Exercise of Electronics for Communication Systems Prof. C. Abbate, G. Busatto - A.A. 2018/2019

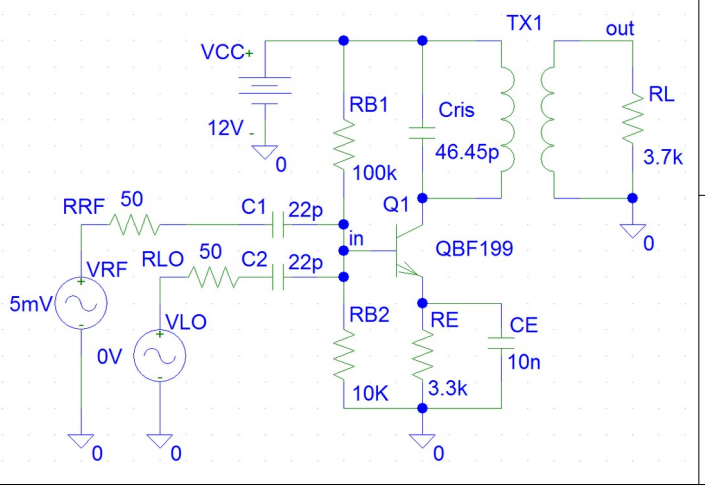
Sizing and PSPICE simulation of a Mixer

18/11/2018 – Diego Tuzi – 50435 – diego.tuzi@studentmail.unicas.it

POINT 1A and 1B

Determine the capacitance Cris in the common emitter amplifier of Fig.1, so as to obtain the resonance frequency of 10.7MHz that is the intermediate frequency of the mixer. Consider that the transformer TX1, which will be used in the experimental circuit, has an inductance of the primary, Lprim, equal to 4.71uH .

Determine the minimum value of resistance RL which allows you to obtain a Q greater than 10 and guarantees a good selectivity of the stage while retaining a bandwidth compatible with the FM signal of interest.



$$\omega_0 = \frac{1}{\sqrt{L_1 \cdot C_{ris}}} \quad , \quad \omega_0 = 2\pi f_0$$

$$C_{ris} = \frac{1}{L_1 (2\pi f_0)^2} \quad , \quad f_0 = 10{,}7\ MHz \, , C_{ris} = 46{,}97\ pF$$

For a parallel RLC circuit

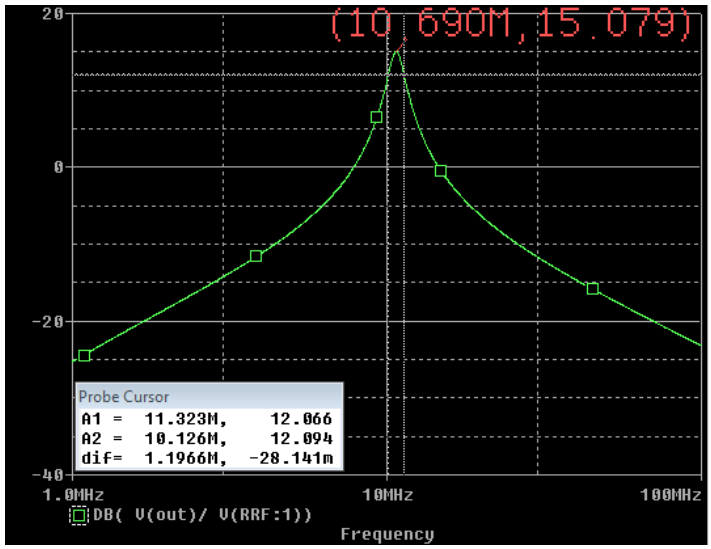
$$Q = R_L \sqrt{\frac{C_{ris}}{L_1}} \quad \rightarrow \quad R_L = Q \sqrt{\frac{L_1}{C_{ris}}}$$

$$Q > 10 \quad \text{when} \quad R_L > 3{,}17\, k\Omega$$

$$Q = \frac{f_0}{BW} \quad \rightarrow \quad BW \simeq 1{,}07\ MHz$$

POINT 2B

Perform the AC analysis to check that the amplifier is tuned to the frequency of interest. Set the AC input generators VRF and VLO to 5mV and 0V, respectively. Determine quality factor Q and gain A of the amplifier at the resonance frequency. Verify that it is gm • r0 // RL.



