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Chebyshev Lowpass Filter (Closed Form): LPFC

Symbol

Summary

LPFC models represent lumped-element Chebyshev lowpass filters. The insertion loss ripples between zero and a specified maximum in the passband. The stopband attenuation increases rapidly beyond the passband edge, is monotonic, and is maximally flat at infinite frequency. This filter type offers simplicity and good selectivity.

Parameters

Name	Description	Unit Type	Default
ID	Element ID	Text	LPFC1
N	Number of reactive elements in the filter		3
FP	Passband corner frequency (when Qu is infinite).	Frequency	1 GHz
AP	Passband corner attenuation (when Qu is infinite).	DB	0.1 dB
*RS	Source resistance.	Resistance	50 ohm
*RL	Load resistance	Resistance	50 ohm
*QU	Average unloaded Q of reactive elements in the filter		1e12

** indicates a secondary parameter*

Parameter Restrictions and Recommendations

1. 0 < N < 27

2. 0 < FP
3. 0 < AP Recommend AP greater than or equal to 0.001 dB.
4. 0 < RS
5. 0 < RL
6. 0 < QU. Recommend QU less than or equal to 1e12.

Implementation Details

The model is implemented as a short-circuit admittance matrix, whose equivalent transfer function squared magnitude is that of a Chebyshev filter:

$$|S_{21}(s)|^2 = \frac{1}{1+\varepsilon^2 C_n^2\left(\frac{s}{j}\right)} = \frac{1}{|g(s)|^2} = \frac{1}{1+|h(s)|^2}$$

where Cn is the Chebyshev polynomial of the first kind, and

$$\varepsilon^2 = 10^{\mathrm{AP}/10} - 1$$

$$C_n(\omega) = \cos(N * \mathrm{acos}(\omega)) \qquad \text{for } 0 \le |\omega| \le 1$$

$$C_n(\omega) = \cosh(N * \mathrm{acosh}(\omega)) \qquad \text{for } 1 < |\omega|$$

$$s = \frac{1}{\mathrm{QU}} + j\omega$$

$$j = \sqrt{-1}$$

and a lowpass-to-lowpass frequency transformation has been applied:

$$\omega = -\frac{\_FREQ}{FP}$$

_FREQ is the variable containing the project frequency, and the admittances are:

$$y_{11} = \left(\frac{1}{\mathrm{RS}}\right)\frac{g(s)+g(-s)-h(s)-h(-s)}{g(s)-g(-s)+h(s)-h(-s)}$$

$$y_{22} = \left(\frac{1}{\mathrm{RL}}\right)\frac{g(s)+g(-s)+h(s)+h(-s)}{g(s)-g(-s)+h(s)-h(-s)}$$

$$y_{12} = y_{21} = \left(\frac{1}{\sqrt{\mathrm{RS}\times\mathrm{RL}}}\right)\frac{2}{g(s)-g(-s)+h(s)-h(-s)}$$

Layout

This element does not have an assigned layout cell. You can assign artwork cells to any element. See “Assigning Artwork Cells to Layout of Schematic Elements” for details.

Recommendations for Use

Note that this model behaves as if it has ideal impedance transformers at its ports, so there is no attenuation due to mismatched source and load impedances. The model expects that the source impedance equals RS and that the load impedance equals RL, but RS need not have any special relationship to RL for ideal transmission (as would normally be the case).

References

[1] Rolf Schaumann, Mohammed S. Ghausi, and Kenneth R. Laker, Design of Analog Filters: Passive, Active RC, and Switched Capacitor, (Prentice-Hall, 1990), pp. 44-48.

[2] Louis Weinberg, Network Analysis and Synthesis, (Robert E. Krieger Publishing, 1975), pp. 507-529.

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