HF&VHF Circuits and Techniques I

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Correction of Serie 9
on the denormalization in frequency and in impedance

Exercise 1

We choose the following topology of the 3rd order low-pass filter:

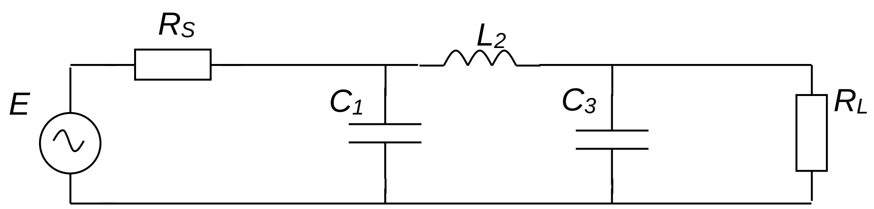

Fig. 1

The components were calculated in Serie 8 for which it is recalled that:
Rs = 1 Ohm and the specifications of Fig. 2 are fulfilled with A_3 = 1 dB and A_1 = 30 dB:

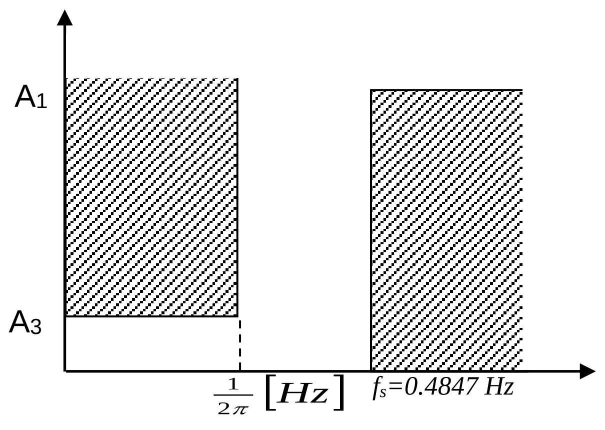

Fig. 2

The parameters are first calculated:

$10 \log (1 + \varepsilon^2) = 1$ dB

which implies that

$\varepsilon = 0.50885$

$$h = \left(\frac{1}{\varepsilon} + \sqrt{1 + \frac{1}{\varepsilon^2}}\right)^{1/N} = \left(\frac{1}{0.50885} + \sqrt{1 + \frac{1}{0.50885^2}}\right)^{1/3} \approx 1.60961$$

$$\xi = h - \frac{1}{h} = 1.60961 - \frac{1}{1.60961} \approx 0.9883$$

The values of the components of Fig. 1, which fulfill the specifications of Fig. 2, are summarized below:

$$C_1 = \frac{4\sin\left(\frac{\pi}{6}\right)}{\xi R_S} = 2.023593\,F$$

$$L_2 = \frac{1}{C_1} \cdot \frac{16\sin\left(\frac{\pi}{6}\right)\sin\left(\frac{3\pi}{6}\right)}{\xi^2 + \left[2\sin\left(\frac{\pi}{3}\right)\right]^2} = 0.994102\,H$$

$$C_3 = \frac{1}{L_2} \cdot \frac{16\sin\left(\frac{3\pi}{6}\right)\cdot\sin\left(\frac{5\pi}{6}\right)}{\xi^2 + \left[2\sin\left(\frac{2\pi}{3}\right)\right]^2} = 2.023593\,F$$

$R_L = 1$ Ohm

Denormalization in frequency and in impedance:

By comparing the specifications represented in Fig. 2 with respect to the new specifications represented in Fig. 3, we see that the end of the band-pass and the beginning of the stop-band have been multiplied by the same factor equal to:
10’000 / (1/2 π) = 2 π 10’000

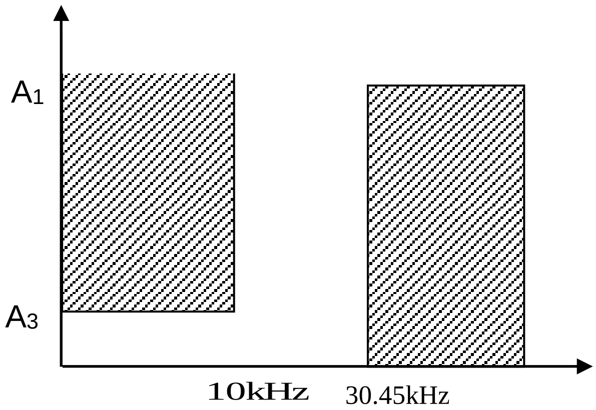

Fig. 3

Moreover, the resistor of the source has been multiplied by 600.