From simulation

f_0 = 10,69MHz
voltage gain (A_db) = 15,08 dB
bandwidth = 1,20 MHz
Q = 8,93

from theory

$$A_{db} = 20 \log_{10}\left(g_m (r_0 \,//\, R_0)\right)$$

$$A_{db} = 20 \log_{10}\left(g_m \left(\frac{r_0 R_0}{r_0 + R_0}\right)\right) \simeq 23{,}58\, dB$$

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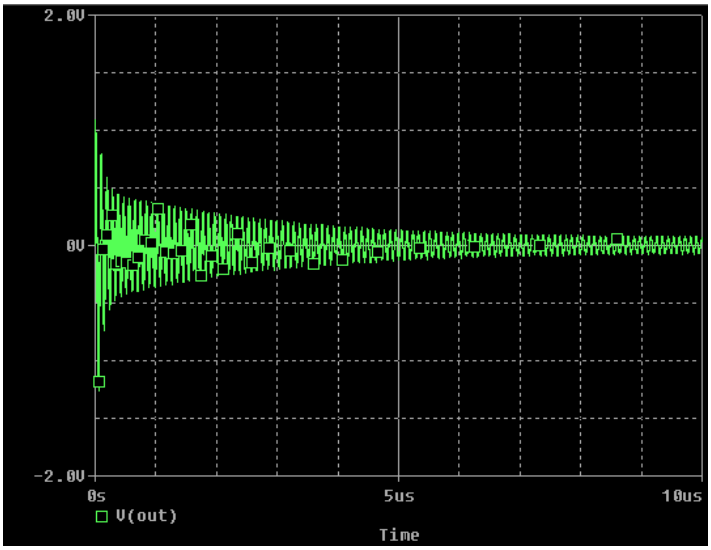
POINT 2C

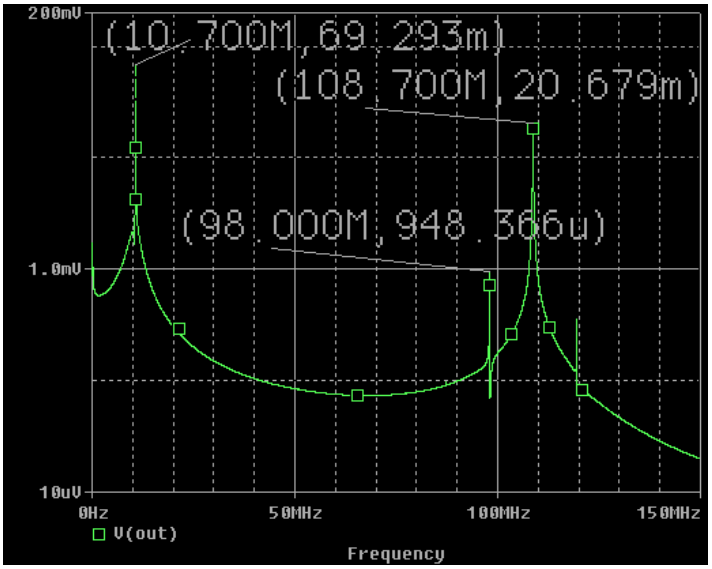
Perform a transient analysis to verify the correct behavior of the mixer.
In simulation set the parameters as :

- *amplitude and frequency of VRF to 10mV and 98MHz, respectively;*
- *amplitude and frequency of VLO to 500mV and 108.7MHz, respectively;*
- *initial condition on the capacitor CE to 0.5595V;*
- *simulation interval to 50 ↄs;*
- *step ceiling to 0.1ns.*

Display the signal in the time domain and its FFT. Identify the harmonics and various intermodulation products and, in particular, recognize RF, LO and intermediate frequency components.



