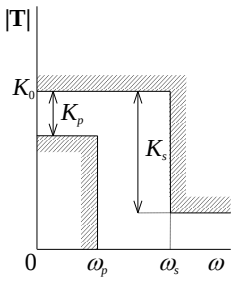
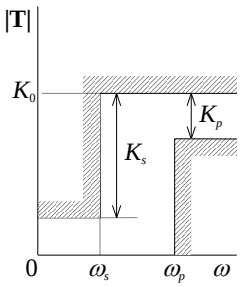
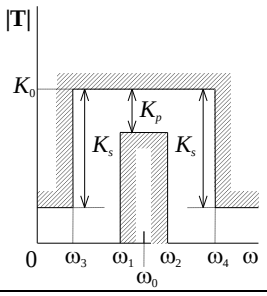
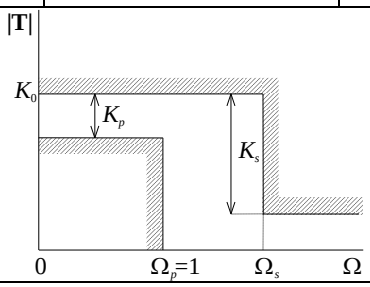
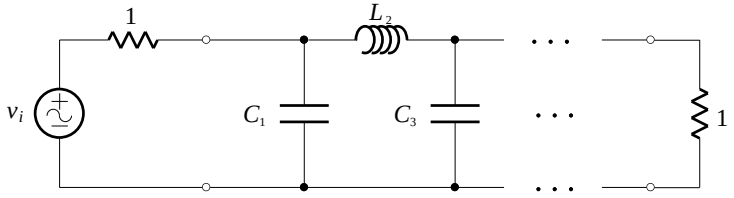
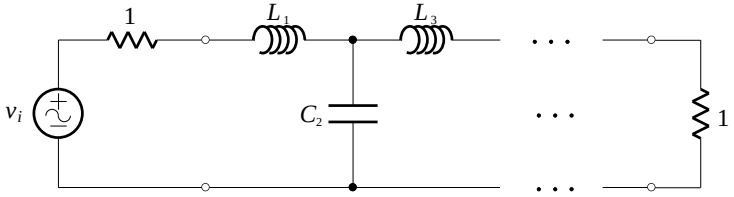
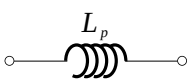
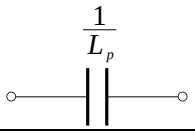
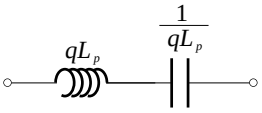
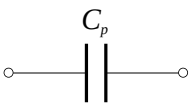
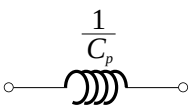
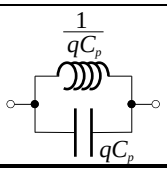
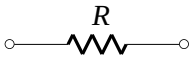
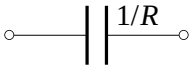
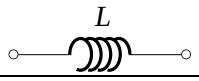
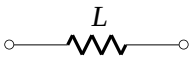
Passive and Active Analog Direct Filter Design

Step-by-step direct design of Butterworth filters for passive lowpass, highpass, and bandpass responses, and simulated element lowpass and highpass responses.

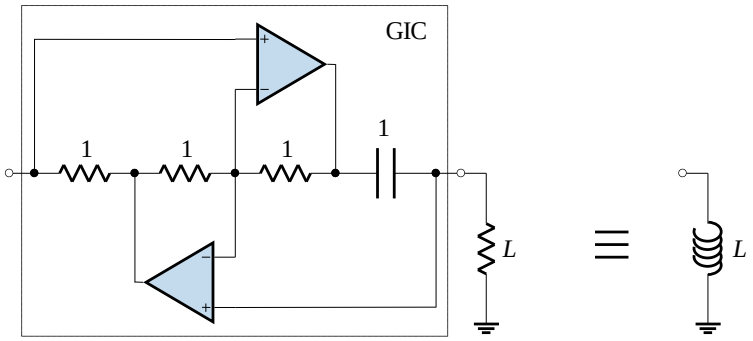
Design Steps

<table>
<tr><td>Specification</td><td>lowpass
 
</td><td>highpass
 
</td><td>bandpass
 
</td></tr>
<tr><td>Frequency Transformation</td><td>$\Omega_s = \dfrac{\omega_s}{\omega_p}$</td><td>$\Omega_s = \dfrac{\omega_p}{\omega_s}$</td><td>$\Omega_s = \dfrac{\omega_4 - \omega_3}{\omega_2 - \omega_1}$
$\omega_0^2 = \omega_1\omega_2 = \omega_3\omega_4$</td></tr>
<tr><td>Lowpass Prototype Specification</td><td colspan="3"> 
</td></tr>
<tr><td>M</td><td colspan="3">$M = \sqrt{\dfrac{10^{0.1K_s} - 1}{10^{0.1K_p} - 1}}$</td></tr>
<tr><td>Butterworth Order</td><td colspan="3">$n = \dfrac{\ln M}{\ln \Omega_s}$
Round up to an integer.</td></tr>
<tr><td>Minimum Inductance Doubly Terminated Lossless Ladder</td><td colspan="3"> 
</td></tr>
<tr><td>Element values for a Butterworth response</td><td colspan="3"><table>
<tr><td>n</td><td>C_1</td><td>L_2</td><td>C_3</td><td>L_4</td><td>C_5</td></tr>
<tr><td>2</td><td>1.414</td><td>1.414</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>1.000</td><td>2.000</td><td>1.000</td><td></td><td></td></tr>
<tr><td>4</td><td>0.7654</td><td>1.848</td><td>1.848</td><td>0.7654</td><td></td></tr>
<tr><td>5</td><td>0.618</td><td>1.618</td><td>2.000</td><td>1.618</td><td>0.618</td></tr>
<tr><td>n</td><td>L_1</td><td>C_2</td><td>L_3</td><td>C_4</td><td>L_5</td></tr>
</table></td></tr>
<tr><td>Minimum Capacitance Doubly Terminated Lossless Ladder</td><td colspan="3"> 
</td></tr>
</table>

D.2

Ω_0 or q	$\Omega_{0p} = \dfrac{1}{\left(10^{0.1K_p}-1\right)^{1/2n}}$ $\Omega_{0s} = \dfrac{\Omega_s}{\left(10^{0.1K_s}-1\right)^{1/2n}}$ $\Omega_0 = \sqrt{\Omega_{0p}\Omega_{0s}}$		$q = \dfrac{\omega_0}{\omega_2 - \omega_1}$
Element Transformation	Prototype (lowpass) elements	Highpass elements	Bandpass elements
			
			
Bruton Transformation (active only)			
			
			
Half-power or Centre Freq.	$\omega_0 = \omega_p\Omega_0$	$\omega_0 = \dfrac{\omega_p}{\Omega_0}$	$\omega_0 = \sqrt{\omega_1\omega_2}$
Scaling	$k_f = \omega_0$, choose k_m for proper element values.		
Gain	Fixed for passive filters, provide gain or attenuation to meet the K_0 specification for active filters.		

Simulated Element Circuits

Inductor	
FDNR