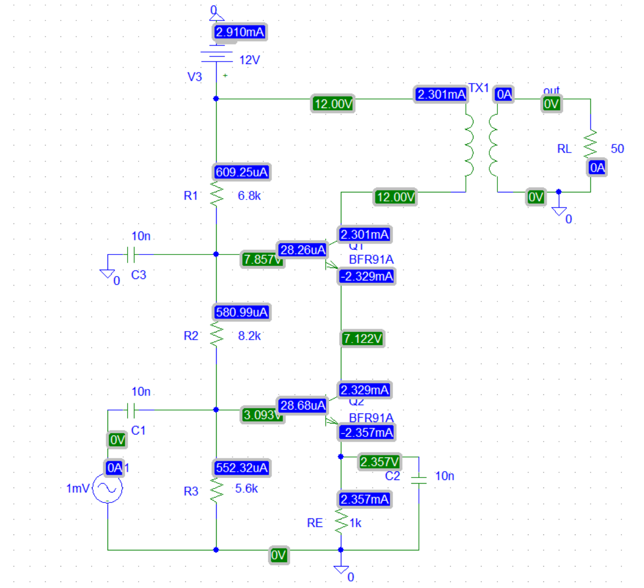
03 – LOW NOISE AMPLIFIERS FOR FM RECEIVERS

18/10/2018 – Diego Tuzi – 50435 – diego.tuzi@studentmail.unicas.it

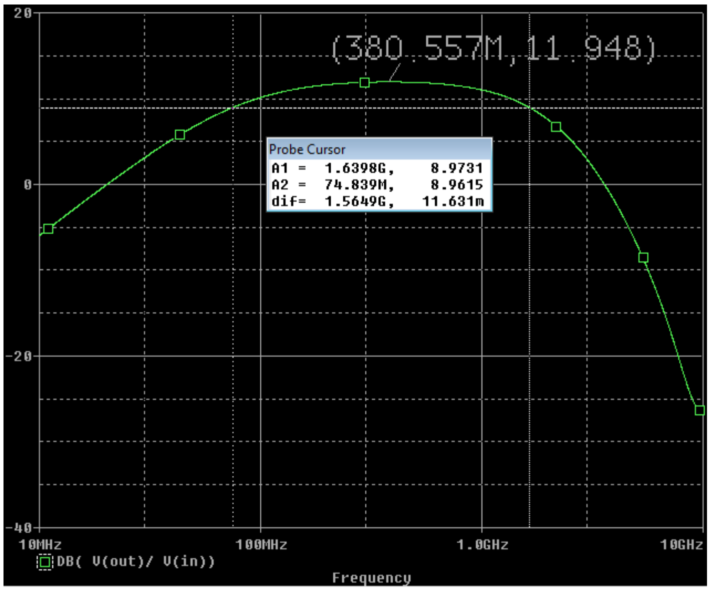
04/06/2020 (rev.1 exam 12/06/2020)

POINT 1

Draw the cascode circuit and insert the output transformer placing an "XFRM_LINEAR" component. Set the value of inductances L1 and L2 in order to have an unitary transformation ratio with an inductance of 100nH. Check the bias operation point and, by means of an AC analysis, determine the midband voltage gain of the amplifier.
Comment on the results.



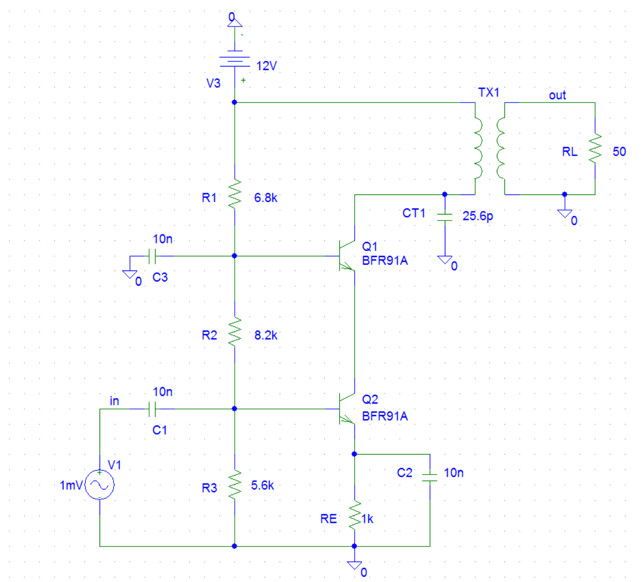
Transistors are polarized in right way

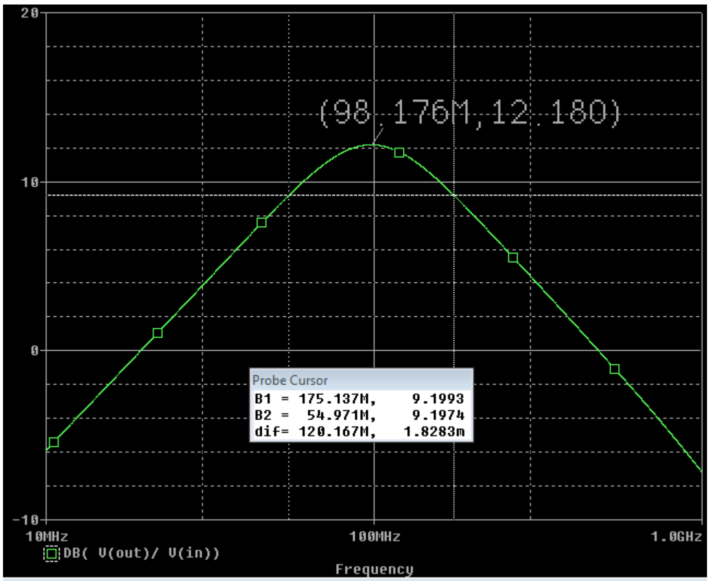


Maximum gain 12dB at 380,56 MHz
Bandwidth 1,56 GHz

POINT 2

Insert the tuning capacitor CT1 imposing a center frequency of 98MHz. Plot the frequency response of the amplifier and measure the resonance frequency, the maximum gain and the quality factor Q of the circuit.





