For a 50 Ω system, design a lumped-element, 0.5 dB ripple, Chebyshev low-pass filter with a cut-off frequency of 2.4 GHz with an attenuation of at least 15 dB at 4.8 GHz using the architecture of Fig. 8.25a. a) Determine the filter order N and the low-pass filter prototype element values. b) Draw a labeled sketch of the scaled filter with component values. c) Draw a labeled sketch of the filter in phasor form with $V_s = 1\angle 0°$ V. d) Plot the amplitude response $|V_L|$ in decibels with horizontal dashed lines at 20log(0.5) & 20log(0.5)-0.5 and a vertical dashed line at 2.4 GHz for $0 \le f \le 5$ GHz & -25 dB $\le |V_L| \le 0$.

a) Calculate $|\omega/\omega_c| - 1 = |4.8/2.4| - 1 = 1$. From Figure 8.27a, we see that a LP prototype filter of order ***N* = 3** is needed to meet the 15 dB attenuation specification.

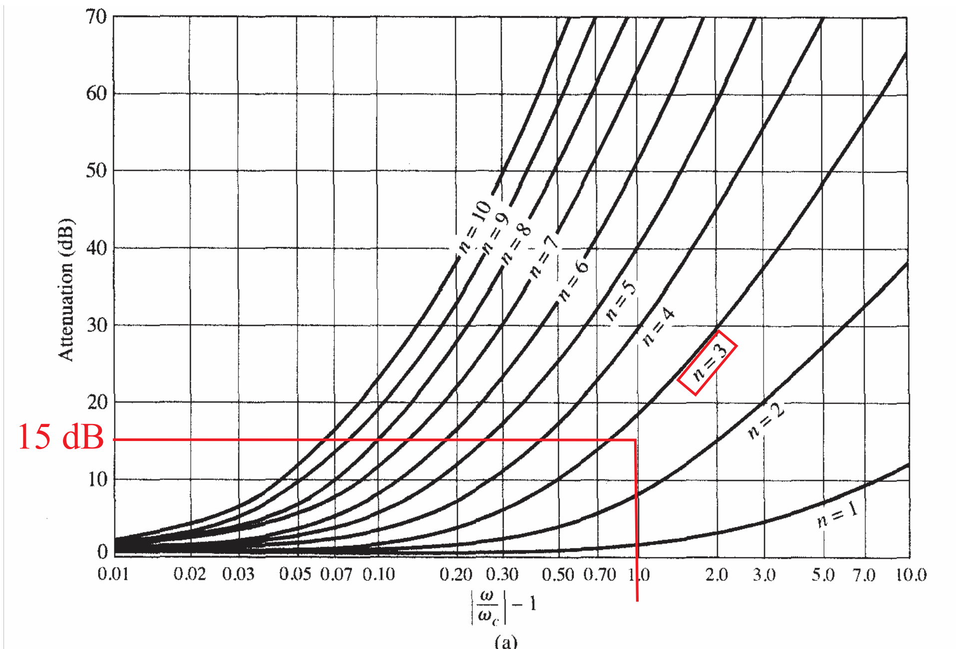


FIGURE 8.27 Attenuation versus normalized frequency for equal-ripple filter prototypes. (a) 0.5 dB ripple level.

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 the immittances:

$g_0 = g_4 = 1$ (resistors), $g_1 = g_3 = 1.5963$ (capacitors), and $g_2 = 1.0967$ (inductor).

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

b) For filter architecture of Fig 8.25a, use the immittances & equations (8.64cd), & (8.67ab) to get necessary scaled & transformed shunt inductances and series capacitances:

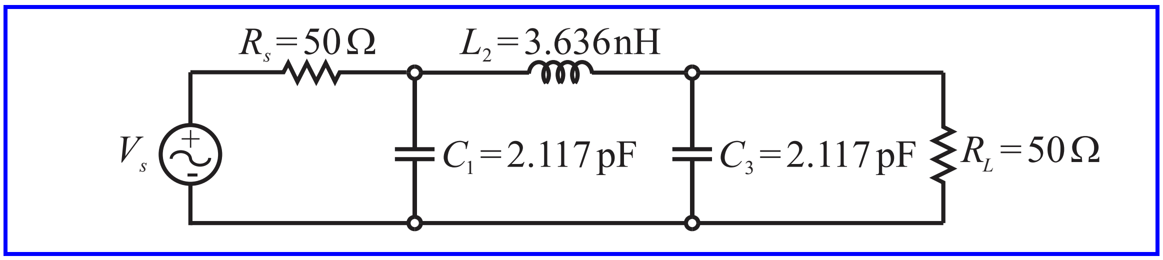
Per (8.64c), $R_S' = R_0 = 50$ $\Rightarrow$ **$R_S' = 50\ \Omega$.**

