

FILTER EXAMPLE 1:

Low-Pass Filter Design Using Stubs

Design a low-pass filter for fabrication using microstrip lines.

The specifications are:

- cutoff frequency of 4 GHz
- third order
- impedance of 50 Ω
- 3 dB equal-ripple characteristic (Chebyshev).
- $E_r = 2.2$
- Thickness of dielectric = 62 mill

Solution

Start up the **rf & microwave toolbox** and select the **low pass** filter tool.

Then select, from the menu, filter type **Chebyshev** and **g-values** as output.

Choose the **shunt filter** configuration.

Fill in the filter specifications and tab the Calculate button.

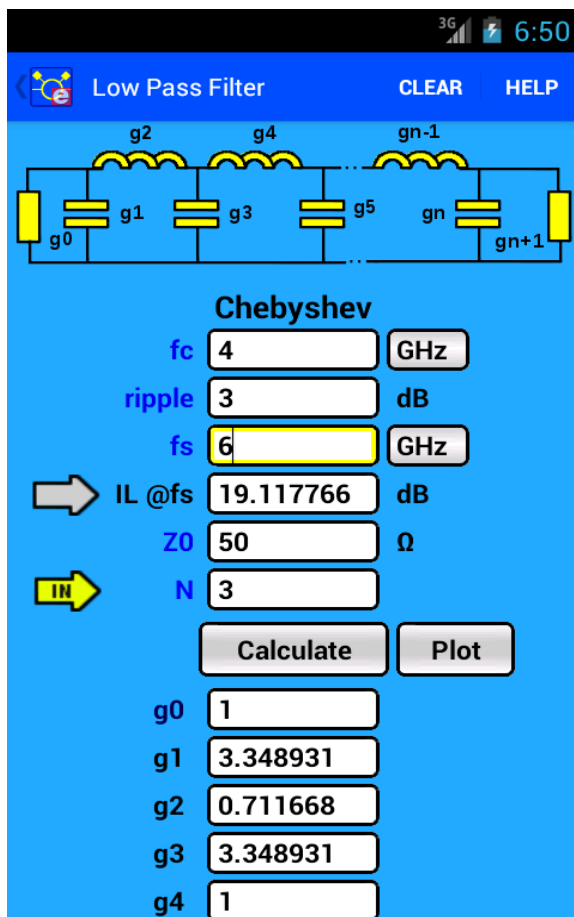


Figure 1: Low pass filter dialog

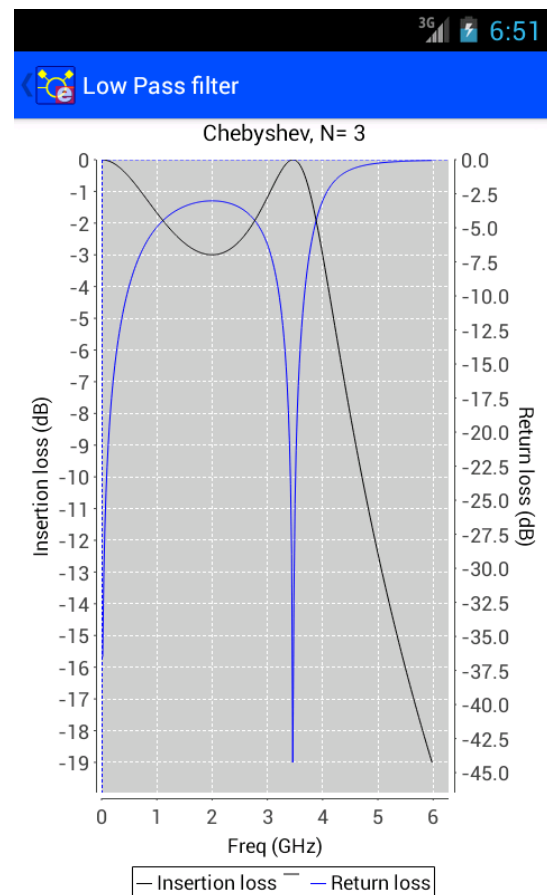


Figure 2: Low pass plot

The normalized low-pass prototype element values are:

$$\begin{aligned} Z_{in} = g_0 &= 1 \\ L_1 = g_1 &= 3.348931 \\ C_2 = g_2 &= 0.711668 \\ L_3 = g_3 &= 3.348931 \\ Z_{out} = g_4 &= 1 \end{aligned}$$

