Magnetically Coupled Chebychev BPF

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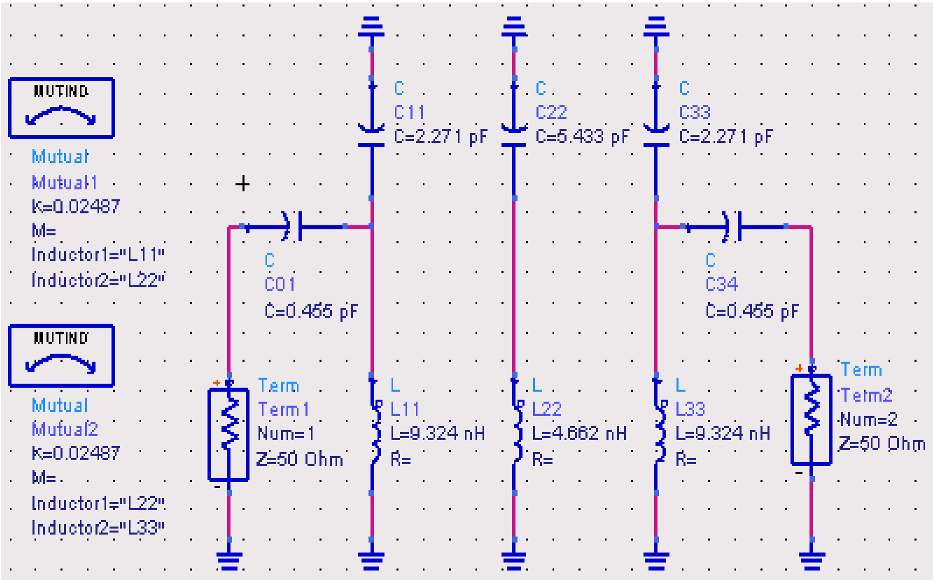


This sheet is used to design a **microwave magnetically coupled BPF**. The maths for this filter is derived from equations in "Theory & Design of Microwave Filters", Ian Hunter, IEE Press.

Main user input area:

$\mu m := 10^{-6} \cdot m$ $\qquad nH := 10^{-9} \cdot henry$

$L_{ar\_db} := 10$ Passband return loss in dB

$N := 3$ Order of the filter, this needs to be above 2

$f_{gm} := 1 \cdot GHz$ $\qquad bandwidth := 20 \cdot MHz$ $\qquad Z_o := 50 \cdot \mathbf{O}$

Start Calculating...

$f_{low} := f_{gm} - \frac{bandwidth}{2}$ $\qquad f_{high} := f_{gm} + \frac{bandwidth}{2}$ $\qquad bw := \frac{f_{high} - f_{low}}{f_{gm}}$

$f_{bp}(f) := \frac{1}{bw} \cdot \left(\frac{f}{f_{gm}} - \frac{f_{gm}}{f} \right) \cdot f_{gm}$ $\qquad bwpercent := bw \cdot 100$ $\qquad \mathbf{a} := \frac{f_{gm}}{bandwidth}$

$bwpercent = 2$

$\mathbf{a} = 50$

LPF Frequency Response, for Chebychev Polynomials

This section plots the frequency response for the Chebychev BPF

$Y_o := \frac{1}{Z_o}$ $\qquad \mathbf{e} := \left(10^{\frac{2 \cdot L_{ar\_db}}{10}} - 1 \right)^{-0.5}$