Time Domain



FFT
IF at 10,7 MHz with 69,3mV of amplitude
RF at 98 MHz with 948,4uV of amplitude
LO at 108,7 MHz with 20,7mV of amplitude

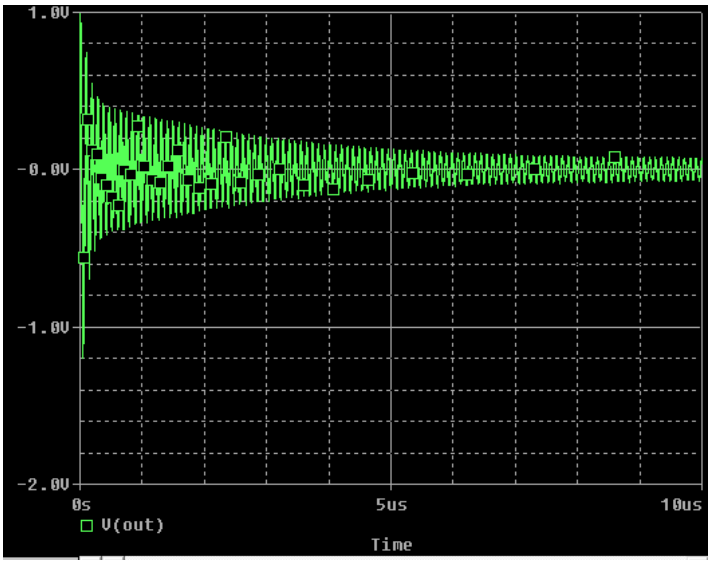
Report on a table the values of the amplitudes and frequencies of the main harmonics up to the 5 th order.

n	+/-	m	f (MHz)	a(mV)
1	-	1	10,70	69,293
1	+	0	98,00	0,948
0	-	1	108,70	20,679
1	-	2	119,40	0,352
1	+	1	206,70	0,369
0	+	2	217,40	5,895
1	-	3	228,10	0,091
2	-	4	238,80	0,002
2	+	1	304,70	0,003
1	+	2	315,40	0,143
0	+	3	326,10	1,819
1	-	4	336,80	0,029
2	+	2	413,40	0,002
1	+	3	424,10	0,052
0	+	4	434,80	0,569
1	-	5	445,50	0,009
2	+	3	522,10	0,001
0	+	5	543,50	0,179
1	+	5	641,50	0,006
2	+	5	739,50	0,001

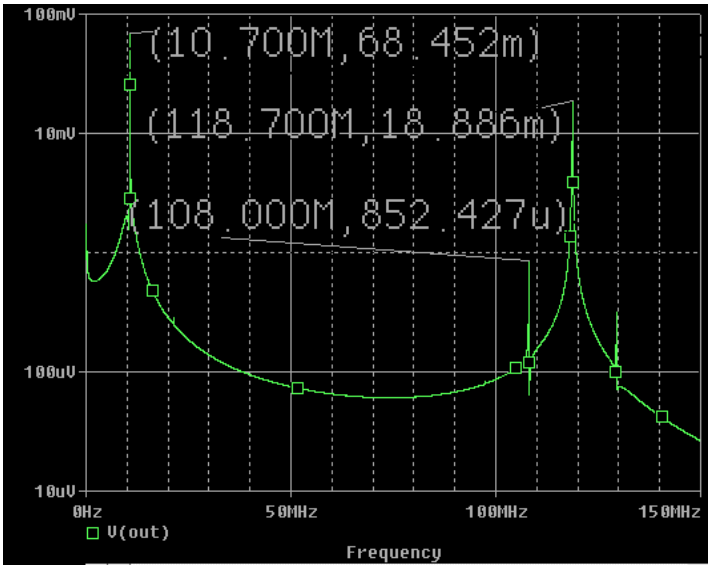
POINT 2D

Repeat the procedure referred to in point c for the maximum frequency RF.

Display the signal in the time domain and its FFT. Identify the harmonics and various intermodulation products and, in particular, recognize RF, LO and intermediate frequency components.



Time Domain



FFT
IF at 10,7 MHz with 68,4mV of amplitude
RF at 108 MHz with 852,4uV of amplitude
LO at 118,7 MHz with 18,9mV of amplitude

Report on a table the values of the amplitudes and frequencies of the main harmonics up to the 5 th order.

n	+/-	m	f	a(mV)
1	-	1	10,70	68,452
1	+	0	108,00	0,852
0	+	1	118,70	18,886
1	-	2	129,40	0,316
2	+	0	216,00	0,014
1	+	1	226,70	0,327
0	+	2	237,40	5,266
1	-	3	248,10	0,082
2	+	1	334,70	0,002
1	+	2	345,40	0,125
0	+	3	356,10	1,602
1	-	4	366,80	0,026
2	+	2	453,40	0,002
1	+	3	464,10	0,045
0	+	4	474,80	0,498
1	-	5	485,50	0,008
2	+	3	572,10	0,001
1	+	4	582,80	0,015
0	+	5	593,50	0,153
1	+	5	701,50	0,005
2	+	5	809,50	0,001

