

Stepped-impedance Lowpass Filter

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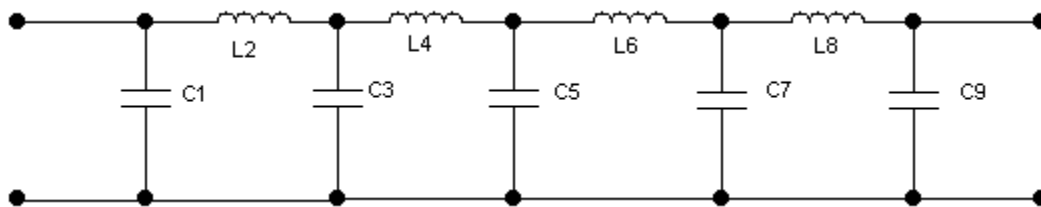
I. Objective: (Jasmine Le)

Design a Lowpass filter using the low and high impedance transmission line with the magnitude equal to 40dB at $f = 1.83\text{GHz}$ with the passband ripple less than 1dB. Also given the cutoff frequency equal to 915MHz.

II. Analysis and Procedure to design the project.

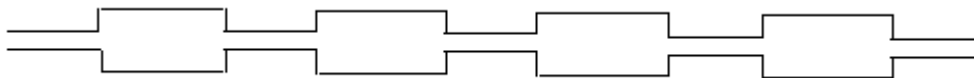
For the center frequency equal to 915MHz, from the table and graph in chapter 8 of the textbook, for the Flat lowpass filter, we come up with $N=9$, and the $f_c=1000\text{MHz}$. The ratio of Z_h/Z_l should be as high as possible in order to have a good filter; however, due to material that available, we choose $Z_l=24\text{ ohms}$ and $Z_h=184\text{ ohms}$.

Henry Nguyen:



Low-pass filter prototype circuit

$$\beta l_1 = g_1 \frac{Z_l}{R_0}; \quad \beta l_2 = g_2 \frac{R_0}{Z_h}; \quad Z_0 = 377 \frac{\ln \frac{b}{a}}{2\pi};$$



