

## Designing a Butterworth Low Pass Filter

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FAISYN enables RF and Microwave design engineers to quickly synthesize and simulate lumped element filters, diplexers and multiplexers.

In this example, a Butterworth low pass filter will be designed to illustrate the main features of the FAISYN filter synthesis program. The discussion will include an overview of the filter synthesis process as well as the results of a MMICAD simulation.

### Getting Started

FAISYN is a fully menu driven program that prompts the designer for all information in a simple and straight forward manner.

You can start the program by typing FAISYN while in the MMICAD sub-directory or by accessing it through the LINKS menu in MMICAD.

### Design Procedure

All the filters synthesized by FAISYN are based on normalized low pass (NLP) prototype circuits. FAISYN can automatically calculate the NLP element values for the Butterworth or Chebyshev filter responses. FAISYN also allows for direct entry of NLP values. This enables the user to design filters with a more specialized response.

Once the normalized low pass circuit is defined, the user instructs FAISYN to transform the circuit into the Lowpass, Highpass or Bandpass domains. During each step of the synthesis process FAISYN connects up the circuit and gives the user an opportunity to create simulation files for the MMICAD or SPICE circuit simulators.

### Circuit Specification

In this example a low pass Butterworth filter is designed to the following specification.

Source resistance = 50 Ohms  
 Load resistance = 50 Ohms  
 3dB frequency = 100 MHz  
 Passband Response = Butterworth  
 Number of poles, N=4

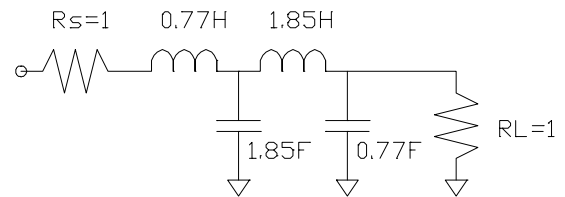
### Filter Synthesis using FAISYN

As mentioned above, the first circuit FAISYN will synthesize is the normalized lowpass prototype (NLP) filter.

To do this, FAISYN will prompt the user for the source and load resistor values, the filter order N and the response type.

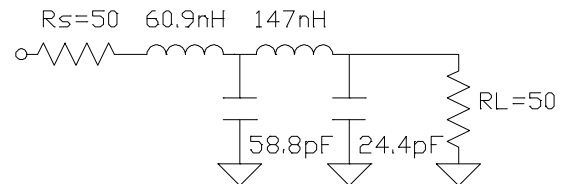
FAISYN will also prompt the designer for preferences in the filter circuit topology. When the specified source and load resistances are equal as in this example, the designer may choose the type of leading element in the normalized low pass circuit.

In this case, the leading element is specified as an inductor. The prototype circuit is shown in Figure 1.



**Figure 1** The Butterworth normalized low pass prototype filter, N=4,  $\omega_c=1$  rad/sec, the leading element is specified as an inductor.

The NLP prototype circuit is now transformed into the low pass domain. FAISYN will prompt the user for the 3dB cutoff frequency and then synthesize the final low pass filter network shown in Figure 2.



**Figure 2** The low pass Butterworth filter synthesized by FAISYN.

## MMICAD Simulation

The MMICAD circuit file written by FAISYN is shown in Figure 3. Note that all the pertinent design information has been documented in the comment block at the top of the circuit file. Furthermore, two output frames (graphs) are specified in order to clearly show both the in band response and the out of band rejection. The circuit file is complete and ready for immediate MMICAD simulation, the results of which are shown in Figures 4 and 5.

```

!== FILTER SYNTHESIS PROGRAM V1.0 ==
!
!
! Butterworth Low Pass Filter
! N= 4
! 3 dB cut off frequency= 100.0000 MHZ
! FILENAME= LOWPASS.CKT
!
!====(c) 1992: OPTOTEK / K.FAISON =====

GLOBAL
DIM  FREQ=1E6 CAP=1E-12 IND=1E-9

VAR
RSOURCE= 50
RLOAD= 50

CKT
IND 1 2 L=60.9060
CAP 2 0 C=58.8160
IND 2 3 L=147.0400
CAP 3 0 C=24.3624
DEF2P 1 3 FILTER

TERM
FILTER RSOURCE RLOAD

FREQ
SWEEP 10.0000 250.0000 1.6000

OUT
FILTER DB[S21] TRANS1
FILTER DB[S11] TRANS1 R
FILTER DB[S21] TRANS2
FILTER DB[S11] TRANS2 R
FILTER S11 SMITH
FILTER SPAR SPAR

GRID
RANGE 10.0000 250.0000 48.0000
TRANS1 -50 0 10 R -60 0
RANGE 10.0000 100.0000 18.0000
TRANS2 -5 0 0.5 R -60 0

LABEL
    
```

Figure 3 The MMICAD circuit file

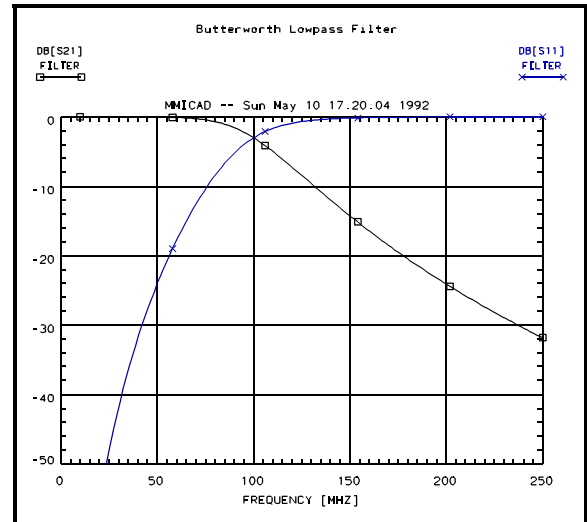


Figure 4 The frequency response of the Butterworth low pass filter.

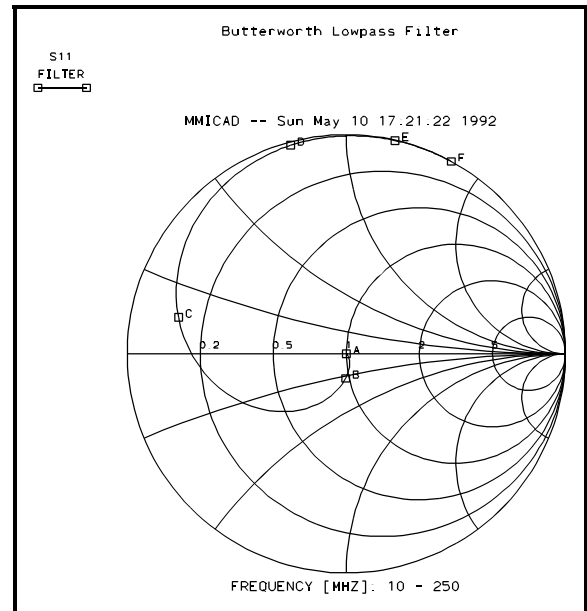


Figure 5 Smith Chart plot of input reflection coefficient.