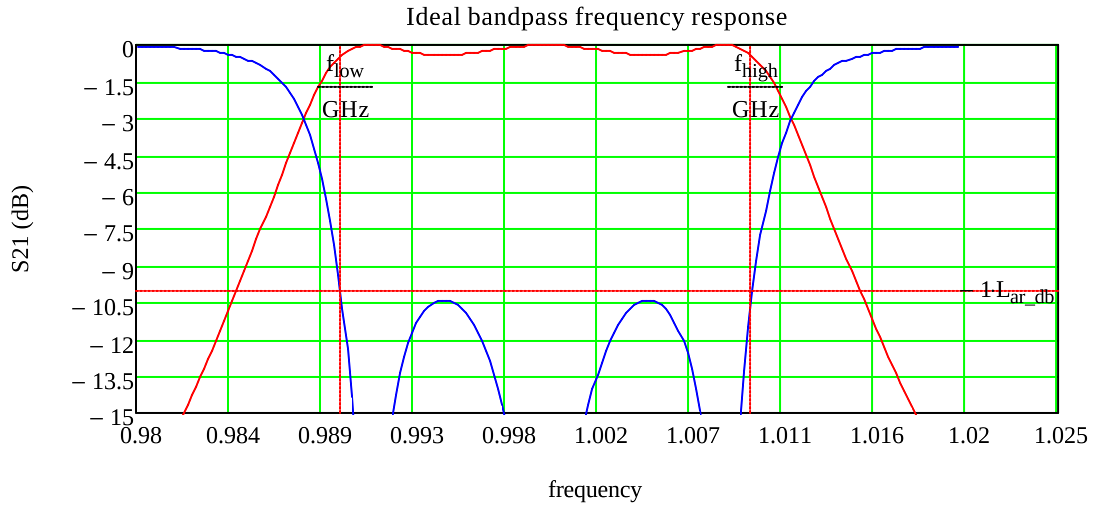
$\mathbf{e} = 0.1005$

$$L_A(f, f_c) := \begin{cases} 10 \cdot \log\left[1 + \mathbf{e} \cdot \left(\cos\left(N \cdot \operatorname{acos}\left(\frac{f}{f_c}\right)\right)\right)^2\right] & \text{if } f \le f_c \\ 10 \cdot \log\left[\left[1 + \mathbf{e} \cdot \left(\cosh\left(N \cdot \operatorname{acosh}\left(\frac{f}{f_c}\right)\right)\right)^2\right]\right] & \text{if } f > f_c \end{cases}$$

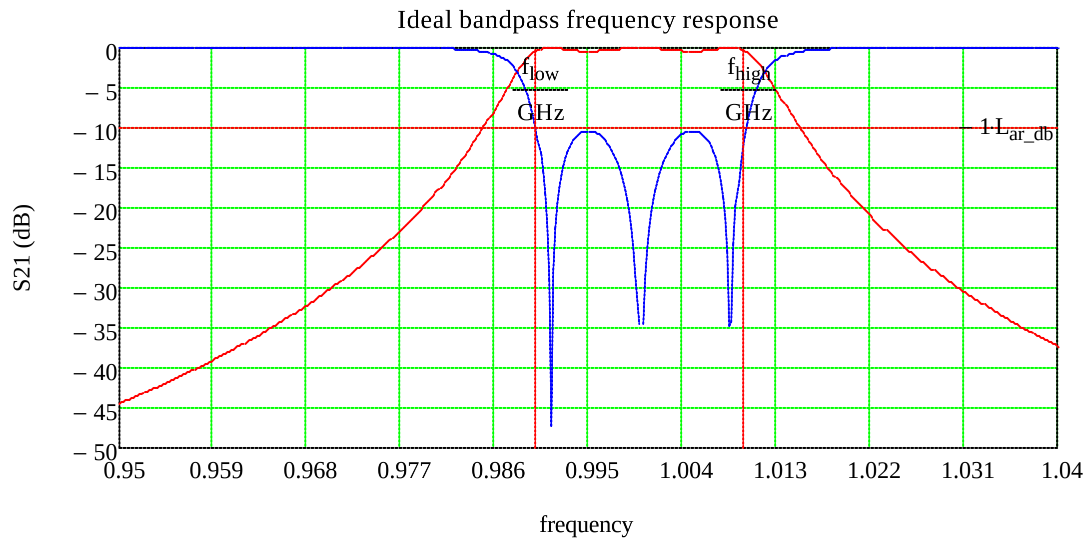
$$S11_A(f, f_1) := 10 \cdot \log\left[1 - 10^{\left(\frac{-L_A(f, f_1)}{10}\right)}\right]$$

$$f\_bp\_narrow := 0.99 \cdot f_{low}, \frac{f_{high} - f_{low}}{100} + 0.99 \cdot f_{low} .. 1.01 \cdot f_{high}$$

$$f\_bp\_wide := (f_{gm} - 3 \cdot f_{gm} \cdot bw), (f_{gm} - 3 \cdot f_{gm} \cdot bw) + \frac{f_{gm} \cdot bw}{100} .. f_{gm} + (3 \cdot f_{gm} \cdot bw)$$



dB(S21)
dB(S11)



dB(S21)
dB(S11)