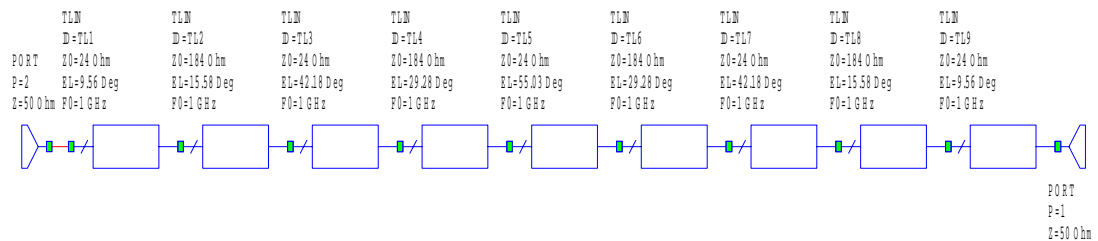
Microstrip layout of final filter

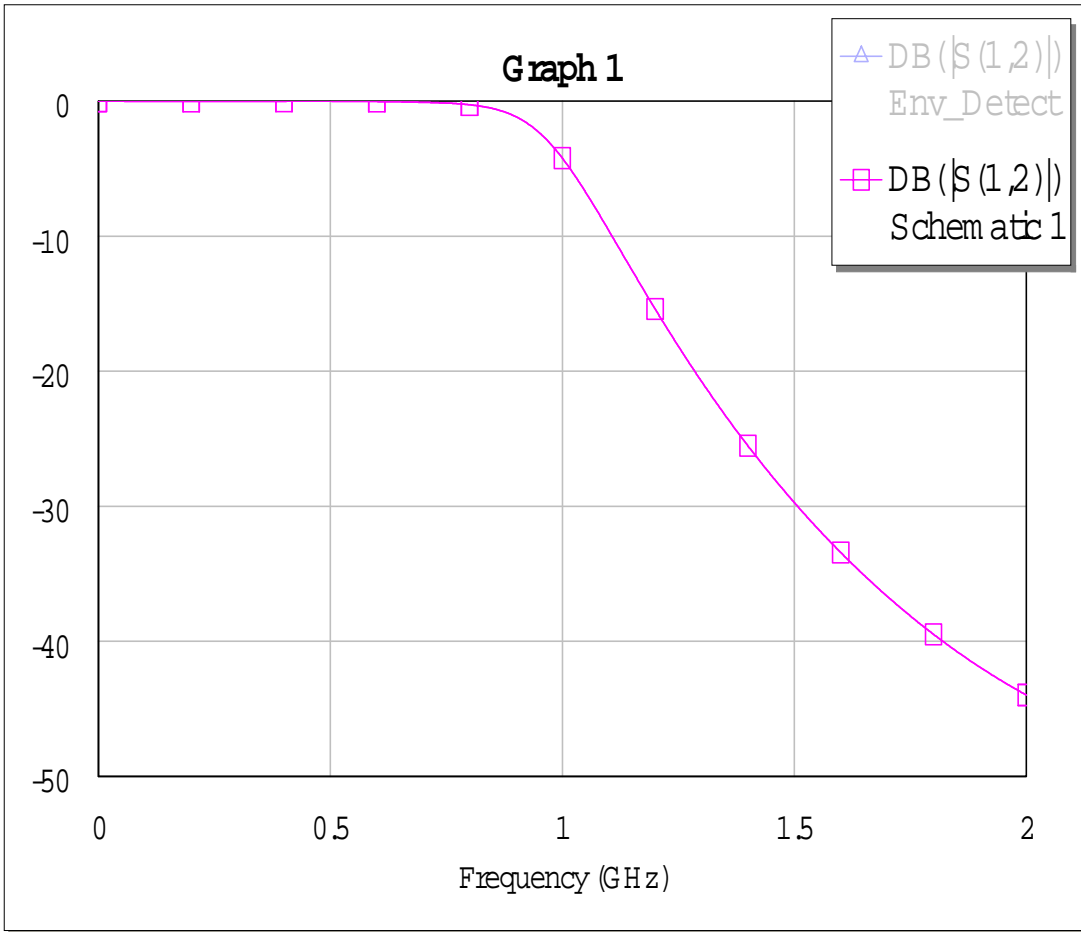
Using the above formulas we calculate the value of $\beta l_1, \beta l_2$, up to $\beta l_9, Z_0$, and the length L of each transmission line. They are shown in the following table

g-values	βL (radian)	βL (Degree) λ (in)	L(in)
			11.818 in
$g_1=C_1=0.3473$	0.1667	9.56	0.3135
$g_2=L_2=1$	0.2717	15.58	0.5111
$g_3=C_3=1.5321$	0.7354	42.18	1.3831
$g_4=L_4=1.8794$	0.5107	29.28	0.9605
$g_5=C_5=2$	0.960	55.03	1.8055
$g_6=L_5=1.8794$	0.5107	29.28	0.9605
$g_7=C_7=1.5321$	0.7354	42.18	1.3831
$g_8=L_8=1$	0.2717	15.58	0.5111
$g_9=C_9=0.3473$	0.1667	9.56	0.3135
		L(Total in)	8.1419

1. Design Using Microwave Office.

From the above table, we obtain the BL in degree and $F_c=1.0\text{GHz}$. We use Microwave Office to construct the following layout.