The next step is to use Richard's transformation to convert series inductors into series stubs, and shunt capacitors to shunt stubs. According to this transformation all lengths for the stubs are $\lambda/8$.

$$\begin{aligned} Z_{L1} &= L_1 \\ Z_{C2} &= C_2 \\ Z_{L2} &= L_2 \end{aligned}$$

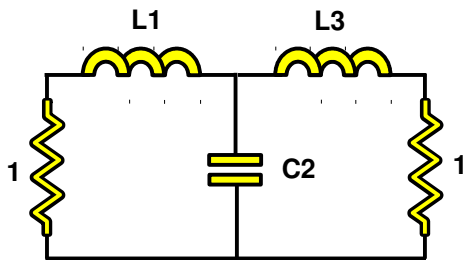
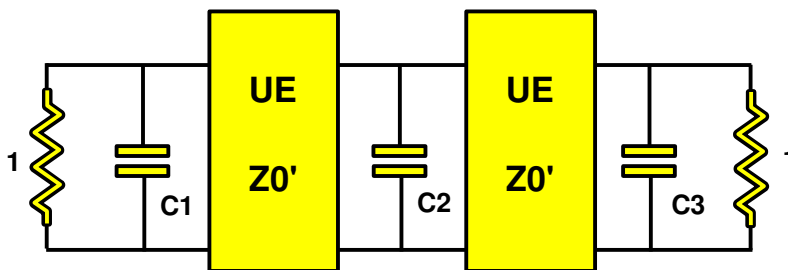


Figure 3: Low pass prototype filter

We will use Kuroda's identity nr 2 to convert the series elements into shunt elements.

Select tool **Filter Design** and the tab button **Kuroda's Identities**.

Fill in the values for Z_0 (Z_{in} , Z_{out}) and L (L_1, L_3)



$$\begin{aligned} Z_0' &= 4.3489 \\ C_1 &= 0.7701 \\ C_2 &= 0.7116 \\ C_3 &= 0.7701 \end{aligned}$$

Figure 4: Low pass filter after using Kuroda's Identities

Now we will use series and shunt equivalent circuit nr 1 to convert the shunt capacitors into shunt stubs. Select tool **Series and Shunt Circuit lines** and calculate the line impedance's. See Figure 5.