Calculate the circuit values.....

$$? := \sinh\left(\frac{1}{N} \cdot \operatorname{asinh}\left(\frac{1}{\mathbf{e}}\right)\right)$$

$$n := 1, 2 .. N$$

$$nn := 1, 2 .. N - 1$$

$$K_{nn,nn+1} := \frac{\left[?^2 + \left(\sin\left(\frac{nn \cdot \mathbf{p}}{N}\right)\right)^2\right]^{0.5}}{?}$$

$$C_n := \frac{2}{?} \sin\left[\frac{(2 \cdot n - 1) \cdot \mathbf{p}}{2 \cdot N}\right]$$

$$Cap_{0,1} := \frac{1}{\left[2 \cdot \mathbf{p} \cdot f_{gm} \cdot (\mathbf{a} - 1)^{0.5} \cdot Z_o\right]}$$

$$Cap_{N,N+1} := \frac{1}{\left[2 \cdot \mathbf{p} \cdot f_{gm} \cdot (\mathbf{a} - 1)^{0.5} \cdot Z_o\right]}$$

$$Cap_{0,1} = 0.455 \cdot pF$$

$$Cap_{N,N+1} = 0.455 \cdot pF$$

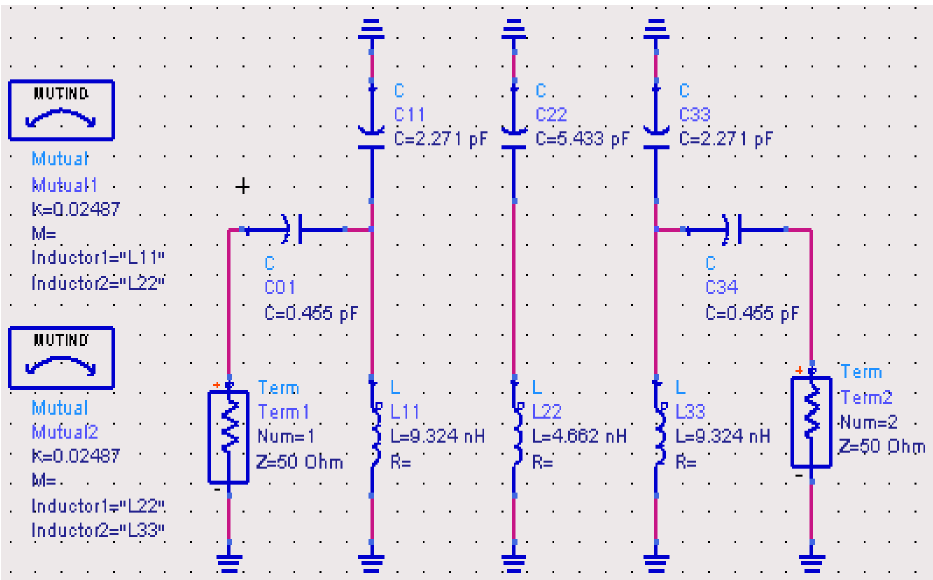
$$Ind_{n,n} := \frac{Z_o}{C_n \cdot 2 \cdot \mathbf{p} \cdot f_{gm}}$$

$$Cap_{n,n} := \frac{C_n}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o}$$

$$Cap_{1,1} := \frac{C_1}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o} - \frac{(\mathbf{a} - 1)^{0.5}}{2 \cdot \mathbf{p} \cdot f_{gm} \cdot Z_o \cdot \mathbf{a}}$$

$$Cap_{N,N} := Cap_{1,1}$$

$Cap_{n,n} =$ (pF)	$Ind_{n,n} =$ (nH)	$\frac{K_{nn,nn+1}}{\mathbf{a}} =$
2.271	9.324	0.02487
5.433	4.662	0.02487
2.271	9.324	



Simulation Results

To test these values I have run a simulation on ADS for N=3, Return Loss 10dB, BW=20MHz, Zo=50R. You can see the results are in good agreement. Both the ripple and return loss (S11) agree.

You can see the downside of these filters that the frequency response repeats and the out of band attenuation is not a good we would like and not as good as expected from the ideal chebychev response.