist
139	Interface With The SPICENET Program
139	Stand-alone Netlist With Monte Carlo Syntax

Appendices

141	Appendix A - Comparison of Approximations
141	General Amplitude Approximations
143	Standard Approximations
147	Appendix B - Case, Terminating Resistance Ratio
156	Appendix C - Conventional/Parametric Bandpass Filters
157	Conventional Bandpass Filters
158	Parametric Bandpass Filters
160	Appendix D - Design With User Defined Circuits
163	Bandstop Filters
164	Appendix E - Calculation Speed

TABLE OF CONTENTS

164	Appendix F - Calculating Component Values
165	Determination Of Variable Pole Pairs
166	Initialization of the variable pole pairs
167	Appendix G - Root Output
169	Appendix H - Dual Circuits
170	Appendix I - Norton's Transformation
175	Appendix J - Circuit Analysis
176	Appendix K - Key Macro Function
181	Appendix L - Data Formats
182	Appendix M - Macro Files (.KDO)
182	Appendix N - Filter Specification Protocol (.SPZ)
183	Appendix O - Polynomial Pole/Zero Protocol (.FDT)
183	Appendix P - Circuit Protocol (.SCH)
184	Appendix Q - SPICE (.CIR)
185	Appendix R - Touchstone (.CKT)
185	Appendix S - Graphics Data (.PLT)
186	Appendix T - Default File (FM.DEF)
196	Appendix U - Frequently Asked Questions
196	Appendix V - Literature

Structure Of The Manual

Welcome to FILTERMASTER PROFESSIONAL.

The manual is divided into the following sections:

Chapter 1 “PROGRAM SUMMARY” - provides you with a short summary of the program’s features.

Chapter 2 “INSTALLATION” - specifies the minimum hardware requirements and shows how to install the software.

Chapter 3 “TUTORIAL” - will acquaint you with the software using a simple example.

Chapter 4 “OPERATING INSTRUCTIONS” - tells you about the operation of FilterMaster Professional.

Chapter 5 “PROGRAM FUNCTIONS” - provides you with detailed information on the functions of the program.

Chapter 6 “APPENDIX” - contains background information on the technical aspects of the program, instructions for creation of key macros for automatic sequences, and a list of useful literature.

Chapter 7 “INDEX” - allows you to find specific explanations of certain key words.

Typefaces

The ↑ ↓ ← → keys are used to represent the cursor keys.

In this manual, instructions for communicating with the program through the keyboard are given as follows:

Example:

- `fm[↵]` Start FILTERMASTER

The column to the right will contain an explanation of the action on the left. The characters on the left, “fm” represent characters to be entered from the keyboard at the DOS prompt or into a value field. All keystrokes that perform a function are grouped in braces, [], to delineate each step.

More examples:

- `10M[↵]` Enter character sequence “10M”, followed by the ENTER key.
- `[A]` Press “A” to access a menu field
- `[Ctrl+U]` Press and hold the CTRL key down while pressing “U”
- Uppercase letters followed by a colon are FILTERMASTER menu entries. For example, SPECIFICATION would refer to the Specification menu.
- Characters or messages which the program displays on the screen are shown as follows:

FILTER NOT YET SPECIFIED.

Installing FILTERMASTER PROFESSIONAL

Hardware Requirements

Minimum configuration:

- IBM PC or compatible with
- 640kB RAM, 1 disk drive 1.2 MB
- CGA, HGC, EGA or VGA graphics
- 1 parallel interface (for hard key copy protection device)
- MS/PC-DOS 3.1 or higher

Optional:

- Mouse (Microsoft or compatible)
- Printer
- Plotter (HPGL format)
- Serial interface (for mouse or output device)

The Hard Key

Plug the supplied hardware key (dongle) into one of the parallel interfaces in your computer. If you already have an output device connected to this interface, install the key between the device and the interface. You will need to switch on the device connected to the parallel port during the use of FILTERMASTER PROFESSIONAL; otherwise, the data lines will be set to LOW and the key will not be recognized.

Installing the Software

Before installing FILTERMASTER PROFESSIONAL;

- Make a backup copy of the program disk: Use the DOS diskcopy command, for example "diskcopy a: a:".

To install FILTERMASTER PROFESSIONAL on your hard disk;

- Insert the program disk into drive A:.

INSTALLING FILTERMASTER PROFESSIONAL

At the DOS prompt type:

- a:[↵] Switch to drive A:
- install[↵] Start install program

The installation program is self explanatory and will prompt you for any information that may be needed.

Note: To avoid having to change to the FILTERMASTER subdirectory each time the program is started, it is recommended that the FILTERMASTER subdirectory name be placed into the DOS PATH statement. Details on this can be found in your DOS manual.

Starting FILTERMASTER PROFESSIONAL

Move to the FILTERMASTER PROFESSIONAL working directory. By default, this is C:\FM. Then type:

- fm[↵] Start FILTERMASTER program

Graphics Related Installation Problems

Computers with color graphics adapter but only a monochrome display (e.g. laptops):

If you are not pleased with the representation of the display on your screen:

- Exit the program (by entering [Q], acknowledge with [Y]) and use extended start command.
- Type either fm /bw[↵] or fm /lcd[↵].

This switches your computer's screen to an other display mode.

If you start the program properly, but still get "junk" on your screen:

When you start the program, FILTERMASTER PROFESSIONAL will automatically check which graphics card is in your computer and set itself accordingly. Under certain circumstances, it may be unable to identify the card.

To solve this problem;

- Exit the program.
- Edit the file FM.DEF in any word processing program (e.g. IsEd, MS Word, etc.)
- After the line BEGIN GRAPHICDEFAULTS, change the entry in the line DISPLAYTYPE to suit your screen.

Possible inputs include:

CGAHi	(640x200, mono)
MCGAHi	(640x48, 2-color)
MCGAMed	(640x200, mono)
EGAHi	(640x350, 16 colors (256K))
EGA64Hi	(640x350, 4-color (64K))
EGAMonoHi	(640x350, mono)
HERCMonoHi	(720x348, mono)
ATT400Hi	(640x400, mono)
ATT400Med	(640x200, mono)

For Example:

The line, DISPLAYTYPE IBM8514HI

will set the display type to the IBM8514 1024x768 standard.

- Save the FM.DEF file as an ASCII file.

Quitting FILTERMASTER PROFESSIONAL

To quit the FILTERMASTER PROFESSIONAL program;

- Select Quit or press Q or Esc until you are at the FILTERMASTER main menu.
- Press Q while in the FILTERMASTER menu. Answer yes to confirm and exit the program.

Program Introduction

Features

FILTERMASTER PROFESSIONAL is a CAE software program for specifying, dimensioning and analyzing analog filters. The program offers the following features:

FILTER TYPES:

- Lowpass
- Highpass
- Bandpass
- Bandstop

APPROXIMATIONS:

Standard approximations

- Elliptic (Cauer filter)
- Butterworth (potence filter)
- Chebyshev
- Inverse Chebyshev, or
- Bessel (for Lowpass only)

General amplitude approximations

- Maximally flat or
- Equal ripple,
each referring to the passband.

CIRCUIT DESIGN:

Passive LC/reactance filters

- Calculation of filters with topologies suggested by the program or
- Design of filters on a modular (piece by piece) basis
With this approach, the user can synthesize the filter step-by-step. FILTERMASTER PROFESSIONAL will provide selections for each element at each step.
- Optimization of synthesized circuits (Norton's transformation etc.)

FEATURES

- Different terminating resistances and extreme terminations may be selected
 - Graphic analysis of the characteristics of the current circuit
 - Interface with the ICAP and Touchstone analysis programs
- Active RC filters
- Interface to `FILTERMASTER ACTIVE` (for designing active filters based on `FILTERMASTER PROFESSIONAL` specifications)

ANALYSIS SECTION:

Graphical analysis of

- Transmission characteristics (magnitude, phase response, group delay etc.)
- Reflections
- Impedances
- Up to four diagrams can be displayed at one time
- Linear or logarithmic scaling
- Auto or manual scaling
- Waveform Cursor function
- Output to plotters, printers, or file

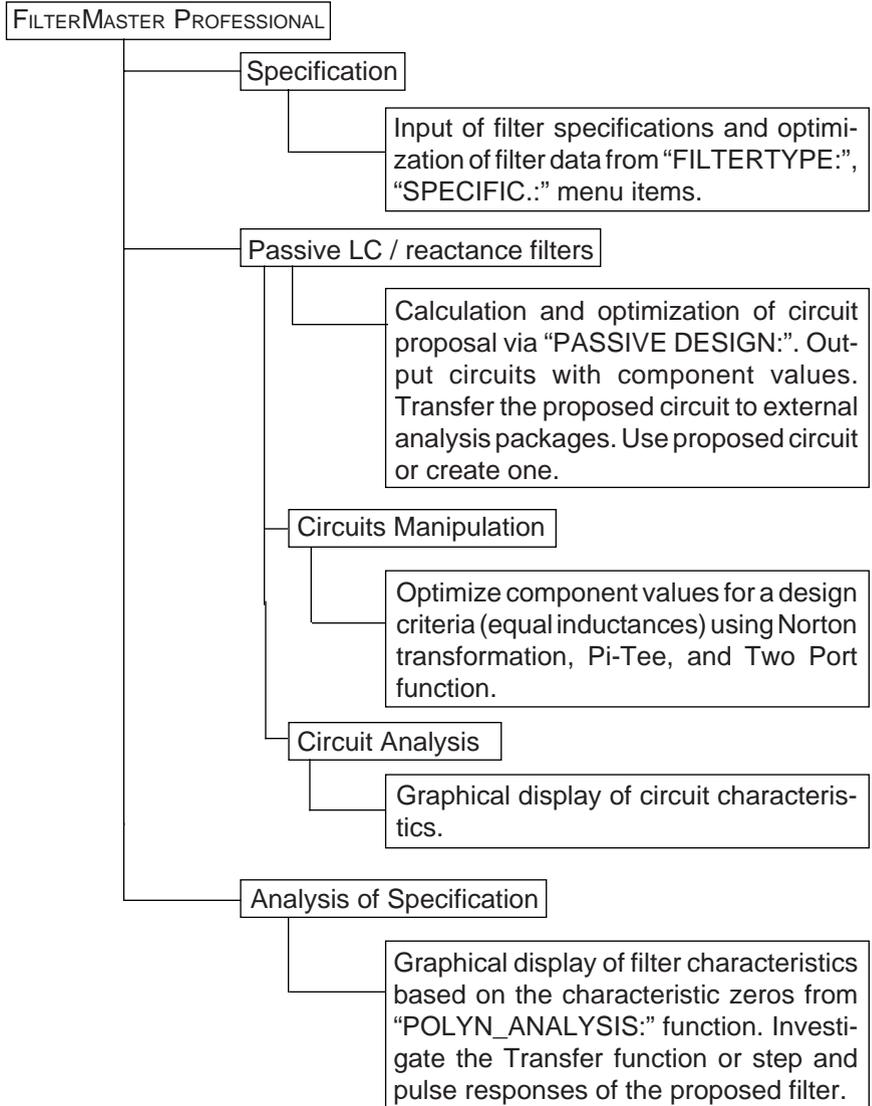
APPLICATIONS:

- Design of passive reactance filter circuits (or RC active filters using the `FILTERMASTER ACTIVE` program)
- Optimization of filter specifications
- Rapid cost estimating
- Feasibility studies of different specifications
- Compare different realization possibilities (approximations, circuit structures etc.)
- Analyze frequency spectra (interface to the DPA-1000 intermodulation software)

INTERFACE:

- Menu-driven
- Mouse support
- On-line help information
- Keystroke macro support

Program Structure



Program Support

All SPICE netlists are in an ASCII format and can be used with virtually any SPICE program.

FILTERMASTER offers interfaces to the following programs:

IsSPICE/SPICENET

Output the filter circuit in an IsSPICE subcircuit format or as a stand-alone IsSPICE netlist. When output as a subcircuit, the file created will have the same format as other SPICE model library files included in the Intusoft ICAPS package. Netlists may also contain component tolerances for use in the Monte Carlo statistical yield analysis.

Touchstone

Output the filter circuit in a Touchstone netlist format.

Tutorial

This chapter will acquaint you with `FILTERMASTER PROFESSIONAL` through the use of a simple example. You will learn how to:

- Operate the program
- Activate the on-line help
- Enter a filter's specifications
- Obtain recommendations for complete filter design
- Analyze a filter's characteristics graphically

Hint for mouse users

All examples in this manual are written based on operation from the keyboard. If you would like to use your mouse in the examples, please read the remarks in the "Selecting Options Using The Mouse" section.

For this tutorial example we will design a bandpass filter with the following specifications:

- Passband: 87.5 MHz ... 108 MHz
- Stopband: 0 - 70 MHz and from 140 MHz
- Stopband attenuation: 45 dB
- Return loss (matching): 16 dB

Selected approximation: Elliptic filter (Cauer)

Starting The Program

At the DOS prompt of the subdirectory where the FILTERMASTER program is located, type:

- `fm[↵]` Starts the program

After a short period, while the program is being initialized, the FILTERMASTER Main Menu will be displayed:



(C) 1992 OMICRON electronic

Filtertype

We are now in the FILTERMASTER PROFESSIONAL main menu. To get to a defined initial state, we will reset the program:

- `[O]` Go to the OPTIONS menu. (You can select various menu function by entering the appropriate capital letter. In the case of the OPTIONS menu, use the letter 'O')
- `[R]` Select the program_Reset option

- [↵] Answer to query (Y/N)
- [Q] Back to the main menu

Now we are ready to start the filter design.

Specifying The Filter

From the main menu, press:

- [↵] Change to the FILTERTYPE menu

The screen will now display the following options:

Filtertype	Approximation
Lowpass	General Equal-ripple
Highpass	General Maximally-flat
Bandpass	Butterworth (potence filter)
Bandstop	Chebyshev
	Inverse Chebyshev
	Elliptic (Cauer filter)
	Bessel (Thomson filter)

FILTERTYPE: **Type** Approximation Quit ?

Initially a Butterworth lowpass is selected. However, we want to calculate a bandpass filter with an Elliptic approximation. To change to the bandpass filter type;

- [↵] Go to TYPE menu
- [B] Bandpass

Now, we specify the desired approximation.

- [A] Change to the APPROXIMATION menu

SPECIFYING THE FILTER

- [E][↵] Elliptic approximation (Cauer filter)

The screen will show changed settings by highlighting the entries.

To use the mouse to activate functions;

- Just click on the desired settings on the screen.

It is now time to enter the filter specifications.

- [Q] Back to the main menu
- [S] Go to the SPECIFICATION menu

The screen will then appear as follows:

SPECIFICATIONS to : Elliptic (Cauer) - bandpass filter		
(O)		
(A)	Lower passband edge frequency	: not defined
(B)	Upper passband edge frequency	: not defined
(C)	Lower stopband edge frequency	: not defined
(D)	Upper stopband edge frequency	: not defined
(E)	Passband bandedge loss	: not defined
(F)	Passband bandedge return loss	: not defined
(R)	Passband reflection factor	: not defined
(G)	Stopband loss	: not defined ◀
(H)	Filter degree	: not defined
(I)	Case (a, b, c)	: b
(J)	Variable value (A,B,C,D,E,F,G,H,R)	: G
	Lower 3dB edge frequency	: not defined
	Upper 3dB edge frequency	: not defined
	Filter quality	: not defined

SPECIFICATION: ? B C D E F R G H I J New cOmment file Printer
 frequency repres. bandwidth repres. rel. bandwidth repres. Quit ?

If you're not clear about any of the terms on the screen, you can call up the on-line help:

- [?] Activates the on-line help

The following help text will then appear:

```

SPEC. (Butterw...): Page 1/5
Once you have entered the filtertype and approximation (FILTERTYPE: menu), you
can use this menu to specify the filter accordingly. Selecting one of the
letters on the menu line will take you to the corresponding field in the mask.
The program will only allow you to enter characteristics applicable to the
filter type selected. Characteristics available:

(Lower) passband limit frequency
      (Lower) limit frequency at which the attenuation exceeds the
      specified passband attenuation.

(Upper) passband limit frequency
      Upper limit frequency at which the attenuation exceeds the
      specified passband attenuation (BP/BS only).

(Lower) stopband limit frequency
      (Lower) limit frequency at which the attenuation reaches the
      specified stopband attenuation.

HELP: Resume Next_page Previous_page Contents

```

The page number in the top right-hand corner tells us that there are more pages available on this topic:

- [N] Next page

```

SPEC. (Butterw...): Page 2/5
(Upper) stopband limit frequency
      Upper limit frequency at which the attenuation reaches the
      specified stopband attenuation (BP/BS only).

Group delay    Only at Bessel approximation (optimizes to constant group
                delay): group delay at frequency 0.

Passband attenuation
                Maximum attenuation in passband

Return loss    Relevant to passive LC filters (reactance filters) only: any
                power which does not reach the output in a loss-free filter is
                reflected to the input. Return loss determines to what extent
                the return wave is suppressed in the passband range. Return
                loss is directly coupled to passband attenuation.

Stopband attenuation
                Attenuation in stopband

HELP: Resume Next_page Previous_page Contents

```

We now have all the information we need, so let's go back to entering our specifications:

- [R] Return to point in program where the help was called up

SPECIFYING THE FILTER

Now, let's choose case "c" for equal terminating resistances:

- [I][C][Enter] Case "c"

Enter the following specifications:

- [A] Lower passband edge frequency
- 87.5M[Ø] Value: 87.5 MHz

Note: please make sure you use the right upper case/lower case scaling units (e.g. m= milli-, M = mega- etc.) This could also be input as 87.5E6.

- 108M[↓] Upper passband edge frequency: 108 MHz
- 70M[↵] Lower stopband edge frequency: 70 MHz

When you confirm the last input, the upper stopband edge frequency will also appear in the mask (135 MHz). The reason for this is that with symmetrical bandpass filters, if any three frequencies are known, the fourth can be calculated. Every time you enter a value, FILTERMASTER PROFESSIONAL checks to see if the entry affects or generates any other values.

We are happy with this value. In fact, it's less than the value we wanted!

Now let's enter the required return loss:

- [F]16[↵] Return loss: 16 dB

Entering the return loss automatically gives the passband attenuation: approximately 0.11 dB.

Next, the stopband attenuation:

- [G]45[↵] Stopband loss: 45 dB

Once this input is confirmed, the program automatically calculates the filter degree and displays it on the screen:

SPECIFICATIONS to : Elliptic (Cauer) - bandpass filter		
(O)		
(A)	Lower passband edge frequency	: 87.500 000 MHz
(B)	Upper passband edge frequency	: 108.000 000 MHz
(C)	Lower stopband edge frequency	: 70.000 000 MHz
(D)	Upper stopband edge frequency	: 135.000 000 MHz
(E)	Passband bandedge loss	: 0.110 483 dB
(F)	Passband bandedge return loss	: 16.00 dB
(R)	Passband reflection factor	: 15.85 %
(G)	Stopband loss	: 53.95 dB
(H)	Filter degree	: 8 ◀
(I)	Case (a, b, c)	: c
(J)	Variable value (A,B,C,D,E,F,G,H,R)	: H
	Lower 3dB edge frequency	: 85.487 587 MHz
	Upper 3dB edge frequency	: 110.542 364 MHz
	Filter quality	: 17.12

SPECIFICATION: ? B C D E F R G H I J New cOmment file Printer
frequency repres. bandwidth repres. rel. bandwidth repres. Quit ?

No doubt you've noticed that when the program calculated the degree, it also revised the stopband attenuation, increasing it to 53.95 dB. With the current value this specification still has a margin that can be used to improve other filter specifications.

We would rather have a better return loss (matching) than a higher stopband loss. So lets' try to use this "margin" to improve the return loss.

Degree, stopband attenuation, return loss and passband attenuation vary with one another, so, before we start changing any of these parameters, we need to know which of the others we can or should change. We can do this by setting any of these fields to "variable".

In this case, we want to optimize return loss:

- [J] Variable value
- [F][←] Return loss set to "variable"

SPECIFYING THE CIRCUIT

The position of the arrows in the right-hand part of the screen shows us that changes were made. The three values are set to variable because all three values are directly linked to one another.

Mouse users:

A change of the variable value can be effected by clicking on the empty space behind the respective field. FILTERMASTER then sets the marking to the selected position.

Now let's enter a new stopband loss which we're more than happy with - let's say 50 dB.

- [G]50[←] Stopband attenuation: 50 dB

The screen will now look like the following:

SPECIFICATIONS to : Elliptic (Cauer) - bandpass filter			
(O)			
(A)	Lower passband edge frequency	:	87.500 000 MHz
(B)	Upper passband edge frequency	:	108.000 000 MHz
(C)	Lower stopband edge frequency	:	70.000 000 MHz
(D)	Upper stopband edge frequency	:	135.000 000 MHz
(E)	Passband bandedge loss	:	0.044 818 dB ◀
(F)	Passband bandedge return loss	:	19.89 dB ◀
(R)	Passband reflection factor	:	10.13 % ◀
(G)	Stopband loss	:	50.00 dB
(H)	Filter degree	:	8
(I)	Case (a, b, c)	:	c
(J)	Variable value (A,B,C,D,E,F,G,H,R)	:	F
	Lower 3dB edge frequency	:	84.698 809 MHz
	Upper 3dB edge frequency	:	111.571 817 MHz
	Filter quality	:	14.50
SPECIFICATION: [?] B C D E F R G H I J New cOmment fiLe Printer frequencyrepreS. bandwidthrepreS. reL.bandwidthrepreS. Quit ?			

The return loss has changed and with it the passband attenuation. These two factors are directly connected. (With loss-free filters, the wave (energy) which does not reach the output returns to the input).

Now we're happy with our specifications, so let's go on and design the filter:

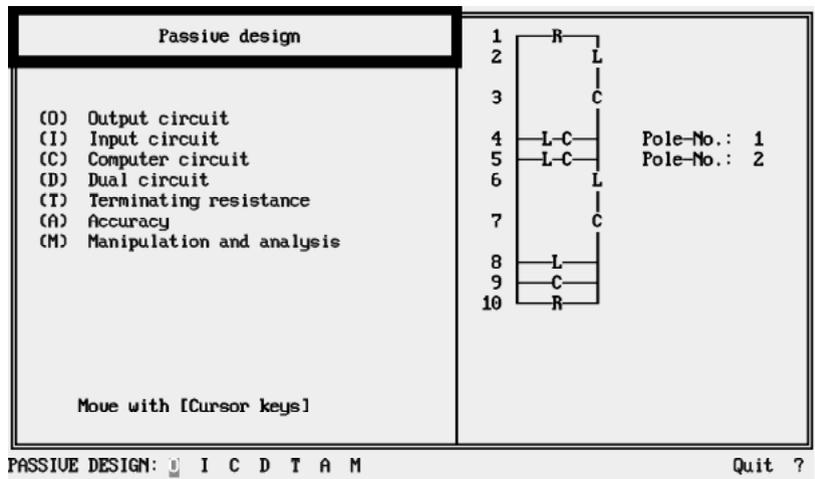
- [Q] Back to the main menu, calculating roots in the process.

Designing The Circuit

From the main menu type:

- [D] Go to the PASSIVE DESIGN menu

The screen will display the following:

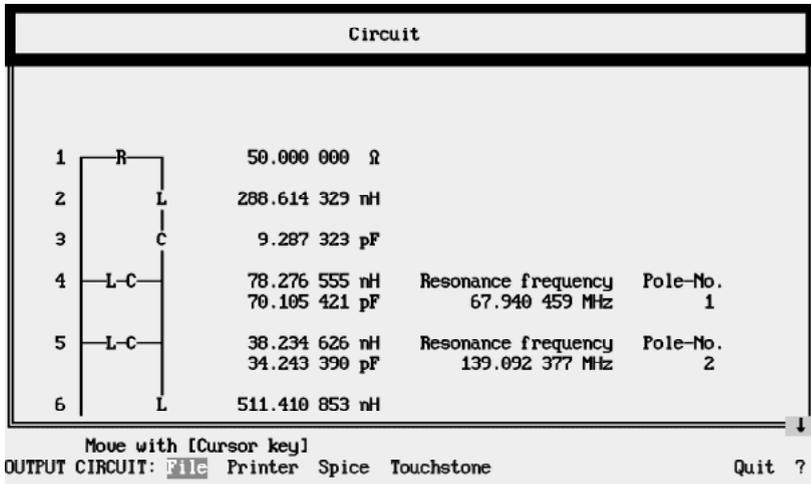


This screen already shows the circuit topology, but does not show component values. To show the values press:

- [↵] Go to the OUTPUT CIRCUIT menu

The program spends a little time performing some calculations (reactances, components), and then displays the circuit on the screen together with all the component values.

DESIGNING THE CIRCUIT



To see the next part of the circuit:

- [↓] Scroll through the circuit

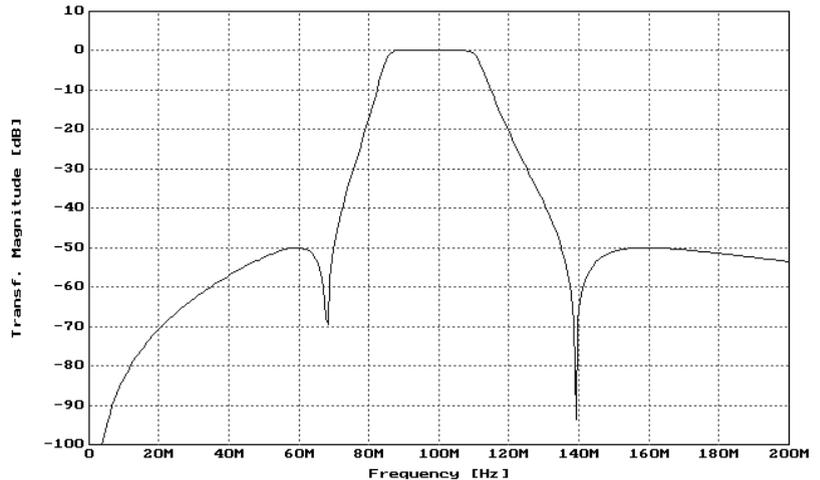
The circuit is displayed with the filter input at the top, the output at the bottom, and the solid line on the left as the ground.

Analyzing Circuits

Let's take a look at the frequency response of the filter circuit we have designed:

- [Q] Back to the PASSIVE DESIGN menu
- [M][A] Go to the CIRCUIT ANALYSIS menu
- [X][X][X][←]200M[←] Upper limit X-axis = 200 MHz
- [O]300[←] 300 calculated points
- [←] Switch to the waveform plotting mode

Once the screen display is complete, it will look like the following:



X-Y: Window ZoomOut Parameters optimize Output Marker Quit ?
(1)

Of course, this leaves a lot of room for improvement (limits, scaling etc.). Let's get back to our starting point:

- [Q][Q][Q][Q] Back to main menu

In the last step we will save the filter data and program status for later use:

- [T][S]example1[↵] The file is saved under Example1.FM.

This ends the tutorial example!

SUMMARY:

In this example, you have seen:

- How to operate the program
- How to ask for help
- How to specify a filter
- How a complete circuit is designed
- How to analyze a circuit's transmission characteristics
- How fast `FILTERMASTER PROFESSIONAL` actually runs, and
- How easy it is to design an Elliptic filter

Further examples are provided in the descriptions of the individual program functions (Chapter 5).

Operating Instructions

Selecting Menu Options

The FILTERMASTER PROFESSIONAL menu system is based on a hierarchical tree structure. Selecting a menu option will take you

- to another menu,
- to an instruction, or
- to the appropriate data field.

The following key functions are valid throughout the whole program:

[ESC]	Interrupt key. Calculations are also stopped. For mouse users: The same function can be achieved by pressing both mouse buttons.
[?]	Invokes the on-line help system.
[Q]	Selects the quit command. Exits from a menu by maintaining all changes; returns to the previous menu.
[F1]	Calls up a list of files when the program expects the entry of a filename.

Selecting Options Using The Keyboard

You can select any menu option by pressing the first UPPER CASE letter in the particular menu entry (usually the first letter, but not always).

SELECTING OPTIONS USING THE KEYBOARD

In most menu function, each upper case letter occurs only once: If that letter is pressed, the appropriate command will be immediately executed.

For example:

To move from the main menu to the OPTIONS menu;

```
MAIN:  Filtertype Specification Roots passive_Design polynomial_Analysis
       Transfer Control Options                               Quit ?
```

- Press [O]. The OPTIONS: menu will be activated.

In menus where the same letter applies to more than one function, the commands are executed as follows:

- Successive presses of the capital letter will alternate between the appropriate functions. To select the desired function, press Enter.

For Example:

You're in the APPROXIMATION menu, and you want to select the Elliptic entry.

```
APPROXIMATION: Equal-ripple  Maximally-flat  Butterworth  Chebyshev
                Inv.-Chebyshev Elliptic      Quit ?
```

Procedure:

- [E] Highlight Elliptic
- [↵] Confirm selection

The items in the menu can also be selected with the [←], [→], [Spacebar] or [Backspace] keys and confirmed with [↵].

Selecting Options Using The Mouse

To select a menu functions with the mouse;

- Move the mouse pointer over the desired function.

- Click the left or right mouse button.

The function you selected will be executed immediately.

To back up one menu level;

- Press both the left and right mouse buttons simultaneously.

Dialog Fields

In many parts of the program the dialog with the program takes place through fields in the screen. Highlighted entries can be selected directly by the user. Entries in normal video contain additional information and cannot be selected.

The highlighted entries can either be:

- numbers/texts that can be edited,
- functions that are executed after being selected,
- the valid setting from a range of options.

Entering Data In Fields

Keystrokes	Results:
[↵]	End and accept the entry
[ESC]	End without accepting the entry
[←], [→]	Move cursor one character to the left/right
[Ctrl+←], [Ctrl+→]	Move cursor one word to the left/right
[Home], [End]	Move cursor to the beginning/end of a string of characters
[Backspace]	Delete character left of the cursor
[Ctrl+Backspace]	Delete the whole entry in the input field
[Ctrl+T]	Delete until the next blank
[Del]	Delete character at the cursor position
[Ins]	Switch from "Insert" to "Overwrite" mode

ENTERING DATA IN FIELDS

Additional input options in numerical fields include:

min[↵]	Smallest possible value desired
max[↵]	Highest possible value desired
nn%[↵]	nn % of the presently shown value desired

Scaling abbreviations for numbers include:

a	Atto	= 1.0E-18
f	Femto	= 1.0E-15
p	Pico	= 1.0E-12
n	Nano	= 1.0E-9
u	Micro	= 1.0E-6
m	Milli	= 1.0E-3
k	Kilo	= 1.0E+3
M	Mega	= 1.0E+6
G	Giga	= 1.0E+9
T	Tera	= 1.0E+12

The scaling abbreviations differ from those used with the IsSPICE analog circuit simulation program.

Entering Filenames

Some program functions require a filename to be entered. For these functions you can enter filenames in two different ways:

- Direct entry of a filename in the corresponding field.
- Selection of a filename from a list.

Filename extension note: FILTERMASTER PROFESSIONAL automatically adds the extension the program expects for the respective data format (see “Data Formats”). If you want to use another extension, you can enter it along with the filename.

Filename path note: If you enter the filename only, data will be transferred with the path specified in the OPTIONS menu. If you want to use another path, you can enter it along with the filename (e.g. a:\test\filter1.ini [↵]).

Instead of entering a filename, you can call up a list of files and select the one you want.

To select a file using the keyboard;

- Press [F1] to call up list the list of existing files.
- Select the file you want by entering the first letter or using the cursor keys.
- Press [↵] to confirm.

To select a file using the mouse;

- Place the mouse pointer in the filename field.
- Press the right mouse button.
- Then either press the left mouse button for selection and Enter for confirmation or,
- Press the right mouse button for selection and simultaneous confirmation.

Options for listing files

Path names and wildcards such as “?” and “*” can be used for listing files.

Examples of entries:

.[F1] All files (no matter what extension) are listed in the directory as stated in the OPTIONS menu.

C:\FM*.FMT[F1] All files are listed that have the extension FMT and that are contained in the directory as stated in the OPTIONS menu.

The first file displayed in the list on the screen is automatically copied to the input field. After confirming the filename, the data will be transferred.

On-Line Help Text

To invoke the on-line help text;

- Press “?”.

You can issue the following instructions from the menu line:

Resume

Return to the FILTERMASTER menu screen.

Next_page

Display the next help screen

Previous_page

Move back to the previous screen

Contents

Open the HELP CONTENTS menu to obtain a list of all the help topics that you can access.

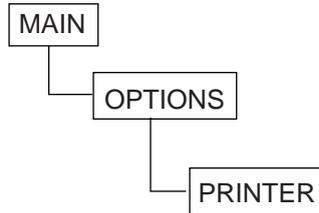
Output

FILTERMASTER PROFESSIONAL provides two types of printer output, text and graphics.

Text Output

This type of output is used in FILTERMASTER PROFESSIONAL for printing tables of data such as specifications, zero positions, etc.

The printer specifications (type of font, margin, etc.) are set in the OPTIONS menu either by entering the respective data field directly (mouse users) or by the menu items in the PRINTER submenu.



Interface printer/plotter

This item is used for selecting the desired interface for the output device.

IBM-char set

Determines whether the printer is able to print the whole IBM character set (line symbols).

Lines/page

Determines after how many lines a new page should begin.

Left border

Determines the left margin in characters.

PostScript

Determines whether your printer is a postscript printer. Relevant only for text outputs.

Char/line

Determines the number of characters per line.