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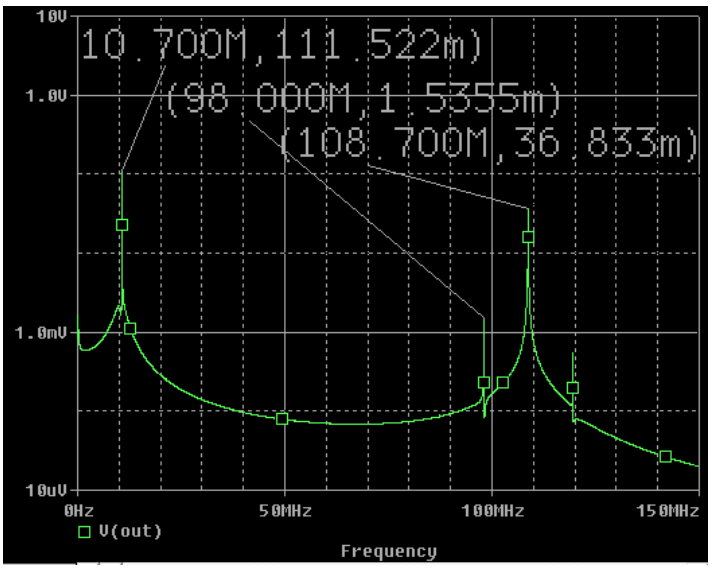
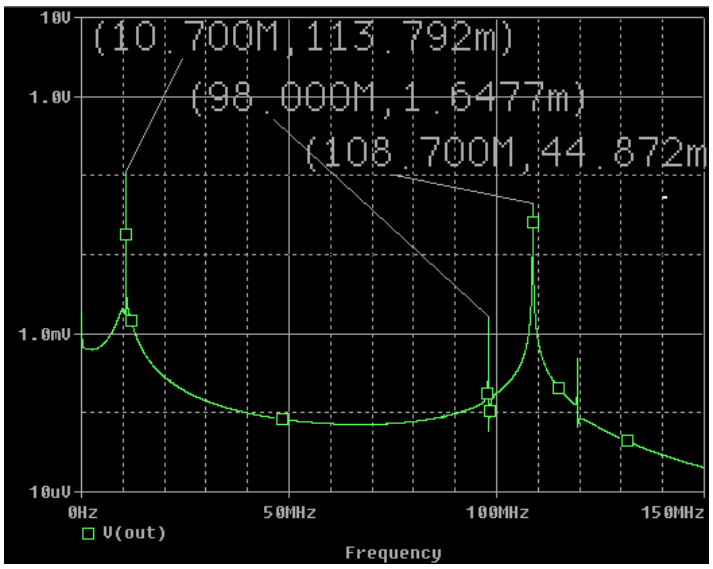
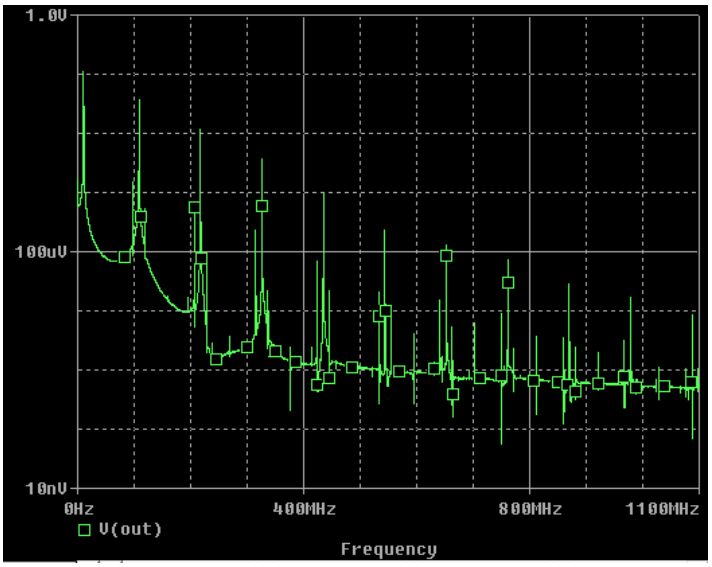
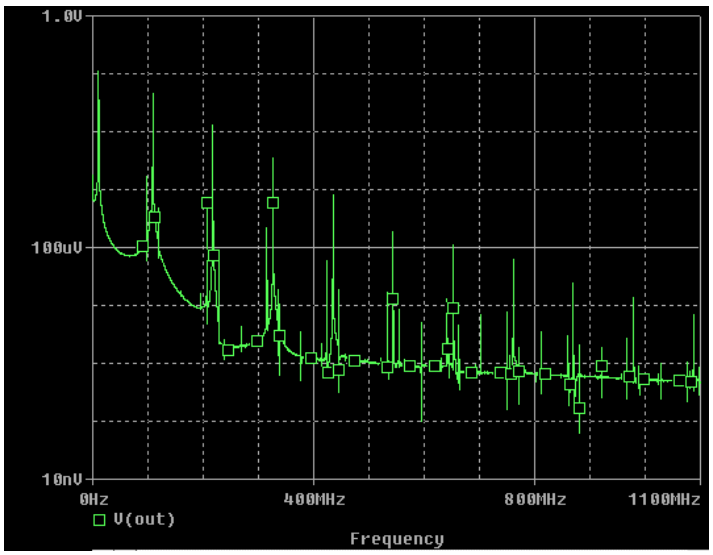
POINT 2E

