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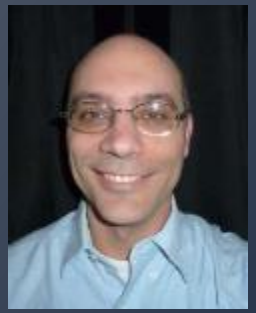


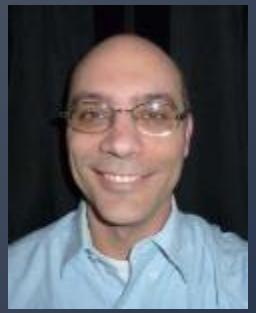
Introduction to Electronics

Dr. Allen Robinson
Academic Professional
School of Electrical and Computer Engineering

An introduction to electronic components and a study of circuits containing such devices.

Georgia Institute of Technology

Second-Order Transfer Functions



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Introduce second-order filter transfer functions

Previous Lesson

- Introduced cascaded first-order op-amp filters

Lesson Objectives

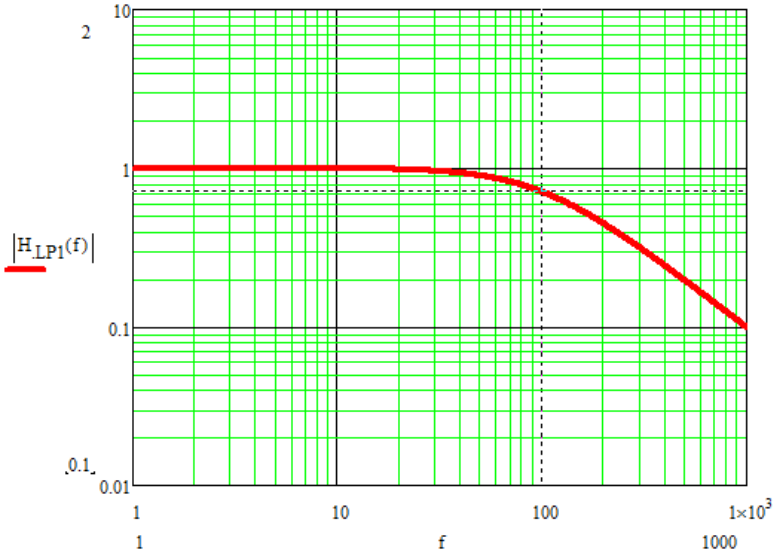
- Introduce second-order filter transfer functions
- Examine features of transfer functions

Filter Transfer Function

- Ratio of output voltage to input voltage as a function of frequency
- For any frequency, the transfer function is a complex number that indicates how the filter modifies the magnitude and phase of the input to produce the output