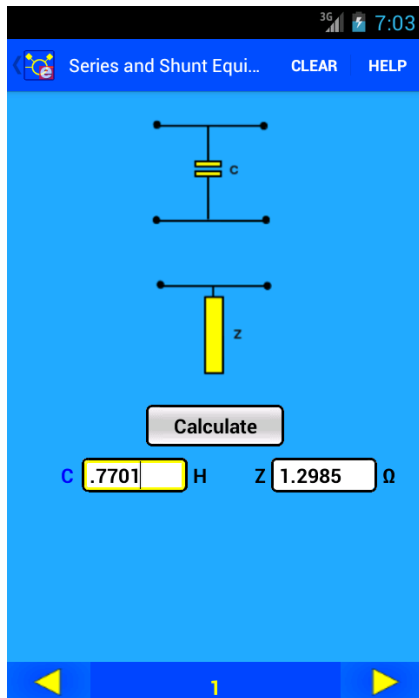


Figure 5: Series and shunt equivalent circuits dialog

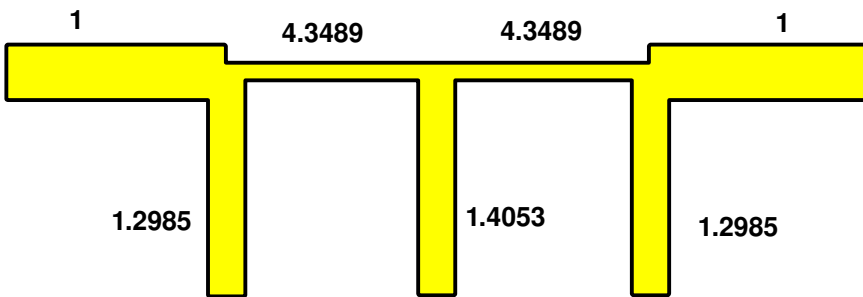


Figure 6: Normalized low pass stub filter. All lengths are $\lambda/8$.

After de-normalization to $Z_0 = 50 \Omega$ we get the following low pass filter using ideal transmission lines:

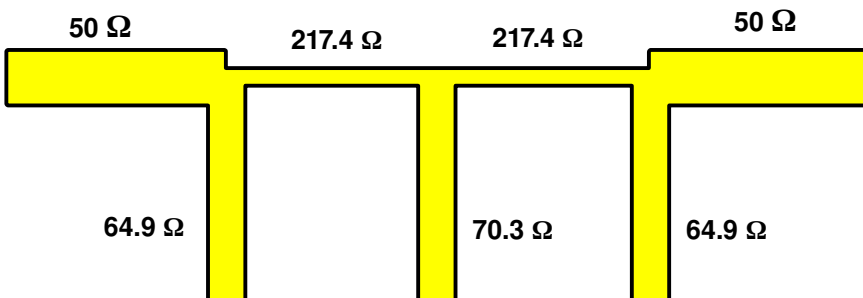


Figure 7: De-normalized low pass stub filter. All lengths are $\lambda/8$.