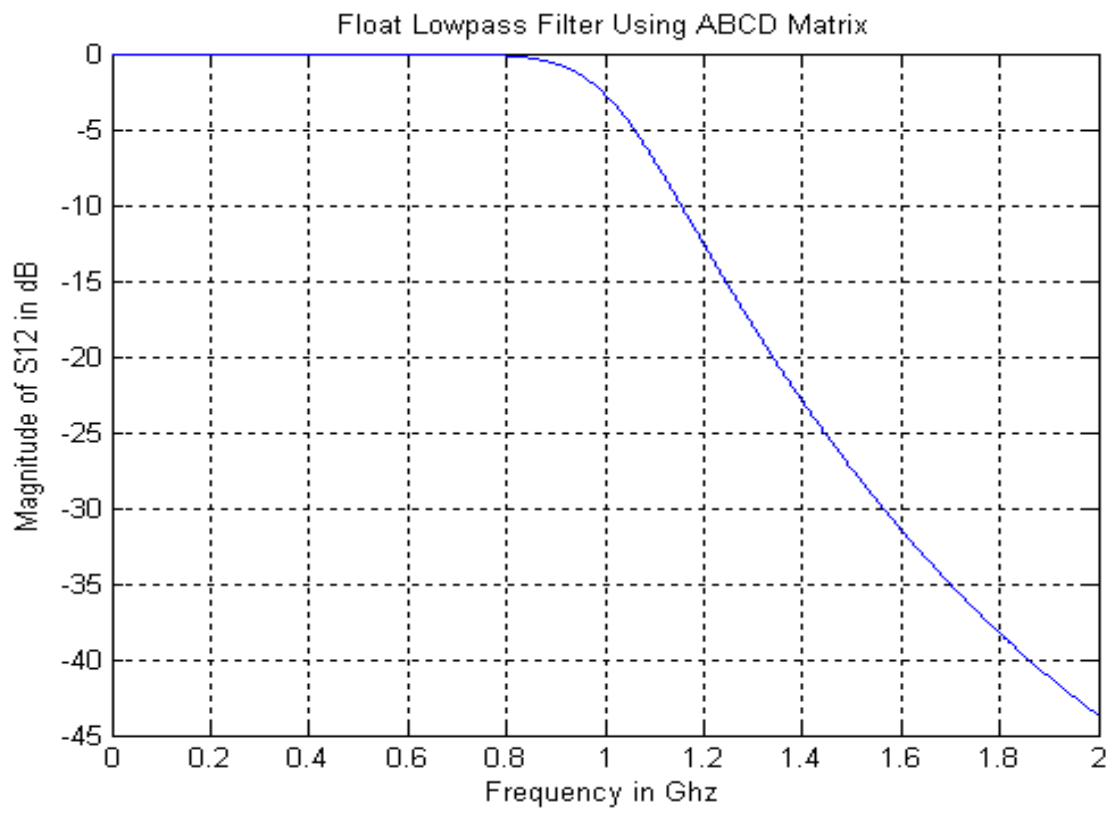




2. Design Using Matlab with ABCD Matrix.

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%EE 172 Filter Design Project
%Using the ABCD matrix with low and high impedance line
Z1=24; Z2=184; Z0=50;
fc=1.0;
j=sqrt(-1);
g1=0.3473; g2=1.00; g3=1.5321; g4=1.8794; g5=2.00; g6=1.8794;
g7=1.5321; g8=1.00; g9=0.3473;
BL1=g1*Z1/Z0; BL2=g2*Z0/Z2; BL3=g3*Z1/Z0; BL4=g4*Z0/Z2; BL5=g5*Z1/Z0;
BL6=g6*Z0/Z2; BL7=g7*Z1/Z0; BL8=g8*Z0/Z2; BL9=g9*Z1/Z0;
k=0;
for f=[0:0.001:2]
    A1=cos(BL1*f/fc);      B1=j*Z1*sin(BL1*f/fc);
    C1=(j/Z1)*sin(BL1*f/fc); D1=cos(BL1*f/fc);
    A2=cos(BL2*f/fc);      B2=j*Z2*sin(BL2*f/fc);
    C2=(j/Z2)*sin(BL2*f/fc); D2=cos(BL2*f/fc);
    A3=cos(BL3*f/fc);      B3=j*Z1*sin(BL3*f/fc);
    C3=(j/Z1)*sin(BL3*f/fc); D3=cos(BL3*f/fc);
    A4=cos(BL4*f/fc);      B4=j*Z2*sin(BL4*f/fc);
    C4=(j/Z2)*sin(BL4*f/fc); D4=cos(BL4*f/fc);
    A5=cos(BL5*f/fc);      B5=j*Z1*sin(BL5*f/fc);
    C5=(j/Z1)*sin(BL5*f/fc); D5=cos(BL5*f/fc);
    A6=cos(BL6*f/fc);      B6=j*Z2*sin(BL6*f/fc);
    C6=(j/Z2)*sin(BL6*f/fc); D6=cos(BL6*f/fc);
    A7=cos(BL7*f/fc);      B7=j*Z1*sin(BL7*f/fc);
    C7=(j/Z1)*sin(BL7*f/fc); D7=cos(BL7*f/fc);
    A8=cos(BL8*f/fc);      B8=j*Z2*sin(BL8*f/fc);
    C8=(j/Z2)*sin(BL8*f/fc); D8=cos(BL8*f/fc);
    A9=cos(BL9*f/fc);      B9=j*Z1*sin(BL9*f/fc);
    C9=(j/Z1)*sin(BL9*f/fc); D9=cos(BL9*f/fc);