Therefore, to fulfill the specifications of Fig. 3 with the assumption that Rs = 600 Ohms:
- The two capacitors are divided by (2 π 10’000 x 600) = 12’000’000 π
- The inductor is divided by (2 π 10’000 / 600) = 33.3333 π
- The resistor of the load is multiplied by 600

The below new values are obtained for the specifications of Fig. 3:
- C1 = C3 = 53.6774715 nF
- L2 = 9.49297493 mH
- R_L = 600 Ohms

Exercise 2

The topology of a passive filter is given below:

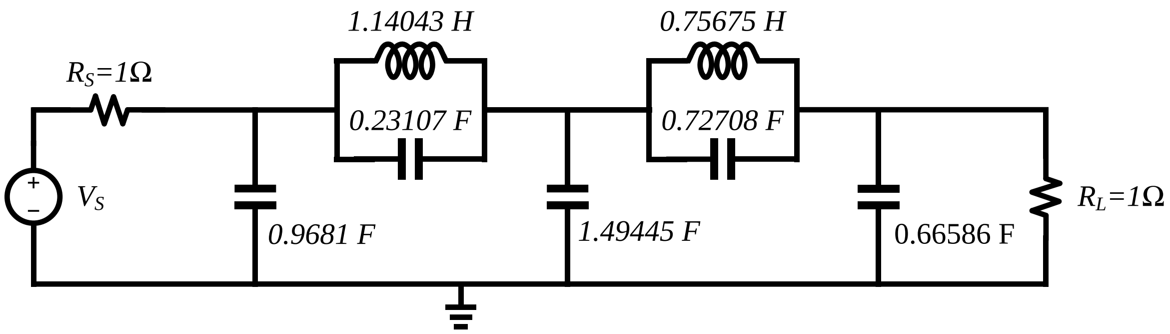

Fig. 1

- R_S = 1 Ohm
- C1 = 0.9681 F
- C2 = 0.23107 F, L3 = 1.14043 H
- C4 = 1.49445 F
- C5 = 0.72708 F, L6 = 0.75675 H
- C7 = 0.66586 F
- R_L = 1 Ohm

a) What is the type of this filter? Thanks to justify your answer.

- In DC (f = 0 Hz), the capacitors corresponds to an open circuit and the inductors to a short circuit. Therefore, active power is delivered to the load R_L. In addition, $R_S = R_L$. Therefore, the maximum of power is delivered to the load in DC.

- At a very high frequency, the capacitors correspond to a short circuit and the inductors to an open circuit. Therefore, no active power is delivered to the load R_L.

The two above properties prove that this filter is a low-pass filter.

b) Determine and calculate the frequencies for which the attenuation is very high

- Each resonant circuit of the filter represented in Fig. 1 can be replaced by an open circuit at its resonant frequency.
- Therefore, at this resonant frequency, the attenuation is very high.

- The components of each resonant circuit and its corresponding resonant frequency are linked by: $4\,\pi^2\, f_0^{\,2} = 1/\,(L\,C\,)$
- Therefore, we have two resonant frequencies which are equal to:
  f_1 = 0.21462004 Hz, f_2 = 0.3100374 Hz
- Moreover, at a very high frequency, the capacitors correspond to a short circuit and the inductors to an open circuit. Therefore, the attenuation is very high at a very high frequency.

In summary, we have three poles of attenuation in:
f_1 = 0.21462004 Hz, f_2 = 0.3100374 Hz, f_3 = infinity.

c) It can be shown that the circuit of Fig. 1 fulfills the specifications of the attenuation represented in Fig. 2.

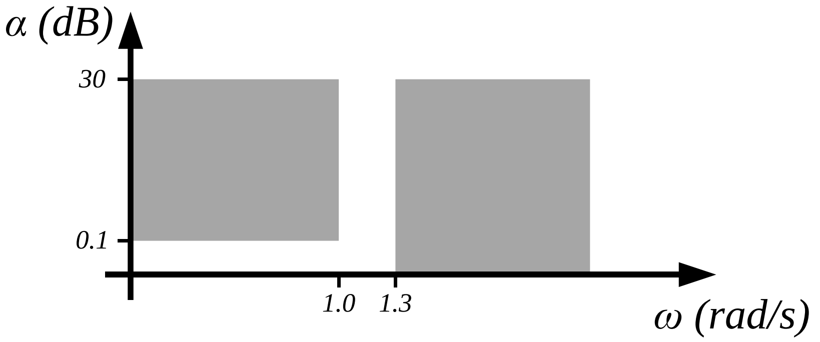

Fig. 2

Calculate the values of the components of the new filter such that:
R_S = R_L = 50 Ohms and its cut-off frequency = 20 MHz.

To fulfill these new specifications:
- the capacitors are divided by ($2\,\pi$ x 20 10^6 x 50) = 2 $10^9\,\pi$
- the inductors are divided by ($2\,\pi$ x 20 10^6 / 50) = 0.8 $10^6\,\pi$
- the resistor of the load is multiplied by 50

Therefore, by starting from the voltage source generator, we obtain the following values of the components:

- R_{S0} = 50 Ohm
- C_{10} = 0.154078 nF
- C_{20} = 0.0367759 nF, L_{30} = 0.453763 uH
- C_{40} = 0.237849 nF
- C_{50} = 0.115718 nF, L_{60} = 0.301101 uH

- C_{70} = 0.105975 nF
- R_{L0} = 50 Ohm

Determine and calculate the frequencies for which the attenuation is very high

In comparison to the question b), the frequencies of the three poles of attenuation are multiplied by $2\ \pi$ x $20\ 10^6$ due to the denormalization in frequency. Therefore, we obtain:

f_{10} = 26.969950 MHz, f_{20} = 38.960448 MHz, f_{30} = infinity

Remark:
The denormalization in impedance has no effect on the values of these frequencies because this denormalization does not affect the multiplication (L x C) for each resonant circuit.