Per (8.67b), $C_1' = C_3' = \dfrac{C_k}{R_0\,\omega_c} = \dfrac{g_1}{R_0\,\omega_c} = \dfrac{1.5963}{50\,(2\pi)2.4\times10^9}$ $\Rightarrow$ **$C_1' = C_3' = 2.117$ pF.**

Per (8.67a), $L_2' = \dfrac{R_0\,L_k}{\omega_c} = \dfrac{R_0\,g_2}{\omega_c} = \dfrac{50\,(1.0967)}{(2\pi)2.4\times10^9}$ $\Rightarrow$ **$L_2' = 3.636$ nH.**

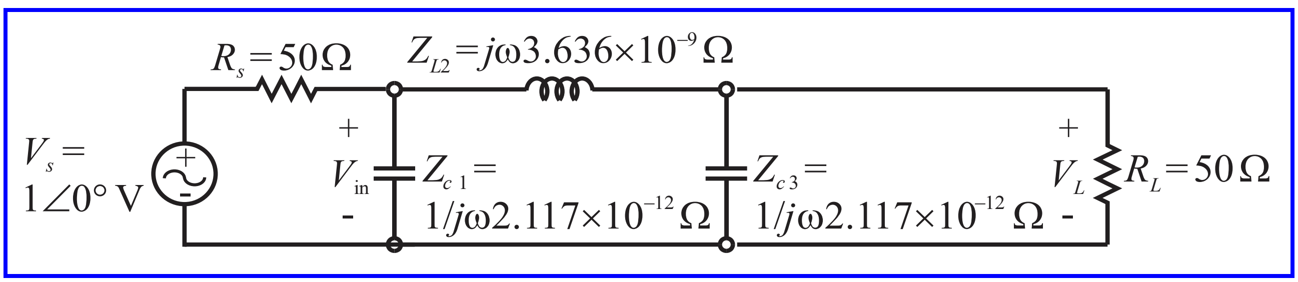
Per (8.64d), $R_L' = R_0\,R_L = R_0\,g_4 = 50(1)$ $\Rightarrow$ **$R_L' = 50\ \Omega$.**

- The resulting **Chebyshev lowpass** filter circuit with component values is:



c) From circuits, use $Z_R = R$, $Z_L = j\omega L$, and $Z_C = 1/j\omega C$.

The resulting **Chebyshev lowpass** filter circuit in phasor form is:



d) Using MathCAD

System impedance Z0 := 50 Ω n := 1 .. 500 $f_n := n\cdot 10^7$

CHebyshev lumped element design N = 3 $fc := 2.4\cdot10^9$ Hz

Table 8.3 LPF prototype g0 := 1 g1 := 1.5963 g2 := 1.0967 g3 := g1 g4 := 1

$RS := g0\cdot Z0$ $C1 := \dfrac{g1}{Z0\cdot 2\cdot\pi\cdot fc}$ $L2 := \dfrac{Z0\cdot g2}{2\cdot\pi\cdot fc}$ $C3 := C1$ $RL := Z0\cdot g4$

VS := 1 V RS = 50 Ω $C1 = 2.11716\times10^{-12}$ F

$L2 = 3.63636\times10^{-9}$ H $C3 = 2.11716\times10^{-12}$ F RL = 50 Ω

Parallel impedance of RL & C3 $$Z1(f) := \left(\frac{1}{RL} + j\cdot 2\cdot \pi\cdot f\cdot C3\right)^{-1}$$

Series impedance of L2 & Z1 $$Z2(f) := j\cdot 2\cdot \pi\cdot f\cdot L2 + Z1(f)$$

Input impedance of LP filter w/ load $$Zin(f) := \left(\frac{1}{Z2(f)} + j\cdot 2\cdot \pi\cdot f\cdot C1\right)^{-1}$$

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

$$VIN_n := Vin(f_n) \qquad VL_n := Vld(f_n) \qquad VL\_dB_n := 20\cdot \log(|VL_n|)$$

$$vert24 := \begin{pmatrix} 0 \\ -25 \end{pmatrix} \qquad vertf := \begin{pmatrix} 2.4\cdot 10^9 \\ 2.4\cdot 10^9 \end{pmatrix}$$