    M1=[A1 B1; C1 D1];      M2=[A2 B2; C2 D2];
    M3=[A3 B3; C3 D3];      M4=[A4 B4; C4 D4];
    M5=[A5 B5; C5 D5];      M6=[A6 B6; C6 D6];
    M7=[A7 B7; C7 D7];      M8=[A8 B8; C8 D8];
    M9=[A9 B9; C9 D9];
    T=M1*M2*M3*M4*M5*M6*M7*M8*M9;
    A=T(1,1); B=T(1,2); C=T(2,1); D=T(2,2);
    S12=2/(A+B/Z0+C*Z0+D);
    k=k+1;
    Y1(k)=S12;
end;
plot([0:0.001:2], 20*log10(abs(Y1))); grid
xlabel('Frequency in Ghz');
ylabel('Magnitude of S12 in dB');
title('Float Lowpass Filter Using ABCD Matrix');
```



3. Assembly the filter.

a. Use the Coax:

$$\text{Since } Z_0 = 377 \frac{\ln \frac{b}{a}}{2\pi} ; \text{ Therefore } \frac{b}{a} = e^{(2*\pi*\frac{Z_0}{377})}$$

$$\text{For } Z_0 = 184 \text{ ohms, } \frac{b}{a_1} = 21. \quad \text{If } a_1 = 0.07 \text{ in, We have } b = 0.75 \text{ in}$$

$$\text{For } Z_0 = 24 \text{ ohms, } \frac{b}{a_2} = 1.5 \text{ in} \Rightarrow a_2 = 0.5 \text{ in}$$

XuanYen Truong:

b. Calculation:

From the calculation above, we obtained the length for each transmission line: 0.3135in, 0.5111in, 1.3831in, 0.9605in, 1.8055in, 0.9605in, 1.3831in, 0.5111in, 0.3135in, respectively.

c. Assembly the all the transmission line together.



d. Testing

After assemble all the transmission line together by soldering, the final layout of the filter is tested using network analyzer in Radio Frequency Laboratory. The result meets the project requirement closely.

	Project Requirement	Actual Result
At 3dB	915MHz	840 MHz
At 40dB	1.83GHz	1.60GHz

III Problems Encounter:

While working on the project, there were some obstacles that we faced. These problems were the limitation of materials, the lack of equipment, and the inaccuracy during the assembling process. The lowpass filter will have a better performance if it has the larger ratio of the low and high impedance; however, due to the availability of material in store, we had to limit its ratio. Therefore, the filter could not reach the designed frequency range perfectly. The result of the filter was also effect due to the lack of equipment. When the SMA connectors connected to both end of the filter, there was a fault distance that unintendedly created since we do not have the right equipment to install them. It also limited us from adjusting the component position to be at the center in order to have a high performance. Another problem that we had during the assembling process was the extra wire was added to each end of the transmission line when we soldered them together. That can also affect the result of the filter. Although there were problems that encountered while building the project, we tried our best to solve and eliminate them. The result of our produce was closely meet the project requirement, and that was a major accomplishment that we proudly had. (XuanYen Truong)