8.10 Design a three-section bandstop lumped-element filter with a 0.5 dB equal-ripple response, a bandwidth of 10% centered at 3 GHz, and an impedance of 75 Ω. What is the resulting attenuation at 3.1 GHz? Use CAD to plot the insertion loss versus frequency.

- Also, draw labeled sketch of design. **Normalize passband to 0 dB.**

➢ Per (8.75), $\Delta\left(\frac{\omega}{\omega_0}-\frac{\omega_0}{\omega}\right)^{-1} = 0.1\left(\frac{3.1}{3}-\frac{3}{3.1}\right)^{-1} = 1.5246$ is the equivalent LP prototype frequency where $\omega_c = 1$ rad/s for this bandstop filter.

➢ Calculate $|\omega/\omega_c| - 1 = |1.5246/1| - 1 = 0.5246$. From Figure 8.27a, we see that a LP prototype filter of order **$N = 3$** has an **expected attenuation of ~10.3 dB**.

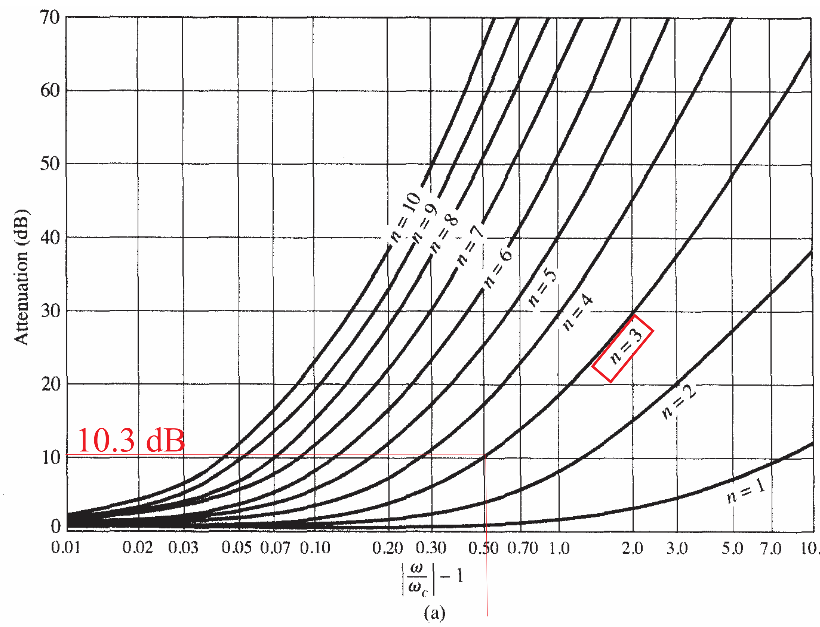


FIGURE 8.27 Attenuation versus normalized frequency for equal-ripple filter prototypes. (a) 0.5 dB ripple level.

Adapted from G. L. Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Dedham, Mass., 1980, with permission.

➢ From Table 8.4, we get immittances: **$g_1 = g_3 = 1.5963$**, **$g_3 = 1.0967$**, and **$g_4 = 1$** (matched).

TABLE 8.4 **Element Values for Equal-Ripple Low-Pass Filter Prototypes ($g_0 = 1$, $\omega_c = 1$, $N = 1$ to 10, 0.5 dB ripple)**

	0.5 dB Ripple										
N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	0.6986	1.0000									
2	1.4029	0.7071	1.9841								
3	1.5963	1.0967	1.5963	1.0000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.0000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6678	1.2690	1.7504	1.0000	
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842	1.9841

- For the filter architecture of Fig 8.25a, the necessary scaled & transformed LP shunt capacitors become a series *LC* using immittances $g_1 = g_3$, equations (8.76c) & (8.76d) for transformed *L* & *C*, and (8.64a) & (8.64b) for impedance scaling:

$g_1 = 1.5963 \Rightarrow$

$$L_1' = L_3' = \frac{R_0}{\omega_0 \Delta L_k} = \frac{R_0}{\omega_0 \Delta g_1} = \frac{75}{(2\pi)3\times 10^9 (0.1)1.5963} \Rightarrow \underline{L_1' = L_3' = 24.9256 \text{ nH}}$$

$$C_1' = C_3' = \frac{\Delta C_k}{\omega_0 R_0} = \frac{\Delta g_1}{\omega_0 R_0} = \frac{0.1(1.5963)}{(2\pi)3\times 10^9 (75)} \Rightarrow \underline{C_1' = C_3' = 0.1129 \text{ pF}}$$

- For the filter architecture of Fig 8.25a, the necessary scaled & transformed LP series inductor becomes a parallel *LC* using immittance g_2, equations (8.76a) & (8.76b) for transformed *L* & *C*, and (8.64a) & (8.64b) for impedance scaling:

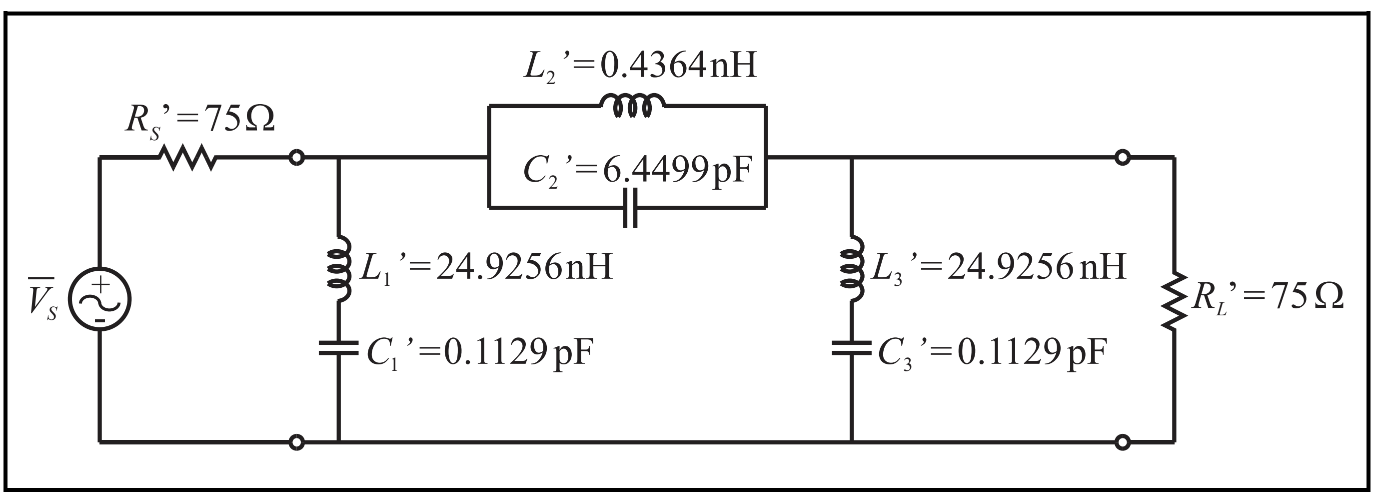
$$g_2 = 1.0967 \quad \Rightarrow \quad L_2' = \frac{\Delta L_k R_0}{\omega_0} = \frac{\Delta g_2 R_0}{\omega_0} = \frac{0.1(1.0967)75}{(2\pi)3\times 10^9} \Rightarrow \underline{L_2' = 0.4364 \text{ nH}}$$

$$C_2' = \frac{1}{\omega_0 \Delta L_k R_0} = \frac{1}{\omega_0 \Delta g_2 R_0} = \frac{1}{(2\pi)3\times 10^9 (0.1)1.0967(75)} \Rightarrow \underline{C_2' = 6.4499 \text{ pF}}$$

- Per (8.64d), $g_4 = 1 \Rightarrow$ $R_L' = R_0 R_L = R_0 g_6 = 50(1) \Rightarrow \underline{R_L' = 50\ \Omega}$.

- Further, the source resistance per (8.64c) is: $R_S' = R_0 \Rightarrow \underline{R_S' = 50\ \Omega}$.

- The resulting **bandstop** filter circuit is:



- See MathCad on next page for actual **filter attenuation of 10.897 dB** at 3.1 GHz which is a bit better than the predicted 10.3 dB.

Define constants

$VS := 1$ V $RS := 75$ Ω $RL := 75$ Ω $fc := 3\cdot 10^{9}$ Hz

$C1 := 0.1129\cdot 10^{-12}$ F $C3 := C1$ $L1 := 24.9256\cdot 10^{-9}$ H $L3 := L1$

$C2 := 6.4499\cdot 10^{-12}$ F $L2 := 0.4364\cdot 10^{-9}$ H

Parallel RL//(ZC3+ZL3)
$$Z1(f) := \left[\frac{1}{RL} + \frac{1}{(j\cdot 2\cdot \pi\cdot f\cdot L3) + \frac{1}{(j\cdot 2\cdot \pi\cdot f\,C3)}}\right]^{-1}$$

Series (ZC2//ZL2) + Z1
$$Z2(f) := \left(\frac{1}{j\cdot 2\cdot \pi\cdot f\cdot L2} + j\cdot 2\cdot \pi\cdot f\,C2\right)^{-1} + Z1(f)$$

Parallel Z2//(ZC1+ZL1)
$$Zin(f) := \left[\frac{1}{Z2(f)} + \frac{1}{(j\cdot 2\cdot \pi\cdot f\cdot L1) + \frac{1}{(j\cdot 2\cdot \pi\cdot f\,C1)}}\right]^{-1}$$

Voltage division to get Vld
$$Vld(f) := VS\cdot \frac{Zin(f)}{RS + Zin(f)}\cdot \frac{Z1(f)}{Z2(f)}$$

$n := 1 .. 6000$ $f_n := n\cdot 10^{6}$ $VL_n := Vld(f_n)$ $VLdeg_n := \arg(VL_n)\cdot \frac{180}{\pi}$

$VLdB_n := 20\cdot \log(|VL_n|)$ $IL_n := VLdB_n - 10\cdot \log(0.25)$ $\boxed{IL_{3100} = -10.897}$ dB