Init

Offers you the option of sending an initialization sequence to your printer. This sequence is sent to the printer before each printout. Nonprintable control characters are provided in the form \nnn with nnn being a three-digit decimal number (e.g. ESC = \027) Hint: Don't enter a sequence if you have a postscript printer.

OUTPUT

For example:

Control sequence for the HP laser printer IID for 10 pt Courier font is:

```
\027(10U\027(s0p12.00h10.0u0s0b3T
```

Graphic Output

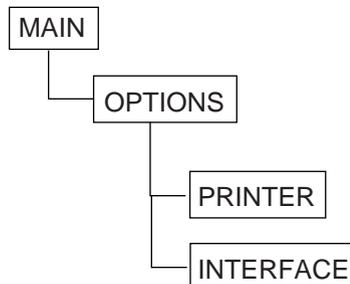
This type of output is used in FILTERMASTER PROFESSIONAL for printouts of the filter analysis results.

As different output formats are required for the individual printers, FILTERMASTER first “translates” the respective graphics data into the printer language and then transmits the data through the predefined interface. The program contains its own conversion software for this purpose.

The printer settings (type of printer, desired size of the drawing, etc.) are made in the PRINTER OPTIONS menu (from the menu OUTPUT GRAPHIC, select in the graphics section). For more details please refer to the “Output Graphic” section.

Program Setup

FILTERMASTER PROFESSIONAL allows you to set certain program options. The program automatically switches to these settings at start-up. The respective settings are made in the OPTIONS menu. For settings activated from the keyboard (without mouse support), there are additional submenus.



For example, the following settings can be programmed:

- The DOS path where data is searched/saved. (If no alternate path has been added to the filename.)
- Interface parameters for the peripheral output devices (printer, plotters, etc.).
- The type of decimal point used (./).
- Number groupings (yes/no)

The OPTIONS menu also tells you how much memory is left and gives you the precise version number of this program.

The entries in the OPTIONS menu are:

Drive, Path

This entry contains the path to the DOS directory where data files will be saved. (If an alternate path was not provided when the filename was entered.)

Interface Printer

This sets the printer interface parameters.

Interface Plotter

This sets the plotter interface parameters.

If you would like to print your diagrams through another interface (e.g. IEC interface), you can proceed as follows:

- Instead of printing the output on a printer, save the graphics data to a file using the HPGL format (menu item File in the OUTPUT GRAPHIC menu),
- Exit from FILTERMASTER and plot the graphics from the DOS prompt. (copy the contents of the file to the respective plotter port).

Decimal-sign

Determines whether the "." or "," is used as the decimal point.

Grouping

Determines whether “longer” numbers in fixed point displays are to be divided into groups of three for clarity. When selecting the groups of numbers, the decimal separating point is used that is inverse to the selected decimal sign.

Printer Setup

Determines the printer settings for text output.

Parameters Of Serial Port(s)

Determines the parameters for the serial interface(s) COM1/COM2:. If the mouse is installed on one of these ports, then the settings cannot be altered.

The following parameters can be selected:

Baud rate: 110, 150, 300, 600, 1200, 2400, 4800, 9600

Parity: No, Even, Odd

Data bits: 7, 8

Stop bits: 1, 2

Note: FILTERMASTER PROFESSIONAL automatically determines which ports are present in the computer.

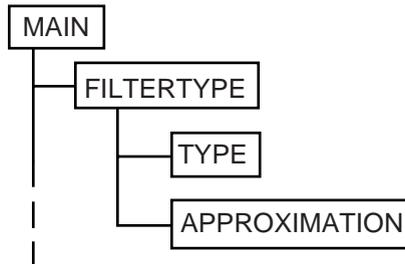
The OPTIONS menu also contains the Prog_Reset menu item, through which the program can be reset to a defined initial state. You should be absolutely sure when activating this function, because all previously entered information will be lost!

Note: The saving/loading of program status (program setups with filter data, graphic parameter, etc.) is possible through the TRANSFER menu item in the main menu.

Program Functions

Specifications

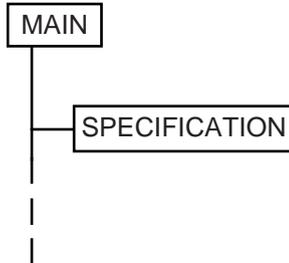
The desired type of filter and the approximation are selected in the FILTERTYPE menu. The FILTERTYPE menu is selected from the main menu.



After determining the desired type of filter, various filter characteristics are entered in the SPECIFICATION menu.

Standard Approximations

For standard filter approximations, specifications are made in the SPECIFICATION menu.



Depending on the type of the filter, the following menu lines will be shown:

Lowpass or highpass filters:

```
SPECIFICATION: A C E F R G H I J New cOmment fiLe Printer Quit ?
```

Bandpass or bandstop filters:

```
SPECIFICATION: A B C D E F R G H I J New cOmment fiLe Printer  
freqUencyrepres. bandwidthrepreS. reL.bandwidthrepres. Quit ?
```

Selections are made by pressing the appropriate key letter corresponding to the field on the screen that you would like to edit. Depending on the type of filter, only the relevant settings will be available for entry. These are:

(Lower) passband edge frequency

The (lower) frequency at which the attenuation exceeds the specified passband attenuation (see diagram at the end of this section).

Upper passband edge frequency

The upper frequency at which the attenuation exceeds the specified passband attenuation (BP/BS only, see diagram at the end of this section).

(Lower) stopband limit frequency

The (lower) frequency at which the attenuation reaches the specified stopband attenuation (see diagram at the end of this section).

Upper stopband limit frequency

The upper frequency at which the attenuation reaches the specified stopband attenuation (BP/BS only, see diagram at the end of this section).

Note: As an alternative to the individual edge frequency values, FILTERMASTER PROFESSIONAL also allows you to enter data in the bandwidth/relative display. (Only for the standard approximations of bandpass or bandstop filters using symmetrical responses.)

Change through the menu items bandwidthrepreS. and reL.bandwidthrepres.; with freqUencyrepres. You can return to the frequency display.

The center frequency stated in the bandwidth display refers to the geometrical center with reference to the logarithmically applied frequency axis.

Group delay

Used only for Bessel lowpass filters. The value is the desired group delay at zero frequency.

Passband bandedge loss

Maximum attenuation in the passband (see diagram at the end of this section).

Passband bandedge return loss

This entry is relevant to passive LC filters (reactance filters) only. Any power which does not reach the output in a loss-free filter is reflected to the input. Return loss determines to what extent the return wave is suppressed in the passband range. Return loss is directly coupled to passband attenuation.

Passband reflection factor

Ratio of the amount of the reflected signal to the amount of the input signal in percent. The reflection factor is directly coupled to the passband and return loss.

Stopband loss

Attenuation in the stopband (see diagram at the end of this section).

Filter degree

The number of attenuation peaks of the filter circuit (peaks where $s \rightarrow \infty$ included). The degree of a filter is an indication of the number of components required.

Case

In some approximations, we differentiate between various "cases" in terms of the designability of a filter.

- a** The required transmission characteristic can only be achieved actively or by using mutual inductances. In this case, the peaks and zeros are calculated, but FILTERMASTER PROFESSIONAL cannot undertake the synthesis of the circuit itself. (Case "a" applies to Elliptic and Inverse Chebyshev only.)
- b** This transmission characteristic is feasible using a passive circuit; input and output resistances may differ.
- c** Passive-feasible. Input and output resistances are equal (Elliptic and Chebyshev only).

These cases affect the end result only in even degree high and lowpass filters and in bandpass or bandstop filters whose degree is divisible by four. For more informations see the section "Case, terminating resistance ratio".

Variable value

You can use this field to specify which characteristic of a filter FILTERMASTER PROFESSIONAL can or should change if any of the screen inputs changes (e.g. during optimization).

The screen contains the following additional information:

3dB edge frequency

The frequency at which the passband reaches -3 dB of its maximum value (precisely: 3.0103 dB).

Filter quality

Maximum pole quality of the zero positions of polynomial e.

Passive filter design

Used for assessing the losses in the passband. The inductors quality should be designed with a factor of 3 to 5 higher than the stated filter quality when realizing the filter.

The following options are also available:

New

Deletes all data contained on the screen in preparation for new input.

cOmment

FILTERMASTER PROFESSIONAL automatically labels all outputs (roots, circuits, graphs) with comments that you can enter via this option.

fiLe

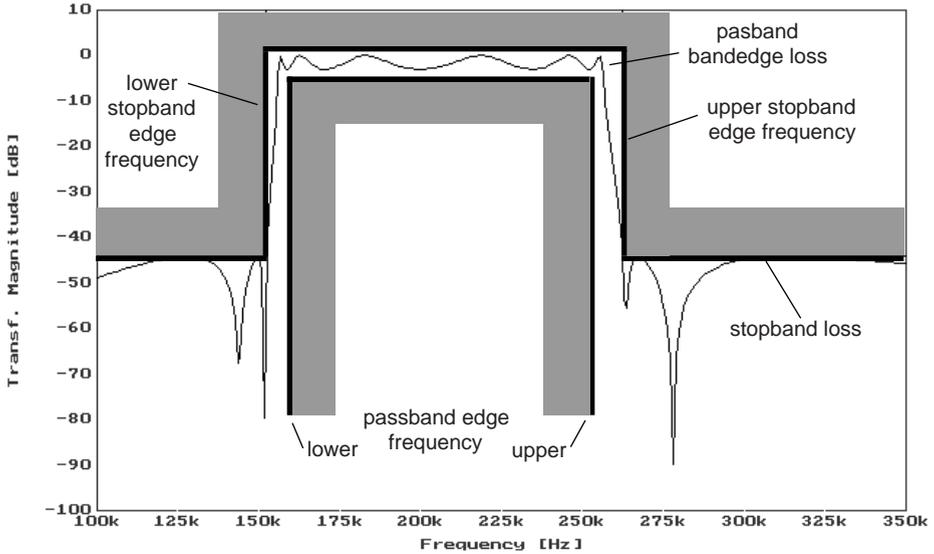
Saves the entered filter specifications in a file. The default extension is .SPZ. For more information on this data format see the section on "Filter Specification Protocol".

For more details please refer to the section on "Output".

STANDARD APPROXIMATIONS

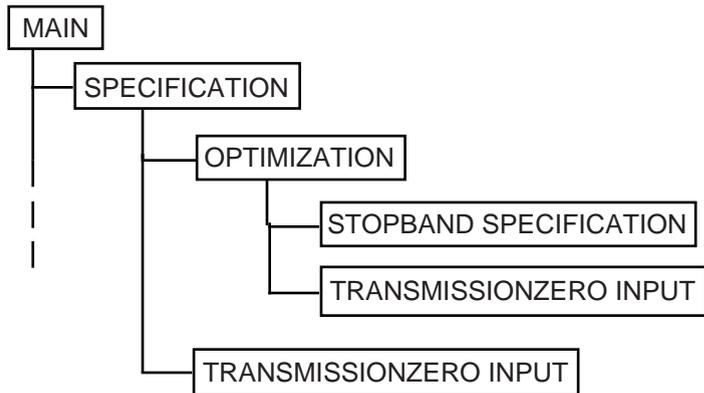
Printer

Prints the filter specifications.



General Amplitude Approximations

When selecting a general amplitude approximation (equal ripple or maximally flat), further specifications for the filter are made in the SPECIFICATION menu and its respective submenus:



SPECIFICATION Menu (for general amplitude approx.)

| For lowpass, highpass and bandstop filters:

```
SPECIFICATION: A E F R G W V                                quality
Stopbandopt. fiXtrans.zeros cOmment New fiLe Printer Quit ?
```

| For bandpass filters:

```
SPECIFICATION: M A B E F R G H quality Conventional Defaultparam.
Stopbandopt. fiXtrans.zeros cOmment New fiLe Printer Quit ?
```

Once you have entered the filter type and the approximation (FILTRTYPE menu), you can use this menu to specify the filter. Selecting one of the letters in the menu will take you to the corresponding field on the screen. The program will only allow you to enter the characteristics that apply to selected the filter type. The available characteristics are:

(Lower) passband edge frequency

The (lower) frequency at which the attenuation exceeds the specified passband attenuation (see the diagram at the end of the “Standard Approximations” section).

Upper passband edge frequency

The upper frequency at which the attenuation exceeds the specified passband attenuation (BP/BS only, see the diagram at the end of the “Standard Approximations” section).

Note: After completing the specification for bandstop filters it is only possible to change one of the edge frequencies. When one edge frequency is changed, the other edge frequency is automatically changed while the center frequency is kept constant. This is due to the fact that bandstop filters are always symmetrical and the pole frequencies should not be changed.

If the edge frequencies are changed after all the specifications have been entered, the changes will be limited by the pre-defined tolerance scheme, the fixed pole frequencies and, in parametric filters, by the parameters. A maximum frequency factor $KFMAX < 1$ is maintained between the edge frequencies and the pole frequencies.

If the minimum distance between the passband and the stopband edge frequency permitted by `FILTERMASTER PROFESSIONAL` is still too high, then change `KFMAX` in the external file `FM.DEF`. If unexpected problems with the limits arise, `KFMAX` can be changed in the file `FM.DEF`. (For more details see the Appendix on the `FILTERMASTER Defaults File (FM.DEF)`)

Parameter (Only in parametric bandpass filters)

In bandpass filters you have to distinguish between conventional or parametric types of responses (change in Parametric/Conventional menu item). If the parametric form is selected, the screen will contain an input field for the parameter. This gives you more freedom for dimensioning. (For more details please refer to the section “Parametric Bandpass Filter” and the explanations in the Appendix “Conventional/Parametric Bandpass Filters”).

By selecting the `Defaultparam` menu item you will be able to accept the default parameter provided by the program. It is the geometric mean of the lower and upper passband edge frequencies.

Parameter limits are determined by the factor `PAMAX` set in the `FM.DEF` menu and the respective default parameters:

Minimum: $\text{Default parameter} / \text{Pamax}$

Maximum: $\text{Default parameter} * \text{Pamax}$

(For more details see the Appendix on the `FILTERMASTER Defaults File (FM.DEF)`)

A negative parameter value can also be entered. However, it will only have an influence on the structure of the circuit in parametric filters of odd degree.

Passband bandedge loss

Maximum allowable attenuation in passband. (see the diagram at the end of the “Standard Approximations” section)

Passband bandedge return loss

This parameter is relevant in passive LC filters (reactance filters) only. Any power which does not reach the output in a loss-free filter is reflected to the input. Return loss determines to what extent the return wave is suppressed in the passband range. Return loss is directly coupled to passband attenuation and the reflection factor.

Passband reflection factor

Ratio of the amount of the reflected signal to the amount of the input signal in percent. The reflection factor is directly linked to the passband and return loss.

Transm. zeros at zero/infinity (BS: Transm. zero pairs at center)

The number of the poles desired can be entered here in the “extreme” frequencies depending on the type of the filter. The entries are understood as fixed transmission zeros.

Default settings:

- Lowpass: 1 pole at infinity
- Highpass: 1 pole at zero
- Bandpass: 1 pole each at zero and infinity
- Bandstop: 1 pair of poles at center frequency

When entering the poles at zero in conventional bandpass filters, the number of poles at infinity is corrected in such a way that the filter always has an even degree. Parametric bandpass filters require at least one pole each at zero and infinity.

How the number of fixed transmission zeros can be determined in a given circuit is discussed in the “Design With User-Defined Circuits” section.

Note: If a sufficient number of poles is set at zero and/or infinity, for achieving the minimum losses (with no fixed or variable transmission zeros in the finite stopband), you will receive a filter with a monotonic loss curve in the stopband.

Resistance ratio

This parameter is only valid in lowpass and highpass filters of even degree and bandstops with a degree that can be divided by 4. This field allows you to enter the desired ratio between the terminating resistors for double terminations.

For more details please refer to the section on “Equal Ripple Approximations”.

The screen contains the following data:

Fixed transm. zero pairs

This entry informs you about how many fixed pairs of transmission zeros (equal to the blocking frequencies) you have provided with finite frequencies (menu item `fiXtrans.zeros`).

Var. transm. zero pairs

This entry informs you about how many variable pairs of poles lie within the finite stopband. If the position of the variable pairs of poles was optimized by `FILTERMASTER PROFESSIONAL` (`OPTIMIZATION` menu), the remark `opt.` can be seen in this screen (field directly behind their number).

Note: `FILTERMASTER` exclusively deals with symmetrical bandstops and the number of the pairs of transmission zeros is always even in the finite frequency range.

Filter Degree

The degree is the number of attenuation peaks of the circuit. (the poles at zero and infinity are also counted). Beware: Pairs of poles always mean two transmission zeros. The degree of a filter is an indication for the number of components required. Maximum degree: 50

The entry in this screen depends on the settings in the OPTIMIZATION menu.

In conventional bandpass and bandstop filters the degree must be even.

3dB edge frequency

Provides the setting at which frequency/frequencies the loss passes the 3dB edge (precisely: 3.0103 dB).

Note: The calculation of the 3dB limits after changing the data requires a certain amount of time. A coprocessor will speed up the calculation. In higher degrees, however, waiting periods can become quite lengthy. Therefore, it is also possible to turn off the calculation of the 3dB limits (For more details see the Appendix on the FILTERMASTER Defaults File (FM.DEF)). The calculation will take place when the filter quality - if desired - is to be calculated.

Filter quality

Maximal pole quality of the zero positions of the polynomial e.

Passive filter design

Serves for assessing the losses in the bandpass. The quality of the inductors should be designed with a factor 3 to 5 higher than the stated filter quality when realizing the filter.

The filter quality is only calculated if the quality menu item is selected.

Since the zero position of the polynomial e with the highest pole quality cannot be determined alone, FILTERMASTER PROFESSIONAL will determine all zero positions of this polynomial and select the one with the highest quality. For calculating the zero positions of the polynomial e, it is necessary to first determine the zero positions of the polynomials f and p. The calculation of the zero positions is started by selecting the quality menu item, which would otherwise commence only when exiting from the SPECIFICATION menu.

Stopbandopt.

Activates the OPTIMIZATION menu. Here the required minimum loss curve in the stopband (entry of the tolerance scheme) is specified and the optimization of the position of the transmission zeros lying in the finite stopband is performed.

For further details please refer to “OPTIMIZATION Menu” section.

fiXtrans.zeros

Activates the TRANSMISSIONZERO INPUT submenu for entering the position of fixed transmission zeros. These will also be considered when optimizing the position of the variable poles in the OPTIMIZATION menu. A practical application would be the suppression of pilot frequencies. For further details please refer to the “TRANSMISSIONZERO INPUT” section.

cOmment

FILTERMASTER PROFESSIONAL automatically labels all outputs (roots, circuits, diagrams) with comments which you can enter via this option, e.g. if you specify a project number, you will always know which printout belongs to which project.

New

Clears the screen for the specification of a new filter.

fiLe

Saves the filter specifications in a file. Default extension: .SPZ

Printer

Sends the filter specifications to a printer.

OPTIMIZATION Menu

```
OPTIMIZATION: A B C D G Lower_stopband-spec. Upper_stopband-spec.
Variable-transmissionzeros Optimization Iteration Quit ?
```

A maximum of fifty steps is allowed for the tolerance scheme.

In this menu you can enter the a curve of the minimum losses in the stopband (tolerance scheme). You can also optimize the number and position of the transmission zeros, which are arranged within the stopband, allowing the required stopband loss curve to be reached (modified Remez algorithm).

General Sequence Of Entries

The “classical” sequence of entries in this program takes place in the following order:

Entry Of The Tolerance Scheme

From the OPTIMIZATION menu...

For lowpass, highpass and bandstop filters use the sTopband-specification menu item.

For bandpass filters, use the Lower/Upper_stopband-spec menu item.

This brings you to the STOPBAND SPECIFICATION menu.

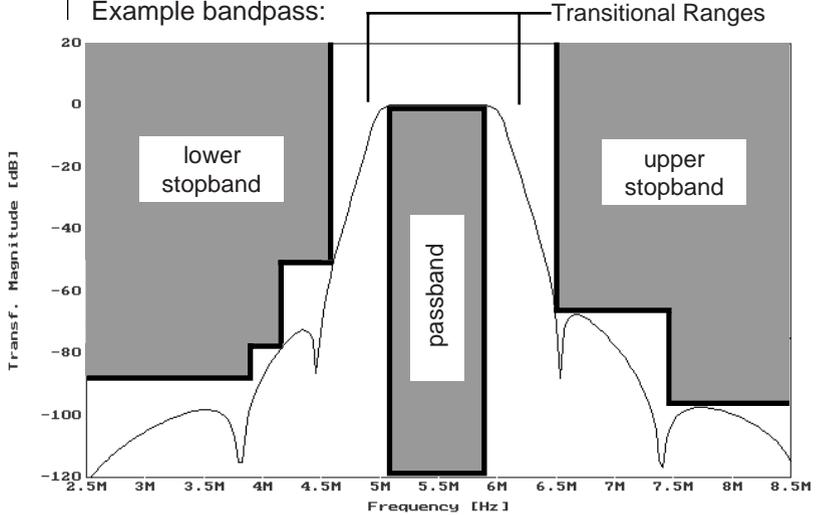
The tolerance scheme has a stepped profile. In the case of an individual curve, the tolerance scheme can be approximated in small steps. The tolerance scheme serves as a unilateral edge, i.e. the optimization tries, through the optimal arrangement of the positions of the poles, to move the real loss curve at each point as far away as possible from the tolerance scheme.

The tolerance scheme is only valid in the stopband and must be defined before the optimization can proceed. In bandpass filters, you have to distinguish between the upper and lower stopbands. If no particular requirements are set on one of the two bands, the optimization can only be carried out with one specified stopband (e.g. only the lower tolerance scheme).

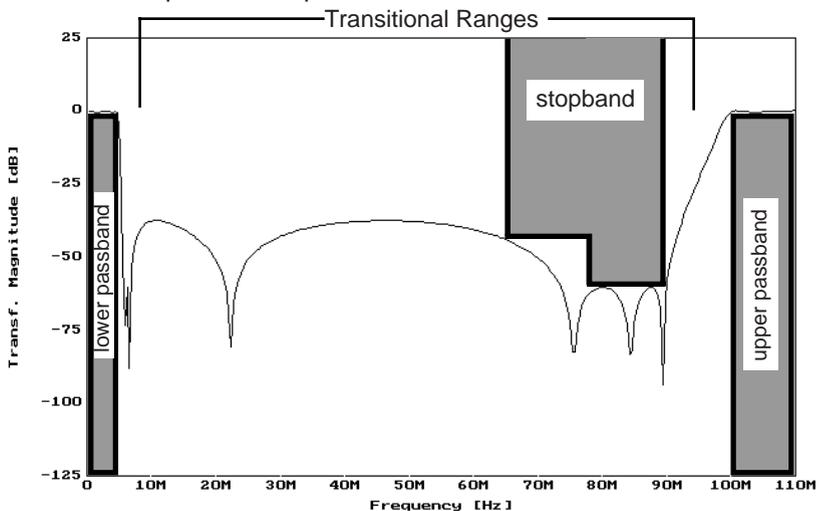
FILTERMASTER PROFESSIONAL does not care about the filter's loss outside of the stopband frequency range (transitional range between the stopband and the passband) and this range will not be taken into account for determining the loss reserve.

Explanation of the terms

Example bandpass:



Example bandstop:



The specified tolerance scheme is automatically saved. It can be included in the graphical display of the loss curve in dB along with the actual filter response. For more details please refer to “Circuit Analysis” section.

Automatic Initialization Of The Variable Poles

When exiting the STOPBAND SPECIFICATION menu, FILTERMASTER PROFESSIONAL will make a proposal for the required number and position of the variable poles that will achieve the required stopband loss curve in the respective frequency range. These values are the initial values that will be used for the subsequent optimization process.

Note: The evaluation does not take into account the number of already specified fixed poles at zero, infinity, and the center frequency (bandstop filters). It also does not take into account the pairs of fixed transmission zeros in the finite frequency range already entered by the user.

More details on how FILTERMASTER PROFESSIONAL establishes the number and position of the transmission zeros for the initial values of the optimization can be found in the “Determination Of Variable Pole Pairs” section.

Changing The Number Of Proposed Poles

The determined number of variable poles will be stated in the OPTIMIZATION screen. This value can be increased or decreased as desired before the optimization is started. A new initialization is made whenever the number of poles is changed in this manner.

Note: From this menu it is also possible to change the number of poles at zero, infinity, or the center frequency (in bandstop filters) When making these changes, the entry in the SPECIFICATION menu is also altered. If no variable poles are entered, the loss reserve can, nevertheless, be determined by selecting Optimization or Iteration. If there are also no fixed poles, the loss curve in the stopband is monotonic.

Viewing and Editing The Variable Poles

For special cases, FILTERMASTER PROFESSIONAL allows you to preset the individual positions of the variable poles in the stopband, or to modify the result of the program's initialization. In order to perform these functions, enter the TRANSMISSIONZERO INPUT menu through the Variable-transmissionzeros menu function. FILTERMASTER PROFESSIONAL presumes that the user would like to pursue a particular goal, for example, changing the initial condition for the optimization. Hence, there is no automatic initialization of the poles afterwards. For more details on the TRANSMISSIONZERO INPUT menu please refer to the "Transmissionzero Input" section.

Note: Variable poles can only be positioned within the range of the tolerance scheme.

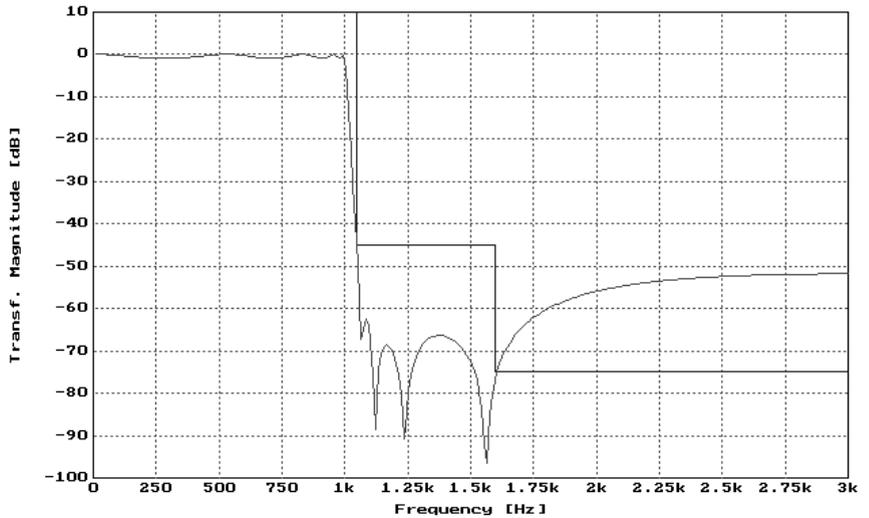
Optimization Of The Positions Of The Poles

After having finished determining the number and the initial positions of the variable poles in the stopband, the optimization can be carried out by the program. The optimization is started by the Optimization menu function.

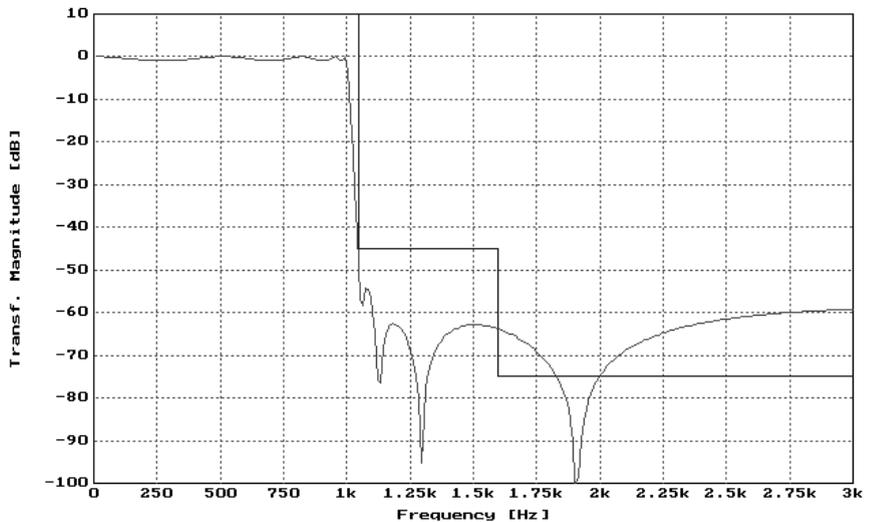
The variable transmission zeros lead to "arcs" in the loss curve. Each of these "arcs" comprises a minimum distance to the predetermined tolerance scheme (in most cases the "cusp point" of the arc). During the optimization the variable poles are moved in iterative steps in the stopband in such a way that all the minimum distances have the same distance and that the difference between the highest and the lowest minimal distance converges towards zero. The program proposes a difference of 0.1 dB as the stop limit for the optimization. However, this value can be changed individually, if desired. If after concluding the optimization, better values can be achieved, further single iterations can be carried out through the Iteration menu item.

Example for a lowpass:

1. Arrangement after the initialization:

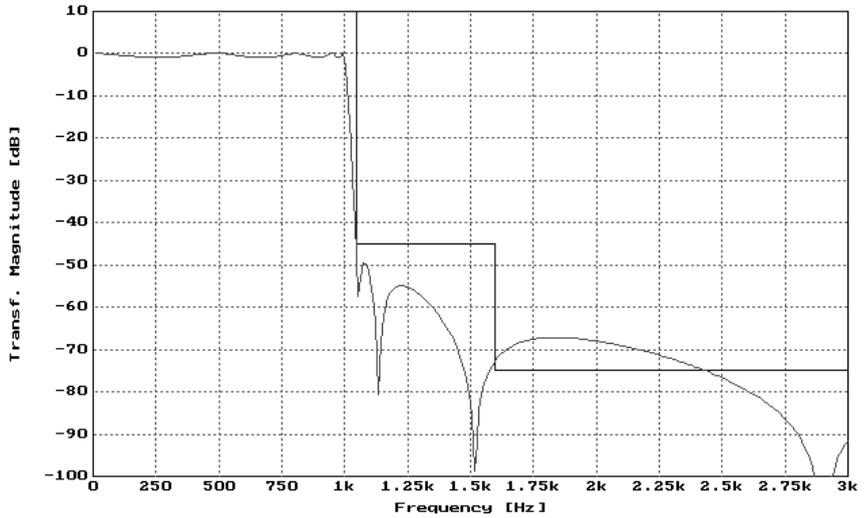


After the first iteration step:

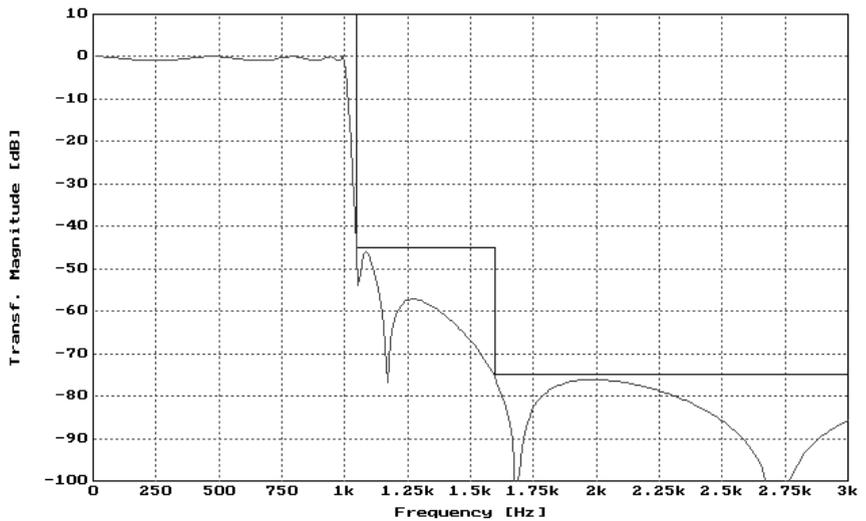


OPTIMIZATION MENU

After the third iteration step:



After completing the optimization (6 iterations):



The optimization may lead to a loss reserve that is greater than required. If this is the case, then either the degree of the filter can be reduced by decreasing the number of variable poles or a reduction in the passband loss can be made. One can usually increase the return loss by approximately the value of the reserve. In both cases, however, it is necessary to carry out a new optimization and check whether the change makes the loss fall below the required value. This would be indicated by a negative sign in the value of the minimum loss reserve after completing the optimization.

Bandpass filters

During the optimization of certain bandpass filters, it is possible for a pair of transmission zeros to assume real values instead of the required imaginary values. You can recognize this by the number of pairs of poles in the upper and lower stopband. The total of which does not result in the set number of variable pairs of poles. In any case, the optimization can maximally yield one real pair of poles.

However, there are cases where such real pairs of poles occur during the optimization and then disappear. It is also possible that such a real pair of poles is required for the optimum solution. But with a passive circuit of the form presently used, it is not possible to realize it.

In order to remedy this problem you can displace the real pair of poles to zero or infinity. This solution is successively requested by `FILTERMASTER PROFESSIONAL` in such a case. If you do not agree with either of the two, the optimization is ignored and `FILTERMASTER PROFESSIONAL` will use the values provided before the optimization as the variable poles.

It is also possible to make only one iteration. Again, the same problems with real pairs of transmission zeros might occur.

Variable transmission zeros can also be moved back and forth between the upper and lower stopband during the optimization.

STOPBAND SPECIFICATION Menu

In this menu, the stopband settings for general equal ripple and maximally flat approximations are entered.

First entry

The edge frequencies of the stopband specifications are numbered consecutively and listed according to frequency.