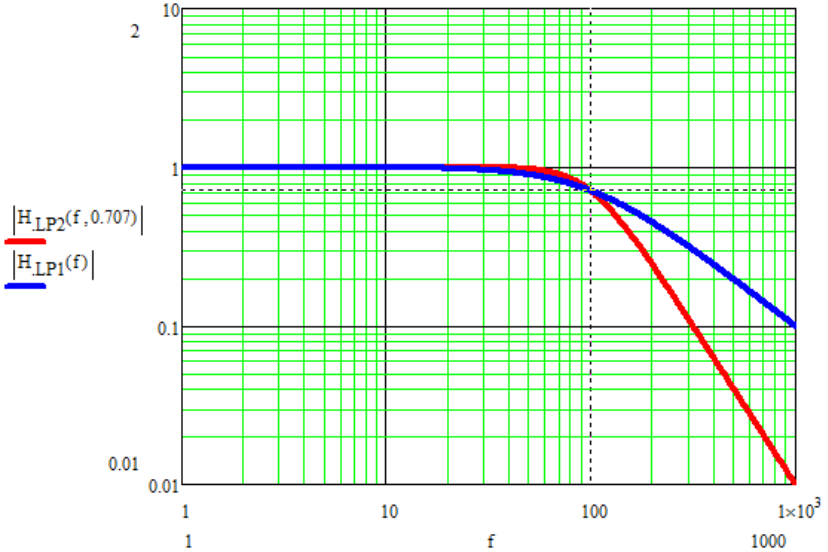
$$H(f) = \frac{V_{out}(f)}{V_{in}(f)}$$

First-Order Low-Pass Filter



$$H_{LP1}(f) = K\frac{1}{\frac{jf}{f_0}+1}$$

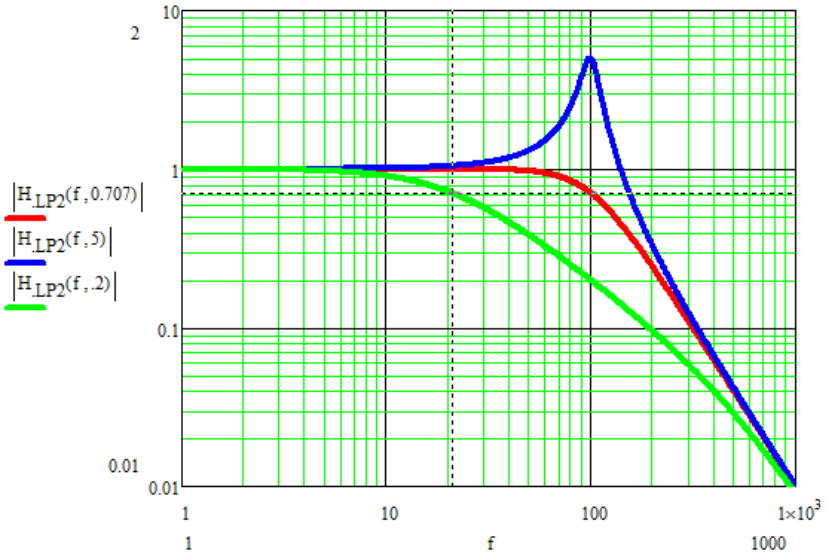
Second-Order Low-Pass Filter



$$H_{LP1}(f) = K\frac{1}{\frac{jf}{f_0}+1}$$

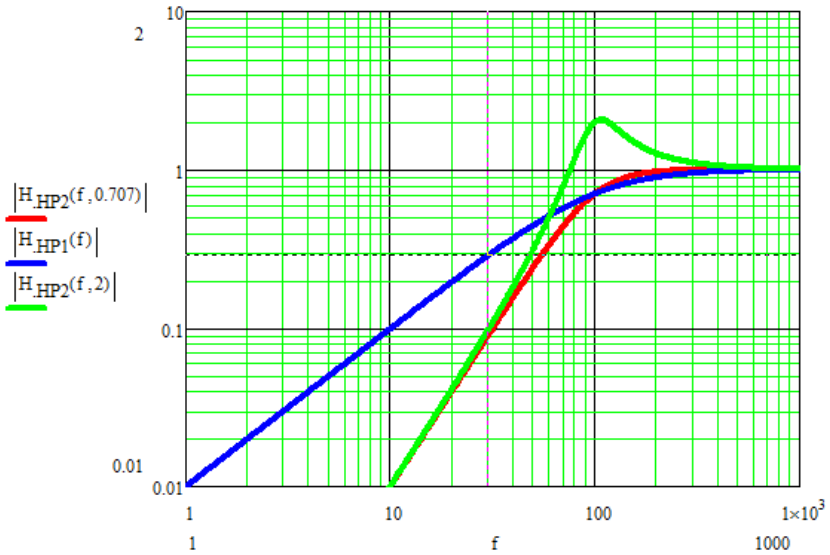
$$H_{LP2}(f) = K\frac{1}{\left(\frac{jf}{f_0}\right)^2+\frac{jf}{f_0}\frac{1}{Q}+1}$$

Effect of Quality Factor (Q)



$$H_{LP2}(f) = K \frac{1}{\left(\frac{if}{f_0}\right)^2 + \frac{if}{f_0}\frac{1}{Q} + 1}$$

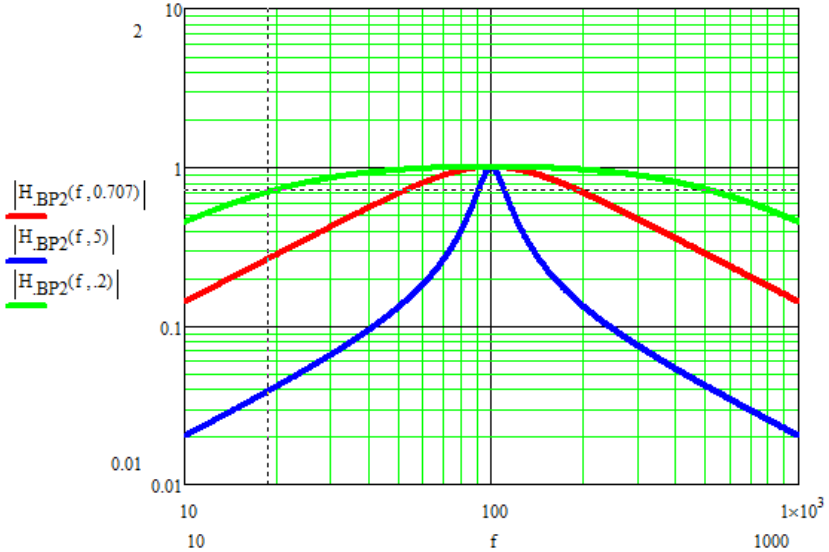
High-Pass Filters



$$H_{HP1}(f) = K\frac{\frac{jf}{f_0}}{\frac{jf}{f_0}+1} \qquad H_{HP2}(f) = K\frac{\left(\frac{jf}{f_0}\right)^2}{\left(\frac{jf}{f_0}\right)^2+\frac{jf}{f_0}\frac{1}{Q}+1}$$

$$H_{LP1}(f) = K\frac{1}{\frac{jf}{f_0}+1} \qquad H_{LP2}(f) = K\frac{1}{\left(\frac{jf}{f_0}\right)^2+\frac{jf}{f_0}\frac{1}{Q}+1}$$