S-PARAMETERS

S_Param

SP1

Start=2.0 GHz

Stop=7.0 GHz

Step=.05 GHz

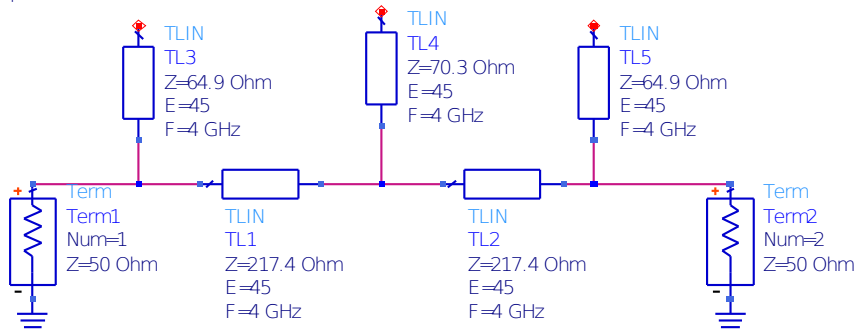


Figure 8: ADS circuit of the low pass filter using ideal transmission lines

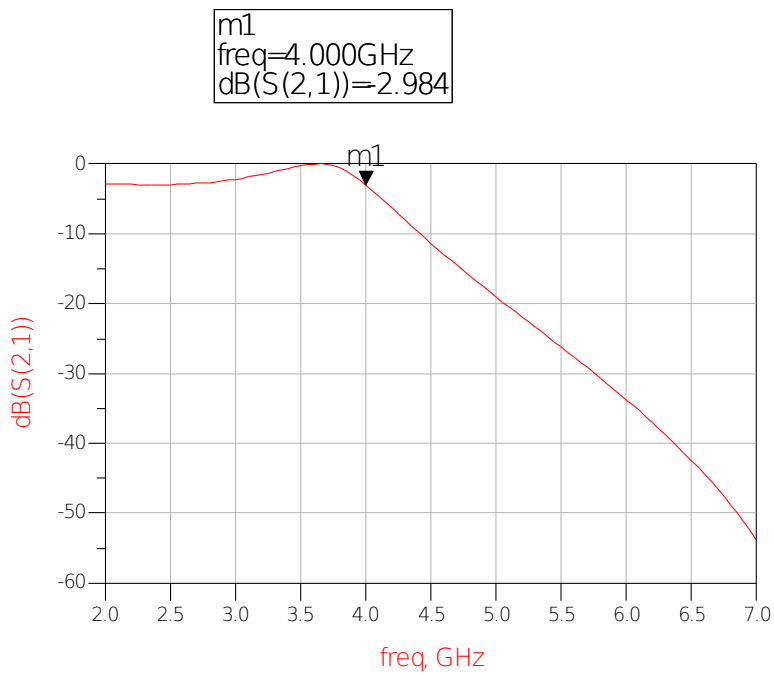


Figure 9: ADS simulation of the low pass filter using ideal transmission lines

Next step is to convert the ideal transmission lines to real microstrip lines.

Select tool **Microstrip line** Calculator and fill in the values for ϵ_r (2.2) and substrate height (62

mil).

Fill in a phase of 45 deg ($\lambda/8$) and F is the cutoff frequency (4Ghz)

Leave all other parameters to default.

Fill in the desired impedance of the transmission lines and synthesize the width and length of the microstrip lines.

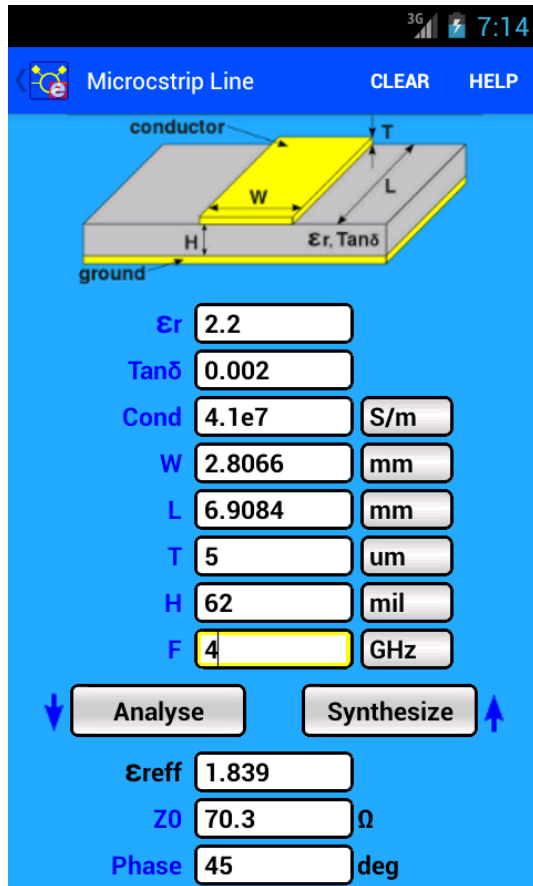
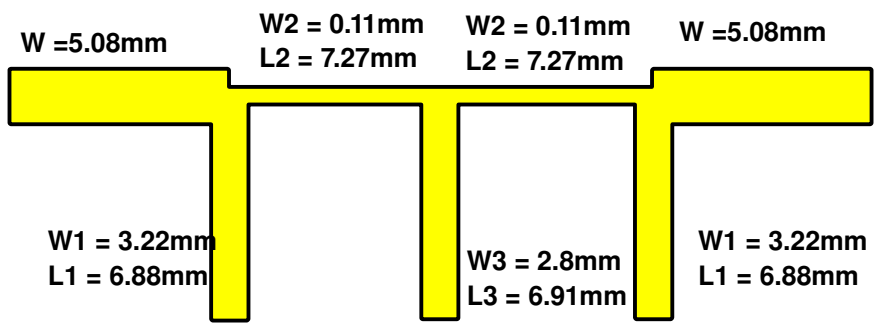