Proceed as follows for the first entry:

- Select the Add menu item.
- Confirm the proposed number in the range.

The following steps will depend on the type of the filter being synthesized:

Lowpass

- Enter the frequency from which a certain stopband loss is to be achieved.
- Then enter the desired loss value. The range ends at infinity if no further range is specified afterwards or at the beginning of the next range.

Highpass

- Enter the frequency up to which a specific stopband loss is desired.
- Then enter the desired loss value. The range begins at zero if a range was not entered before or from the end of a previous range.

Bandpass

Lower stopband: like highpass

Upper stopband: like lowpass

Bandstop

- Enter the frequency from which a specific loss is to be reached and then the frequency up from which this is desired.

- Then enter the desired loss value.

In the next range FILTERMASTER PROFESSIONAL will use the upper edge frequency of the last range as the “initial frequency” and expects the entry of the frequency up to which the new loss is set. Then enter the loss value for this range.

Note: The number of frequency ranges that can be entered for lowpass, highpass and bandpass filters is 50 (bandstop 49).

Change stopband settings

To change individual values;

- Click on the fields in the screen with your mouse (scroll with the mouse pointer on the screen edge if the table is longer)
or
- Select the Edit menu item, then select the desired value with up and down arrows and make the pertinent changes.

Insertion of a new range

A range with another loss can also be “inserted” afterwards by entering the number of the range within which a new range is to be specified. FILTERMASTER PROFESSIONAL will then allow you to enter frequency values which lie within the range that has already been specified.

Delete

Deletes individual ranges by entering the respective number.

New

Deletes all stopband settings shown on the screen.

When exiting the menu, the poles are initialized first, i.e. FILTERMASTER PROFESSIONAL makes a first proposal for the number and positions of the variable poles in the stopband. This serves as the initial setting for the following optimization. For more details please refer to the OPTIMIZATION menu section.

TRANSMISSIONZERO INPUT Menu

This menu is used for entering and changing fixed, as well as, variable transmission zeros.

In lowpass, highpass and bandstop filters, the entered poles are sorted in two columns with rising frequencies. In bandpass filters, the poles of the lower stopband are entered in the left column and the poles of the upper stopband in the right column.

Notes:

Bandpass filters: If there is insufficient space in the column for all of the stopband poles, the sorting arrangement according to the upper and lower stopband is dropped. The frequencies will also be sorted according to rising frequencies in the two columns. For optical separation a blank line is inserted between the poles of the upper and lower stopband.

Bandstop filters: In bandstop filters, two transmission zeros are always treated symmetrically to the center frequency. It is only possible to have an even number of pairs of transmission zeros. When making entries or changes, the complementary frequency, belonging to a specific pole frequency, is also updated automatically.

Add

Used to add a pole frequency to the existing list.

Edit

To edit a specific field;

- Select the field with the up or down arrows and enter the data.
- Then, confirm the entry with [↵].

Under certain circumstances, the table might be sorted again (in accordance with rising frequencies).

New

Deletes all entries in preparation for a new filter.

To delete individual pole frequencies;

- Switch to the editing mode using Edit menu item.
- Select the pole frequency to be deleted using the down arrow.
- Delete the entry in the field using the control backspace key combination.
- Then, confirm the entry with [↵].

Mouse users: Instead of performing the first two items, just click on the respective field with the mouse pointer.

Example 1: Lowpass Filter

For this filter, we desire a loss curve in the passband with equal ripple. The stopband will be optimized to a tolerance scheme with stepped profile.

Specifications:

Passband edge frequency: 1 kHz
Maximum allowed ripple in dB: 1 dB
Stopband loss:
from 1.05 kHz: 45 dB
from 1.6 kHz: 75 dB

EXAMPLE 1: LOWPASS FILTER

From the main menu proceed as follows:

- [↵] Change to the FILTERTYPE menu
- [↵] Change to the TYPE submenu
- [↵] Set the type of filter to lowpass
- [A] Change to the APPROXIMATION submenu
- [↵] Set the equal ripple approximation

The following entries are selected in the screen:

Filtertype	Approximation
Lowpass	General Equal-ripple
Highpass	General Maximally-flat
Bandpass	
Bandstop	Butterworth (potence filter)
	Chebyshev
	Inverse Chebyshev
	Elliptic (Cauer filter)
	Bessel (Thomson filter)

FILTERTYPE: Type Approximation Quit ?

Now select:

- [Q] Return to main menu
(If any other requirements were entered, confirm the request with [Y])
- [S][N] Change to the SPECIFICATION menu and prepare for a new filter
- [↵]1k[↵] Passband edge frequency: 1 kHz

- 1[↵] Passband bandedge loss: 1 dB

The following will be seen on the screen:

SPECIFICATIONS to : Equal ripple - lowpass filter	
(D)	
(A) Passband edge frequency	: 1.000 000 kHz
(E) Passband bandedge loss	: 1.000 000 dB
(F) Passband bandedge return loss	: 6.87 dB
(R) Passband reflection factor	: 45.35 %
(H) Transm. zeros at zero	: 0
(H) Transm. zeros at infinity	: 1
	Fixed transm. zero pairs: 0
	Var. transm. zero pairs: 0
Filter degree : 1	
3dB edge frequency : 1.965 227 kHz	
Filter quality : not defined	

SPECIFICATION: ? E F R H quality
 Stopbandopt. fixtrans.zeros cOmment New fiLe Printer Quit ?

Now enter the stopband specifications:

- [S] Enter the OPTIMIZATION menu
- [T] Enter the STOPBAND SPECIFICATION menu
- [↵][↵]1.05k[↵] 45[↵] Enter the stopband loss of 45 dB from 1.05k
- [↵][↵]1.6k[↵]75[↵] Enter the stopband loss of 75 dB from 1.6k

EXAMPLE 1: LOWPASS FILTER

| The following screen will appear:

Stopband specifications				
No.	Frequency range			Loss
1	1.050 000 kHz	to	1.600 000 kHz	45.00 dB
2	1.600 000 kHz	to	infinity	75.00 dB

STOPBAND SPECIFICATION: Add Edit Delete New Quit ?

Now continue with the optimization of the pole positions:

- [Q] Return to the OPTIMIZATION menu

In the OPTIMIZATION menu, FILTERMASTER PROFESSIONAL proposes as the initial values for the optimization four variable pairs of poles in the finite stopband and one pole at infinity. This will result in a filter of the 9th degree. We accept this proposal and continue.

- [O] Select the optimization function

After six iterations (see the entry in the Iteration field), the variable pairs of poles are positioned in the finite stopband, in such a manner, that the resultant loss curve fills the tolerance scheme throughout the whole stopband.

| The screen after the optimization:

stopband optimization		
(A) Variable transmission zero pairs	(proposal : 4) :	4
(B) Transmission zeros at infinity	:	1
Filter degree	:	9
Minimum of loss reserve	:	1.10 dB
Difference of the minima	:	0.04 dB
Iteration	:	6
(G) End accuracy of the optimization	:	0.10 dB

OPTIMIZATION: ? B G sTopband-specification
 Variable-transmissionzeros Optimization Iteration Quit ?

The screen shows us that there is a loss reserve of 1.1 dB. We will use this reserve to obtain a slightly higher return loss.

- [Q] Return to the SPECIFICATION menu
- [F]7.7[-] Increase the return loss by a little less than the value of the loss reserve
- [S] Enter the OPTIMIZATION menu
- [O] Optimize of the position of the variable pairs of poles.

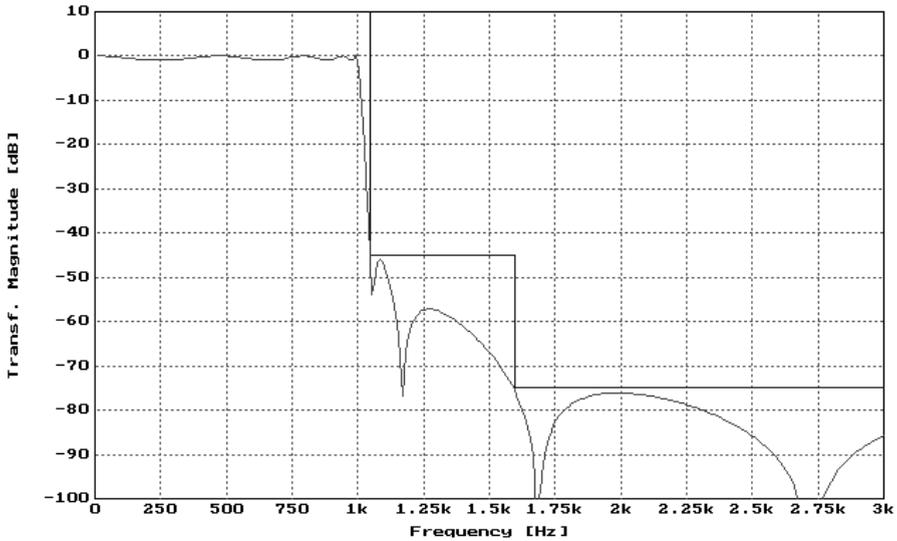
Note: Since the results of the last optimization are used as initial values, it is not necessary to repeat all of the iterations.

We can see on the screen that there is only a minimal loss reserve of 0.07 dB, which is sufficient for our purposes. Let's return to the main menu.

- [Q][Q] Return to the main menu

EXAMPLE 1: LOWPASS FILTER

This completes the specification of the filter. Using these values we would have developed a filter with the following loss curve:



Example 2: Bandpass Filter

For this filter we desire the loss curve in the passband to be maximally flat. The stopband will have a fixed blocking point at a certain frequency. Otherwise the loss in the stopband will rise monotonically.

Specifications:

Passband: 100 kHz to 150 kHz

Passband loss: 1 dB

Stopband:

up to 70 kHz: 35 dB

from 190 kHz: 45 dB

fixed blocking frequency at 210 kHz

First enter the specifications:

Starting point: Main menu

- [↵] Enter the FILTERTYPE menu
- [↵] Enter the TYPE submenu
- [B] Select Bandpass
- [A] Enter the APPROXIMATION menu
- [M] Select Maximally-flat
- [Q][Y][S][N] Enter the SPECIFICATION menu, delete all entries (if any)
- [A]100k[↓] Lower passband edge frequency = 100 kHz
- 150k[↓] Upper passband edge frequency = 150 kHz
- 1[↵] Passband bandedge loss: 1 dB
- [S] Enter the OPTIMIZATION menu
- [L] Enter the STOPBAND SPECIFICATION menu for entering the lower tolerance scheme
- [↵][↵]70k[↵]35[↵] up to 70 kHz: minimum loss 35 dB
- [Q][U] Enter the STOPBAND SPECIFICATION menu for entering the upper tolerance scheme
- [↵][↵]190k[↵]45[↵] from 190 kHz: minimum loss 45 dB
- [Q][Q] Return to the SPECIFICATION menu

EXAMPLE 2: BANDPASS FILTER

| The following screen will be displayed:

SPECIFICATIONS to : Maximally flat - bandpass filter	
(O) Kind of bandpass	: conventional
(A) Lower passband edge frequency	: 100.000 000 kHz
(B) Upper passband edge frequency	: 150.000 000 kHz
(E) Passband bandedge loss	: 1.000 000 dB
(F) Passband bandedge return loss	: 6.87 dB
(R) Passband reflection factor	: 45.35 %
(G) Transm. zeros at zero : 1	Fixed transm. zero pairs: 0
(H) Transm. zeros at infinity : 1	Var. transm. zero pairs : 4
Filter degree	: 10
Lower 3dB edge frequency	: 97.243 638 kHz
Upper 3dB edge frequency	: 153.766 389 kHz
Filter quality	: not defined

SPECIFICATION: **B E F R G H** quality Parametric
 Stopbandopt. fixtrans.zeros cOment New file Printer Quit ?

We will now set the desired losses in the stopband:

Enter the fixed blocking frequency at 210 kHz.

- [X] Jump into the TRANSMISSIONZERO INPUT menu
- [↵]210k[↵] Fixed transmission zero at 210 kHz

Now enter the setting that poles are only desired at extreme frequencies.

- [Q][S] Jump into the OPTIMIZATION menu
- [↵]0[↓]0[↵] The number of the variable pairs of poles in the lower and upper stopband is set to 0 for each of these ranges

It is quite clear that we can no longer manage with only one pole at zero and infinity. Let's set their number to 4.

- [C]4[↓]4[↵] 4 poles each at frequency, zero and infinity
- [O] Selects the OPTIMIZATION menu in order to calculate the minimal loss reserve

The negative value of the minimum of loss reserve shows us that we have to slightly increase the number of poles and thus the degree of the filter.

- [C]5[↵] 5 poles at zero

You can see that the number of poles at infinity was reduced to three. This was due to the fact that conventional bandpass filters can only have an even degree, therefore, FILTERMASTER PROFESSIONAL corrects the number of poles/pairs of poles accordingly. As we are not able to fulfill the requirements with only 3 poles at infinity (check by selecting Optimization), we also set the number of poles at infinity to 5.

- [D]5[↵] 5 poles at infinity

Let's see whether our requirements have been met.

- [O] Evaluation of the minimal loss reserve

It fits because we receive a loss reserve of 3.44 dB. The filter has a degree of 12 (equal to the total number of the poles: one pair of poles at 210 kHz, five poles at zero and five poles at infinity).

We have thus specified our filter.

- [Q] Return to the SPECIFICATION menu

Let's calculate the filter quality:

- [Y][↵] Calculate the filter quality

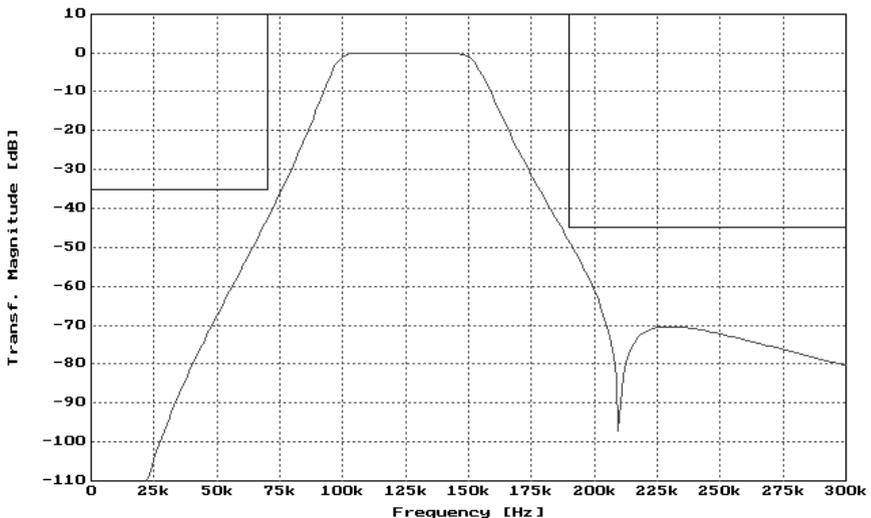
EXAMPLE 2: BANDPASS FILTER

| The following screen appears:

SPECIFICATIONS to : Maximally flat - bandpass filter			
(C)	Kind of bandpass	:	conventional
(A)	Lower passband edge frequency	:	100.000 000 kHz
(B)	Upper passband edge frequency	:	150.000 000 kHz
(E)	Passband bandedge loss	:	1.000 000 dB
(F)	Passband bandedge return loss	:	6.87 dB
(R)	Passband reflection factor	:	45.35 %
(G)	Transm. zeros at zero	:	5
(H)	Transm. zeros at infinity	:	5
		Fixed transm. zero pairs:	1
		Var. transm. zero pairs:	0
	Filter degree	:	12
	Lower 3dB edge frequency	:	97.327 399 kHz
	Upper 3dB edge frequency	:	153.024 850 kHz
	Filter quality	:	10.35

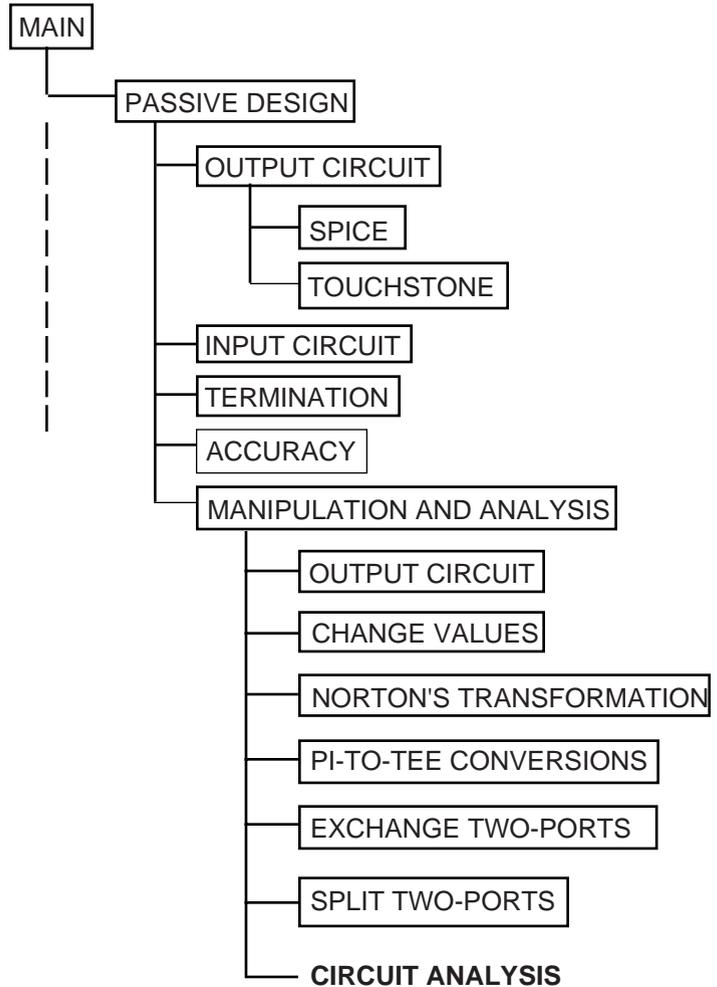
SPECIFICATION: B E F R G H quality Parametric
 Stopbandopt. fixtrans.zeros comment New file Printer Quit ?

| The filter we have designed will have the characteristic shown below:



Circuit Design

The polynomial roots are automatically calculated when the SPECIFICATION menu is exited. By using these roots, FILTER-MASTER PROFESSIONAL can calculate a complete proposal for the LC (reactance) filter.



PASSIVE DESIGN menu

This menu is used to access various synthesis and analysis features. The following options are available:

(O) Output circuits

In this menu you can send the actual circuit topology (including component values) to the, screen, printer, or file. File formats include ASCII, SPICE, (for programs such as IS`SPICE`) or Touchstone.

(I) Input circuits

Here, you can construct your own filter piece by piece.

(C) Computer circuit

Returns you to `FILTERMASTER`'s initial circuit suggestion.

(D) Dual circuit

Switches to the corresponding dual circuit. The duality constant used for this transformation is the reference resistance entered via option (T) Terminating resistance. For more details on dual circuits, see the "Dual Circuits" section.

(T) Terminating resistance

Switches to the `TERMINATION` menu, where you can specify the reference resistance and the type of filter termination.

(A) Accuracy

Switches to the `ACCURACY` menu, where you can adjust the accuracy of calculations by specifying the number of significant decimal places.

(M) Manipulation and analysis

Switches to the `MANIPULATION AND ANALYSIS` menu, where you can modify the filter and analyze the circuit characteristics graphically.

Note: If the message:

*The filter cannot be realized without mutual inductances!
At least one attenuation pole at zero and infinity is necessary. Press any key to continue!*

appears when you enter the PASSIVE DESIGN menu from the main menu, then,

In standard approximations:

- Select a case that can be realized passively (case b or c)
or
- Carry out the active realization using the FILTERMASTER ACTIVE program.

In equal ripple or maximally flat approximations:

- Select the pertinent poles.

OUTPUT CIRCUIT Menu

This menu is used to output a circuit with component values. The circuit will be shown on the screen as soon as you switch to this menu. Other destination devices can be selected via the menu line.

File

Outputs the circuit to an ASCII file. Default extension: .SCH

Printer

Outputs the circuit to the printer.

Spice

Outputs the circuit, shown on the screen, to a file in a standard SPICE format that is compatible with all IS_{SPICE} versions. Default extension: .CIR

Touchstone

Outputs circuit data to a file in a form which can be read by Touchstone. Default extension: .CKT

Note: The following messages may appear:

*** *The circuit calculation is inaccurate!* ***

This means inaccuracies were found when the circuit was constructed. The component values are calculated from the input and output sides of the circuit. The quotient of the component values derived from both calculations is obtained. An average of the quotients is used to determine the output resistance. For calculations to be valid they must fall within a specified range around the calculated average. If the quotients vary from the average too much, this error message will appear.

Remedy: Increase the accuracy in the ACCURACY menu.

*** *Attention: Negative component values!* ***

Negative components are (physically) impossible. This is not a calculation error - filter table books would have equivalent entries, except that they don't show them very often!

Remedy: Manipulate the circuit using the MANIPULATION AND ANALYSIS menu. FILTERMASTER'S analysis section can handle negative component values.

SPICE Menu

Here you can preview and manipulate the IsSPICE netlist files generated by FILTERMASTER PROFESSIONAL.

Save

Saves the output in one of the two following formats:

Standalone

The output is written to a single circuit file including terminating resistors, input voltage source and analysis state-

ments (.AC and .PRINT). It can be used directly for in an IsSPICE simulation. Default extension: .CIR

Subcircuit

The output is added to a library file in an IsSPICE subcircuit format and can be identified by specifying a subcircuit name. Default extension of the library file: .LIB

Tol R-tol L-tol C-tol

The component tolerances [in %] can be set for individual components with the Tol function or for component groups with the R-tol, L-tol and C-tol functions. These tolerances are for use with the Monte Carlo analysis features of Intusoft's ICAPS package.

qualitY L-qual. C-qual.

The quality can be entered for individual components (qualitY) or for all inductors or capacitors simultaneously (L-qual. or C-qual.). The corresponding series or parallel resistors are added automatically.

fBegin fEnd Points Lin Dec

These menu options define the IsSPICE .AC frequency analysis.

fDefault

Set the .AC frequency sweep parameters to FILTERMASTER PROFESSIONAL defaults.

Digits

Select the number of digits used for numerical representation.

TOUCHSTONE Menu

In this menu you can preview and manipulate the Touchstone output generated by FILTERMASTER PROFESSIONAL. The data window allows you to scroll through the entire file.

TOUCHSTONE MENU

Save

Saves the output to a file in Touchstone format. Default extension: .CKT

Name

Allows you to enter an individual name for the subcircuit.

fBegin fEnd Step

These menu options define the AC-sweep.

fDefault

Set the AC-sweep parameters back to FILTERMASTER'S defaults.

Digits

Select the number of digits used for numerical representation.

INPUT CIRCUIT Menu

This menu allows you to design your own circuits by putting the filter together piece by piece in single steps.

Bandpass filter circuits allow a wide variety of representations; lowpass, highpass and bandstop filters offer fewer representations. At each stage, FILTERMASTER PROFESSIONAL checks which components can be used without losing the desired filter characteristics, and will only offer valid components.

Definition of the screen entries:

Act(ual) - act.

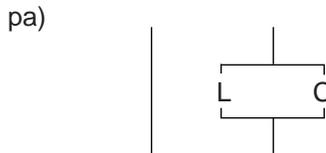
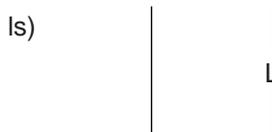
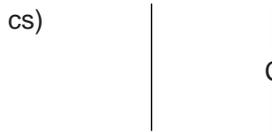
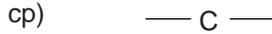
Indicates the number of attenuation poles the circuit has so far. The system assumes that the circuit terminates with a resistor.

Req(quired) - req.

Indicates how many attenuation poles the filter specification requires.

The saved circuit data is in a binary format that cannot be accessed via an external word processing package.

You can combine the following quadripoles:



If you select pa or se, the system will ask which pole frequency to use. Once an attenuation pole has been used, it cannot be selected a second time.

TERMINATION Menu

In this menu you can determine whether the filter is doubly terminated or is provided with an extreme termination either on the input or output side (short-circuit or open, depending on the selected type of circuit (dual types of circuits!)). You can also determine the value of the reference resistance.

Only the real resistance of the source, or the subsequently added network, is taken into account.

Note: If the load impedances are complex, which happens from time to time, it is possible to partly take this into account. If the load impedances can be simulated by a model of an ohmic resistance and a parallel capacitor, it is possible to synthesize the desired filter with a filter structure that starts with a parallel capacitor. The capacity determined by the program is then distributed by value to the capacity of the model's load impedance and a residual capacity of the filter. Naturally, other models that are based on analog principles can also be realized.

ACCURACY Menu

You can use this menu to specify the accuracy of calculations by entering the number of significant decimal places.

General remarks on the accuracy of filter design:

By its nature, circuit design is highly sensitive to round-off errors. This means that almost all filter design programs fail with low pass filters from the 9th degree on - even if they use the math coprocessor's high-resolution data format. FILTERMASTER PROFESSIONAL uses its own computing algorithm, written in assembler, with a very high internal accuracy (up to 120 decimal places). This enables filters up to the 50th degree to be calculated. FILTERMASTER PROFESSIONAL'S accuracy is one of its main strengths.

Screen entries:

Accuracy

Indicates the number of significant decimal places being used. If the number of places you enter is greater than the previously specified value, the roots will be reiterated before the circuit is designed.

Accuracy of the refinement

This shows what accuracy was previously used.

FilterMaster proposal

FILTERMASTER PROFESSIONAL makes its own proposal in light of the approximation and degree selected. The system will then use this accuracy unless you specify a greater accuracy.

Note: Internal calculations for FILTERMASTER PROFESSIONAL use 16-bit words. Therefore, the program rounds accuracy up to the next highest number of decimal places.

Refinement of the roots is only necessary for doubly-terminated filters. The Feldtkeller equation (see “Zero Output” section) must be fulfilled.

MANIPULATION And ANALYSIS Menu

You can use this menu to modify the calculated circuits.

Beware: Any changes are lost upon exiting this program section. Make sure you save your circuit before exiting!

The following selections are available:

(L) Load circuit

Loads circuits previously saved via the (S) Save circuit function.

(S) Save circuit

Saves the current circuit. Default extension: .SH

(O) Output circuit

Switches to the OUTPUT CIRCUIT menu to output circuits (with component values) to the:

MANIPULATION AND ANALYSIS MENU

- Screen
- Printer
- File in
 - ASCII format (as displayed on screen)
 - IsSPICE (SPICE analysis software)
 - Touchstone format (analysis software)

(R) Reverse circuit

Circuit input and output are reversed (mirror-image).

(D) Dual circuit

Used for selecting the dual circuit. Before FILTERMASTER PROFESSIONAL proposes the respective dual circuit, the entry of the duality constant is requested. The reference resistance determined in the PASSIVE DESIGN menu is used as the initial proposal.

(V) Change component values

Allows the component values to be changed.

(N) Norton's transformation

Switches to the NORTON'S TRANSFORMATION menu, where you can optimize component values for bandpass filters without changing the filter's transmission characteristics.

(T) PI-to-TEE conversion

Switches to the PI-TO-TEE CONVERSION menu where PI arrangements can be transformed into TEE structures (or vice-versa), if such arrangements arise due to Norton's transformation.

(E) Exchange two-ports

Switches to the EXCHANGE TWO-PORT menu, where you can switch any two two-ports.

(P) Split two-ports

Switches to the SPLIT TWO-PORTS menu, where you can split any two-port into two two-ports (L -> parallel circuit, C -> series circuit), giving another degree of freedom for Norton's transformation.

(C) Combine two-ports

The system examines the circuit and combines similar quadripoles (switched in series or parallel).

(A) Circuit analysis

Switches to the CIRCUIT ANALYSIS menu, where you can analyze the characteristics of the filter.

DUAL CIRCUIT Menu

In this menu, you will be asked for the value of the duality constant to be used in the transformation to the dual version of the current circuit. The transformation is executed when you exit the menu using Quit.

CHANGE VALUES Menu

From this menu you can change component values.

To change a component's value;

- Use the arrow keys to move the cursor to the component you want to change ([↓] or [↑])
- Go to the appropriate field.
- Enter the required value and execute the change by pressing [↵].

Note: FILTERMASTER PROFESSIONAL will take the new value as fixed, and will modify the filter's characteristics accordingly.

NORTON'S TRANSFORMATION Menu

You can use this menu to optimize component values without affecting the filter's transmission characteristics. Since Norton's transformation invariably creates circuit components with bandpass characteristics, it is only available with bandpass filters.

Norton's transformation:

- Multiplies (L's and R), or divides (C), for all subsequent component values, by the transformation factor (t), and
- Gives a new component arrangement within the chosen combination of components.

The following options are available:

(N) Next component combination

Norton's transformation can only be used with certain circuit combinations. Selecting this command switches you to the next combination which can be subjected to Norton's transformation.

(V) Previous component combination

Switches to the previous component combination on which Norton's transformation can be carried out.

(A) Min. factor, (B) Max. factor

Positive component values can only be achieved if the transformation is kept within certain limits. These limits are calculated for the selected combination and entered into this field. If you select (A) or (B), that value will be used as the transformation factor (entered field (D) Factor), and the transformation will be carried out using that factor.

(C) Nominal factor

FILTERMASTER PROFESSIONAL uses this field to enter the transformation factor required to give the value entered in (G) for the component in (E). If (G) is blank, then field (C) is missing.

Nominal factor (C) = Nominal value (G) / Current component value (E)

This function replaces the pocket calculator commonly used for this purpose.

If you select (C), the corresponding value will be used as the transformation factor (entered in (D) Factor), and the transformation will be carried out accordingly. Values outside the limits are also allowed. (see notes on (D)).

(D) Factor

The transformation will be carried out using the factor entered here.

Entries can be made in two ways:

- By using the value of (A), (B), or (C). This is accomplished by selecting one of these options. FILTERMASTER will assume that value and carry out the transformation immediately.
- By entering a value directly into the input field. The transformation will run as soon as you confirm the value.

FILTERMASTER PROFESSIONAL also allows transformations with factors outside the limits in each case. This usually generates negative component values, but if negative values already exist, it may be possible to convert them to positive ones.

(E) Component No.

This is used to enter the number of the circuit component whose value is to be modified to the nominal value in (G). Each component number is visible in the circuit. If a number is allocated to a resonant circuit, then the number always refers to the inductance. The current value of the component selected at any time is shown under "Current value". Only components, which are in the component combination selected for transformation, can be selected.

NORTON'S TRANSFORMATION MENU

(F) Nominal component

This is used to enter a component whose value will be given to the component shown under (E) once the transformation is complete. If a nominal component is selected, its value is used as the nominal value (G). Only those components, which are placed before the component combination selected for transformation, can be used as nominal components.

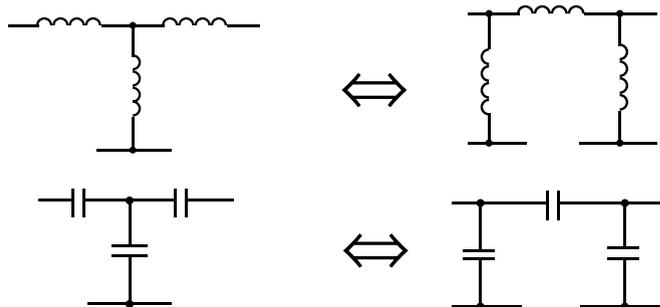
(G) Nominal value

Specifies the value that the component shown under (E) is to have once the transformation is complete. This nominal value can be input in two ways:

- By selecting a nominal component via (F), whose value is then used as the nominal value (useful in circuits with equal L values)
- Entering the individual value directly.

PI-TO-TEE CONVERSION Menu

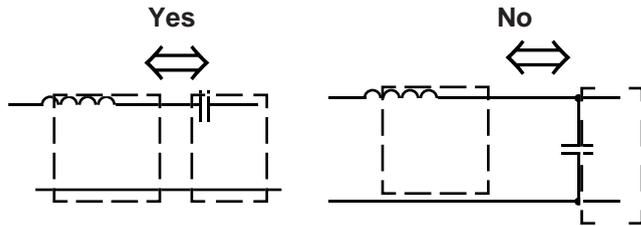
You can use this menu to transform component combinations in a circuit from a PI to a TEE configuration (or vice versa) provided that Norton's transformation produced these for L's or C's.



EXCHANGE TWO-PORTS Menu

Use this menu to exchange adjacent two-ports (only allowed if this does not change the filter characteristics).

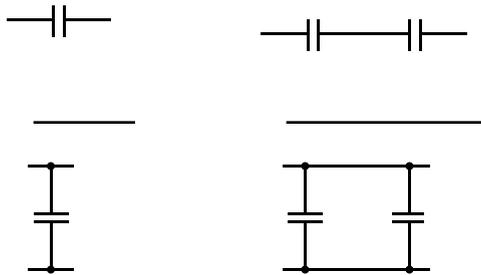
Examples:



SPLIT TWO-PORTS Menu

In this menu, you can split two-ports into two two-ports (L - parallel circuit, C - series circuit). This gives an extra degree of freedom for Norton's transformation. The value of component 1 can be entered; FILTERMASTER PROFESSIONAL will then automatically calculate the value of component 2. Together, these two two-ports will then have the same value as the original.

Examples:



Example: Bandpass Filter

In this example, we will design a filter for a satellite receiver's second intermediate frequency.