Study the effect of variation of the biasing point on the frequency response of the mixer. For this purpose, using the parameters indicated in point c, analyze the two following cases:

- *RE=1k and RB2=10k;*
- *RE=3.3k and RB2=22k.*

RE=1k and RB2=10k	**RE=3.3k and RB2=22k**
	
	
FFT IF at 10,7 MHz with 111,5mV of amplitude RF at 98 MHz with 1,5mV of amplitude LO at 108,7 MHz with 36,8mV of amplitude **Gain is increased respect to case with RE=3,3k and RB2=10k**	FFT IF at 10,7 MHz with 113,8mV of amplitude RF at 98 MHz with 1,65mV of amplitude LO at 108,7 MHz with 44,9mV of amplitude **Gain is increased respect to case with RE=3,3k and RB2=10k**

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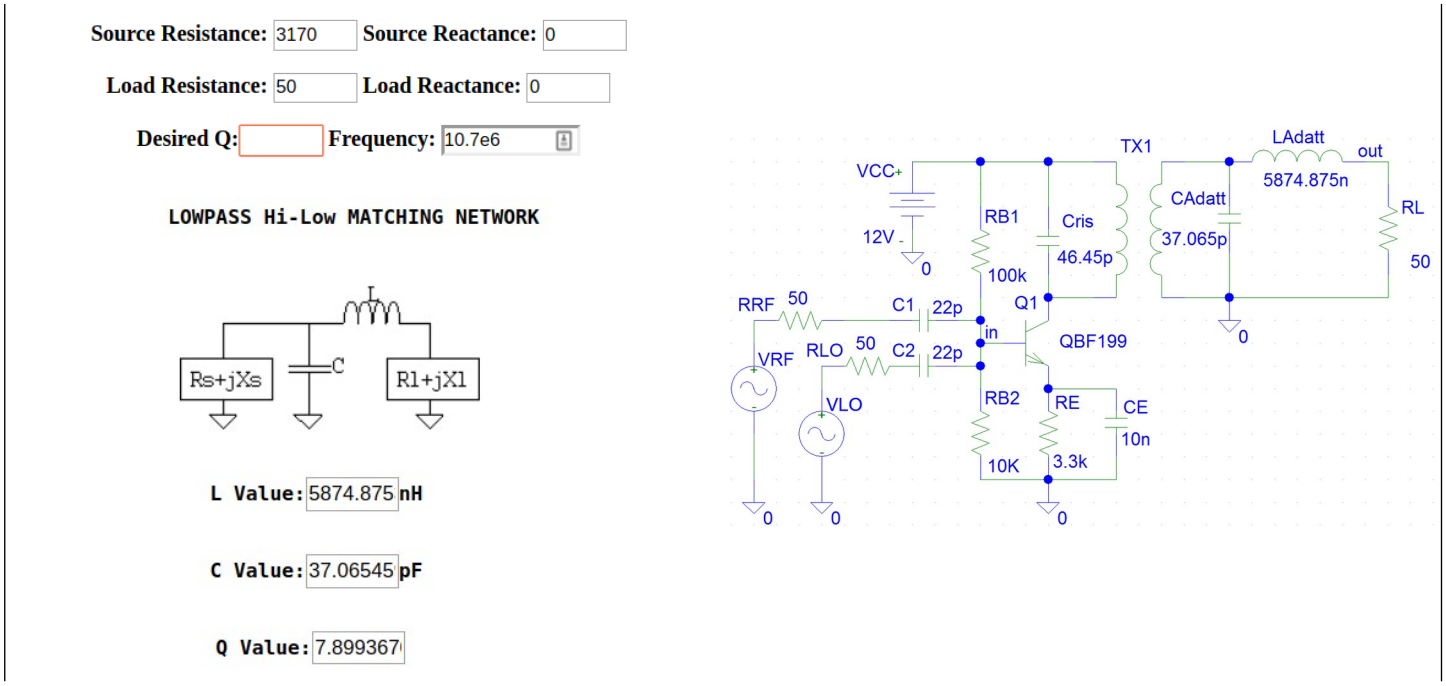