Band-Pass Filters



$$H_{BP2}(f) = K \frac{\frac{jf}{f_0}\frac{1}{Q}}{\left(\frac{jf}{f_0}\right)^2 + \frac{jf}{f_0}\frac{1}{Q} + 1}$$

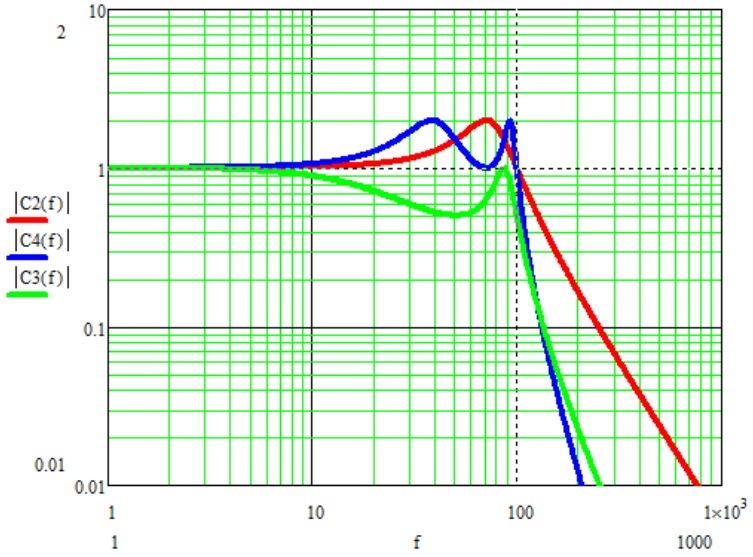
$$Q = \frac{f_0}{BW}$$

$$BW = Bandwidth = f_u - f_l$$

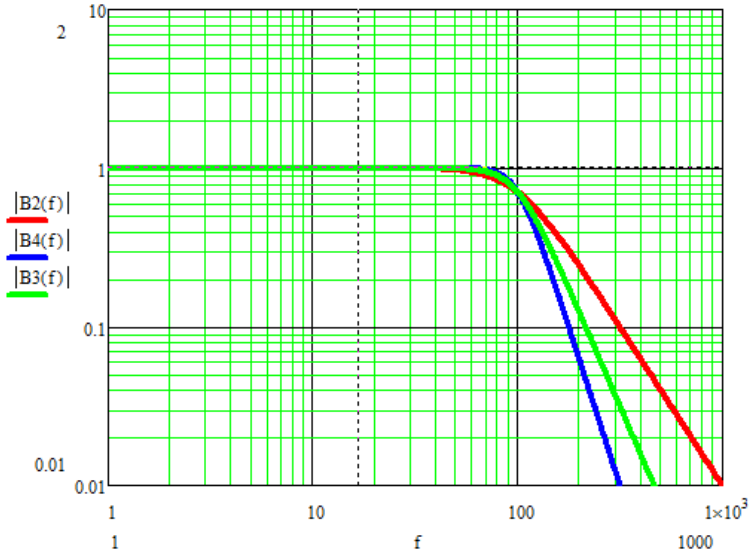
Butterworth and Chebyshev

- Types of transfer functions
- For second-order filters, the type is determined by the Q value
- $Q = 1/\sqrt{2}$ Butterworth (Maximally Flat)
- $Q > 1/\sqrt{2}$ Chebyshev

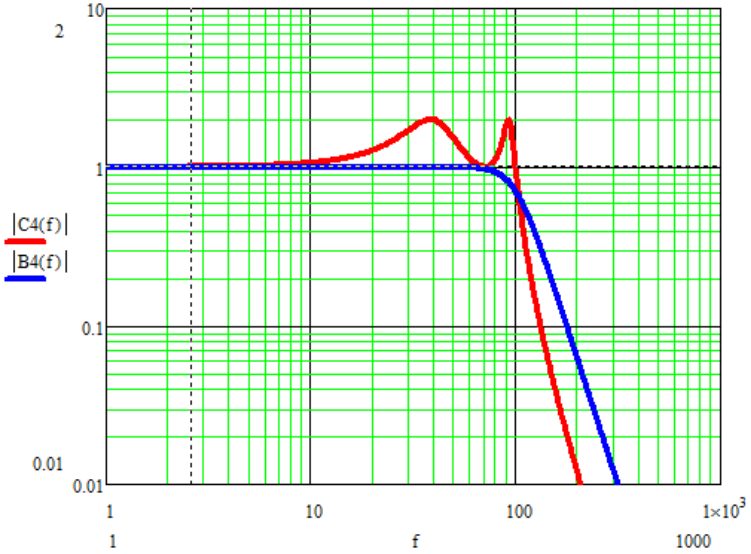
Chebyshev Filters



Butterworth Filters



Fourth-Order Butterworth vs. Chebyshev



Summary

- Introduced second-order transfer functions
- Examined features of transfer functions

Next Lesson

- Op-Amp Second-Order Filter Circuits