The example will demonstrate how to:

- Make changes in a circuit proposed by FILTERMASTER (for example, to achieve equal inductor values),
- Make use of the Norton's transformation option,
- Perform a PI-to-TEE transformation, and
- Design a combinational filter structure (for example, for developing a bandpass by placing a lowpass and a highpass in sequence).

Specifications:

Center frequency: 70 MHz

Bandwidth: 27 MHz

Upper stopband edge frequency: 97 MHz

Return loss: 20 dB

Stopband loss: 25 dB

Chosen approximation: Chebyshev

Additional requirement: For manufacturing reasons all inductors should have the same value.

Let's enter the filter specifications first.

Enter the following from the main menu:

- [↵] Activate the FILTERTYPE menu
- [↵][B] Select Bandpass
- [A][C] Select the Chebyshev approximation
- [Q][Y][S][N] Activate the SPECIFICATION menu, delete all existing entries (if any)

- [A]56.5M[↓] Lower passband edge frequency: Value 56.5 MHz
- 83.5M[↓][↓] Upper passband edge frequency: 83.5 MHz
- 97M[↓][↓] Upper stopband edge frequency: 97 MHz
- 20[↓][↓] Passband bandedge return loss: 20 dB
- 25[←] Stopband loss: 25 dB

This completes the specification with the following results on the screen:

SPECIFICATIONS to : Chebychev - bandpass filter			
(D)			
(A)	Lower passband edge frequency	:	56.500 000 MHz
(B)	Upper passband edge frequency	:	83.500 000 MHz
(C)	Lower stopband edge frequency	:	48.636 598 MHz
(D)	Upper stopband edge frequency	:	97.000 000 MHz
(E)	Passband bandedge loss	:	0.013 648 dB
(F)	Passband bandedge return loss	:	20.00 dB
(R)	Passband reflection factor	:	10.00 %
(G)	Stopband loss	:	25.59 dB
(H)	Filter degree	:	10 ◀
(I)	Case (b, c)	:	b
(J)	Variable value (A,B,C,D,E,F,G,H,R)	:	H
	Lower 3dB edge frequency	:	54.537 582 MHz
	Upper 3dB edge frequency	:	86.504 569 MHz
	Filter quality	:	13.28

SPECIFICATION: [?] B C D E F R G H I J New cOmment fiLe Printer
 frequencyrepres. bandwidthrepres. rel.bandwidthrepres. Quit ?

Now let's move on to the "Passive design" program section:

- [Q][D] Activate the PASSIVE DESIGN menu

EXAMPLE: BANDPASS FILTER

The following screen appears:

Passive design

(O) Output circuit
 (I) Input circuit
 (C) Computer circuit
 (D) Dual circuit
 (T) Terminating resistance
 (A) Accuracy
 (M) Manipulation and analysis

Move with [Cursor keys]

PASSIVE DESIGN: O I C D T A M
Quit ?

Note: If your screen shows another circuit (a product of a manual circuit entry), please enter [C][Y] to reset FILTERMASTER PROFESSIONAL.

Take a look at the component values for the proposed circuit.

- [↵] Activate the OUTPUT CIRCUIT menu

After a short calculation phase the following screen appears:

Circuit

1	R	50.000 000 Ω
2	L	286.835 317 nH
3	C	18.718 572 pF
4	L	33.187 727 nH
5	C	161.781 115 pF
6	L	531.451 120 nH
7	C	10.102 806 pF

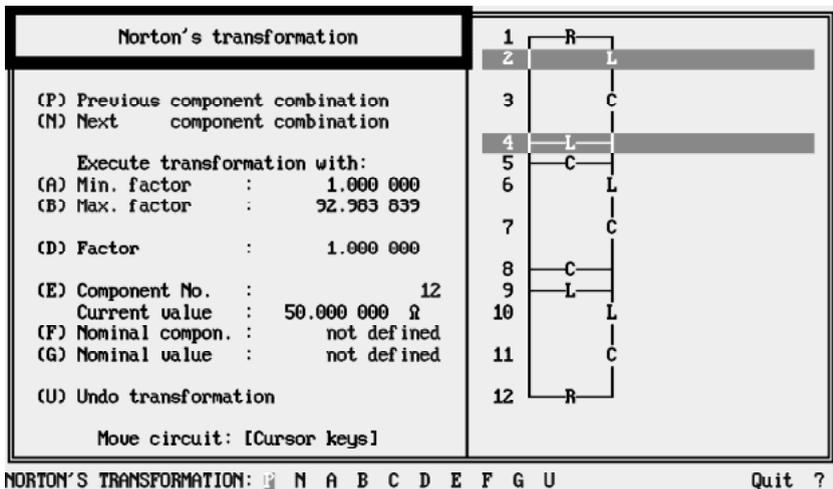
Move with [Cursor key]
OUTPUT CIRCUIT: Filc Printer Spice Touchstone
Quit ?

Use the arrow keys to move around screen. We can use the [↓] key to run through the circuit step by step. Notice that our 'equal inductances' specification is unfulfilled.

The next step is to modify the circuit with the appropriate transformations in order to optimize the component values to suit our requirements without affecting the filter's transmission characteristics. To do this, we will use Norton's transformation.

- [Q][M][N] Switch to NORTON'S TRANSFORMATION menu

The screen appears follows:



The position of the "bars" in the circuit shows which combination of components can be subjected to Norton's transformation. However, this is an L combination - which, of course, we can't use for a transformation (after all, we want equal inductances). So let's move to the next possible combination of components:

- [N] Next combination of components which can be subjected to Norton's transformation

EXAMPLE: BANDPASS FILTER

Let's stop here. The components currently numbered 3 and 5 will be used for the transformation (numbers are reallocated each time the circuit is transformed).

Note: Don't let the fact that the inductance we want to adjust is between the capacitors mislead you. FILTERMASTER PROFESSIONAL is clever enough to put L4 behind C5.

Now let's enter the current number of the component we want to change.

- [E]4[-] Indicates that component 4 should have the "nominal value" to be defined under "G" after the transformation

The current value of component 4 is approx. 33.19 nH. We will use the calculated value of the first inductance, L2, as the nominal value.

- [F]2[-] After the transformation, component 4 should have the same value as component 2

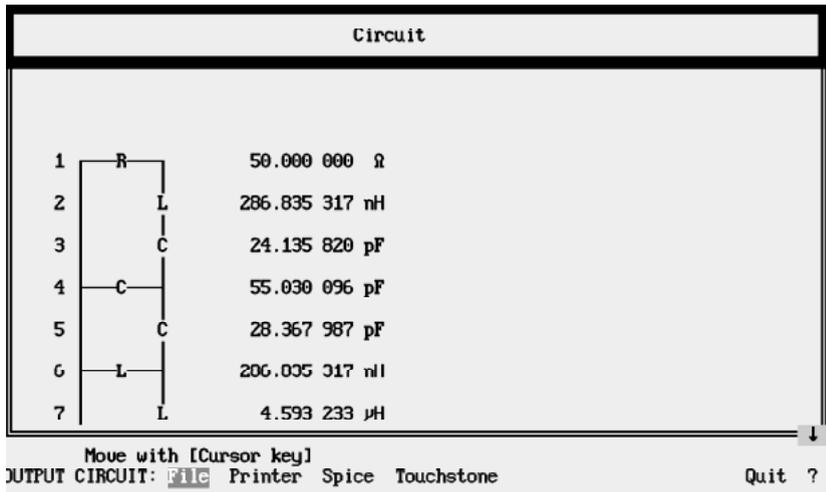
We enter the necessary transformation factor in field (C). Since it is between the limits specified in (A) and (B) (anything outside these limits will usually give negative component values), we can run the transformation using this nominal factor.

- [C] Enter nominal factor as the transformation factor in field (D) and run the transformation

FILTERMASTER PROFESSIONAL transforms the two capacitors into a new circuit with three capacitors. The inductance, which was formerly numbered 4, now appears as 6. Now, let's check whether this does in fact have the value we want.

- [Q][O] Switch to the CIRCUIT OUTPUT menu

The screen shows that it has clearly worked:



Now change the value of the next inductance, component 7.

- [Q][N] Back to NORTON'S TRANSFORMATION menu

Let's go on to the next combination of components eligible for Norton's transformation.

- [N] Next combination

We can't use this one, since a transformation would also change the value of component 6, which is already correct. But the next combination of C's is past the component to be changed (components 8 and 9). What do we do now? FILTER-MASTER PROFESSIONAL's built-in PI-to-TEE conversion function can help us out. Let's turn the T circuit consisting of components 3, 4, and 5 into the equivalent Pi circuit.

- [Q][T] Switch to PI-TO-TEE CONVERSION menu

EXAMPLE: BANDPASS FILTER

We have already selected our T-circuit, so we can run the transformation.

- [E] Transform the T to a Pi circuit

Let's see if we can use Norton's transformation now.

- [Q][N] Back to NORTON'S TRANSFORMATION menu.

We can't use the combination displayed, so on to the next.

- [N] Next combination

We can't use this either as it would change the value of 6.

- [N] Next combination

This combination will work because FILTERMASTER PROFESSIONAL is clever enough to avoid changing 6 (arranged before C5) and treat 7 as though it were past the components to be transformed (after C8).

We can now specify our transformation.

- [E]7[↵] Indicates that the component currently numbered 7 should have the nominal value entered in "G" after the transformation

The current value of component 7 is approx. 4.59 uH; but we want this inductance to have the calculated value of L2. So we enter this as a nominal value once again.

- [F]2[↵] After the transformation, component 7 should have the value as component 2

We enter the transformation factor required in (C) once again. This is also within the limits set in (A) and (B); so there is nothing to stop the transformation.

- [C] Enter the nominal factor as the transformation factor in field (D) and execute transformation

This time, FILTERMASTER PROFESSIONAL has transformed the two capacitors into a Pi circuit. The inductance, which was numbered 7, is now numbered 9. If you like, you can switch to the CIRCUIT OUTPUT menu again to see if this value is what we want.

Now we've seen how to use Norton's transformation; but, to tidy up any loose ends, let's transform the last two inductance values as follows:

- [Q][T][N][E] PI to-TEE conversion of capacitors 6, 7 and 8
- [Q][N][N][N][N] Select capacitors 8 and 10 for the next transformation, to optimize the value of L11
- [E]11[↵] Component 11 selected
- [F]2[↵] Value of component 2 selected as nominal
- [C] Execute transformation with nominal factor
- [Q][T][N][E] PI-to-TEE conversion, capacitors 9, 10 and 11
- [Q][N][N][N][N][N] Select capacitors 11 and 14 for the next transformation, to optimize value of L13

EXAMPLE: BANDPASS FILTER

- [E]13[↵] Component 13 selected
- [F]2[↵] Value of component 2 selected as nominal
- [C] Execute transformation with nominal factor

That's it. Let's look at the result.

- [Q][O] Switch to the circuit output

We can use the cursor keys to run through the circuit. We find that all the L's do in fact have the same value.

1	— R —	50.000 000 Ω
2		286.835 317 nH
3	— C —	12.351 421 pF
4		6.367 151 pF
5	— L —	286.835 317 nH
6		19.353 573 pF
7	— C —	58.093 331 pF
8		286.835 317 nH
9	— C —	18.516 177 pF
10		6.168 594 pF
11	— L —	286.835 317 nH
12	— C —	9.890 122 pF
13		6.367 151 pF
14	— C —	12.351 421 pF
15		286.835 317 nH
16	— R —	50.000 000 Ω

We will end this example by having a quick look at how you can use FILTERMASTER PROFESSIONAL to generate your own circuits piece by piece.

Instead of using the circuit FILTERMASTER PROFESSIONAL suggests, our aim here is to build up our own circuit as follows:

1st filter section: lowpass
2nd filter section: highpass

The first thing we need to do is to switch from the OUTPUT CIRCUIT menu, where we were at the end of the last section, back to the PASSIVE DESIGN menu.

- [Q][Q][Y] Back to the PASSIVE DESIGN menu, with the screen showing FILTERMASTER PROFESSIONAL'S first suggested circuit
- [I] Switch to the INPUT CIRCUIT menu
- [H] Delete the complete circuit

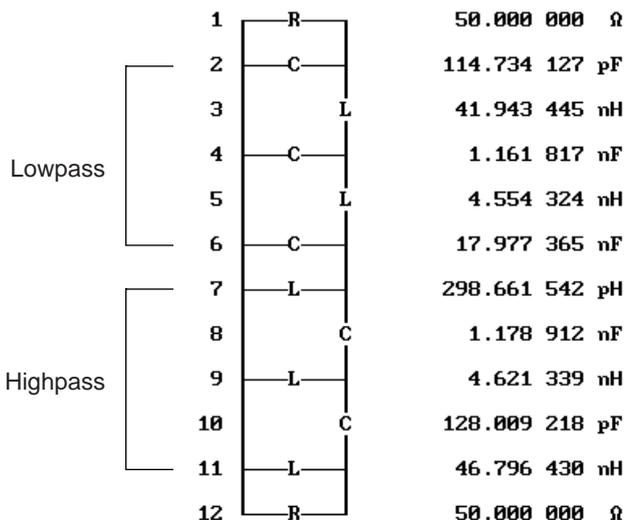
Now FILTERMASTER PROFESSIONAL will expect us to specify which components to put together on a modular basis. At each stage, FILTERMASTER PROFESSIONAL will check which components can be used next without affecting the filter's transmission characteristics. We will only be allowed to select from among those components (highlighted). Our inputs run:

- [A] Parallel capacitor
- [D] Series inductance
- [A] Parallel capacitor
- [D] Series inductance
- [A] Parallel capacitor
- [C] Parallel inductance
- [B] Series capacitor

EXAMPLE: BANDPASS FILTER

- [C] Parallel inductance
- [B] Series capacitor
- [C] Parallel inductance

Our circuit will now look like the following:



We could keep on rearranging this circuit to suit our own requirements, but that is outside the scope of this example. So let's end by going back to the main menu.

- [Q][Q] Back to the main menu

SUMMARY

In this example, you have learned how to:

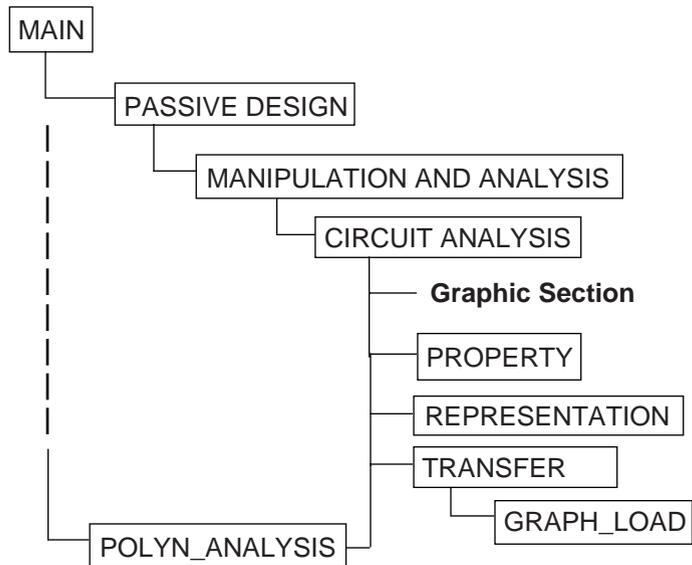
- Change a circuit suggested by FILTERMASTER PROFESSIONAL
- Use Norton's transformation facility
- Execute PI-to-TEE transformations, and
- Design circuits on a piece by piece basis.

Analysis

The filter's properties can be investigated graphically in one of two levels:

- Analysis based on the determined polynomial roots.
- Analysis of calculated circuits.

Before entering the actual graphics section, the waveforms which are to be entered in the diagrams and their mode of display, are determined. The respective program section has the following structure:



CIRCUIT ANALYSIS Menu

You can use this menu to analyze the characteristics of FILTER-MASTER PROFESSIONAL circuits.

To analyze a filter;

- Select a diagram 1 - 4
- Select the property
- Select the representation
- Select the limits, scale, and number of analysis points
- Select the quality factors (optional)

The menu options are as follows:

Graph

Switches to the graphics mode. The characteristic(s) will be displayed in accordance with the parameters entered in the dialog.

Hold

This menu item saves the diagram(s) last shown in the graphics section to a file called HOLD.GDF and then automatically integrates this file as future curves are loaded. This process can be repeated several times. HOLD.GDF will be overwritten, but the new data will be linked to the curves already loaded. The data will remain integrated until they are deleted in the GRAPH_LOAD menu.

Property

Here you can specify which property to use in the current diagram (highlighted). The required diagram is selected by using the arrow keys.

Note: The Property selected will only be entered in the diagram field once the Representation has also been specified.

Representation

Switches to the REPRESENTATION menu. Here you can specify the form by which the desired Property is to be shown in the diagram. The entry will be made in the appropriate field as soon as this is selected.

Note: When selecting the Magnitude [dB] of the transmission function, FILTERMASTER PROFESSIONAL allows you to include the tolerance scheme as specified in the STOPBAND SPECIFICATION menu. The respective setting is made in the withOut-spec/With_spec menu items, which is additionally offered in the menu line.

To delete a diagram field's input;

From the keyboard:

- Select the diagram field using [PgUp]/[PgDn] keys, then select Delete from the REPRESENTATION menu.

Using the mouse:

- Point the mouse at the diagram field and click on the corresponding input in the Representation section of the screen.

Transfer

Switches to the TRANSFER menu. This function is used to load and save graphics parameters and curves.

XDefault

Sets the X limits of the current diagram automatically using the following rules:

Linear scale:

X-from = 0

X-to: next highest default value (1 2 5 10 20 50 100) from 2 x fu

Logarithmic scale:

X-from = X-to/100

X-to: next highest default value from 5 x fu

fo = reference frequency

In lowpass and highpass filters, the passband edge frequency. In bandpass and bandstop filters, the center frequency (geometric mean of the passband edge frequencies).

YDefault

Sets the Y limits of the current diagram automatically. The system will try to find appropriate values in light of the desired diagram contents. The Y limits will be reset to the default values each time the desired display content is changed (property/representation).

Y-from, Y-to, X-from, X-to

Enables you to enter limits manually for each diagram.

pOints

Indicates the number of computation points within the specified frequency range.

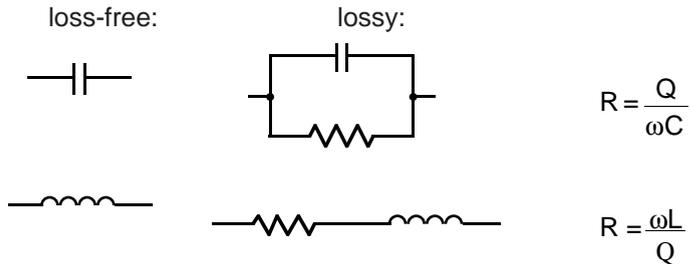
Lin, Log

Specifies the scale required for the diagram.

Ind, Cap

This feature enables you to consider losses in components:

If a quality factor is entered, FILTERMASTER PROFESSIONAL allocates parallel resistors to capacitances and series resistors to inductances.



The quality, in this case, is dependent on the frequency. The equivalent resistances are also frequency dependent.

POLYNOMIAL ANALYSIS Menu

| This menu description is the same as the PASSIVE ANALYSIS menu. Only the Ind and Cap menu items are missing.

PROPERTY menu

| *For circuit analysis:*

```
PROPERTY: Transmission_function  Input_impedance  Output_impedance
Input_reflection_coeff.  Output_reflection_coeff.  Quit ?
```

| *For polynomial analysis:*

```
PROPERTY: Transmission_function  Pulse_response  Step_response  Quit ?
```

You can use this menu to specify which property of the filter will be represented in the selected diagram. The menu line shows only those characteristics applicable in any given case.

The options available depend on the analysis section. For polynomial analysis, the impedance analyses and reflection factors are not offered as these are of no interest to active filter designers. On the other hand, time analysis is offered.

Note: No entry will be made in the current diagram field (highlighted) until the desired representation has been selected.

REPRESENTATION Menu

You can use this menu to specify which form of the already chosen property you want to display. To insert the waveform in the appropriate diagram field, exit the menu by using Quit.

Note: The menu line will only show the representations available for the selected property.

REPRESENTATION MENU

Delete

Used to delete diagram field inputs.

To delete a diagram;

- Select a diagram field using the [PgUp] or [PgDn] keys. Then select Delete. You don't have to leave the REPRESENTATION menu.

Magnitude [dB]

When selecting the display "Magnitude [dB]" of the transmission function, FILTERMASTER PROFESSIONAL allows you to include the tolerance scheme as specified in the STOPBAND SPECIFICATION menu. The respective setting is made in the withOut_spec/With_spec menu items, which is additionally offered in the menu line.

Polynomial Analysis Only

Time domain analysis is available when filters are analyzed on the basis of the roots of their polynomials (pulse response, step response). FILTERMASTER PROFESSIONAL has two special menu lines for this analysis:

```
REPRESENTATION: Delete Voltage[V] ImpulseStrength[V]      Quit ?
```

```
REPRESENTATION: Delete Voltage[V] StepStrength[V]         Quit ?
```

where:

Impulse strength = Area of pulse whose width tends towards 0

Step strength = Magnitude of step in volts

TRANSFER menu

Menu line:

```
TRANSFER: Load(Parameters)  Save(Parameters)  Reset(Parameters)  
Load(Data)   Save(Data)      Delete(Data)   Quit ?
```

This menu allows you to:

- Save diagrams
- Link diagram contents
- Save graphics settings for fast resetting

Load(Parameters)

Loads settings saved with the Save(Parameter) option.

Save(Parameters)

Saves all settings (but not the data).

Reset(Parameters)

Resets graphics parameters to their default values and deletes selected properties in diagram fields 1 - 4.

Load(Data)

Activates the LOAD_GRAPH menu, where you can load saved curves and merge them with the current diagram(s). For more details see next section.

Save(Data)

Saves the last diagram(s) displayed in graphics mode. Default extension: .GDF.

Please note: Curves can only be re-merged with diagrams in which they were included at the time they were saved. For example, a curve from diagram 2 cannot be displayed in diagram 3.

Delete(Data)

Deletes all diagram contents previously merged via the LOAD_GRAPH menu.

GRAPH_LOAD Menu

Use this menu to merge stored graphics data from memory with current diagram(s).

The menu options are as follows:

Load

Loads previously saved curves (together with their diagram's data) into the lower part of the screen where you can check their characteristics and units before merging them with the current display.

Data from the following functions can be loaded:

- Save(Data) in the TRANSFER menu.
- Save(Curve) in the MARKER menu.
- Hold in the POLYN_ANALYSIS or CIRCUIT ANALYSIS menus (file HOLD.GDF).

Note: It is necessary to invoke the Merge function in order to include graphics in the diagram.

Merge

Use this command to merge loaded graphics data with the current display. Merged graphics are numbered in sequence. Newly merged data is added on to any already existing data.

Diagram parameters (units, axis data) are displayed in the upper part of the screen, but are lost in the display. The display continues to use the units and labels of the original diagram(s). Comments (input through the SPECIFICATION menu) are retained to identify the curve. If units conflict when merging, a message will be displayed.

Delete_last

Deletes last curve block merged at any time.

Delete_all

Deletes all merged curves (equivalent to the Delete(data) command in TRANSFER menu).

Selection(merged_graphs)

Displays a merged curve block at the top of the screen by selecting the number FILTERMASTER PROFESSIONAL allocated to it when it was merged.

Selection(loaded_graphs)

If the files INIPOLY.GDF or INIPASS.GDF are loaded (explanation below), the curve block determined by this command can be displayed at the bottom of the screen.

Note: You don't have to "copy and merge" stored graphics data each time you want to display them together. If a number of curve blocks have been merged when you exit the POLYN_ANALYSIS or PASSIVE ANALYSIS menus, then these will be saved. They will be automatically retrieved the next time you go into analysis mode.

When you exit from menu the merged curve blocks will be stored in:

POLYN_ANALYSIS: INIPOLY.GDF

PASSIVE ANALYSIS: INIPASS.GDF

Example: Elliptic Bandpass

In this example, we will investigate the Elliptic bandpass specified in Chapter 3 more closely.

If you have saved the data for this example, it is fairly easy to make the necessary initial settings.

Enter from the main menu:

- [T] Activate the TRANSFER menu
- [↵] Select the Load menu item

EXAMPLE: ELLIPTIC BANDPASS

- [F1] List all filenames with the extension .FM

Now select EXAMPLE1.FM (↑) and confirm it with [↵].

Briefly check the data in the SPECIFICATION menu.

- [S] Activate the SPECIFICATION menu

You should see the following screen:

SPECIFICATIONS to : Elliptic (Cauer) - bandpass filter			
(O)			
(A)	Lower passband edge frequency	:	87.500 000 MHz
(B)	Upper passband edge frequency	:	108.000 000 MHz
(C)	Lower stopband edge frequency	:	70.000 000 MHz
(D)	Upper stopband edge frequency	:	135.000 000 MHz
(E)	Passband bandedge loss	:	0.044 818 dB ◀
(F)	Passband bandedge return loss	:	19.89 dB ◀
(R)	Passband reflection factor	:	10.13 % ◀
(G)	Stopband loss	:	50.00 dB
(H)	Filter degree	:	8
(I)	Case (a, b, c)	:	c
(J)	Variable value (A,B,C,D,E,F,G,H,R)	:	F
	Lower 3dB edge frequency	:	84.698 809 MHz
	Upper 3dB edge frequency	:	111.571 817 MHz
	Filter quality	:	14.50

SPECIFICATION: [←] B C D E F R G H I J New cOmment file Printer
 frequencyrepres. bandwidthrepres. rel.bandwidthrepres. Quit ?

Note: If the data on the screen does not coincide with this sample, please make the pertinent changes. Details on how to proceed are shown in Chapter 3.

Lets investigate some of the filter's properties more closely. Carry out an analysis on the basis of the calculated polynomial roots, through which the filter is uniquely described:

- [Q] Return to the main menu

- [A] Activate the POLYN_ANALYSIS menu

EXAMPLE: ELLIPTIC BANDPASS

Now on to diagram 2. Here the phase-frequency characteristics are entered.

- [PgDn] Change to diagram 2
- [R][P][P][←][Q] Set the transfer function phase [°]
- [X][X][X][←]200M[←] Reduce the upper limit X to 200 MHz
- [O]300[←] Increase the number of points to be calculated to 300

Enter the group delay in diagram 3:

- [PgDn] Change to diagram 3
- [R][D][←][Q] Set the transfer function Group delay
- [X][X][X][←]200M[←] Reduce the upper limit X to 200 MHz
- [O]300[←] Increase the number of points to be calculated to 300

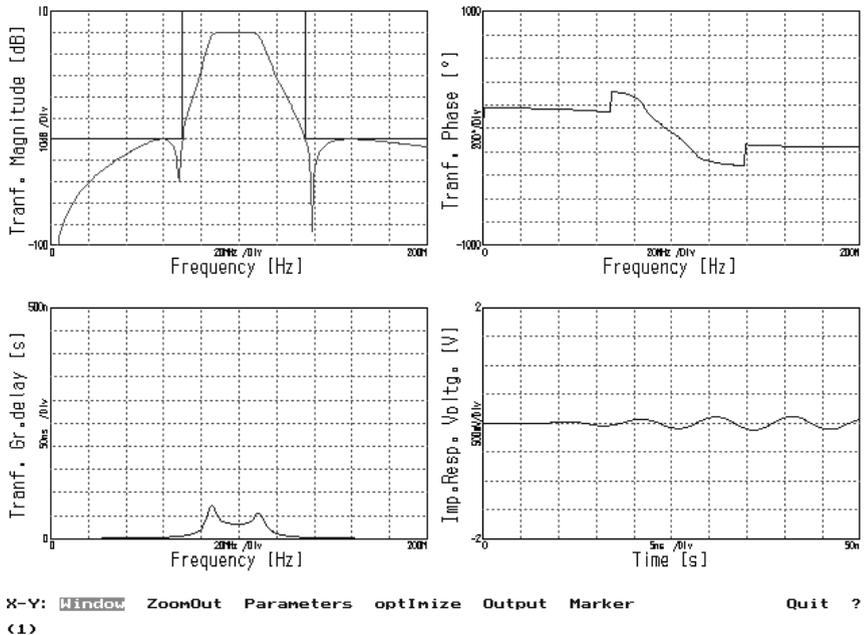
This completes the settings. However, one diagram is still free. Let's use this for displaying the pulse response.

- [PgDn] Change to diagram 4
- [P] Activate the PROPERTY menu
- [P][Q] Select pulse response
- [R][V][Q] Include in the diagram field
- [O]300[←] Increase the number of points to be calculated to 300

After having made all settings, activate the graphics section.

- [↵] Select the Graphic menu item

After waiting a few moments (depending on the type of computer you have), you will see the following diagrams on your screen:



Naturally, you could make quite a number of changes to these diagrams. However, let's only do this for the Y-limits of diagrams 2 and 3.

- [PgDn] Select diagram 2 as the current diagram (stated on the lower left hand side of the screen in brackets)
- [I] Optimize the Y-limits of diagram 2
- [PgDn] Select diagram 3 as the current diagram

EXAMPLE: ELLIPTIC BANDPASS

- [I] Optimize the Y-upper limits of diagram 3

The contents of diagram 3 are of particular interest. Let's zoom in on this diagram.

- [↵] Activate the X-Y WINDOW menu
- 3 Display diagram 3 enlarged

That is enough for the moment. Let's have a look at how to delete the diagrams:

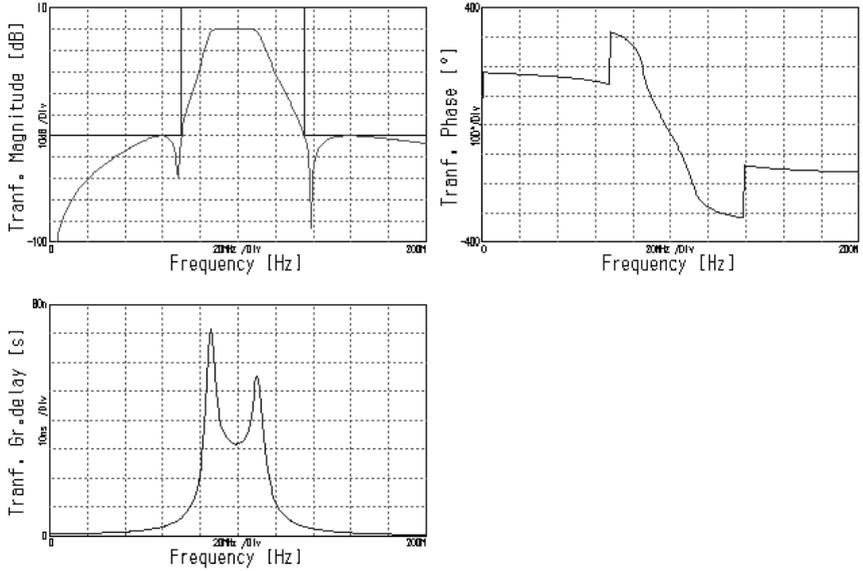
- [Q] Return to the POLYN_ANALYSIS menu

Let's assume that we are no longer interested in the contents of diagram 4 and want to delete it.

- [R] Activate the REPRESENTATION menu
- [↵][Q] Select the Delete menu item for deleting the respective contents of the diagram.

Mouse users: The same effect can be achieved by clicking directly on the display that you want deleted. For example: click on entry Voltage [V].

If we entered the graphics mode again, we would see the following picture:



X-Y: **Window** ZoomOut Parameters optIimize Output Marker Quit ?
(1)

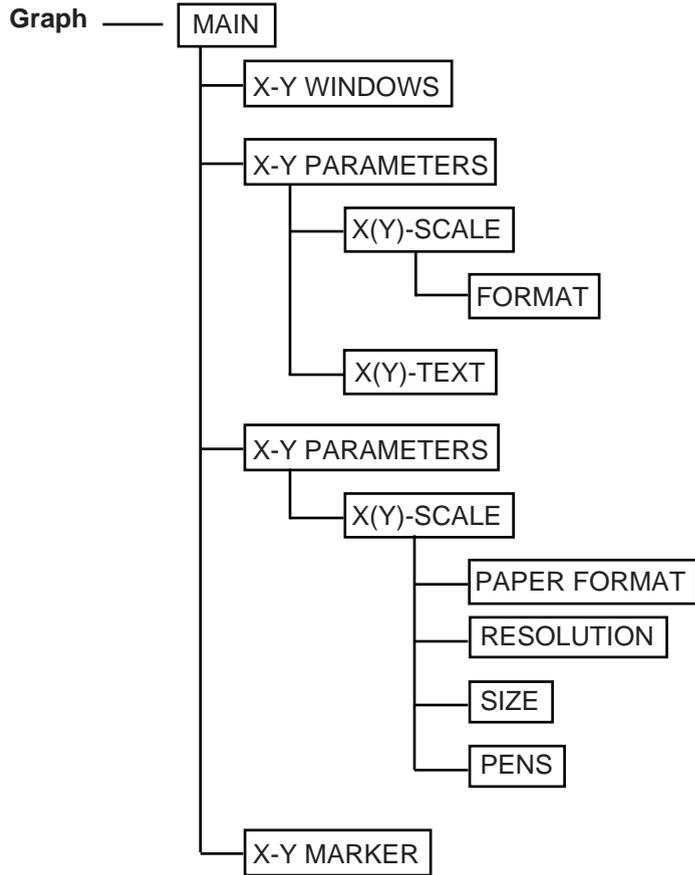
This completes our example. More details on the graphics section are provided in the next section.

