2018-09-05/MS

Signal Processing, lecture 1

Topics:

Introduction:
- Course overview
- Analog filters: Applications
- Ideal and real filters.

Filter design procedure and approximations:
- Normalization and de-normalization
- The Butterworth approximation

Literature:

The analog filter part of the course will be based on: Kendall Su: ”Analog Filters”, Kluwer Academic Publishers, 2nd ed. 2002, ISBN 1-4020-7033-0 (Springer: ISBN 978-1-4020-7033-4)
The book is available in electronic form at http://www.en.aub.aau.dk where you can read the book and print a few pages.

Topic	Pages ({*} ⇔ supplementary lit.)
Introduction, ideal filters, normalization and de-normalization	{1-2, 7-16} 3-7
Butterworth characteristics	25-30
Transfer functions	49-57

Supplementary: Lecture presentation “slides”

Exercises:

1.1

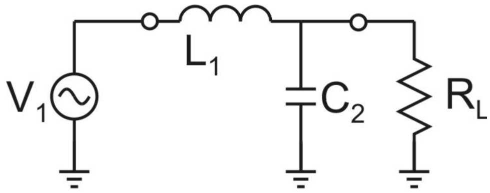
A Butterworth low-pass filter is wanted, with the two (standard) requirements:
- $20 \cdot \log|H(j \cdot 1 \text{ rad/s})| = -3$ dB
- $20 \cdot \log|H(j0)| = 0$ dB

a. Calculate and plot the pole locations for filters of order n = 4 and n = 5.
b. Find an expression for the transfer function from the pole locations for n = 4.
c. Check the results from a and b using Matlab

1.2

A 2nd order Butterworth low-pass filter is to be used in a class-D audio amplifier to pass the audio signal and attenuate the signal at the switching frequency.
- The attenuation at 20 kHz shall be 0.5 dB
- The attenuation at the switching frequency shall be 30 dB

a. For a normalized ($\omega_{3dB} = 1$ rad/s) 2nd order Butterworth filter, find the radian frequency, where the attenuation is 0.5 dB.
b. For the normalized filter, find the radian frequency, where the attenuation is 30 dB, and find the transition band ratio, $\omega_{30dB}/\omega_{0.5dB}$.



- A 2^{nd} order Butterworth filter with ω_{3dB} = 1 rad/s, can be made using the circuit shown with L_1 = 1.4142 H and C_2 = 0.7071 F and R_L = 1 Ω.

c. Make a frequency scaling so that the scaled filter has an attenuation of 0.5 dB at 20 kHz. What is the needed frequency scaling factor?
d. Find the frequency, where the scaled filter has an attenuation of 30 dB.
e. Plot the magnitude of the transfer function (dB) in Matlab
f. Make an impedance scaling to R_L = 4 Ω and find the new values, $L_{1,scaled}$ and $C_{2,scaled}$.

1.3

The following requirements are set for a Butterworth low-pass filter:

- The attenuation at ≥ 30 kHz shall be ≥ 20 dB
- The attenuation at ≤ 10 kHz shall be ≤ 1 dB

a. Find the necessary filter order.
b. Find the 3-dB bandwidth, when the attenuation at 10 kHz is chosen to be 1 dB.

Results:

1.1

1.2

•

a. *0.591 rad/s*
b. *5.62 rad/s, 9.51*
c. *6.65 μH, 3.33 μF, 212.6e3*
d. *190 kHz*
e.
f. *26.6 μH, 831 nF*

1.3

•

a. *3*
b. *12.53 kHz*