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Butterworth Lowpass Filter: LPFB

Symbol

Summary

LPFB models represent lumped-element Butterworth lowpass filters. They offer simplicity and a compromise between high selectivity and flat group delay. The insertion loss is maximally flat at zero frequency and the stopband attenuation increases monotonically with increasing frequency at an asymptotic rate of 6N dB per octave.

Parameters

Name	Description	Unit Type	Default
ID	Filter ID	Text	LPFB1
N	Number of reactances in the filter		3
FP	Passband corner frequency (when Qu is infinite).	Frequency	1 GHz
*AP	Passband corner attenuation (when Qu is infinite).	DB	3.0103 dB
*RS	Expected source resistance.	Resistance	50 ohm
*RL	Expected load resistance	Resistance	50 ohm
*QU	Uniform unloaded Q of lowpass reactances		1e12

** indicates a secondary parameter*

Parameter Restrictions and Recommendations

1. 0 < N < 29

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 Butterworth filter:

$$|S_{21}(s)|^2 = \frac{1}{1+(-1)^N \varepsilon^2 S^{2N}} = \frac{1}{|g(s)|^2} = \frac{1}{1+|h(s)|^2}$$

where

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

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

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

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 equal 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. 40-44.

[2] Louis Weinberg, Network Analysis and Synthesis, (Robert E. Krieger Publishing, 1975), pp. 493-498.

[3] Adel S. Sedra and Peter O. Brackett, Filter Theory and Design: Active and Passive, (Matrix Publishers, 1978), pp. 105-111.

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