Last step:

- [Q] Return to the main menu

Graphics

After determining which properties of the filter should be displayed in the PASSIVE DESIGN or POLYN_ANALYSIS menus, we can enter the graphics section of FILTERMASTER PROFESSIONAL through the Graph menu item. It is arranged as follows:



X-Y Menu

This menu can be used to:

- Change diagram parameters
- Output graphics to plotter, printer, or file
- Activate a waveform cursor
- Select which diagram(s) are to be displayed

FILTERMASTER PROFESSIONAL provides a special zoom function for enlarging portions of the diagram.

To zoom in on a portion of a graph;

- Place the mouse pointer on one corner of a desired section and click the left mouse button.
- Move the mouse. As the mouse is moved a box will be created. Pull the box outline around the portion of the graph that you want to zoom in on.
- Click the left mouse button again to zoom in on the section.

You can return to the previous display by selecting the ZoomOut menu item.

The X-Y menu offers the following options:

Windows

After selecting this menu item (if there is more than one diagram displayed), the X-Y WINDOW submenu will be activated. This menu allows you to display either a “full view” of one of the displayed diagrams or, if this has already happened, to return to the display of all the diagrams.

Note: If you are currently in the “enlarged” mode, you can switch back to the “full” display of the previous or following diagram in the X-Y menu by using the [PgUp]/[PgDn] keys. You do not have to return to the simultaneous display of all the diagrams through the X-Y WINDOWS menu.

Mouse users: You can select the full display of a diagram by clicking on the diagram with the right mouse button. A further click on the right mouse button will bring you back to the display of all the diagrams.

ZoomOut

Only works after zooming in with the mouse. This menu item returns you to the display mode that was set before the “zoom” was executed.

Parameters

Takes you into the X-Y PARAMETERS menu, where you can alter various diagram parameters. The current diagram is the one whose number is indicated in brackets on the lower left-hand side of the screen. The current diagram can be changed through the cursor keys [PgUp], [PgDn], [Home] and [End].

optimize

Automatic scaling of diagram axis/axes is set to “Auto” in X-Y PARAMETERS screen.

Output

Takes you into the OUTPUT GRAPHIC menu, where you can output the diagrams to a:

- Plotter, (in HPGL format)
- Printer, or
- File (HPGL format)

Marker

Switches to the X-Y MARKER menu. Here you can:

- Analyze curves in more detail using various cursor/marker functions
- Optimize diagram limits with respect to a particular curve
- Save individual curves from a diagram

X-Y PARAMETERS Menu

This menu allows you to:

- Optimize diagram limits
- Switch to other menus where you can modify other diagram parameters
- Change the suggested diagram

Options include:

Window

Indicates which diagram you wish to use.

optimize

Optimizes the diagram scaling.

X-Scale

Switches to X-SCALE menu, where you can modify the following x-axis parameters:

- Axis limits
- Scaling Grid (linear or logarithmic)
- Number of divisions
- Method used for number display

Y-Scale

Same as the X-Scale function.

Text

Switches to X-Y TEXT menu where you can change the suggested diagram labels.

Note: If desired, you can vary the size of the labels used for printing and plotting. For more details see the section on the default file (FM.DEF).

Data_points

Indicates whether the data points in the diagram should be connected by lines or not.

X(Y)-SCALE Menu

You can use this menu to set the following parameters:

- Axis limits
- Scaling grid (linear/logarithmic)
- Number of subdivisions
- Method used for number display

Options Include:

Auto

Determines whether the y-axis can be automatically rescaled from the X-Y menu.

From

Accesses the lower y-axis limit input field.

To

Accesses the upper y-axis limit input field.

Lin

Selects linear y-axis scaling for this diagram.

Log

Selects logarithmic y-axis scaling for this diagram. If the spread between the upper and lower limits is less than one decade, only linear scale is allowed.

Divisions

Indicates the y-axis grid divisions. The variable "Units/division" changes each time this field is changed.

format(Number)

Takes you to the FORMAT menu, where you can specify how numbers are to be shown in the fields and on the y-axis.

Decimals

If you select this option, the system will ask for the number of decimal places you want. This applies to all display formats.

If, for example, you specify 3 decimal places, the various display modes will appear as follows:

Fixpoint

Use this option to indicate that all figures must appear in fixed format mode. For example: 12345.000

Scientific

Display in powers of 10. For example: 1.234E+04

Engineer

Display in powers of 10 with the exponent divisible by 3. For example: 12.345E+03

Technical

Technical display mode. For example: 12.345 k

Y(X)-Scale

Takes you to the Y(X)-SCALE menu, where you can specify the y(x)-axis parameters for the current diagram including:

- Axis limits
- Scaling Grid (linear or logarithmic)
- Number of divisions
- Method used for number display

OUTPUT GRAPHIC Menu

You can use this menu to output the screen contents to a:

- Plotter, (HPGL format)
- Printer, or
- File (HPGL format)

The following options are available:

printer

Prints the diagram to printer. The printer settings are made via the printerOptions menu item.

printerOptions

Move to the PRINTER OPTIONS menu where various printer settings can be changed.

Plotter

Selecting this option causes FILTERMASTER PROFESSIONAL to start to plot the diagram on the plotter (HPGL format).

File

Saves the diagram in a file using the HPGL format (Hewlett-Packard Graphics Language). This file can then be plotted at a later time from the DOS prompt, moved to another system for plotting, or inserted into a desk top publishing program. Default extension: .PLT

PRINTER OPTIONS Menu

The printer settings for graphics output are made in this menu. Options include:

to_Printer/to_File

Determines whether the output is made directly to the printer or to a file.

When selecting File, the contents of the file can be sent to the printer at a later time through the DOS copy command.

For example: "Copy *filename* LPT1"

Model

Selects the type of printer.

Format

Moves to a submenu where the paper format can be selected. The menu items “Length” and “Width” allow you to set any desired size.

Resolution

In this submenu you can determine your printer’s resolution. Some printers only allow one resolution.

Invert

Switches from normal to inverse video display.

Rotate

Rotates the output by 90°.

Copies

Determines the number of copies to be printed.

Size

Switches to a submenu used for setting scale factors and displacements.

Pens

Move to the PENS submenu. Here, the line attributes (width, scale of grey) for the individual diagram components can be set.

Pen Number	Object
1 ... 8	curve 1 ... 8
9	logo
10	diagram border
11	gridpoint (at logarithmic scaling)
12	gridline (at linear scaling)
13	text y-axis
14	text x-axis
15	label y-axis (for printer/file output)
16	axis number

Options in the PENS menu include:

- Selection of the desired “pen” with the arrow keys
- Width: Sets the line width in pixels
- Grayscale: Sets the grey scale (1...light grey, 9....black)
- Copy: The values of the current pen are copied to all other pens.

X-Y MARKER Menu

This menu allows you to analyze the curve(s) displayed in more detail by using a marker. The marker is also known as a waveform cursor. The following paragraphs answer most common cursor questions.

Where and how do the cursors appear when I switch to this menu?

When you select the Marker option from the X-Y menu, a cross-hair cursor will appear in the diagram marked “current”. The current diagram is shown on the screen on the bottom left-hand side and can be changed by using the [PgUp], [PgDn], [Home] and [End] keys. The cursor can be moved to the left or right using the cursor keys. The cursor will stop at the calculation points. The X and Y coordinates of the cursor’s position will be displayed at the bottom of the screen.

Mouse users: The cursor can also be positioned in the X-Y MARKER menu with the mouse (left mouse button). Only the X-position of the mouse is taken into account. The Y-position will be determined by the selected curve.

What happens if I select another option?

Coarse

Causes the step width between the calculated points on the x-axis to be increased by a factor of 2.

Fine

Causes the step width to be reduced by a factor of 2.

optimize(Curve)

Optimizes the limits of a diagram for a given curve on that diagram (the curve on which the cursor is positioned). This diagram must have the “autoscale” mode set for at least one axis in the parameters menu.

If there is more than one diagram, how do I switch from one to another?

To move the cursor between diagrams, use the [PgUp], [PgDn], [Home] and [End] keys.

If there is more than one curve in a diagram: how do I switch to another curve?

You can use the arrow keys ([↑] and [↓]) to move the cursor from one curve to another. If you are using a color monitor, the appropriate line and coordinate details are shown in different colors depending on which curve the cursor is positioned.

Macros

FILTERMASTER PROFESSIONAL allows you to record certain sequences of commands and data and to play them back whenever desired. Below are some details on recording keystroke macros.

Generation of keystroke macros

The first step consists of opening a macro. Enter the MACRO menu directly from the main menu.

Depending on how you intend to invoke the macro you can either:

- Save the macro under a filename (Record menu item) or
- Save the macro under a function keys (or a combination of function keys (function_Key menu item)).

In the latter case, FILTERMASTER PROFESSIONAL allows you to use a maximum of 48 different key combinations (depending on the keyboard):

[F1] to [F12]
[Shift+F1] to [Shift+F12]
[Ctrl]-[F1] to [Ctrl+F12]
[Alt+F1] to [Alt+F12]

After opening the macro, you will be in the program's "record" mode. From this point forward, each keystroke will be recorded until you exit the record mode by pressing [Ctrl+z] or by exiting the program.

The main advantage of assigning macros to function keys over storing them in files is that function key macros can be started from any menu. To start a macro stored under a filename you must first change to the MACRO menu.

While you're in the "record" mode you have the following options:

Set an interruption

If you press [Ctrl+p] during the recording of a keystroke macro then the macro will halt at this point when it is played back. This gives you the ability to adjust various entries and change the result of the macro.

Practical example: When developing a parametric bandpass filter the values of the components can be optimized by changing the parameters. In order to avoid having to re-enter all the data in each optimization step, we recommend using a keystroke macro.

Output a text file or message/provide a wait loop

If you press [Ctrl+u] during the recording of a the keystroke macro, the RECORD menu will appear in the message line. Here you can determine whether a text file is displayed, a message is displayed, or a wait loop is initiated when the keystroke macro is played back.

The default extension of macro files is .KDO.

For more information on the macro file format see the section on "Macro Files".

Invoking key macros

Keystroke macro files can be invoked in various ways:

To start a macro file from DOS prompt;

- Add the name of the respective macro file to the program name "FM" (separate by a blank). You don't have to add the extension .KDO.

For example:

- `fm approx[↵]` Start FILTERMASTER and immediately begin the macro APPROX.KDO.

Note: Macros can only be invoked in this way if they were saved to the same directory where the FILTERMASTER PROFESSIONAL program is stored (key macro files are not searched according to the path name).

To start a macro file from within the program;

For filename macros:

- Select the filename (with or without the path name) in the MACRO menu under the Call menu function.

The execution of the macro instantly begins after confirming the entry in the field.

For function key macros:

- Press the appropriate key combination assigned to the macro.

The program automatically changes to the main menu, from which the macro commences.

The following “options” can be built into macros:

- Predefined interruptions in the automatic execution of the macro. This allows you to change the course of a macro. The macro can be continued by pressing [Ctrl+p]. Remember to return to the program section where the macro was interrupted!
- Time or wait loops during which the contents on the screen remain displayed. A message or text file can also be displayed on the screen.

Changing the desired mode of execution

If the key combination [Ctrl+u] is pressed before invoking a macro, a menu will appear in the message line which will allow you to determine whether you intend to:

- Continue the execution after pressing the space bar instead of using the waiting periods (0 .. Waitmode),
- Take the waiting periods provided in the macro file into account (1 .. Timemode),
- Have the macro file processed without considering waiting periods or interruptions (2 .. Fastmode).

Note: When creating macro files through the key combination [Ctrl+u] the RECORD menu is called up instead of this menu.

Example: Keystroke Macros

See the “Specification” and “Parametric Bandpasses” sections for more information.

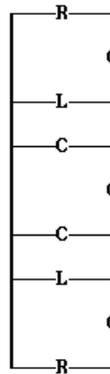
When developing a parametric bandpass filter, the component values can be optimized by changing the parameter field. To avoid having to enter all the specifications again in each optimization step, we can use the keystroke macro function.

The desired structure of the circuit is predefined. This example, therefore, also shows you how to enter your own circuit structure.

The filter must fulfill the following requirements:

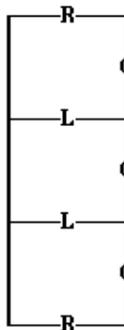
- Parametric equal ripple bandpass
- Passband: 100 kHz to 120 kHz
- Passband loss: 1 dB

Predefined structure of the circuit:



First step: Determine the number of poles at zero/infinity and pairs of poles at finite frequencies (you can proceed in accordance with the rules set out in the “Design with user-defined circuits” section):

Number of poles at zero:



1th Change (to C)

2th Change (to L)

3th Change (to C)

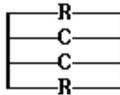
4th Change (to L)

5th Change (to C)

Result: 5 poles at zero

EXAMPLE: KEYSTROKE MACROS

Number of poles at infinity:



1st Change (to C)

Result: 1 pole at infinity

Number of pairs of poles at finite frequencies

There are no pairs of poles because the circuit does not include any resonating circuits.

The filter in question is a bandpass of the 6th degree (5 + 1).

Now let's enter the data.

Opening the macro

From the main menu:

- [↵] Activate the FILTERTYPE menu
- [↵][B] Set Bandpass
- [A][↵] Set equal ripple approximation.
- [Q][↵][S][N] Activate SPECIFICATION menu, delete data (if any)
- [P][↵] Select parametric type of bandpass
- [A]100k[↓] Lower passband edge frequency = 100 kHz
- 120k[↓] Upper passband edge frequency = 120 kHz
- 1[↵] Passband loss = 1 dB

- [G]5[←] Set 5 poles at zero
- [D] Set the default parameter
- [Y] Calculate the filter quality

You will see the following screen:

SPECIFICATIONS to : Equal ripple - bandpass filter			
(O)			
	Kind of bandpass	:	parametric
(M)	Parameter	:	109.544 512 kHz
(A)	Lower passband edge frequency	:	100.000 000 kHz
(B)	Upper passband edge frequency	:	120.000 000 kHz
(E)	Passband bandedge loss	:	1.000 000 dB
(F)	Passband bandedge return loss	:	6.87 dB
(R)	Passband reflection factor	:	45.35 %
(G)	Transm. zeros at zero	:	5
(H)	Transm. zeros at infinity	:	1
		Fixed transm. zero pairs:	0
		Var. transm. zero pairs :	0
	Filter degree	:	6
	Lower 3dB edge frequency (≈)	:	98.385 603 kHz
	Upper 3dB edge frequency (≈)	:	122.959 982 kHz
	Filter quality	:	11.80

SPECIFICATION: A B E F R G H qualityY Conventional Defaultparam.
 Stopbandopt. fixtrans.zeros cOmment New fiLe Printer Quit ?

We will develop the filter based on this data. The optimization of the component values is achieved by changing the parameter field in the SPECIFICATIONS menu. As the same entries have to be made repeatedly, we will use the keystroke macro function:

- [Q] Return to the main menu
- [M] Activate the MACRO menu
- [K] Select the function_Key menu item
- [F10] Allocate the following macro to the function key [F10]

EXAMPLE: KEYSTROKE MACROS

- [S] Activate the SPECIFICATION menu

Insert an interruption here, so that the value of the parameter can be changed during the execution of the macro. The remainder of the calculations will be continued automatically.

- [Ctrl+P] Insert an interruption into the key-stroke macro

Now let's go on to the circuit design.

- [Q][D] Activate the PASSIVE DESIGN menu

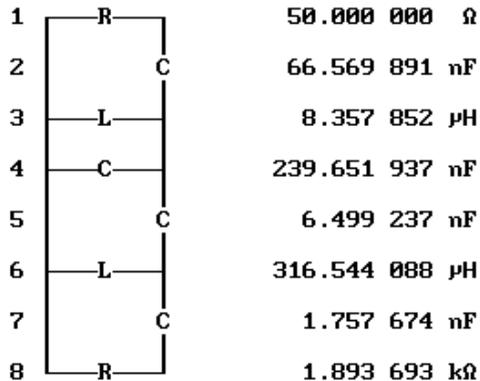
The circuit proposed by FILTERMASTER PROFESSIONAL is not of interest. Delete it and replace it with your own circuit.

- [I][H] Activate the INPUT CIRCUIT menu, delete the present circuit

Now create the circuit piece by piece.

- [B] Series capacitance
- [C] Parallel inductor
- [A] Parallel capacitance
- [B] Series capacitance
- [C] Parallel inductor
- [B] Series capacitance

The circuit should look like this:



The missing C is added through the Norton's transformation, which is necessary to achieve equal terminating resistances:

- [Q][M][N] Activate the NORTON'S TRANSFORMATION menu

- [N] Switch to the next combination of elements which can be applied to the Norton's transformation

- [F]1[↵] Enter the value of the termination input resistance as the reference value of the component

The reference transformation factor (C) lies within the limits and, therefore, the transformation can be carried out.

- [C] Carry out the transformation in accordance with the reference factor

Now you have your circuit. Take a closer look at the values of the components.

- [Q][O] Output of the circuit

EXAMPLE: KEYSTROKE MACROS

Before investigating the circuit more closely, end the keystroke macro.

- [Ctrl+Z] End the key macro

You have calculated the following circuit:

1	—R—	50.000 000 Ω
2	C	66.569 891 nF
3	—L—	8.357 852 μ H
4	—C—	206.153 739 nF
5	C	39.997 435 nF
6	—C—	206.153 739 nF
7	—L—	8.357 852 μ H
8	C	66.569 891 nF
9	—R—	50.000 000 Ω

Note: If your circuit shows other values, you might have forgotten to enter the value of 50 Ohms in the TERMINATION menu. You can enter this menu from the PASSIVE DESIGN menu.

You can scroll through the circuit with the arrow, [↓] and [↑], keys. You will see that all inductor values have the same value. However, we would like to have them at a more “nominal” value.

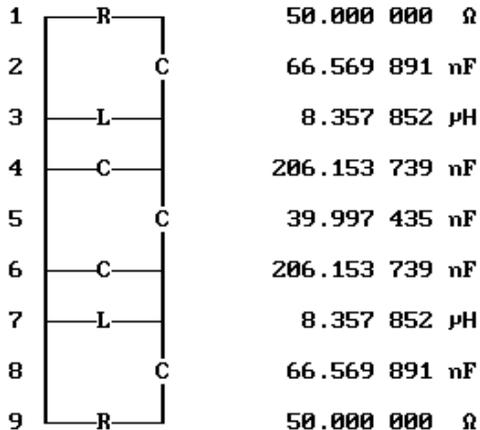
Try changing the parameter to change the inductor values to 10 μ H:

- [F10] Invoke of the previously generated key macro

If all entries were made correctly, the keystroke macro should stop in the SPECIFICATION menu. Then enter:

- [M]50k[↵] Change the parameter to 50 kHz
- [Ctrl+P] Continue the macro

After carrying out the macro, the following circuit will appear on the screen:



The values of the inductors reveal that you have overdone the change slightly. The value of the parameter field was changed too much. The best value for the parameter actually lies between the default value (approx. 110 kHz) and 50 kHz. After several tries you would find that the optimum value is: 77.38 kHz.

Execute the macro again with this value.

- [F10] Start the macro

When the interruption in the SPECIFICATION menu occurs enter:

- [M]77.38k[↵] Change the parameter to 77.38 kHz
- [Ctrl+P] Continue the macro

EXAMPLE: KEYSTROKE MACROS

After completing the macro you will have the following circuit:

1	R	50.000 000 Ω	
2		C	44.046 038 nF
3	L	10.000 426 μ H	
4	C	168.123 523 nF	
5		C	33.119 150 nF
6	C	168.123 523 nF	
7	L	10.000 426 μ H	
8		C	44.046 038 nF
9	R	50.000 000 Ω	

That's it! This completes the example.

- [Q][Q][Y][Q] Return to the main menu

FILTERMASTER Output to IsSPICE

A special feature of the FILTERMASTER program is its direct interface with the IsSPICE and ICAPS simulation system. Filters designed with FILTERMASTER can be saved in one of two SPICE compatible netlists formats.

As a stand-alone netlist, your filter can be immediately simulated in IsSPICE or any other SPICE compatible simulator. This provides access to the powerful features of IsSPICE such as time domain and temperature analyses. As a subcircuit netlist, your filter design can be easily integrated with the rest of your circuit through the use of the SPICENET schematic entry module in ICAPS.

Component tolerances may also be included in either netlist format allowing Monte Carlo statistical yield analyses to be conducted on your filter when used in conjunction with Intusoft's ICAPS package.

Stand-alone Netlist

This example will show how to use FILTERMASTER's IsSPICE interface to create a stand-alone netlist. The filter specification is shown next.

STAND-ALONE NETLIST

- Center frequency: 70 MHz
- Bandwidth: 27 MHz
- Upper stopband limit frequency: 97 MHz
- Return loss: 20 dB
- Stopband attenuation: 25 dB
- Approximation: Chebyshev

After this information is entered proceed to the SPICE menu.

- [D] Activate the PASSIVE DESIGN menu
- [O] Activate the OUTPUT CIRCUIT menu
- [S] Activate the SPICE menu

The following screen will appear as:

```
Spice - Output: Standalone Analysis
* Chebychev - bandpass filter
*
*
*           1991-11-06  14:17:39
*
* Reference Frequency : 83.500 000 MHz
*
L2      2      3      2.868353E-07
C3      3      4      1.871857E-11
L4      4      0      3.318773E-08
C5      4      0      1.617811E-10
L6      4      5      5.314511E-07
C7      5      6      1.010281E-11
C8      6      0      1.617811E-10
L9      6      0      3.318773E-08
L10     6      7      2.868353E-07
C11     7     100     1.871857E-11
```

Move with [Cursor keys]

```
SPICE: Save Standalone Subcircuit Name Tol R-tol L-tol C-tol quality
L-qual. C-qual. fBegin fEnd fDefault Points Lin Dec Digits Quit ?
```

Notice that the representation is already in a stand-alone format. If the format was previously changed, it will have to be changed back to stand-alone by typing:

- [S][↵] Activate the Standalone output format

The IsSPICE analysis is controlled by the following parameters:

fBegin	This is the FSTART parameter in the .AC statement (The starting frequency)
fEnd	This is the FSTOP parameter in the .AC statement (The ending frequency)
fDefault	Invokes the FILTERMASTER defaults for the fBegin and fEnd parameters
Points	This controls the number of points taken by the AC analysis
Lin, Dec	This specifies how the Points will be taken, either linearly over the entire frequency span or per decade of frequency

The syntax for the .AC statement is repeated for reference:

```
.AC [LIN, DEC, OCT] [Number of points] [fStart] [fStop]
```

Since the center frequency is 70MHz and the bandwidth is 27MHz, satisfactory start and stop frequencies for the .AC statement are 10MEG and 100MEG, respectively.

- [B] Edit the fBegin field
- 10M[↵] Enter 10MEG as the start frequency
- [E] Edit the fEnd field
- 150M[↵] Enter 150MEG as the stop frequency

We will collect data in this frequency range linearly by entering LIN in the .AC statement.

- [L][L][L][↵] Enter LIN into the .AC statement

Over this linear scale we will collect 200 points.

- [P] Edit the Points field
- 200[↵] Enter 200 points

At any point, the number of digits used after the decimal point for the component values can be altered. This is done by selecting the Digits option. We will now alter the netlist to use 4 significant digits for all values.

- [D][D][D][↵] Edit Digits field
- 4[↵] Enter 4 as the number of significant digits

At this point we can save this circuit for simulation.

- [↵] Enter Save field
- CIRCUIT1[↵] Enter a name for the file

The file CIRCUIT1.CIR can now be simulated by IS_{SPICE}.

Subcircuit Netlist

This example will demonstrate how to output the filter as an IS_{SPICE} subcircuit. It may then be used with the ICAPS package. In addition to demonstrating the subcircuit feature, we will use FILTERMASTER to change the quality factor, Q, of the inductors in the filter.

We will use the filter from the previous circuit as a foundation. At this point type:

- [S][S][↵] Activate the Subcircuit representation of the filter circuit

The output will be shown in the standard IsSPICE subcircuit format with three connections to the filter, input, output, and reference (normally ground). The netlist will also contain information about the particular filter in the form of the approximation, reference frequency, and input and output resistances. An example is shown below:

```

Spice - Output: Subcircuit
.SUBCKT FILTER 2 100 99
* 2-Input 100-Output 99-Reference
*
* Chebychev - bandpass filter
*
*
*           1991-11-06 14:26:31
*
* Reference Frequency : 83.500 000 MHz
*
* Rin = 5.000000E+01
* Rout = 5.000000E+01
*
L2      2      3      2.868353E-07
C3      3      4      1.871057E-11
L4      4      99     3.318773E-08
C5      4      99     1.617811E-10

```

```

Move with [Cursor keys]
SPICE: Save Standalone Subcircuit Name Tol R-tol L-tol C-tol quality
L-qual. C-qual. fBegin fEnd fDefault Points Lin Dec Digits Quit ?

```

To investigate the filter further, the quality factor of a component can be altered from its ideal initial position. Quality factors can be added in one of two ways, either on a particular type of component, (i.e. all inductors or all capacitors), or on an individual component. In this case, we want to investigate the effect of low inductor Q on the performance of the circuit.

- [L][L][←] Edit the L-qual. field
- 20[←] Enter a quality factor of 20 to all inductors

The subcircuit representation will change to show the effect of the new inductor Q. Series resistances will be added to all the inductors in the circuit. A comment line is also added to each inductor/resistor combination as a reminder of the Q value.

SUBCIRCUIT NETLIST

| The subcircuit will now appear as:

```
Spice - Output: Subcircuit
.SUBCKT FILTER 2 100 99
* Z-Input 100-Output 99-Reference
*
* Chebychev - bandpass filter
*
*
*           1991-11-06 14:28:37
*
* Reference Frequency : 83.500 000 MHz
*
* Rin = 5.000000E+01
* Rout = 5.000000E+01
*
L2      2      3      2.868353E-07
* Q=20.00
RL2     3      4      7.524350E+00
C3      4      5      1.871857E-11
```

The subcircuit can now be saved.

- [↵] Activate the Save field
- FILTER[↵] Enter the name FILTER

The file will be saved using the default extension of .LIB. Multiple filter designs can be saved into one single library file in this way. The library file will be in the format compatible with the PRESPICE program. However, in order to distinguish one filter from another in the library, it is necessary to change the name of the subcircuit using the Name option. Do this by typing:

- [N] Edit the Name field
- FIL1[↵] Enter the name for the altered subcircuit

Notice that the name in the .SUBCKT line changes. There can be any number of filter subcircuits in a library file, but each must have its own unique name.

Interface With The SPICENET Program

The SPICENET schematic entry program is included in the ICAPS simulation system.

The easiest way to use the filter subcircuit is with the SPICENET schematic entry program. A symbol, called FILTER, has been created for SPICENET that will interface directly to the filters saved in the subcircuit format. The filters must be stored in a library file called FILTER.LIB because the symbol causes a *INCLUDE Filter.Lib to be entered into the final IsSPICE netlist.

To include a FILTERMASTER designed filter in a SPICENET schematic:

- Create the filter and select the Subcircuit netlist format in the SPICE menu.
- Change the name of the filter to a unique name (FIL1, for example).
- Save the filter subcircuit netlist into a file called FILTER.LIB. Make sure that the FILTER.LIB file is stored in your SPICE model library directory, normally C:\SPICE\PR.
- Enter SPICENET and place the symbol called FILTER.
- Select the FILTER symbol and display its label menu. Enter the unique name you gave the filter (FIL1, for example) in the value field. The name in the value field links the symbol to the unique name used in the .SUBCKT line.
- Enter “*INCLUDE FILTER.LIB” into the control menu.

The Get Symbol function can be used to get the Filter symbol.

Stand-alone Netlist With Monte Carlo Syntax

The last example will deal with placing Monte Carlo tolerances on components using a stand-alone netlist. The method is easy and straight forward. We will use the same filter so there is no need to re-enter any information. However, we will have to

STAND-ALONE NETLIST WITH MONTE CARLO SYNTAX

remove the Q placed on the inductors in the previous example and switch the output to Standalone.

- [L][L][↵] Edit the L-qual. field
- 0[↵] Enter a 0 Quality factor. This changes the inductor Q to infinite.
- [S][↵] Activate the Standalone netlist option

Now that the screen is showing a stand-alone netlist we will enter device tolerances for the inductors and capacitors. We will place a 5% tolerance on the inductors and a 10% tolerance on the capacitors.

- [L][↵] Edit the inductor tolerance field
- 5[↵] Enter a 5% tolerance on all inductors
- [C][↵] Edit the capacitor tolerance field
- 10[↵] Enter a 10% tolerance on all capacitors

At this point the screen should look similar to the first example with the addition of the TOL=% tolerance statements. This file can now be saved and used with the ICAPS simulation system to run an extensive Monte Carlo statistical yield analyses on this filter.

Note: Monte Carlo tolerances may be inserted in netlists that use the subcircuit format, as well as non-ideal quality factors.

For more information about the Monte Carlo analysis please refer to the PResPICE User's Guide.

Appendix A - Comparison of Approximations

A comparison between all the approximations supported by FILTERMASTER PROFESSIONAL is shown below. The following settings were used for the example:

Lowpass

Passband: up to 1 kHz

Stopband loss:

from 1.15 kHz: 55 dB

from 1.3 kHz: 40 dB

(The lower stopband loss from 1.3 kHz can only be taken into account in general amplitude approximations).

Passband loss max. 3 dB

As an indicator of the amount of work required for the individual approximations, we have included the respective degree in each diagram.

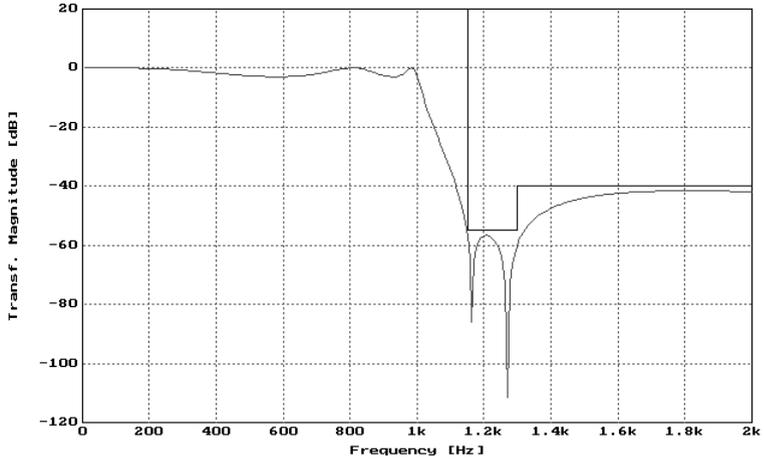
General Amplitude Approximations

Equal Ripple Approximation

- Equal ripple in the passband
- Loss curve in the stopband can be selected with either monotonic rise or optimized for the same minimum distance to the tolerance scheme defined by the user
- Optional: setting of fixed blocking places

APPENDIX A - GENERAL AMPLITUDE APPROXIMATIONS

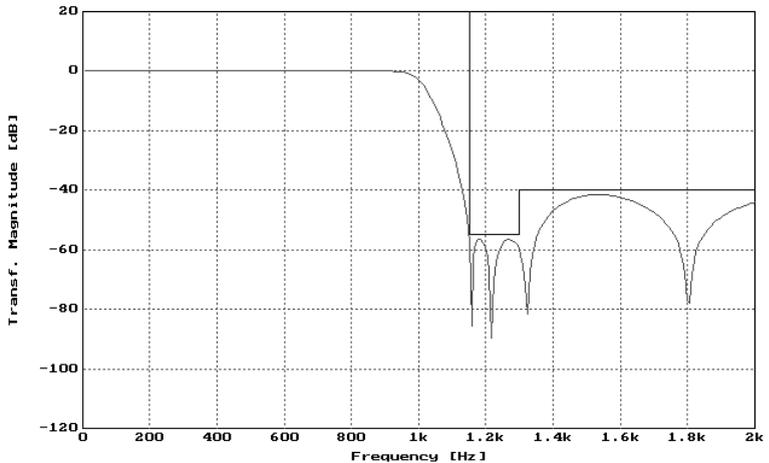
Example: Lowpass, Equal ripple approximation



Maximally Flat Approximation

- Maximally flat loss curve in the passband
- Loss curve can be individually set in the stopband as in the equal ripple case

Example: Lowpass, Maximally flat approximation



General maximally flat LP (12th degree)

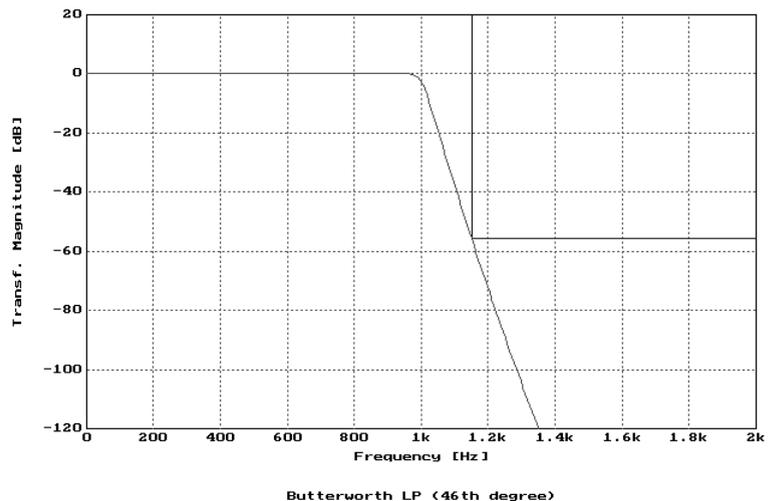
Standard Approximations

Listed below are special cases of the general amplitude approximations described above. The most essential difference, as compared to the general approximation, is the fact that in standard approximations only one specific stopband loss can be set for the whole stopband.