Figure 10: Microstrip line calculator dialog



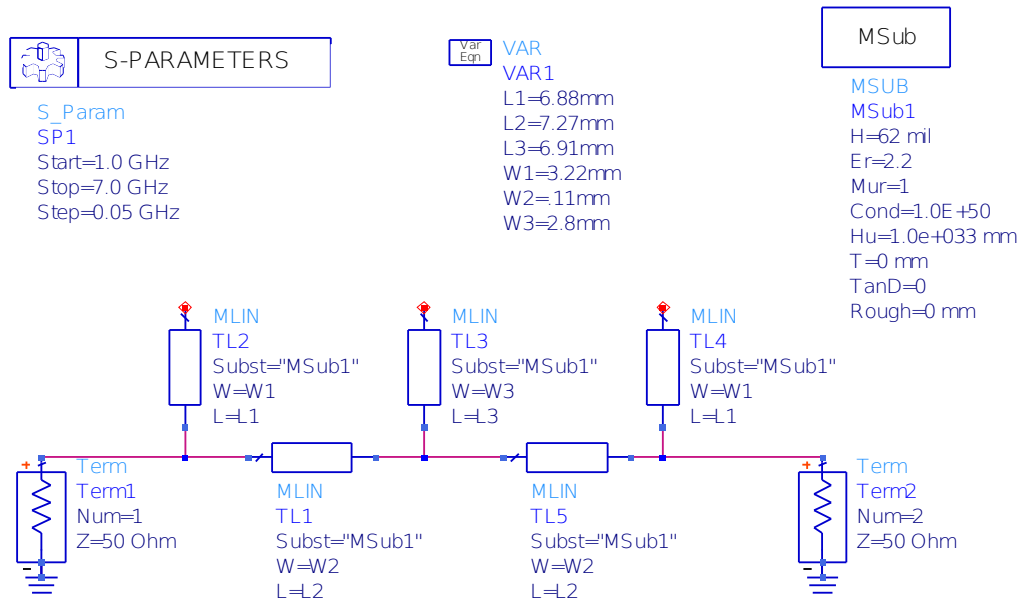


Figure 11: ADS circuit of the low pass filter using microstrip lines

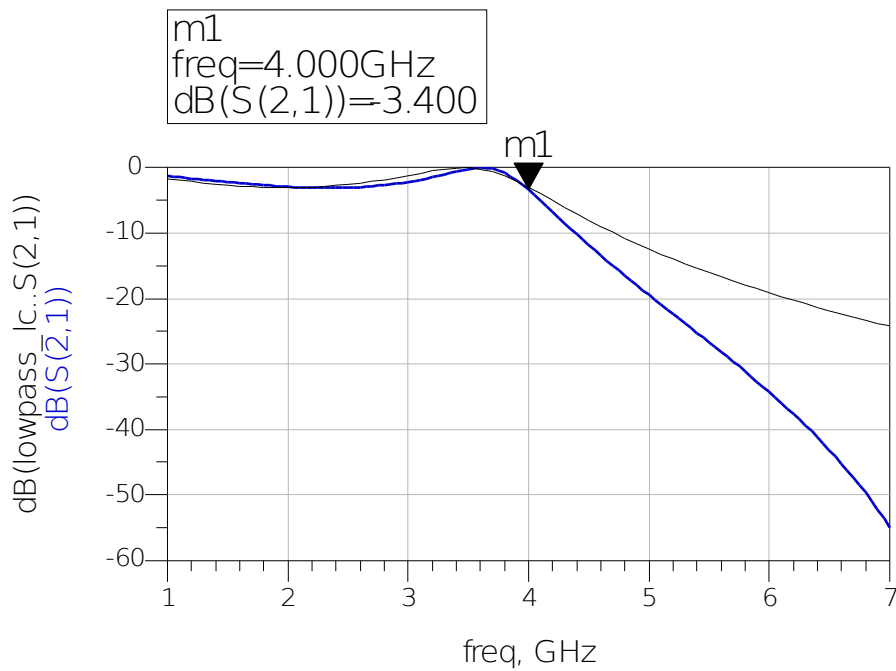


Figure 12: ADS simulation of the low pass filter using microstrip lines.
 Black: Plot of prototype filter (LC-network). Blue: Plot of microstrip filter.