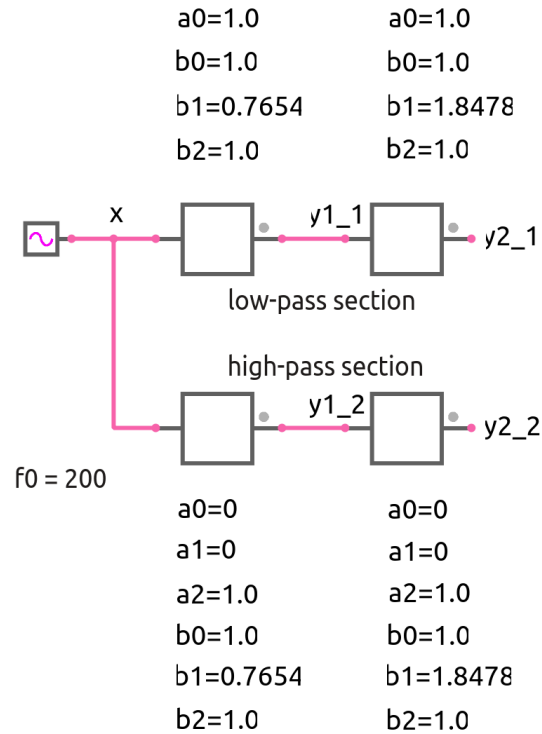


butterworth_4_ac.sqproj



Shown in the figure are 4th-order low-pass and 4th-order high-pass Butterworth filters. Note that the high-pass transfer function is obtained from the low-pass function by substituting $s \leftarrow 1/s$. The filter functions have been implemented with normalised coefficients. The actual coefficients are computed internally using the parameter `f0` of the filter elements.

Exercise Set

1. Run the simulation. Plot the outputs `y2_1`, `y2_2` versus frequency (log-log plot), and verify the low-pass and high-pass functionality.
2. From the plots, verify that they are 4th-order filters, and that the cut-off frequency is as specified by the parameter `f0`.
3. The normalised and factorised 5th-order Butterworth polynomial is given by

$$H(s) = (s + 1)(s^2 + 0.618s + 1)(s^2 + 1.618s + 1).$$

Modify the circuit suitably to implement low-pass and high-pass 5th-order Butterworth filters with a cut-off frequency of 1 kHz. Verify with simulation.

References

1. A. S. Sedra, K. C. Smith, and A. N. Chandorkar, *Microelectronic Circuits: Theory and Applications*, Fifth edition, Oxford University Press, 2009.
2. S. Franco, *Design with Operation Amplifiers and Analog Integrated Circuits*, McGraw-Hill, 1998.