Butterworth Approximation

- Maximally flat loss curve in the passband
- Monotonic rise of the loss in the stopband (special maximally flat approximation)

Example: Lowpass, Butterworth approximation

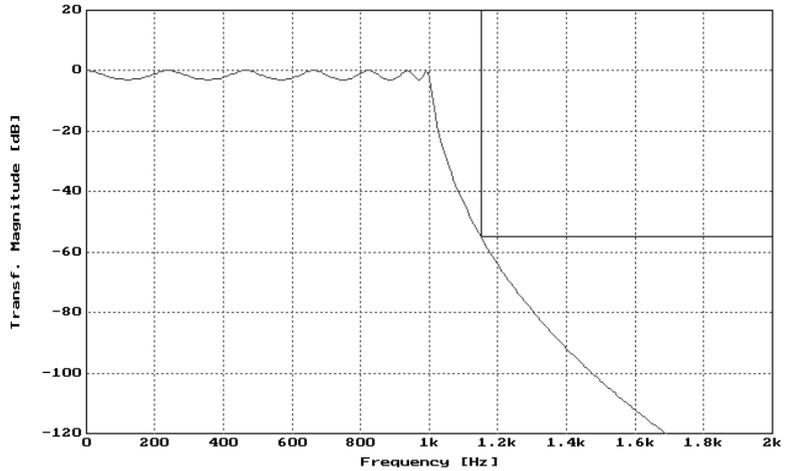


Chebyshev Approximation

- Equal ripple in the passband
- Monotonic rise of the loss in the stopband (special equal ripple approximation)

APPENDIX A - STANDARD APPROXIMATIONS

Example: Lowpass, Chebyshev approximation

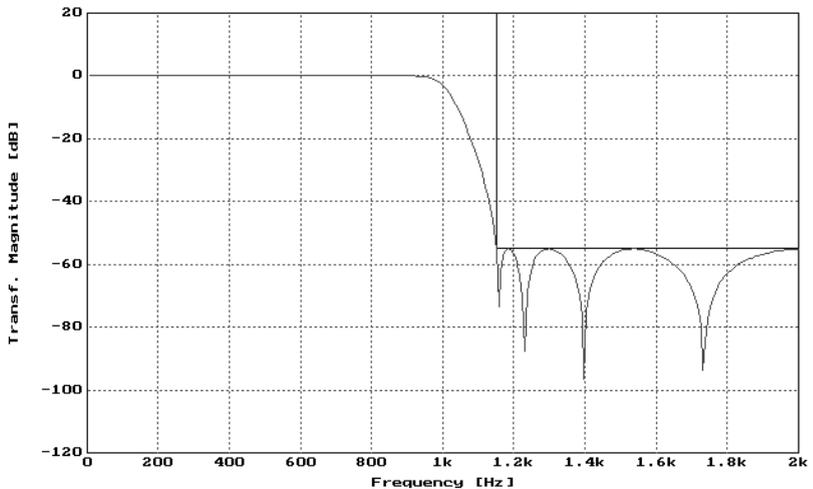


Chebyshev LP (13th degree)

Inverse Chebyshev Approximation

- Maximally flat loss curve in the passband
- Loss “arcs” with the same minimum in the stopband (special maximally flat approximation)

Example: Inverse Chebyshev approximation

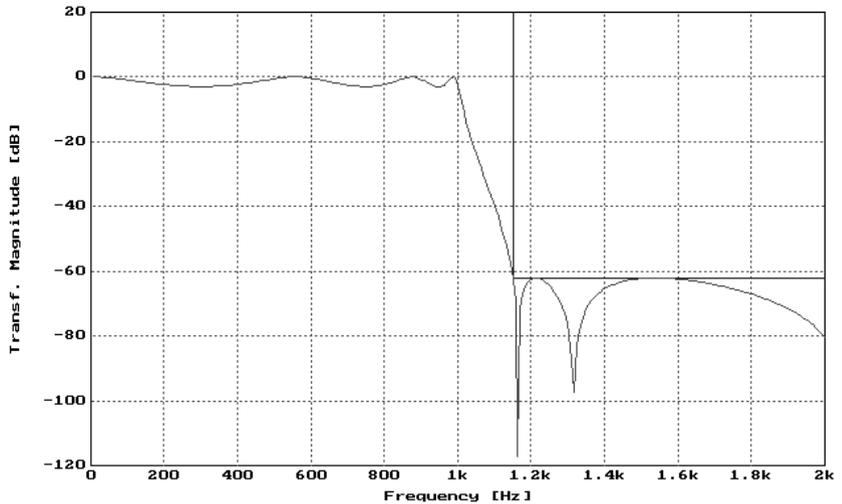


Inv. Chebyshev LP (13th degree)

Elliptic Approximation (Cauer filter)

- Equal ripple in the passband
- Loss “arcs” with the same minimum in the stopband (special equal ripple approximation)

Example: Lowpass, Elliptic



Elliptic (Cauer) LP (7th degree)

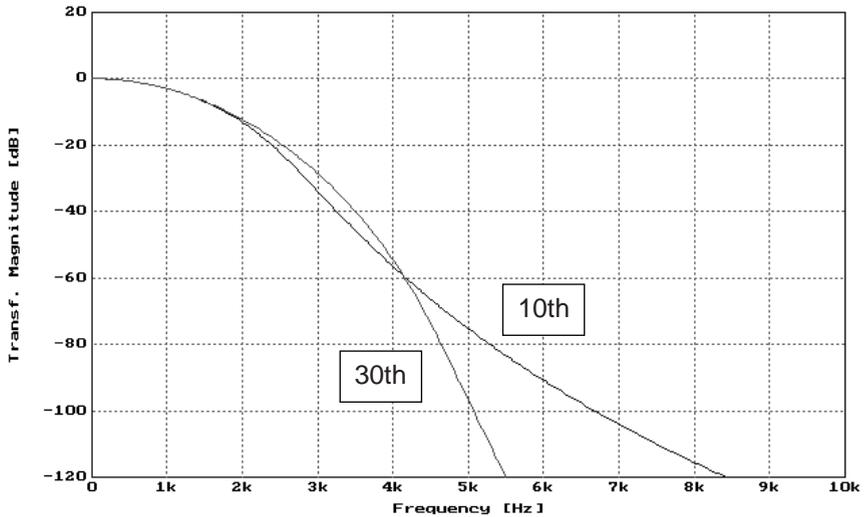
Bessel (Thomson) Approximation

This approximation (only for lowpass filters) is optimized to constant group delay (linear phase). In contrast to the other approximations described above, it is not possible to always achieve a desired steepness in the amplitude-frequency characteristic with the Bessel approximation.

The loss curve approaches a parabola with increasing order (see [1] “Literature” section).

APPENDIX A - STANDARD APPROXIMATIONS

Example:



Bessel (Thomson) LP (10th, 30th degree)

The advantages of the design with the general amplitude approximation over that of the standard approximation are:

- More freedom in the stopband specification; you can enter a tolerance scheme with different loss values, set fixed transmission zeros (blocking places), select the number of transmission zeros at extreme frequencies, etc.
- Save on costs for the components by exact approximation to the required loss curve.
- Calculation of unsymmetrical bandpass filters.
- More freedom with regard to the ratio of the input/output resistance in lowpass, highpass and bandstop filters.
- Additional manipulations of the component values in the bandpass by providing the parametric form option.

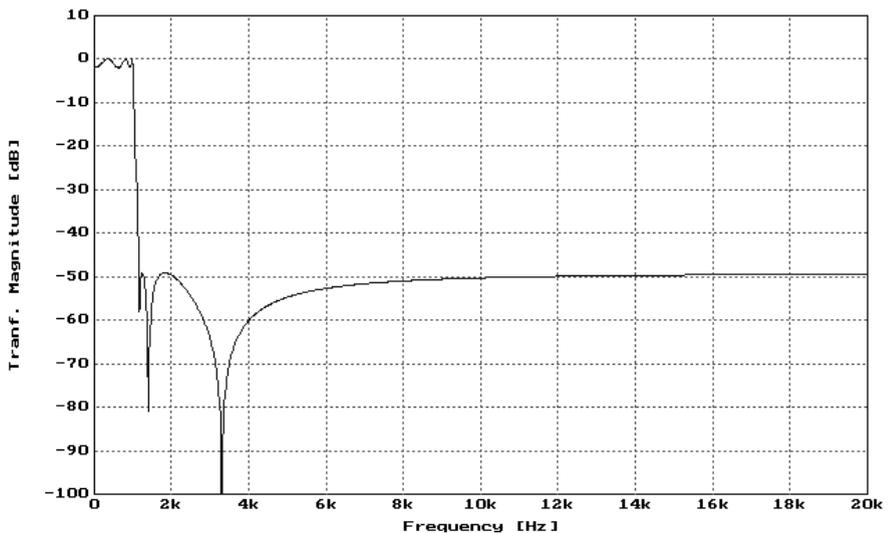
Appendix B - Case, Terminating Resistance Ratio

Standard Approximations

Case a

In filters with poles in the finite stopband, (Elliptic and Inverse Chebyshev filters) there exists an optimal approximation equal to the optimal use of the tolerance scheme in the passband with a maximally achievable minimum stopband loss. In commonly available literature, as well as in *FILTERMASTER PROFESSIONAL*, this is termed “case a”.

Example: Elliptic (Cauer) lowpass in case a

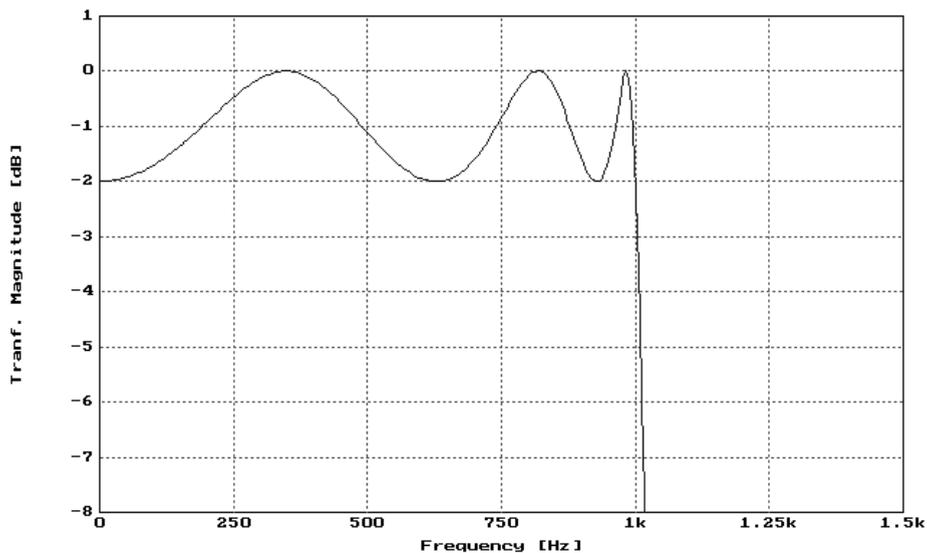


Note: Since the loss has a finite value when the frequency is infinite, this case can only be realized with active filters or with mutual inductances in passive filters, neither of which are supported by *FILTERMASTER PROFESSIONAL*.

APPENDIX B - CASE, TERMINATING RESISTANCE RATIO

With Case "a" type Elliptic lowpass filters we find that due to the position of the zeros in the passband, there is a loss at zero frequency equal to the value of the maximally allowed passband loss. This leads to different values of the terminating resistances (resistance ratio not equal 1), which does not disturb an active realization.

Example: Passband of a Cauer lowpass in case a.



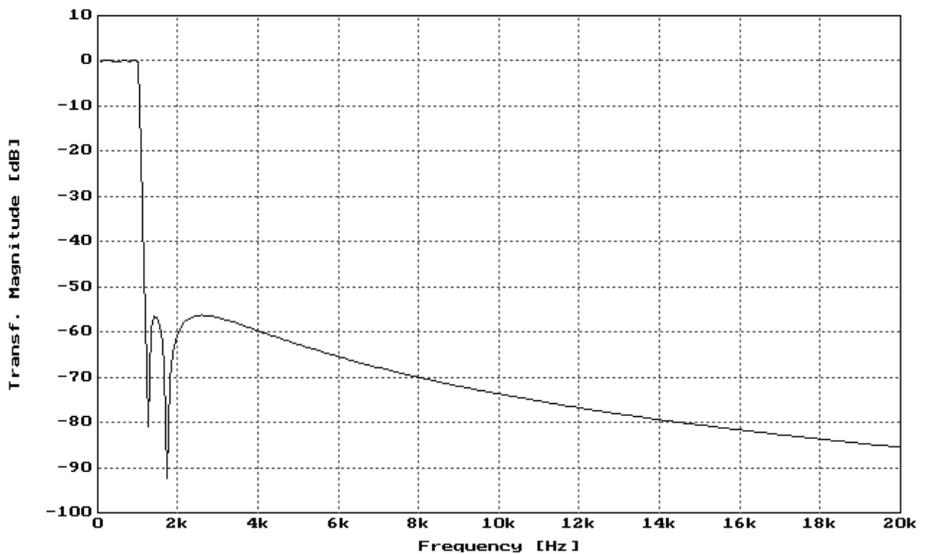
Case b

It is possible, by way of a transformation, to move the highest pole position towards infinity in the approximations described previously, which allows the filter to be realized passively.

However, this leads to a slight “deterioration” in the achievable stopband loss when compared with case “a”.

This case is named “case b”.

Example: Cauer lowpass in case b.



APPENDIX B - CASE, TERMINATING RESISTANCE RATIO

Note: The “initial loss” remains in zero frequency approximations with ripples in the passband. This results in differing terminating resistances for case b passive filters. If the resistors must be equivalent, then you will have to select case c.

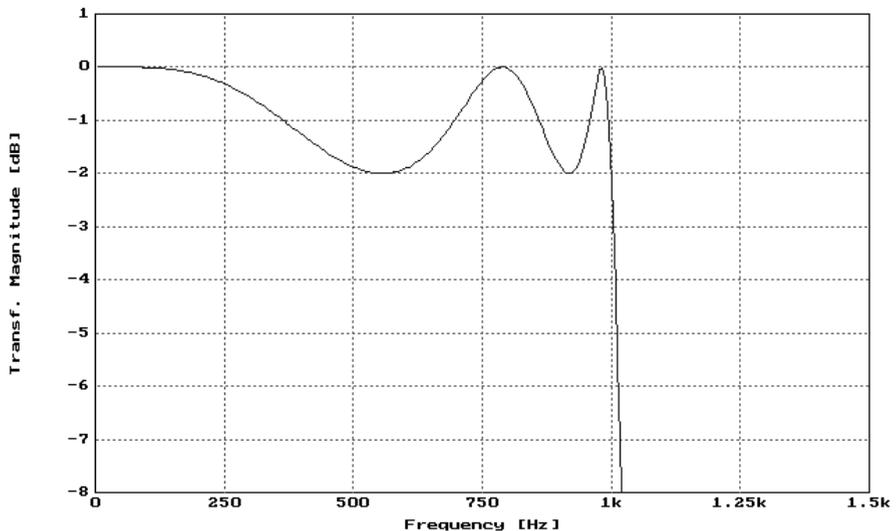
Case c

In filters with ripples in the passband (Chebyshev and Cauer), it is possible to displace, by way of a transformation, the first zero position in the passband to zero frequency. This causes the ratio of the input and the output resistances to become 1 (the two terminating resistances have the same value).

However, this leads to another slight deterioration in the filter data when compared to the filter in case b.

This case is referred to as “case c”.

Example: Cauer lowpass in case c.



Summary:

Approximation	Possible Cases	Remarks
Butterworth	none	no zeros in the passband no finite poles in stopband
Chebyshev	b or c	only ripple in the passband
Inv.-Chebyshev Elliptic (Cauer)	a or b a, b or c	only ripple in the stopband ripple in pass and stopband

Note: The case studies only have an influence on the result of the calculation in lowpass and highpass filters of even degree and in bandpass and bandstop filters whose degree can be divided by four.

Equal Ripple Approximation

As mentioned before, the position of the first zero position in the passband of a lowpass can be displaced by a transformation, which changes the “initial loss” at zero frequency.

This enables two extremes in the standard Chebyshev and Elliptic (Cauer) approximations:

Case b: Loss at zero frequency = maximum allowed passband loss

Case c: Loss at zero frequency = zero

The ratio between the input and output resistance is determined by the initial loss at zero frequency. For the standard approximation this can either be a specific value (case b) or 1 (case c).

In the equal ripple approximation, the user has the ability to select the resistance ratio. FILTERMASTER PROFESSIONAL will then “displace” the respective zero position to the best position in the passband using a special transformation.

APPENDIX B - CASE, TERMINATING RESISTANCE RATIO

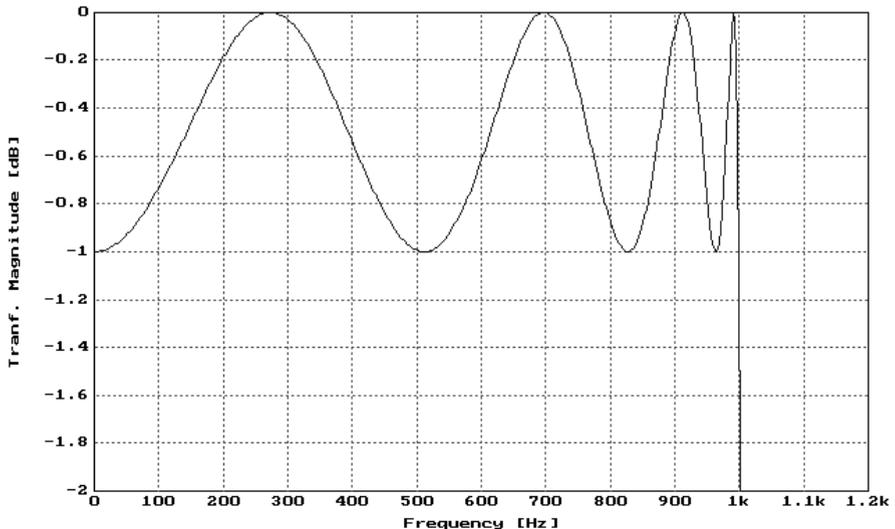
This can be performed in lowpass filters of an even degree, highpass filters of an even degree, and bandstop filters with a degree that can be divided by four.

Note: In lowpass and highpass filters with an odd degree and bandstop filters whose degree cannot be divided by four (because bandstops are transformed to lowpasses with half degree), the resistance ratio is generally 1, i.e. the terminating resistances are equivalent.

It is not necessary to enter the resistance ratio in bandpass filters because it is possible to influence the values of the terminating resistances by using Norton's transformation! The entry is made in the SPECIFICATION menu. The following options are available:

Resistance ratio = Proposal

Results in the optimal equal ripple approximation by optimizing use of the tolerance scheme in the passband and optimal stopband loss at the given degree. Loss at $f = 0$ (the maximally allowed passband loss).

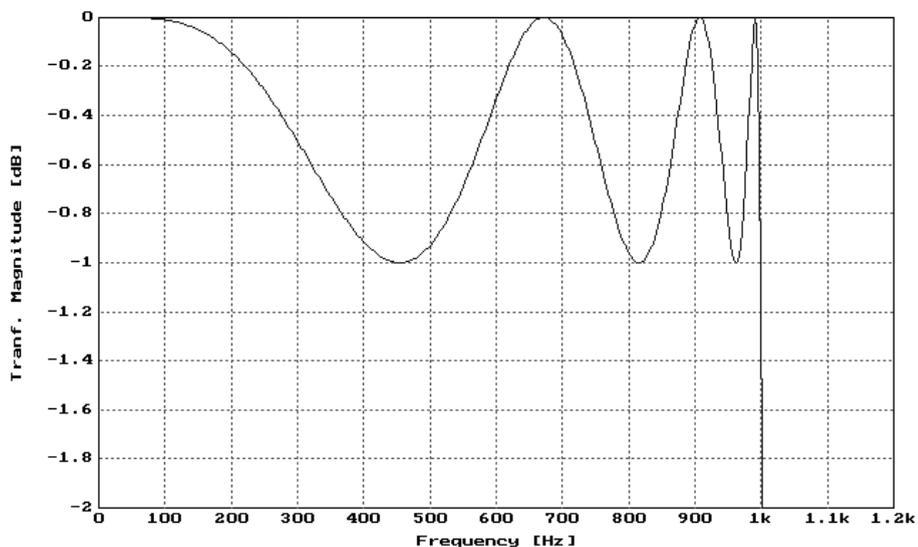


This is equivalent to standard approximations using cases a and b.

Note: We recommend accepting the proposal for the resistance ratio if you intend to realize the filter actively because the resistance ratios of the terminations are not of importance for active realizations.

Resistance ratio = 1

No loss at $f = 0$

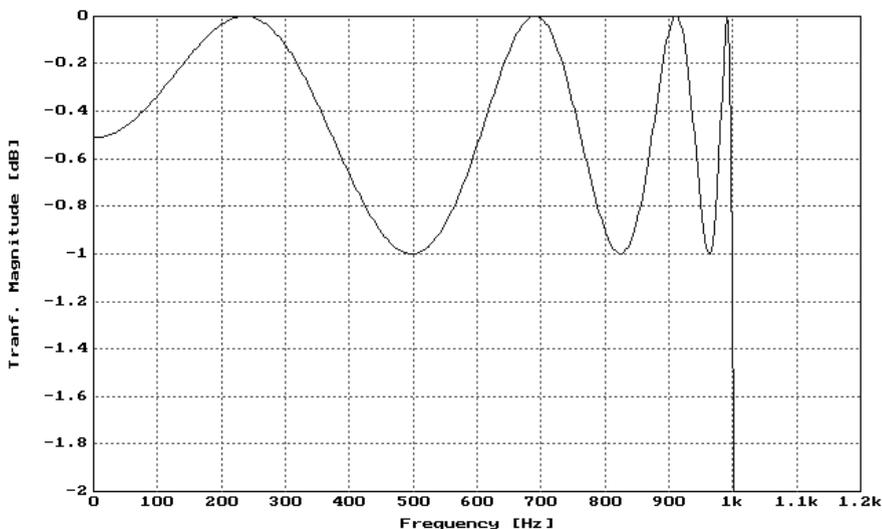


This is equivalent to case c in the standard approximations.

APPENDIX B - CASE, TERMINATING RESISTANCE RATIO

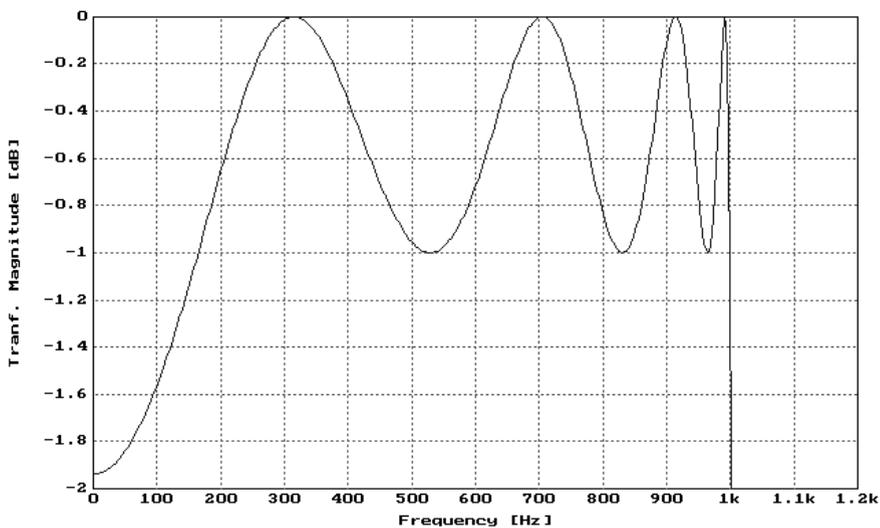
Resistance ratio between 1 and the proposal

The loss at $f = 0$ lies between zero and the maximally allowed passband loss.



Resistance ratio higher than proposal

The loss at $f = 0$ is higher than the maximally allowed passband loss.



Note: The filter no longer fulfills the requirements! (This option is, however, provided for special cases).

Definition of “resistance ratio”

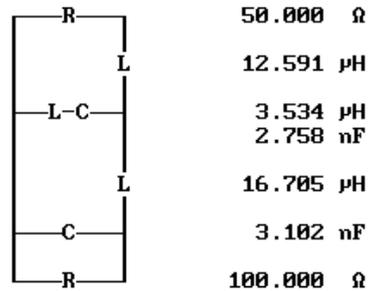
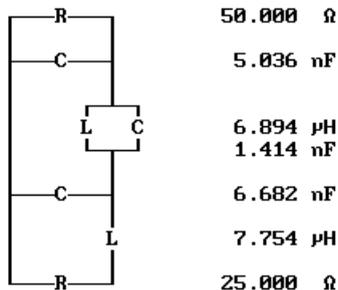
The resistance ratio in the SPECIFICATION menu is the ratio between input and output resistance. The higher of the two resistance values is understood to be the numerator of this ratio. Therefore, the resistance ratio can be selected either higher than or equal to 1.

The value set in the TERMINATION menu refers to the input. If the calculated output termination is not in a direct inverse ratio to this value, the output termination can be changed to the desired value by selecting the dual circuit.

Example (resistance ratio = 2):

First proposal:

Dual circuit:



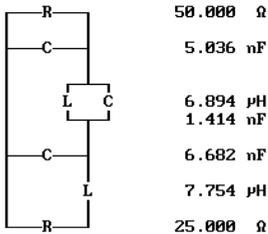
Alternatively:

- Set the terminating resistance in the TERMINATION menu to the value which is desired at the output of the circuit.
- Then, reverse the circuit in the MANIPULATION AND ANALYSIS menu.

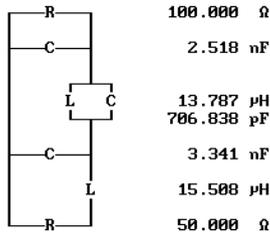
APPENDIX B - CASE, TERMINATING RESISTANCE RATIO

| For example:

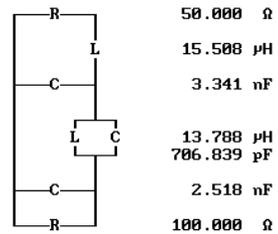
First proposal



Double input resistance



Reverse circuit



Limitations

There are cases where the frequency transformation is not possible for certain terminating resistances. This can happen in

lowpass filters: if there is no pole at infinity and all the poles are located near the passband edge,

highpass filters: if there is no pole at zero and all the poles are located near the passband edge, and

bandstops filters: if there are no poles near the center frequency and all the poles are located near the passband edge.

In such cases FILTERMASTER PROFESSIONAL will use the proposed resistance. This is indicated by a message. The resistance ratio is purely theoretical in such cases, because these approximations cannot be realized passively and the resistance ratio is unimportant for the active filter.

Appendix C - Conventional/Parametric Bandpass Filters

For bandpass filters of the general, equal ripple, and maximally flat approximations, FILTERMASTER PROFESSIONAL allows you to select between two different types of circuits:

- conventional
- parametric

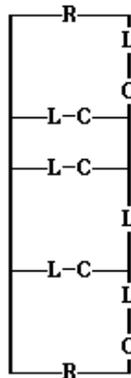
Conventional Bandpass Filters

This type of bandpass was the only one used until about thirty years ago (hence the name “conventional”). Conventional bandpass filters can only be developed with an even degree. (FILTERMASTER PROFESSIONAL automatically corrects the number of the poles at zero and infinity in such a way as to automatically achieve a filter of an even degree).

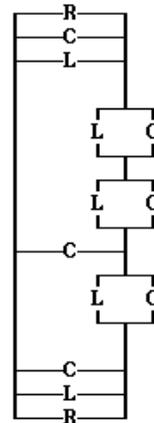
A significant feature of this type of filter is that its input impedance at zero and infinite frequency always has the same extreme value (zero or infinite). The same applies to the output impedance.

Examples of a conventional bandpass filter (8th degree):

Computer circuit:



The pertinent dual circuit:



Input and output impedance (at zero and infinite frequency):

Infinite

Zero

Parametric Bandpass Filters

The desire to obtain bandpass filters with fewer inductances led to the development of the parametric type of bandpass. Parametric filters can be designed with an even or odd degree. However, it is necessary to have at least one pole at zero and infinity.

Note: For passive filters, only parametric bandpass filters of an even degree are interesting.

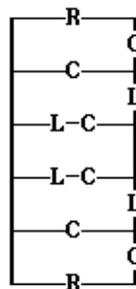
In even degree parametric filters, the value of the input or output impedance at infinite frequency assumes the opposite value (zero or infinite) of the impedance at zero frequency.

In odd degree parametric filters, only the input or output impedance assumes this behavior. If the output impedance assumes the behavior, then there is a negative sign in the parameter field.

The term “parametric” is used because this type of bandpass filter has an additional free parameter that is equal to the zero position of the polynomial f . Through this parameter (actually labeled “parameter” in the FILTERMASTER PROFESSIONAL SPECIFICATIONS menu) you can influence the values of the components during the design.

Examples of parametric bandpass filters:

Bandpass filter of even (8th) degree:



Parameter refers to the value of the Parameters field in the SPECIFICATIONS menu.

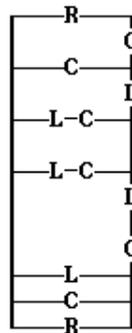
Input and output impedance at zero frequency: infinite

Input and output impedance at infinite frequency: zero

Note: The dual circuit is not of interest because it would yield a maximum number of inductors.

Bandpass filter of odd (9th) degree:

Positive parameter value:

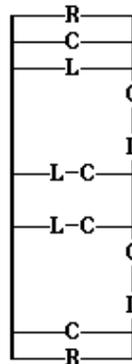


Input impedance at zero frequency: infinite

Input impedance at infinite frequency: zero

Output impedance: zero for each

Negative parameter value:



Output impedance at zero frequency: infinite

APPENDIX C - PARAMETRIC BANDPASS FILTERS

Output impedance at infinite frequency: zero

Input impedance: zero for each

Advantages of parametric bandpass filters over the conventional filters:

- Fewer inductors (when selecting the best circuit)
- Additional options for varying the values of the components through parameter variation. This option does not require additional components like the Norton's transformation.

Disadvantages:

- Less stopband loss with the same settings of a conventional filter
- No extreme terminations possible in even degrees

Appendix D - Design With User Defined Circuits

It is often necessary to realize a filter with a given circuit structure. In order to enter this circuit through the program section "Entry of circuits", the number of transmission zeros/pairs of transmission zeros must already be known when the filter is specified. These can be determined in the following way:

Lowpass, Highpass, and Bandpass Filters

A passive filter circuit can be regarded as the sum of series-connected two-ports. You can distinguish between six different types of two-ports:

- Series inductor (I_s)
- Parallel inductor (I_p)
- Series capacitance (C_s)
- Parallel capacitance (C_p)
- Series-resonance circuit that is connected in parallel (se)
- Parallel-resonance circuit that is connected in series (pa)

By mentally "manipulating the circuit" you can easily determine the desired number of transmission zeros.

Determination of the number of transmission zeros at zero

All four-poles except cs and lp are left out of the circuit. The number of changes between cs and lp results in the number of transmission zeros at zero with the first element counting as a change.

Determination of the number of transmission zeros at infinity

All four-poles except cp and ls are left out of the circuit. The number of changes between cp and ls results in the number of transmission zeros at infinity with the first element counting as a change.

Number of the pairs of finite transmission zeros

This number is equivalent to the number of all pa and se two-ports. In the equal ripple and maximally flat approximations, it can be set as the total of the number of fixed and variable pairs of transmission zeros.

Difference between conventional/parametric bandpass filters:

In bandpass filters you have the additional problem of determining whether the given circuit structure is a conventional or parametric filter.

Some hints on distinguishing between the two:

- If the degree is odd, the circuit represents a parametric filter (It is only possible to produce conventional bandpass filters with an even degree).
- If the proposed bandpass has an even degree, we recommend that you check the input impedance's behavior:

Conventional bandpass filters: The input impedance has the same value (zero or infinite) at both zero and infinite frequency.

Parametric bandpass filters: The value of the input and/or output impedance has the opposite extreme value (zero or infinite) at infinite frequency than at zero frequency.

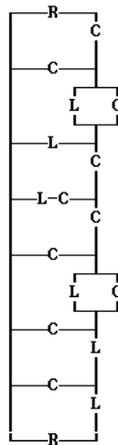
APPENDIX D - DESIGN WITH USER DEFINED CIRCUITS

Important note concerning parametric filters:

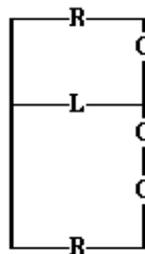
If the proposed filter has the behavior, described above, at only the output, you can either enter a negative parameter for the design or enter the circuit in reverse order and reverse it at the end of the dimensioning.

Example:

Given circuit structure:

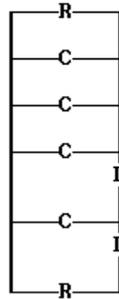


Number of transmission zeros at zero:



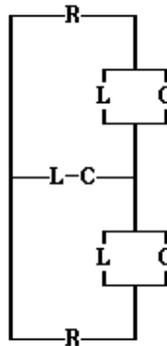
Result: 3 transmission zeros at 0.