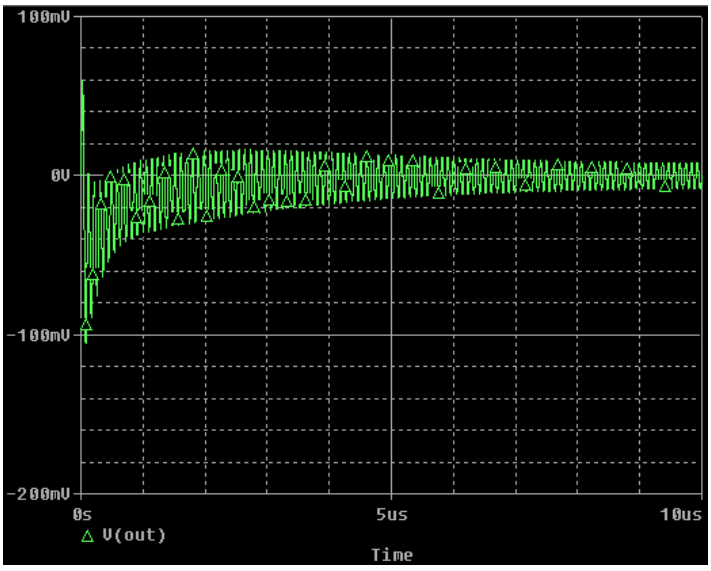
POINT 2F

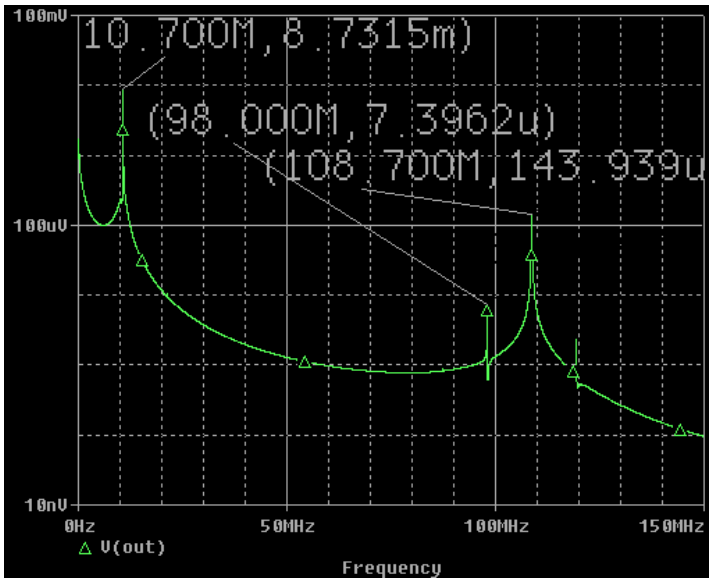
The mixer circuit must be connected with a load adapted to 50 Ohm. For this purpose design a two element matching network as shown in Fig. 2. For computing LAdatt and CAdatt refer to he link used in the previous exercises. Consider the value of RL found in point 1.a at the input side and 50 at the output one.



Repeat the analysis requested in point 2.c to verify the correct operations of the mixer in the whole range of frequency.



Time Domain



FFT

IF at 10,7 MHz with 8,7mV of amplitude
RF at 98 MHz with 7,4uV of amplitude
LO at 108,7 MHz with 143,9uV of amplitude