Low-Pass Filter Design Example

- Design a Low-Pass Filter with cut-off frequency of 900 MHz and a stop band attenuation of 18 dB @1.8 GHz.
- From the Butterworth Nomograph, A_{max} = 1 and A_{min} = 18. A_{max} = 1 since unity gain. And the order of the filter is N = 3.
- From Butterworth Tables, $g_1 = g_3$=1.0 and g_2 = 2.

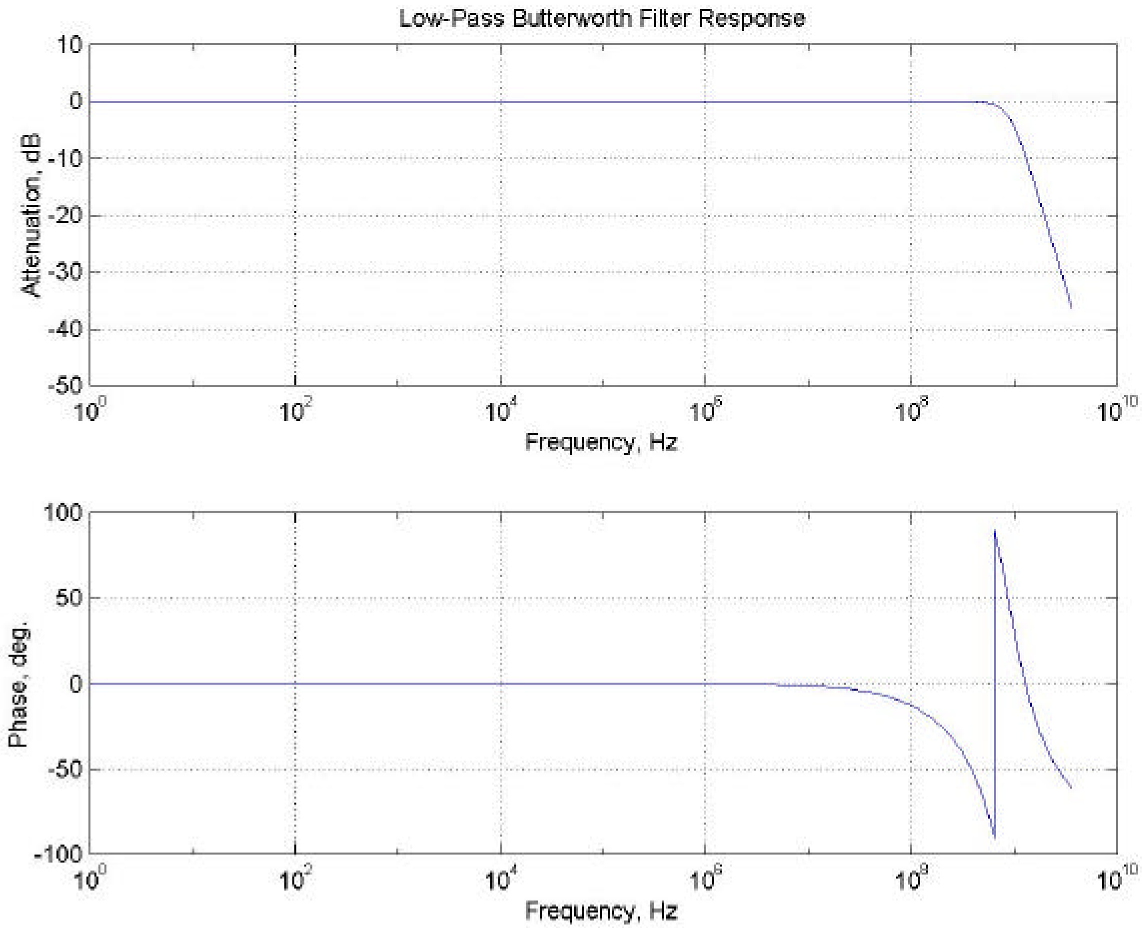
Low-Pass Filter Design Example

- De-Normalized Values For the Tee-Configuration Low-Pass Filter Are:

$$L_1 = L_2 = \frac{g_1 R_L}{2p\left(900\times10^6\right)} = 8.8\, nH$$

$$C_1 = \frac{g_2}{2p\left(900\times10^6\right)R_L} = 7\ pF$$

Low-Pass Filter Design Example



Low- To High-Pass Transformation

- Transform the Low-Pass Filter Normalized Component Values to the Normalized High-Pass Values
- Inductors in Low-Pass Configuration Become Capacitors in High-Pass.
- Capacitors in Low-Pass Configuration Become Inductors in High-Pass
- $C_{HP\_norm} = \dfrac{1}{w_c L_{LP\_norm}}\ ;\quad L_{HP\_norm} = \dfrac{1}{w_c C_{LP\_norm}}$