Number of transmission zeros at infinity:



Result: 4 transmission zeros at infinity

Number of finite transmission zeros:



Summary:

Type of filter: parametric bandpass, positive parameter

Filter degree: $3 + 4 + (2 \times 3) = 13$

Bandstop Filters

Bandstop filters are slightly more complicated. The best way to proceed is to transform the symmetrical bandstop circuit into a lowpass circuit. The following “transformation” allows you to determine, from this circuit, the bandstop’s number of pairs of transmission zeros.

Number of pairs of transmission zeros at the center frequency

This is equal to the number of transmission zeros at infinity in the lowpass.

Number of finite pairs of transmission zeros in the bandstop

This is equal to twice the number of finite pairs of transmission zeros in the lowpass.

Appendix E - Calculation Speed

One outstanding feature of FILTERMASTER is its calculation speed. A computing algorithm, written in assembly code and with a very high internal accuracy, allows you to design filters up to the 50th order. FILTERMASTER PROFESSIONAL avoids iterative procedures where possible, preferring to use analytically-derived formula.

Appendix F - Calculating Component Values

The procedure below for calculating component values has proved itself for loss-free reactance filters (see [1]):

1. Choose a circuit design capable of creating the desired attenuation poles (depending on the transmission function).
2. The input reactance with no load or a short across the filter output is calculated from the transmission function $H(s)$ and characteristic function $K(s)$ (for definitions, see the following pages).
3. The first component value is calculated based on the reactance function and then the reactance of the remainder of the circuit is calculated. In resonance circuits, the attenuation pole value is used for the resonant frequency. This step is repeated until all the component values are known.

4. Reverse the circuit (mirror-image) and calculate the component values in the same way.
5. The two theoretical circuits are compared and the output terminating resistance calculated. This comparison may give rise to numerical problems. With single-side terminated filters, only one circuit is designed. Therefore, these numerical problems cannot arise.

Determination Of Variable Pole Pairs

This is how FILTERMASTER PROFESSIONAL finds the proposal for the number of variable poles:

Assessment in lowpass filters

A mean stopband loss is determined from the entered tolerance scheme. This is equivalent to the mean value of the stopband loss when displayed in the gamma plane.

$$\gamma = 0.5 * \ln \left(1 - \left(\frac{f_g}{f} \right)^2 \right)$$

Then, the degree of a reference filter that has the same stopband edge frequency and uses the previously calculated mean stopband loss as the stopband loss, is determined.

Type of reference filter:

- For equal ripple lowpass filters: Elliptic lowpass
- For maximally flat lowpass filters: Inverse Chebyshev lowpass

Half of the degree number of this reference filter is then entered in the program as the proposal for the number of pair of poles.

Assessment in highpass filters

The tolerance scheme is first transformed to that of a lowpass and, as described above, the number of variable poles is determined.

Assessment in bandpass filters

Here, the number of poles in the upper and lower stopband is determined separately. First, the lower tolerance scheme is transformed to a tolerance scheme of the lowpass and, as already described for the lowpass, the number of variable poles is determined. It is presumed that the bandpass filter is symmetrical. Hence, the same procedure is used to determine the number of poles in the upper stopband.

Assessment in bandstop filters

The tolerance scheme is transformed to a tolerance scheme of the lowpass. However, due to ambiguities in the lowpass bandstop transformation, this generally leads to two lowpass tolerance schemes. From these two schemes a single tolerance scheme is formed, which is equivalent to the respective maximum of each of the two tolerance schemes. As was described for the lowpass, the number of variable poles is determined. The double values of these poles are used as the proposal for the bandstop.

Initialization of the variable pole pairs

This is how FILTERMASTER PROFESSIONAL finds the best initial values of the pole positions for the subsequent optimization.

In lowpass, highpass, and bandstop filters, the tolerance scheme is transformed to a lowpass. The variable poles must be located in the stopband, which results in the range $[\gamma_{\text{stop}}, 0]$ in the γ plane. The variable poles are then favorably distributed in this range in accordance with certain rules.

In bandpass filters, the poles in the upper and lower stopband are initialized separately. In the γ plane, the upper stopband is equivalent to the range $[\gamma_{\text{stop1}}, 0]$ and the lower stopband to the range $[\ln(1/a), \gamma_{\text{stop2}}]$.

The variable poles are initialized after entering their number or the tolerance scheme. The pole frequencies are only used as the initial values for the following optimization. The arrange-

ment of the pole frequencies takes place in such a way that, referring to the transformed frequency variable gamma, γ , they are evenly distributed in the stopband.

$$\text{for lowpass:} \quad \gamma = 0.5 * \ln \left(1 - \left(\frac{f_g}{f} \right)^2 \right)$$

$$\text{for bandpass:} \quad \gamma = 0.5 * \ln \left(\frac{(f^2 - f_{gu}^2)}{(f^2 - f_{go}^2)} \right)$$

Appendix G - Root Output

Here; S_{11} , S_{12} , S_{21} , and S_{22} are the scatter parameters or transmission parameters of the passive filter.

s is the complex radian frequency

n is the degree of the filter

n_p is the number of finite attenuation poles

S_{ek} are the normalized zeros of the polynomial $e(s)$

S_{pk} are the normalized zeros of the polynomial $p(s)$, poles of $H(s)$

ω_o is the reference frequency

$1/S_{21} = 1/S_{12}$ for
passive filters.

$$H(s) = \frac{1}{S_{21}} = \frac{1}{S_{12}} = \frac{e(s)}{p(s)}$$

$$H(s) = C_{ep} \frac{\prod_{k=1}^n \left(\frac{s}{\omega_o} - S_{ek} \right)}{\prod_{k=1}^{n_p} \left(\frac{s}{\omega_o} - S_{pk} \right)}$$

Note: The terms are as shown in the book "Modern Filter Theory and Design" [1] (only used in filter theory). However, the value $H(s)=1/H(s)$ is used as the transmission function when calculating that function in the graphics mode.

Characteristic function

Here,

n_f is the number of finite zeros of $K(s)$

s_{fk} is the normalized zeros of the polynomial $f(s)$

$$K(s) = \frac{S_{11}}{S_{22}} = \frac{f(s)}{p(s)}$$

$$K(s) = C_{fp} \frac{\prod_{k=1}^{n_f} \left(\frac{s}{\omega_o} - S_{fk} \right)}{\prod_{k=1}^{n_p} \left(\frac{s}{\omega_o} - S_{pk} \right)}$$

Reflection Coefficient

$$\rho(s) = S_{11} = \frac{f(s)}{e(s)}$$

$$\rho(s) = C_{fe} \frac{\prod_{k=1}^{n_f} \left(\frac{s}{\omega_o} - S_{fk} \right)}{\prod_{k=1}^{n_p} \left(\frac{s}{\omega_o} - S_{pk} \right)}$$

The relationship between the constants is given by the equation:

$$C_{fp} = C_{ep} C_{fe}$$

The following relationships also apply [1].

$$H(s)H(-s) = 1 + K(s)K(-s) \quad \text{Feldtkeller equation}$$

$$e(s)e(-s) = p(s)p(-s) + f(s)f(-s)$$

where;

$$\rho(s) = \frac{K(s)}{H(s)}$$

$$|\rho(s)|_{s=j\omega} \leq 1$$

$$|H(s)|_{s=j\omega} \geq 1$$

Appendix H - Dual Circuits

In FILTERMASTER, you can create alternative circuits using the dual transformation. The reference resistance is used as the duality constant.

The formula is:

$$Z_A \cdot Z_B = R_B^2$$

where,

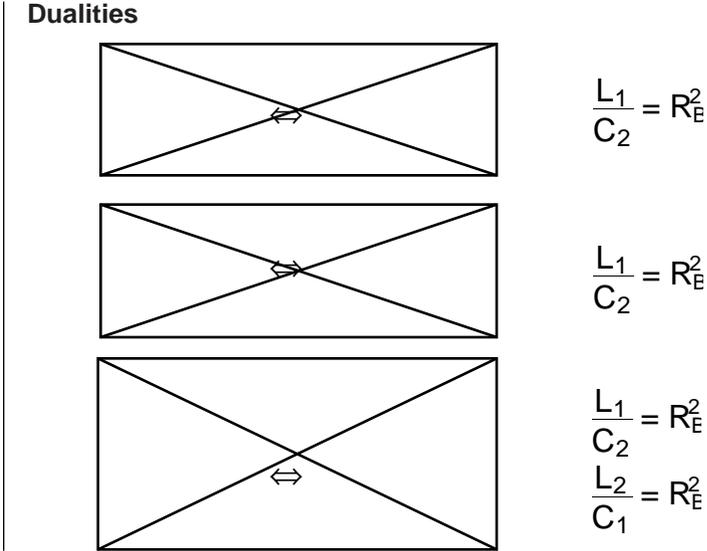
Z_A is the impedance of original circuit

Z_B is the impedance of dual circuit

R_B is the reference resistance. This is based

- with single-termination: on the input resistance
- with double-termination: on the resistance given

If you design a dual circuit from the MANIPULATION AND ANALYSIS menu, you can select your own reference resistance. If you design a dual circuit from the PASSIVE DESIGN menu, the program will use the specified terminating impedance.



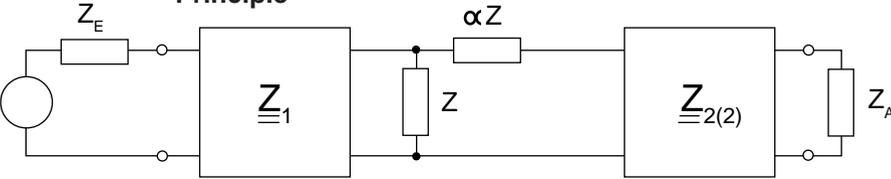
Appendix I - Norton's Transformation

Norton's transformation enables you to transform certain component combinations within a circuit so that all subsequent components are multiplied (L's and R's) or divided (C's) by a given factor. This does not affect the transmission characteristics.

In FILTERMASTER, it can therefore be used to:

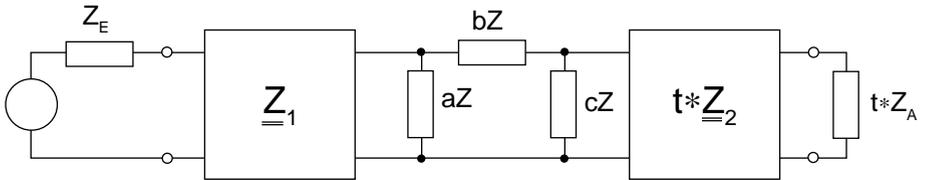
- Achieve a desired termination
- Change problematic component values
- Achieve equal component values

Principle

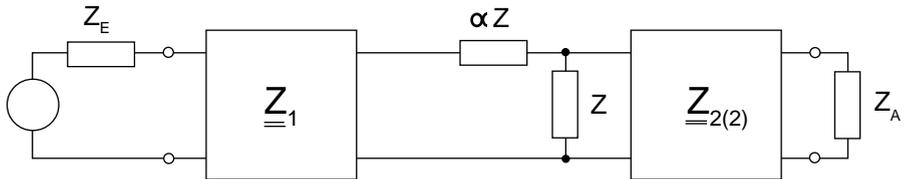
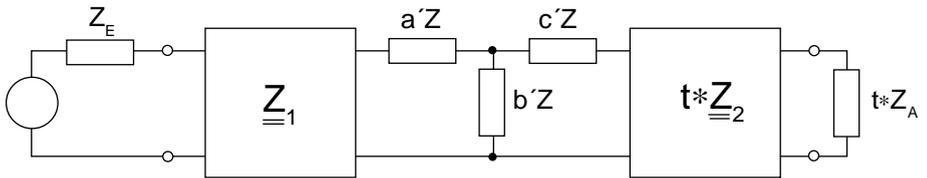


Z_1 is the impedance matrix of two-port 1
 Z_2 is the impedance matrix of two-port 2

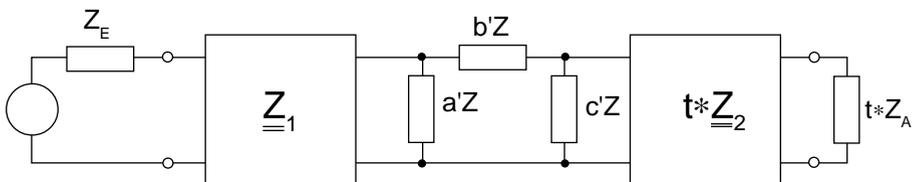
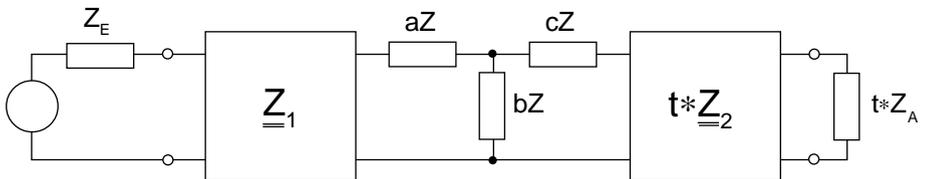
| Circuits with the same S-parameters:



| t is the transformation factor and a , b and c depend on t .

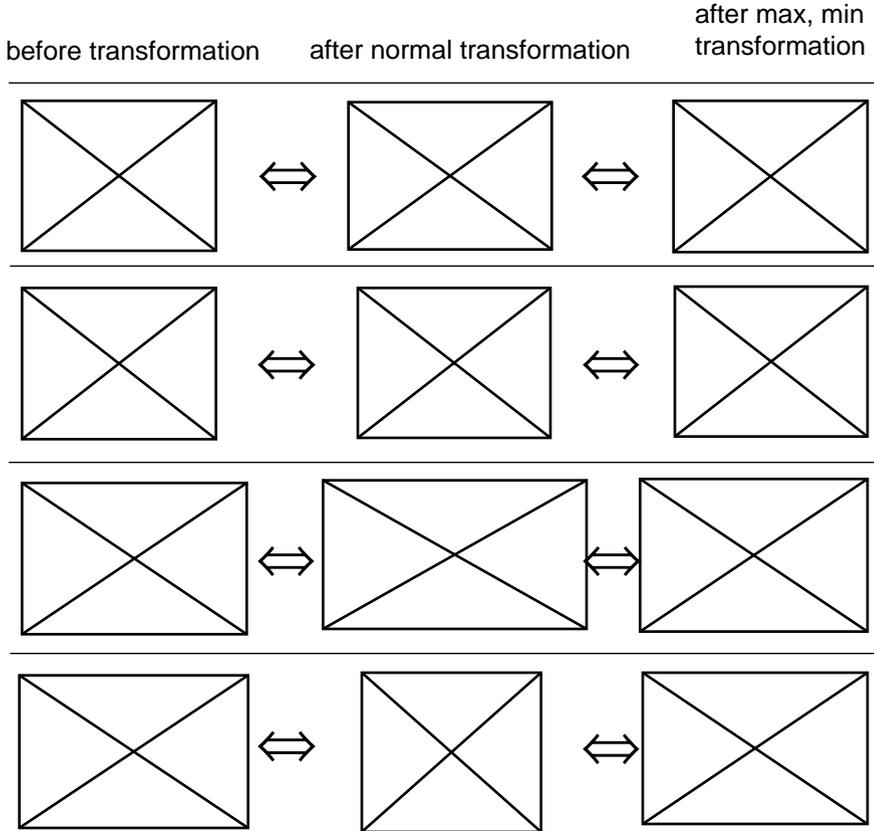


Circuits with the same S-parameters:

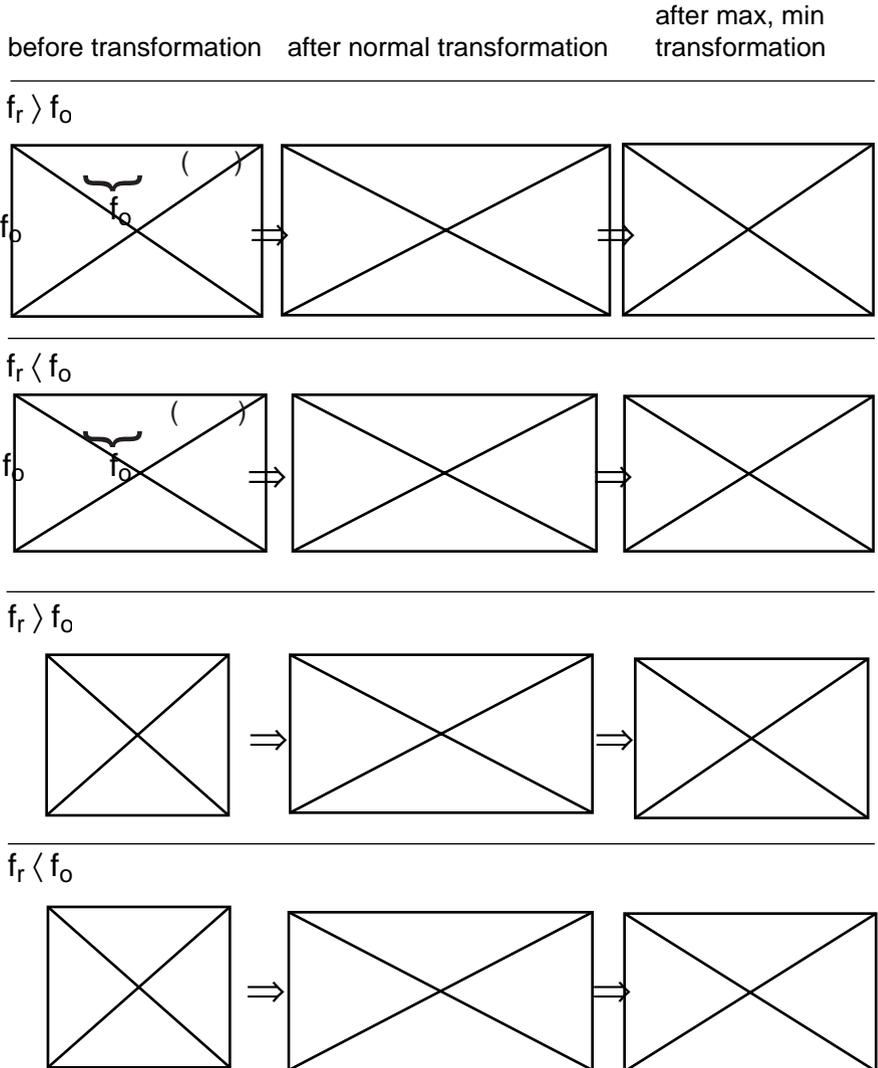


APPENDIX I - NORTON'S TRANSFORMATION

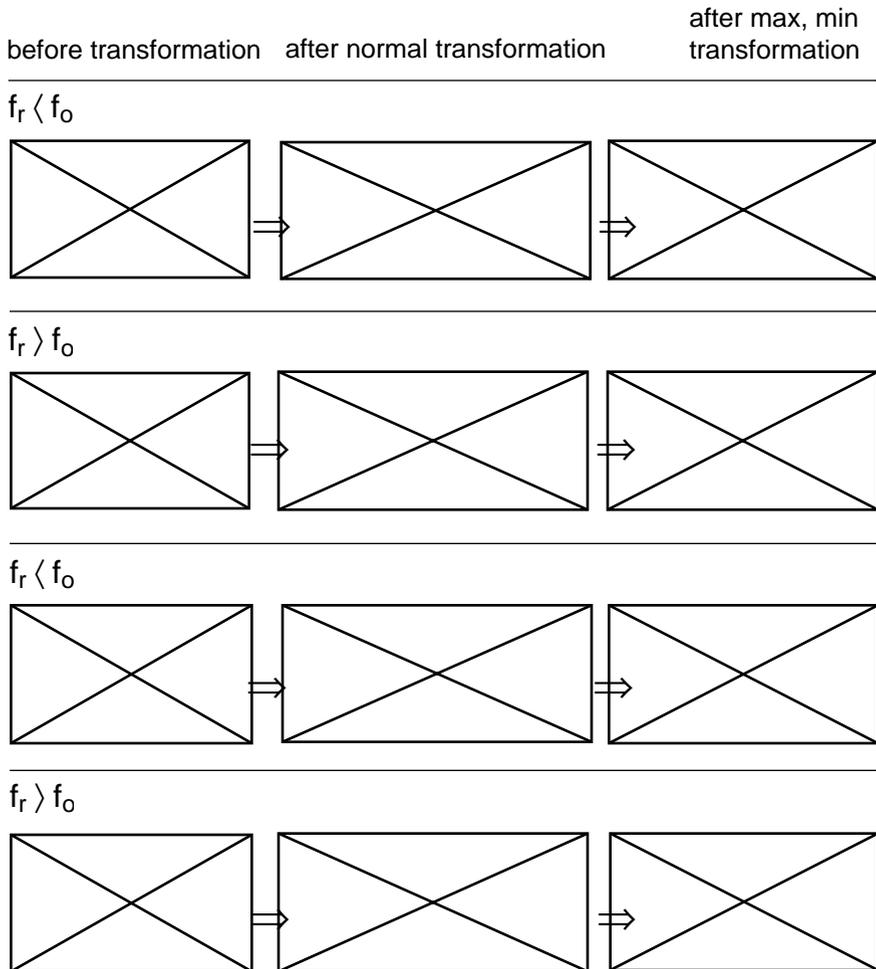
Individual circuit combinations can be converted in TEE or Pi circuits. The possibilities FILTERMASTER uses in each case are shown below. Transformations using the min. or max. factor (extreme transformations) usually use one less component than those using factors between those limits.



Resonance frequencies must be equal before a transformation can be carried out. This is achieved by splitting off either a C or an L.

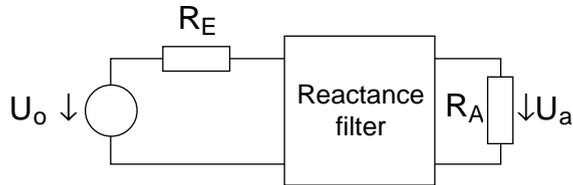


APPENDIX I - NORTON'S TRANSFORMATION



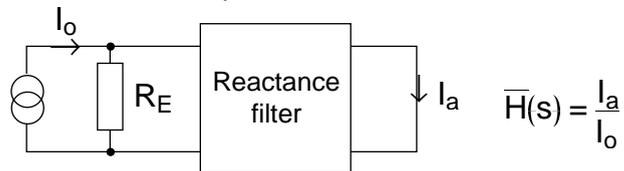
Appendix J - Circuit Analysis

Transmission function: $H(s) = S_{21} = \frac{2U_a}{U_o} \sqrt{\frac{R_E}{R_A}}$

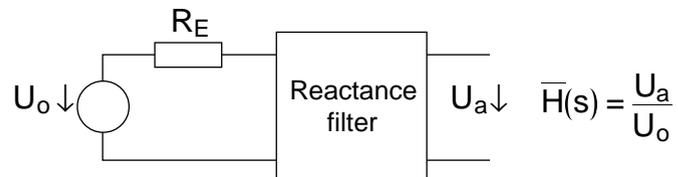


With a single-termination, the current transmission function is determined with a short circuit and the voltage transmission function with no load.

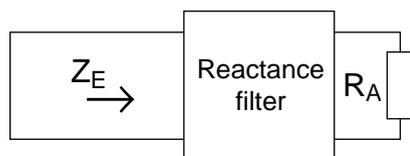
a) Short-circuit at output:



b) No-load at output:

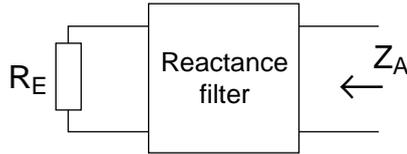


Input impedance:



Output of the filter terminated with R_A

Output impedance:



Input of the filter terminated with R_E

Input reflection coefficient:

$$\rho_E = \frac{Z_E - R_E}{Z_E + R_E} = S_{11}$$

Output reflection coefficient:

$$\rho_A = \frac{Z_A - R_A}{Z_A + R_A} = S_{22}$$

Appendix K - Key Macro Function

FILTERMASTER allows you to save command and data sequences and retrieve them automatically at a later time (creating and recalling macros). This can save a great deal of time in many areas, e.g. in comparative analysis or calculations at the design stage. (Example: selecting the most appropriate approximation for realizing a given specification.) Below are some notes on using macros.

Creating Macros

The first step is to open the macro. This is done via the MACRO menu and Record option. Once you have entered and confirmed the file name, you will be in the program's create mode. Each keystroke will be recorded and saved until you exit this mode using [Ctrl+z] or the program.

In Record mode, you can:

Set a break

If you press [Ctrl + p] while creating a macro and then recall the macro at a later date, the sequence will break at this point, enabling you to change inputs/settings etc. at that point.

Example:

Let's assume you are looking for the best approximation for a given filter. Before running the first approximation type, you open a macro which you can interrupt before you decide on the approximation. Now continue with the macro and complete the calculation sequence. For the next approximation type, you can call up the macro and switch to the new approximation when the break occurs.

Set a text/message output or delay loop

Pressing the key combination [Ctrl+u] makes the RECORD menu appear in the message line. At this point, you can use this to specify whether you want to:

- Display a file
- Issue a message
- Insert a break

at this point when running the macro at a later date.

Note: When inserting delay loops in macros, it may be worth setting the macromode to "timemode" in the macro itself (via the OPTIONS or RECORD menu). Otherwise, the automatic sequence does not run without a break as desired (e.g. if "waitmode" is still set as the result of running a previous macro).

Running Macros

To call a program from DOS;

- At the DOS prompt type the name of the appropriate command file after FM. The .KDO extension is not necessary.
- For example, at the DOS prompt type:

```
fm bandp1 [-]
```

- This will start FILTERMASTER and call the BANDP1.KDO macro.

Restriction: Macros can only be called up in this way if they are saved in the same directory as the FILTERMASTER program and FILTERMASTER is called up from that directory (the system does not look for macro files on a path).

To call a program from within FILTERMASTER;

- Select the Call option from the CONTROL menu and enter the name of the macro file. The macro will start running as soon as you confirm the input field entry.

The following options can be built into macros:

- Preset breaks in the automatic sequence, where you can change inputs, analyze curves or tables and much more. Continue the sequence with [Ctrl+p], but first remember to go back to the same section of the program where you interrupted the sequence.
- Time loops or delay points, during which the screen display is 'frozen' or a message or text appears on the screen.

Changing the Macromode

Pressing the key combination [Ctrl+u] will make the message line display a menu indicating whether you want the automatic sequence to

- Observe the wait times specified in the command file (1 ... Timemode)
- Instead of having a wait time, continue only once the spacebar is pressed (0 ... Waitmode)
- Or whether the command file should be run without wait points or times (2 ... Fastmode).

When creating command files, you can use the key combination [Ctrl+u] to call up the RECORD menu instead.

([Ctrl+U] while recording a macro)

RECORD: 0 .. Filename, 1 .. Message, 2 .. Timedelay, 3 .. Macromode

This is used to:

- Show the contents of a text file
- Display a message
- Bring the macro to a temporary stop
- Alter the macro sequence at this point during macro execution.

The following options are available:

0 .. Filename

This menu option lets you integrate a macro pause to display the contents of a text file. When you activate this option, the program will prompt you for the name of the text file you want the macro to display on the screen. You'll also have to specify for how long you want the text left on the screen.

1 .. Message

When you activate this option, the program will prompt you for the desired message and the time (number of seconds) during which the inserted message is to be displayed.

2 .. Delay

Prompts you for the number of seconds that you want the macro to pause during execution.

3 .. Macromode

Select this command to enter a submenu which offers the following special macro options:

0 .. Waitmode

Instead of stopping for a subsequently specified pause duration, the macro pauses until the spacebar is pressed. Allows the user to determine execution speed.

1 .. Timemode

Macro pauses for the subsequently specified duration.

2 .. Fastmode

The specified pauses are ignored; the macro is executed without a break.

Caution is advised when selecting “Waitmode” or “Fastmode”, as all subsequent pauses will be ignored. If you want to use this for a particular section of your macro, don’t forget to switch back to “Timemode” when defining the macro.

Application:

This is used if you want to invoke another macro while executing one macro, but don’t want the wait loops or wait locations which the second macro contains for this particular application. Before invoking the second macro file, switch to “fastmode” while creating the primary macro, and switch back to “Timemode” after the secondary has been terminated. The macro stops again for all subsequent pauses.

Appendix L - Data Formats

Most files saved in FILTERMASTER are stored in a text format. Because of this, any word processing package can be used to view them. Listed below are the extensions corresponding to text files created by FILTERMASTER.

Default Extension	File Content
.KDO	Macros
.SPZ	Filter specifications (protocol form)
.FDT	Polynomial zeros (protocol form)
.SCH	Circuits (circuit designs with component values, protocol form)
.CIR	Circuit descriptions in a form readable by the IsSPICE circuit analysis program
.CKT	Circuit descriptions in a form readable by the Touchstone analysis program
.LIB	A Collection of filter subcircuits in an IsSPICE format
.PLT	Graphics in HPGL format
.BAK	Backup file, which FILTERMASTER automatically makes if an existing file is overwritten

Some files are designed solely for use within FILTERMASTER and are not in a text format. The extensions for these files are:

.FM	Stored filter characteristics
.SH	Stored circuit description
.GDF	Graphics (diagrams, curves)

Note: The program adds these extensions unless you specify others. If you specify another extension, FILTERMASTER will of course use this when saving the file.

The FM.DEF file is used to store FILTERMASTER preferences. Every time the program is started this file is read for program defaults.

Appendix M - Macro Files (.KDO)

(FILTERMASTER:\Macro:\Record)

Keyboard inputs are saved as ASCII characters, together with remarks to enable them to be edited. Command files can also be created or changed in other programs (word processors). The remarks, which are separated from the commands themselves by spaces, do not need to be input.

Example:

```
f  FILTERMASTER: Filtertype
b  FILTERTYPE: Bandpass
e  APPROXIMATION: Elliptic
q  FILTERTYPE: Quit
s  QUICKFIL: Specification
a  SPECIFICATION: A
100k
#24 Ctrl-X (CuDn)
120k
#24 Ctrl-X (CuDn)
80k
#24 Ctrl-X (CuDn)
150k
#24 Ctrl-X (CuDn)
.2
#24 Ctrl-X (CuDn)
13.467
#24 Ctrl-X (CuDn)
60
#13 [←↵]
i  SPECIFICATION: I
c
#13 [←↵]
q  SPECIFICATION: Quit
a  FILTERMASTER: polynomial_Analysis
p  POLYN_ANALYSIS: Property
p  PROPERTY: Pulse_response
q  PROPERTY: Quit
r  POLYN_ANALYSIS: Representation
v  REPRESENTATION: Voltage[V]
q  REPRESENTATION: Quit
#13 [←↵] POLYN_ANALYSIS: Graph
i  X-Y: optimize
```

Appendix N - Filter Specification Protocol (.SPZ)

(FILTERMASTER:\Specification:\File)

The contents of the SPECIFICATION menu are held in an open text format. For example:

Elliptic (Cauer) - bandpass filter

```

Lower passband limit frequency :      100.000 000 kHz
Upper passband limit frequency :      120.000 000 kHz
Lower stopband limit frequency :       80.000 000 kHz
Upper stopband limit frequency :      150.000 000 kHz

Passband attenuation           :          0.200 000 dB
Return loss                    :           13.47 dB
Stopband attenuation           :          60.17 dB

Degree                         :          8
Case                           :          c
    
```

Appendix O - Polynomial Pole/Zero Protocol (.FDT)

(FILTERMASTER:\Roots:\File)

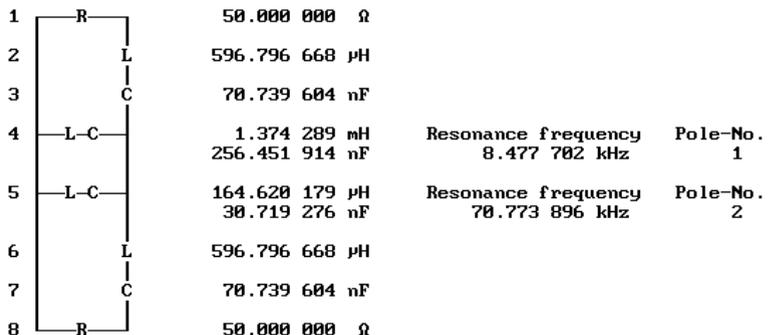
Polynomial poles and zeros are saved in an ASCII text format. Poles are the roots of the denominator of the transfer function, $p(s)$, shown in Appendix D. Zeros are the roots of the numerator of the transfer function.

Appendix P - Circuit Protocol (.SCH)

(FILTERMASTER:\Passive Design:\Output Circuit:\File) or

(FILTERMASTER:\Passive Design:\Manipulation and Analysis:\Output Circuit:\File)

Circuits are saved in an open text format. For example:



Appendix Q - SPICE (.CIR)

(...\Passive Design:\Output Circuit:\Spice) or

(...\Passive Design:\Manipulation and Analysis:\Output Circuit:\Spice)

This format is used to save the filter circuit for use with the IsSPICE circuit analysis program or any other SPICE compatible simulator. Circuits can be saved using standalone (ready to simulate) or subcircuit (IsSPICE Library) formats. Monte Carlo component tolerance syntax can also be activated on any component.

Below is an example of IsSPICE output generated using a standalone netlist format with component tolerance statements set up for a Monte Carlo analysis.

Example:

In the standalone format, a source is added to the input. Its AC value, 1 or 2, will depend on the type of termination. 2 when input and output terminations exist, and 1 for other orientations.

```

* Elliptic (Cauer) - bandpass filter
* -
*           Filter           1991-11-04  10:33:49
*
* Reference Frequency : 50.000 000 kHz
*
L2      2      3      5.968E-04  TOL=1.00%
C3      3      4      7.074E-08  TOL=5.00%
L4      101     0      1.374E-03  TOL=1.00%
C4      4      101     2.565E-07  TOL=5.00%
L5      102     0      1.646E-04  TOL=1.00%
C5      4      102     3.072E-08  TOL=5.00%
L6      4      5      5.968E-04  TOL=1.00%
C7      5      100     7.074E-08  TOL=5.00%
RH7     5      100     1.000E+12
VIN     1      0      AC      2      0
R1      1      2      5.000E+01
R8      100     0      5.000E+01
.AC DEC 20  1.000E+03  1.000E+05
.OPTIONS LIMPTS=10000
.PRINT AC  V(100)  VP(100)
.END

```

Appendix R - Touchstone (.CKT)

(...\Passive Design:\Output Circuit:\Touchstone) or

(...\Passive Design:\Manipulation and Analysis:\Output Circuit:\Touchstone)

This format is used to save the filter circuit for use with the Touchstone circuit analysis program.

Appendix S - Graphics Data (.PLT)

(...\X-Y:\Output Graphic:\File)

This stores graphics displayed on the screen in the X-Y menu in HPGL format under the name entered. This data can be used in DOS to output a diagram to a plotter or to a DTP package.

Appendix T - Default File (FM.DEF)

This file is used to save program parameters (e.g. printer and plotter interface, extensions, etc.). This file is read every time FILTERMASTER is started. Any attribute changes made within FILTERMASTER will be added to this file when FILTERMASTER is exited. These attributes include:

- Graphics attributes (linestyle, color, height, width etc.)
- Default extensions
- Default limits

Example:

REM Last update: 1992-4-12 12:19:07

BEGIN PROGRAMDEFAULTS

```
MOUSETYPE MSBUS
DECIMALSIGN .
GROUPING ON
PRINTINTERFACE LPT1:
PLOTINTERFACE COM1:
SERIALPORT COM1: 9600,N,8,1
SERIALPORT COM2: 9600,N,8,2
END PROGRAMDEFAULTS
```

ProgramDefaults
contains parameters
from the OPTIONS
menu.

BEGIN FILENUMBERS

```
FILENUMBER 1, 1
FILENUMBER 2, 1
FILENUMBER 3, 1
FILENUMBER 4, 1
FILENUMBER 5, 1
FILENUMBER 6, 1
FILENUMBER 7, 1
FILENUMBER 8, 1
FILENUMBER 9, 1
END FILENUMBERS
```

BEGIN GRAPHICDEFAULTS

```
DISPLAYTYPE Autodetect
REM Format for LineAttr: Id,Color,LineStyle,Pen
REM Format for TextAttr: Id,Height,Width,Angle,Color,Pen
TEXTATTR AXISNUMBERX,3.1000,1.1000,0.0000,WHITE,1
TEXTATTR AXISNUMBERY,2.0000,1.7000,90.0000,WHITE,1
TEXTATTR AXISTEXTX,6.0000,2.2000,0.0000,WHITE,1
```

```

TEXTATTR AXISTEXTY,4.0000,3.4000,90.0000,WHITE,1
LINEATTR GRIDPOINT,LIGHTGRAY,DOT,1
LINEATTR GRIDLINE,LIGHTGRAY,DASH,1
LINEATTR GRIDBORDER,WHITE,FULL,1
LINEATTR LOGOLINE,LIGHTCYAN,FULL,1
LINEATTR CURVE1,YELLOW,FULL,1
LINEATTR CURVE2,LIGHTGREEN,FULL,1
LINEATTR CURVE3,LIGHTCYAN,FULL,1
LINEATTR CURVE4,LIGHTBLUE,FULL,1
LINEATTR CURVE5,LIGHTMAGENTA,FULL,1
LINEATTR CURVE6,BLUE,FULL,1
LINEATTR CURVE7,GREEN,FULL,1
LINEATTR CURVE8,LIGHTRED,FULL,1
END GRAPHICDEFAULTS

```

GraphicDefaults
contains
parameters that
cannot be changed
in the program, but
which the user may
want to alter in
special cases.

BEGIN FILTERMASTER

```

IBMPRINTER FALSE
EXTENSION-TOUCHSTONE CKT
EXTENSION-CIRCUIT-PICTURE SCH
EXTENSION-CIRCUIT SH
EXTENSION-ZEROS FDT
EXTENSION-FMINIT FM
EXTENSION-SPEZ SPZ
EXTENSION-PASSIVPARAM PP
EXTENSION-POLYPARAM PN
EXTENSION-GRAFIK GDF
RINIT 50.000000
END FILTERMASTER

```

Some brief notes on the individual entries:

Block/Entry	Equivalent To Program Setting
--------------------	--------------------------------------

REM last update:	Contains details of when FM.DEF was last overwritten or otherwise amended.
------------------	--

PROGRAMDEFAULTS

MOUSETYPE:

NONE	No mouse
MSBUS	MS-bus mouse
MSCOM1	Serial MS mouse to COM1:
MSCOM2	Serial MS mouse to COM2:

APPENDIX T - DEFAULT FILE (FM.DEF)

Block/Entry	Equivalent To Program Setting
DECIMALSIGN	
.	OPTIONS: Decimal_point
,	OPTIONS: Decimal_comma
GROUPING	
OFF	OPTIONS: Grouping_off
ON	OPTIONS: Grouping_on
PRINTINTERFACE	
LPT1(2,3):	Printer interface: LPT1(2,3):
COM1(2):	Printer interface: COM1(2):
PLOTINTERFACE	
LPT1(2,3):	Plotter interface: LPT1(2,3):
COM1(2):	Plotter interface: COM1(2):
SERIALPORT:	Specifies interface parameters for COM1: and COM2:
FILENUMBERS:	Not used in FILTERMASTER (provided only for using the same program library in other programs).

GRAPHICDEFAULTS

The entry in the first line, "DISPLAYTYPE", tells the program which monitor to use. This normally contains the entry "Autodetect". This means that the program automatically detects what graphics card is installed. If it fails to do so, the appropriate monitor data can be entered manually at this point, requiring the program to use the proper resolution.

The "DEF" file can also be used to change line and text attributes, which govern the appearance of lines and text on the screen and when printed/plotted. The following diagram components can be changed: Curve 1 through Curve 8, Logoline, Gridborder, Gridpoint, AxistextX, Axistexty, AxisnumberX, and AxisNumberY.

Id is the identity of the attribute and must NOT be changed.

Id is the identity of the attribute and must NOT be altered.

Listed below are some hints for possible settings:

LINEATTR Id,Color,LineStyle,Pen

Id can be:

CURVE1 to CURVE8, GRIDBORDER, GRIDLINE, GRIDPOINT, LOGOLINE

“Color” can be set to:

BLACK, BLUE, GREEN, CYAN, RED, MAGENTA, BROWN, LIGHTGRAY, DARKGRAY, LIGHTBLUE, LIGHTGREEN, LIGHTCYAN, LIGHTRED, LIGHTMAGENTA, YELLOW, WHITE

“LineStyle” can be set to:

FULL,DOT,DASH,DASHDOT

“Pen (number of pen in plotter output) can be set to: 1 to 16

TEXTATTR Id,High,Width,Angle,Color

Id can be:

AXISTEXTX,AXISTEXTY,AXISNUMBERX,AXISNUMBERY

“Height” and “width” are stated (approximately) as a percentage of the screen width/height. We recommend that you try this out for yourself until you find the settings you want.

The “angle” is reckoned counter-clockwise (0 degrees is horizontal). “Color” is like LINEATTR.

Practical Example:

If you would like to double the font size in the graphic output;

- Change the lines
 “TEXTATTR AXISTEXTY 4.0 3.4 90.0 WHITE, 13”
 “TEXTATTR AXISTEXTX 6.0 2.2 0.0 WHITE, 14”

APPENDIX T - DEFAULT FILE (FM.DEF)

RASTERIZER

In this section FILTERMASTER PROFESSIONAL saves all printer parameters set in the PRINTER OPTIONS menu (for the output of graphics). For example:

```
BEGIN RASTERIZER
DRIVER  HP LaserJet
RESOLUTION 2
PAPER  198,270
COPIES  1
INVERSE FALSE
ROTATE  -90
SCALE  0.500,0.500
OFFSET  0.000,20.000
TEMPDIR  A:\
FILEOUT FALSE
PEN  1,4,9
PEN  2,4,8
.
.
PEN  19,1,9
PEN  20,1,9
END RASTERIZER
```

FILTERMASTER

In this section you can change the extensions which FILTERMASTER PROFESSIONAL, automatically adds to a filename if no extension is specified. Also, it is possible to enter an initialization resistance for the passive design part. For example (with default values):

```
BEGIN FILTERMASTER
EXTENSION-SPICE CIR
EXTENSION-TOUCHSTONE CKT
EXTENSION-CIRCUIT-PICTURE SCH
EXTENSION-CIRCUIT SH
EXTENSION-ZEROS FDT
EXTENSION-AFIL QFT
EXTENSION-QFINIT QF
EXTENSION-SPEZ SPZ
EXTENSION-PASSIVPARAM PP
EXTENSION-POLYPARAM PN
EXTENSION-GRAFIK GDF
RINIT 50.000000
END FILTERMASTER
```

BTICFILT

This part contains constants which control the input limits for Butterworth, Chebyshev, inverse Chebyshev and Elliptic filter calculations. For example (with default values):

```
BEGIN BTICFILT
  FMIN 1.000000m
  FMAX 100.000000G
  KPMIN 0.001000
  KPMAX 1.000000
  DSMIN 5.000000
  DSMAX 200.000000
  KFMIN 0.010000
  KFMAX 0.999900.K.kfmax
  QMAX 1000.000000
END BTICFILT
```

Meaning:

FMIN Lowest edge frequency to be entered. This is the lower limit for passband edge frequencies and stopband edge frequencies.

FMAX Maximum edge frequency as in FMIN.

The calculated values can either exceed or fall below the values mentioned above. However, it is not possible to enter values outside of these limits. This also applies to the entry of the bandwidth or relative bandwidth if the results are to be "re-transformed" to frequency values.

KPMIN Minimum value of the factor k_p
Typical value: 0.001

The factor k_p depends on the passband loss, return loss, the reflection factor, and the proposed resistance ratio. A value of 0.001 is equivalent to a maximum return loss of 60 dB and a minimum reflection factor of 0.1%. The minimum must be higher than zero.

APPENDIX T - DEFAULT FILE (FM.DEF)

KPMAX Maximum value of the factor kp
Typical value 1.000

The maximum must be less than or equal 1, so that the 3 dB edge frequencies are calculated correctly. If you drop the 3 dB limits, you can increase the factor as much you like. The value $KPMAX = 1$ is equivalent to a maximum passband loss of 3.0103 dB.

DSMIN Minimum stopband loss

DSMAX Maximum stopband loss

When calculating stopband losses it is possible for your values to exceed or fall below the above limits. However, it is not possible to make entries outside of these limits.

KFMIN Minimum frequency factor
($0 < kfmin < kfmax < 1$)

This factor determines the minimum ratio between the passband edge frequency and the stopband edge frequency in a lowpass. In the other types of filters the factor refers to the transformed lowpass filter.

KFMAX Maximum frequency factor
($0 < kfmin < kfmax < 1$)
The value is slightly less than 1 and should not be selected too high to avoid "runtime errors".

This factor determines the maximum ratio between the passband edge frequency and the stopband edge frequency in a lowpass. In the other types of filters, the factor refers to the transformed lowpass filter.

QMAX Determines the maximum operating quality for the bandpass and bandstop.
 $Q = \sqrt{fd_0 * fd_u} / (fd_0 - fd_u)$

ERMFFILT

This part contains constants which control the entry limits for equal ripple and maximally flat filters calculations.

Example:

```
BEGIN ERMFFILT
AUSG3DB TRUE
FMIN 1.000000m
FMAX 100.000000G
KPMIN 0.001000
KPMAX 1.000000
DSMAX 200.000000
KFMIN 0.000010
KFMAX 0.999900
PAMAX 1.000000
WIDMAX 10.000000
MINOPT 0.010000
END ERMFFILT
```

AUSG3dB (TRUE/FALSE) The automatic calculation of the 3 dB edge frequency can be switched off. The 3 dB edge frequency is then only calculated in combination with the filter quality. This parameter can always be changed.

FMIN Minimum frequency of the passband edges

FMAX Maximum frequency of the passband edges

KPMIN Minimum value of the factor k_p

The factor k_p depends on the passband loss, return loss, the reflection factor and the proposed resistance ratio. A value of 0.001 is equivalent to a maximum return loss of 60 dB and a minimum reflection factor of 0.1 %. The minimum must be higher than zero.

KPMAX Maximum value of the factor k_p

This parameter also influences the calculation precision when determining the extreme values of the loss function in the stopband. The precision lies around 1/4 of MINOPT. If MINOPT is reduced considerably, the calculating time increases during the optimization.

BESSELFILTER

This section contains constants controlling the entry limits for Bessel lowpass filter calculations.

Example:

```
BEGIN BESSELFILTER
  FMIN 1.000000m
  FMAX 100.000000G
  DRMAX 20.000000
  DDMAX 10.000000
END BESSELFILTER
```

Meaning:

FMIN	Minimum passband edge frequency
FMAX	Maximum passband edge frequency

Calculated frequencies might exceed or fall below these values. However, it is not possible to make entries outside of these limits.

DRMAX	Maximum return loss
DDMAX	Maximum passband loss

Appendix U - Frequently Asked Questions

Up to what frequency range can FILTERMASTER PROFESSIONAL be used?

Estimates: no practical upper limit; for circuit design, only as far as designs are feasible with discrete components (L's and C's).

Does the circuit synthesis consider parasitic components?

No. Synthesis assumes that components are ideal. In analysis, the quality of inductors and capacitors can be taken into account when assessing the expected filter characteristics.

What language is the program written in?

Mostly Turbo Pascal with some parts in assembler.

Does the program support the numeric coprocessor?

Partially. But not for calculations since the coprocessor is not accurate enough. This is why we have written our own mathematical routines in the assembler. The coprocessor is used mainly for graphics.

Appendix V - Literature

[1] Gabor C. Temes and Sanjit K. Mitra, "Modern Filter Theory and Design", ISBN 0-471-85130-2, John Wiley & Sons, New York

[2] W. Cauer, "Theorie der linearen Wechselstromschaltungen" Akademie - Verlagsgesellschaft, Berlin, Ger., 2nd ed. 1954

[3] R. Saal and E. Ulbrich, "On the design of filters by synthesis" IRE Trans. Circuit Theory, vol. CT-5, pp 284-327, December 1958

[4] R. Saal und W. Entenmann, "Handbook of Filter Design" Elitera Verlag, Berlin, 1979

[5] H.J. Orchard and G.C. Temes, "Filter design using transformed variables", IEEE Trans. Circuit Theory, vol CT-15, pp. 385-408, December 1968

[6] Jozef k. Skwirzynski, "On Synthesis of filters", IEEE Trans. Circuit Theory, vol CT-18, pp. 152-163, January 1971

Index

- ** 33,
- *INCLUDE statement 139,
- .AC analysis 75, 135,
 - value 184,
- .CIR extension 73, 75, 184,
- .CKT extension 74, 76, 185,
- .FDT extension 183,
- .KDO extension 123, 178, 182,
- .LIB extension 75, 138,
- .PLT extension 118, 185,
- .PRINT 75,
- .SCH extension 73, 183,
- .SH extension 79,
- .SPZ extension 182,
- 3dB edge frequency 43, 49,
- ? key 33, 34,

A

- a, atto 32,
- AC value 184,
- accuracy 164,
 - menu 78,
 - Accuracy of the refinement 79,
 - Passive Design menu 72,
- Act(ual) Input Circuit menu 76,
- active filters 147,
 - design 43, 49,
- analysis 97,
 - summary 14,
- analyzing circuit 26,
- applications summary 14,
- approximations
 - comparison 141,
 - summary 13,
- arrow keys 8, 30,

- Auto X(Y)-Scale menu 116,
- axis parameters 104,

B

- backspace 30,
- Bandpass filters 57,
 - Elliptic example 105,
 - example 17, 66, 86,
 - parametric vs. conventional 161,
 - Stopband Specification menu 58,
 - variable pole pairs 166,
- Bandstop filters 163,
 - Stopband Specification menu 58,
 - variable pole pairs 166,
- bandwidthrepreS 41,
- baud 38,
- Bessel filter 41,
 - approximation features 145,
 - limits 195,
- building a circuit 95, 160,
 - example 128,
- Butterworth filter,
 - approximation features 143,
 - case 151,

C

- calculating component values 164,
- calculation speed 164,
 - 3dB limits 49,
- Case 42, 43, 147, 149, 150,
- Cauer filter example 17,

- changing
 - component values 59, 81,
 - Manipulation and Analysis menu 80,
 - fields 60,
 - macro mode 124,
 - stopband settings 59,
- Change Values menu 81,
- characteristic function 168,
- Chebyshev
 - aproximation features 143,
 - case 151,
 - example 86,
- circuit analysis 26, 175,
 - Manipulation and Analysis menu 81,
 - menu 26, 98,
 - properties 101,
- circuit data format 76,
- circuit design 71,
 - file 181, 183,
- circuit synthesis 25,
- Coarse
 - X-Y Marker menu 120,
- Combine two-ports
 - Manipulation and Analysis menu 81,
- Comment 43, 50,
 - graph 104,
- Component No.
 - Norton's Transformation menu 83,
- component
 - quality factors 100,
 - tolerances 75, 133,
 - value
 - changing 81,
 - calculating 164,
 - display 25,
- Computer circuit
 - Passive Design menu 72,
- connections 137,
- contents help menu 34,
- conventional filters 47, 49,
 - Bandpass 157,
- Copies
 - Printer Options menu 119,
- coprocessor 196,
 - accuracy 78,
 - calculation speed 49,
- copy protection 9,
- creating macros 176,
- ctrl+p 131, 177, 178,
- ctrl+z 130, 176,

- cursor 114,
 - keys 8,
 - moving 121,
 - X-Y Marker menu 120,

D

- data bits 38,
- data, entering 31,
- Data_points
 - X-Y Parameters menu 115,
- decimal places, significant 78,
- decimal-sign
 - Options menu 37,
- Decimals
 - X(Y)-Scale menu 117,
- Delete
 - Representation menu 102,
 - Stopband Specification menu 59,
- Delete(Data)
 - Transfer menu 103,
- Delete_all
 - Graph_Load menu 104,
- Delete_last
 - Graph_Load menu 104,
- deleting
 - a graph 102, 110,
 - a graph field 99,
- designing a circuit 25,
- determining variable pole pairs 165,
- dialogs 31,
- Digits
 - Spice menu 75,
 - Touchstone menu 76,
- displays monochrome 10,
- DISPLAYTYPE 11,
- Divisions
 - X(Y)-Scale menu 116,
- dongle 9,
- DOS Path 10,
- doubly terminated 77,
- drive, path
 - Options menu 37,
- Dual Circuit menu 81,
 - Manipulation and Analysis menu 80,
 - Passive Design menu 72,
- dual circuits 169,

E

Elliptic (cauer) filters
 approximation features 145,
 Bandpass example 17,
 case 151,
 Lowpass
 case a 147, 150,
 case b 149,
 Engineer, units
 X(Y)-Scale menu 117,
 entering data 31,
 Equal Ripple Approximation
 case 151,
 features 141,
 resistance ratio 151,
 error messages 74,
 Esc key 29,
 Examples
 Lowpass filter 61,
 Bandpass filter 17, 66, 86,
 building a circuit 128,
 Elliptic Bandpass 105,
 generating an IsSpice netlist 134,
 IsSpice subcircuit netlist 136,
 keystroke macros 124,
 parameteric Bandpass filter 124,
 Exchange Two-Ports menu 85,
 Manipulation and Analysis menu 80,
 Example1.fm 106,
 extensions 32, 181,

F

f, femto 32,
 F1, selecting a file 33,
 Factor
 Norton's Transformation menu 83,
 fastmode 124, 179,
 fBegin fEnd Points Lin Dec
 Spice menu 75,
 fBegin fEnd Step
 Spice menu 135,
 Touchstone menu 76,
 fDefault Spice menu 75, Spice menu 135,
 Touchstone menu 76,
 Feldtkeller equation 79, 169,
 fEnd
 Spice menu 135,

fields 31,
 fiLe 44, 50,
 file formats 181,
 File Output
 Circuit menu 73,
 Graphic menu 118,
 filename 32,
 extensions 181, 187, 190,
 wildcards 33,
 filter
 characteristics file 181,
 degree 42, 48,
 limitations 191,
 quality 43, 49,
 specification file 181, 182,
 types summary 13,
 FILTER.LIB file 139,
 FilterMaster
 defaults Fm.Def 186, 187,
 features 13,
 installation 9,
 language 196,
 proposal
 Accuracy menu 79,
 quitting 12,
 saving a filter 27,
 starting 18,
 filtertype example 19,
 Filtertype menu 39,
 Fine
 X-Y Marker menu 121,
 fixed transmission zeros 47, 48,
 Fixpoint
 X(Y)-Scale menu 117,
 fiXtrans.zeros 50,
 Fm.Def 181,
 calculation speed 49,
 file contents 186,
 graph label 115,
 graphics 11,
 input limits 191,
 KFMAX 46,
 fo=reference frequency
 Format menu 116,
 Format
 Printer Options menu 119,
 format(Number)
 X(Y)-Scale menu 116,

frequency
 limitations 191, 193,
 range 196,
freqUencyrepres 41,
From
 X(Y)-Scale menu 116,

G

g, giga 32,
general amplitude approximations 44, 141,
 advantages 146,
 summary 13,
Graph
 Circuit Analysis menu 98,
 menu 112,
graph
 cursor 121,
 deleting 102, 110,
 displaying 107,
 elements 104,
 grid 116,
 merging 105,
 optimizing limits 109, 121,
 scaling 99, 114,
 selection 101,
 switching 121,
 y-axis scaling 116,
 zooming 113,
graphics
 card 11,
 display
 Fm.Def 186, 187, 188,
 file 185,
 output 36,
 problems 10, 11
Graph_Load menu 103,
grid divisions 116,
group delay 41, 145,
 example 108,
grouping
 Options menu 38,

H

hard key 9,
hardware requirements 9,
help
 index 21,

 menu 34,
Highpass filters
 Stopband Specification menu 58,
 variable pole pairs 165,
Hold
 Circuit Analysis menu 98,
HPGL
 file 181, 185,
 format 37, 118,

I

ICAPS program 133,
impedance analysis 101,
impulse strength 102,
Ind, Cap
 ircuit Analysis menu 100,
inductances, equal 89,
Init
 Output menu 35,
Initialization of variable pole pairs 166,
input and output resistances 42,
Input Circuit menu 76,
 example 95,
Input circuits
 Passive Design menu 72,
input impedance 175,
 conventional Bandpass 157,
 parametric Bandpass 158,
input reflection coefficient 176,
installing FilterMaster 9,
interface plotter 35,
 Options menu 37,
interface printer 35,
 Options menu 37,
Inverse Chebychev
 approximation features 144,
 case 151,
Invert
 Printer Options menu 119,
invoking key macros 123,
IsSpice 16, 72, 74, 80,
 .AC statement 135,
 file 181, 184,
 interface 133,
 netlist
 example 134,
 output 73,
 significant digits 136,

subcircuit
 connections 137,
 example 136,
 Iteration 54,
K
 k, kilo 32,
 keystroke macros 121,
 KFMAX 46,
L
 laptops 10,
 Lin
 X(Y)-Scale menu 116,
 Spice menu 135,
 Circuit Analysis menu 100,
 Load circuit
 Manipulation and Analysis menu 79,
 Graph_Load menu 104,
 Load(Data)
 Transfer menu 103,
 Load(Parameters)
 Transfer menu 103,
 Load_Graph menu 103,
 Log
 X(Y)-Scale menu 116,
 loss reserve 69,
 optimization 57,
 loss-free elements 100,
 lossy elements 100,
 Lower passband edge frequency 40, 45,
 Lower stopband limit frequency 41,
 Lowpass filter
 example 61,
 Stopband Specification menu 58,
 variable pole pairs 165,
M
 m, milli 32,
 Macros 121, 176,
 creating 176,
 ctrl+p 131,
 ctrl+z 130,
 example 124,
 file 182,
 key combinations 122,

 message 122,
 mode 124, 179,
 running 178,
 saving 121,
 setting an interruption 122, 177,
 setting a text/message 177,
 starting 123, 126,
 wait loop 122,
 macromode changing 179,
 Magnitude [dB]
 Representation menu 102,
 Manipulation and Analysis menu 79,
 Passive Design menu 72,
 manual instructions 8,
 Marker
 X-Y menu 114,
 max 32,
 Max.factor
 Norton's Transformation menu 82,
 maximally flat approximation 66,
 features 142,
 maximum
 degree 48,
 frequency 191, 193,
 menu system, selecting 29,
 Merge
 Graph_Load menu 104,
 micro 32,
 min 32,
 Min.factor
 Norton's Transformation menu 82,
 minimum frequency 191, 193,
 Model
 Printer Options menu 118,
 monochrome display 10,
 Monte Carlo analysis 75, 133, 139,
 tolerances 140,
 mouse
 requirements 9,
 usage 17, 30,
 mutual inductances 42, 73, 147,
N
 n, nano 32,
 Name
 Touchstone menu 76,
 negative component values 74, 83,
 netlists formats 133,

- New 43,50,
 - Stopband Specification menu 59,
- next_page
 - Help menu 34,
- nn% 32,
- Norton's Transformation 85,
 - definition 170,
 - example 85, 129,
 - Manipulation and Analysis menu 80,
 - menu 82, 83,
 - Next component 82,
 - Nominal component 84,
 - Nominal factor 82,
 - Nominal value 84,
 - Previous component 82,
- notation 8, 29,

O

- on-line help 29,
 - using 20,
- open termination 77,
- optimization 43,
 - limits 54,
 - menu 50, 51,
 - example 68, 69,
- optimize
 - X-Y menu 114,
 - X-Y Parameters menu 115,
- optimize(Curve)
 - X-Y Marker menu 121,
- options 37,
 - printing 119,
- Options menu 37,
- output 34,
- Output circuit
 - Manipulation and Analysis menu 79,
 - menu 73,
 - Passive Design menu 72,
- Output Graphic menu 114, 117,
- output impedance 176,
 - conventional Bandpass 157,
 - parametric Bandpass 158,
- output reflection coefficient 176,
- Output X-Y menu 114,
- outputting a message 122,

P

- p, pico 32,
- PAMAX 46,
- Parameter 46,
- Parameters
 - X-Y menu 114,
- parametric
 - Bandpass
 - advantages 160,
 - disadvantages 160,
 - filters 158,
 - example 124,
 - parameter value 162,
 - parameter value vs. impedance 159,
 - bandpasses 46,
 - filters transmission zeros 162, 163,
 - parasitic components 196,
 - parity 38,
- Passband
 - bandedge loss 41, 47,
 - bandedge return loss 42, 47,
 - reflection factor 42, 47,
- Passive Design menu 72,
- passive filter design 43, 49,
- path 10,
 - filename 32,
- Pens
 - Printer Options menu 119,
- Pi-to-Tee Conversion
 - example 91,
 - Manipulation and Analysis menu 80,
 - menu 84,
- Plotter
 - file 181,
 - Output Graphic menu 118,
 - pens 119,
 - requirements 9,
- pOints
 - Circuit Analysis menu 100,
 - Spice menu 135,
- poles 54,
 - changing 53,
 - optimization 54,
 - viewing and editing 53,
- Polynomial Analysis menu 101,
- polynomial
 - analysis properties 101,
 - e(s) 167,

- p(s) 167,
- pole/zero file 183,
- roots 71,
- zeros file 181,
- analysis only 102,
- postScript 35,
- PreSpice 138,
- Library file 184,
- User's guide 140,
- previous_page
 - Help menu 34,
- Printer 44, 50,
- Options menu 118,
- Output
 - Circuit menu 73,
 - Graphic menu 118,
 - setup Options menu 38,
- printerOptions
 - Output Graphic menu 118,
- printing 118,
- graphics 36,
- text 34,
- program
 - limitations 191,
 - reset 18,
 - setup 36,
 - structure summary 15,
- Property
 - Circuit Analysis menu 98,
 - menu 101,
- pulse response example 108,

Q

- Q, quality factor 136,
- quadripoles, combining 77,
- quality factor 100, 136,
- adding 137,
- quality L-qual C-qual
 - Spice menu 75,
- quitting 12, 29,

R

- reference resistance 169,
- reflection coefficient 168,
- reflection factors 101,
- reL.bandwidthrepres 41,

- Representation
 - Circuit Analysis menu 99,
 - menu 101,
- Req(uiired)-req.
 - Input Circuit menu 76,
- Reset(Parameters)
 - Transfer menu 103,
- resetting the program 18,
- resistance 42, 77,
- limitation 157,
- ratio 48, 147,
- definition 155,
- example 155, 156,
- equals 1 153,
- proposal 152, 154,
- reference 169,
- Resolution
 - Printer Options menu 119,
- resume
 - Help menu 34,
- return loss 42,
- Reverse circuit
 - Manipulation and Analysis menu 80,
- root output 167,
- Rotate
 - Printer Options menu 119,
- running macros 178,

S

- s-parameters 167,
- Save circuit
 - Manipulation and Analysis menu 79,
- Save
 - Spice menu 74,
 - Touchstone menu 76,
- Save(Data)
 - Transfer menu 103,
- Save(Parameters)
 - Transfer menu 103,
- saving
 - a filter 27,
 - macros 121,
- scaling 32,
- axis 114,
- optimization 121,
- units 22,
- schematic entry interface 139,

- Scientific
 - X(Y)-Scale menu 117,
- screen elements 189,
- selecting
 - a file 33,
 - a graph 101,
 - menu options 29,
- Selection(loaded_graph)
 - Graph_Load menu 105,
- Selection(merged_graph)
 - Graph_Load menu 105,
- serial ports 38,
- setting an interruption 122,
- short-circuit termination 77,
- significant digits, IsSpice 136,
- Size
 - Printer Options menu 119,
- spacebar 30,
- Specification menu 39, 45,
 - example 20,
 - resistance ratio 155,
- SPICE 72,
 - file 184,
 - menu 74,
 - model library file 138, 139,
 - netlist 133,
 - Output Circuit menu 73,
- SpiceNet 16,
 - interface 133, 139,
- Split Two-Ports
 - Manipulation and Analysis menu 80,
 - menu 85,
- Standalone
 - Spice menu 74,
- standard approximations 40,
 - features 143,
 - terminating resistance ratio 147,
- starting
 - a macro 123, 126,
 - FilterMaster 18,
- statistical analysis 133,
- step strength 102,
- stop bits 38,
- Stopband
 - loss 42,
 - range, adding 59,
 - settings changing 59,
 - Specification menu 51, 58,
 - example 67,
- Stopbandopt 50,

- subcircuit
 - netlists 136,
 - Spice menu 75,
 - file 181,
- symmetrical bandstop filters 48,

T

- t,tera 32,
- Technical
 - X(Y)-Scale menu 117,
- temperature analysis 133,
- terminating resistance 148,
 - example 130, 155, 156
 - limitations 157,
 - Passive Design menu 72,
 - ratio 147,
- Termination menu 77,
- text output 34,
- Text
 - X-Y Parameters menu 115,
- time domain analysis 101, 102, 133,
- timemode 124, 179,
- To
 - X(Y)-Scale menu 116,
- Tol R-tol L-tol C-tol
 - Spice menu 75,
- tolerance scheme 50,
 - displaying 107,
 - entry 51,
 - graphing 102,
 - limits 54,
 - optimization 54,
- tolerances 75,
 - component 133,
 - Monte Carlo 140,
- Touchstone 16,
 - file 185,
 - menu 75,
 - Output Circuit menu 74,
- to_Printer/to_File
 - Printer Options menu 118,
- Transfer
 - Circuit Analysis menu 99,
 - menu 102,
- transformation factor 83,
- transm.zeros 47,

transmission
 function 175,
 zeros 60,
 Bandpass determining 161,
 variable 54,
 Transmissionzero Input menu 60,
 example 68,
 two-port elements 160,
 typefaces 8,

U

u, micro 32,
 units 22, 32, 116,
 graph 104,
 Upper passband edge frequency 41, 45,
 Upper stopband limit frequency 41,
 user defined circuits 160,

V

Var.transm.zero pairs 48,
 variable
 pole pairs
 determining 165,
 Initialization of 53, 166,
 optimization 54,
 transmission zeros 54, 57,
 value 43,

W

wait loop 122,
 waitmode 124, 179,
 waveform cursor 120,
 switching 121,
 Window
 X-Y Parameters menu 115,
 X-Y menu 113,
 without_spec 102,
 with_spec 102,
 X(Y)-Scale menu 116,
 X-from
 Circuit Analysis menu 100,
 X-Scale
 menu 115,
 X-Y Parameters menu 115,
 X-Y Marker menu 114, 120,
 X-Y menu 113,

X-Y Parameters menu 115,
 X-Y Text menu 115,
 xDefault
 Circuit Analysis menu 99,

Y

Y(X)-Scale
 X(Y)-Scale menu 117,
 y-axis scaling 116,
 Y-from
 Circuit Analysis menu 100,
 Y-Scale
 X-Y Parameters menu 115,
 Y-to
 Circuit Analysis menu 100,
 yDefault
 Circuit Analysis menu 100,

Z

zero output 168,
 zooming in on a graph 113,
 ZoomOut
 X-Y menu 114,