RF Filter Parameters

- Insertion Loss: $IL = 10\,log\,\dfrac{P_{in}}{P_L} = -10\,log\left(1 - \left|\Gamma_{in}\right|^2\right)$
- Ripple
- Bandwidth: $BW^{3dB} = f_u^{3dB} - f_L^{3dB}$
- Shape Factor: $$SF = \frac{BW_{A_{min}}}{BW_{A_{max}}}$$
- Rejection

De-Normalizing Filter Component Values

- All Normalized Component Values Are De-Normalized Using the Following:

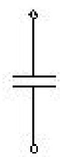
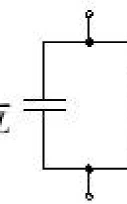
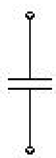
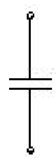
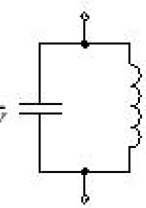
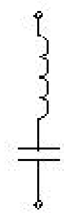
$$C_{actual} = \frac{C_{normalized}}{R_g}$$

and

$$L_{actual} = L_{normalized} R_g$$

Transformation From Low-Pass Filter

Table 5-5 Transformation between normalized low-pass filter and actual bandpass and bandstop filter
$(BW = \omega_U - \omega_L)$

Low-pass prototype	Low-pass	High-pass	Bandpass	Bandstop
 $L = g_k$	 $\frac{L}{\omega_c}$	 $\frac{1}{\omega_c L}$	 $\frac{L}{BW}$ $\frac{BW}{\omega_0^2 L}$	$\frac{1}{(BW)L}$  $\frac{(BW)L}{\omega_0^2}$
 $C = g_k$	 $\frac{C}{\omega_c}$	 $\frac{1}{\omega_c C}$	$\frac{C}{BW}$  $\frac{BW}{\omega_0^2 C}$	 $\frac{1}{(BW)C}$ $\frac{(BW)C}{\omega_0^2}$

Normalized Low- to Band-Pass Filter Transformation

- Normalized Band-Pass Shunt Elements from Shunt Low-Pass Capacitor:

$$L_{BP\_norm\_shunt} = \frac{w_{upper} - w_{lower}}{w_o^2 C_{LP\_norm}}$$

$$C_{BP\_norm\_shunt} = \frac{C_{LP\_norm}}{w_{upper} - w_{lower}}$$

Normalized Low- to Band-Pass Filter Transformation

- Normalized Band-Pass Series Elements from Series Low-Pass Inductor:

$$L_{BP\_norm\_series} = \frac{L_{LP\_norm}}{w_{upper} - w_{lower}}$$

$$C_{BP\_norm\_series} = \frac{w_{upper} - w_{lower}}{w_o^2 L_{LP\_norm}}$$

Normalized Low- to Band-Stop Filter Transformation

- Normalized Band-Stop Shunt Component Values from Low-Pass Shunt Capacitor:

$$L_{Stop\_norm\_shunt} = \frac{1}{\left(w_{upper} - w_{lower}\right) C_{LP\_norm}}$$

$$C_{Stop\_norm\_shunt} = \frac{\left(w_{upper} - w_{lower}\right) C_{LP\_norm}}{w_o^2}$$

Normalized Low- to Band-Stop Filter Transformation

- Normalized Band-Stop Series Component Values from Low-Pass Series Inductor:

$$L_{Stop\_norm\_series} = \frac{\left(w_{upper} - w_{lower}\right) L_{LP\_norm}}{w_o^2}$$

$$C_{Stop\_norm\_series} = \frac{1}{\left(w_{upper} - w_{lower}\right) L_{LP\_norm}}$$