CT1 = 25,6 pF
Maximum gain 12,2 dB at 98,176 MHz
Bandwidth = 120,167 MHz

$$Q=\frac{f_0}{BW}\simeq 0{,}82$$

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POINT 3

As shown in Fig.3, add a type L matching network on the output of the transformer in order to obtain a voltage gain greater than 35dB at the resonance. For the design of L network use the online tools presented in the previous exercise: http://home.sandiego.edu~ekim/e194rfs01/jwmatcher/matcher2.html

$$(A_v)_{dB}=35\,dB \rightarrow A_V=56{,}23$$

**** BIPOLAR JUNCTION TRANSISTORS

NAME	Q_Q1	Q_Q2
MODEL	BFR91A	BFR91A
IB	2.83E-05	2.87E-05
IC	2.30E-03	2.33E-03
VBE	7.35E-01	7.36E-01
VBC	-4.14E+00	-4.03E+00
VCE	4.88E+00	4.76E+00
BETADC	8.14E+01	8.12E+01
GM	8.80E-02	8.91E-02
RPI	9.37E+02	9.23E+02
RX	1.00E+01	1.00E+01
RO	1.93E+04	1.90E+04
CBE	4.10E-12	4.11E-12
CBC	6.09E-13	6.12E-13
CJS	0.00E+00	0.00E+00
BETAAC	8.25E+01	8.23E+01
CBX/CBX2	0.00E+00	0.00E+00
FT/FT2	2.97E+09	3.00E+09

Using an approximated formula

$$A_v=-\frac{R_{in}}{R_s+R_{in}}g_{m2}R_L$$

and

$$R_{in}=R_{B1}//R_{B2}//r_{\pi 1}$$

$$R_s=-\left(\frac{R_{in}}{A_v}g_{m2}R_L+R_{in}\right)$$

$$R_{in}=731\,\Omega$$

Using Impedance Matching Network Designer

Input values

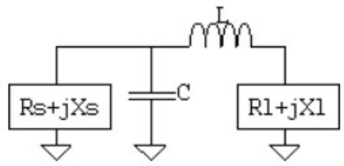
Source Resistance: 731 **Source Reactance:** 0

Load Resistance: 50 **Load Reactance:** 0

Desired Q: **Frequency:** 98e6

Output values

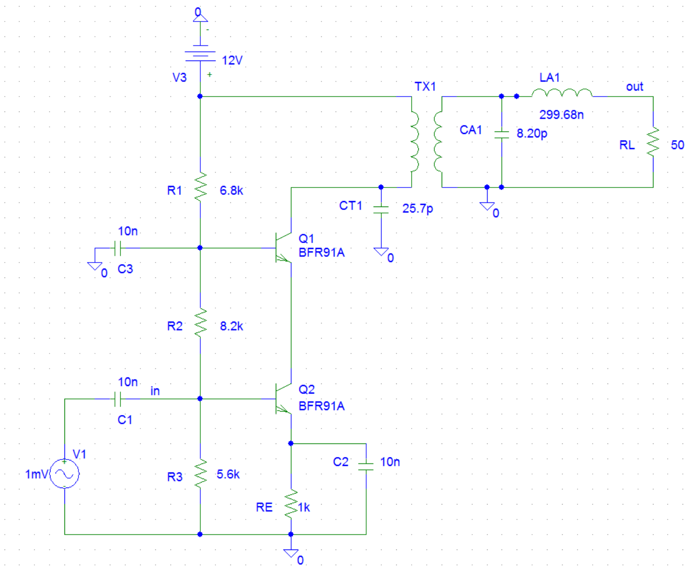
LOWPASS Hi-Low MATCHING NETWORK

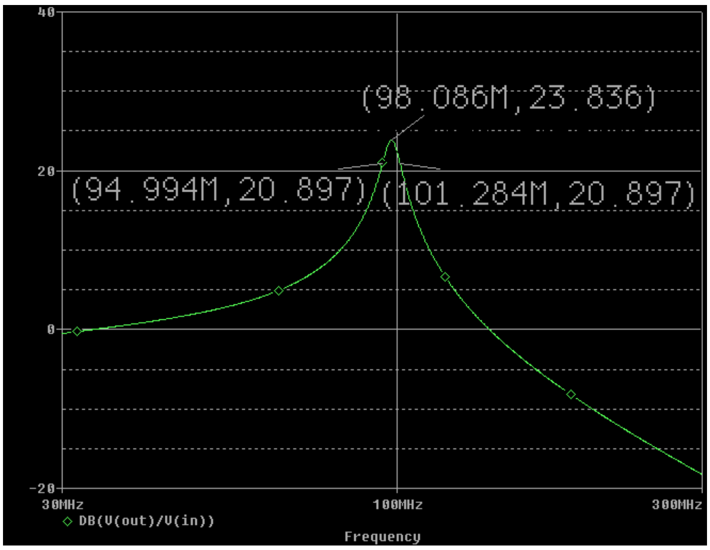


L Value: 299.6764 **nH**

C Value: 8.199082 **pF**

Q Value: 3.690528



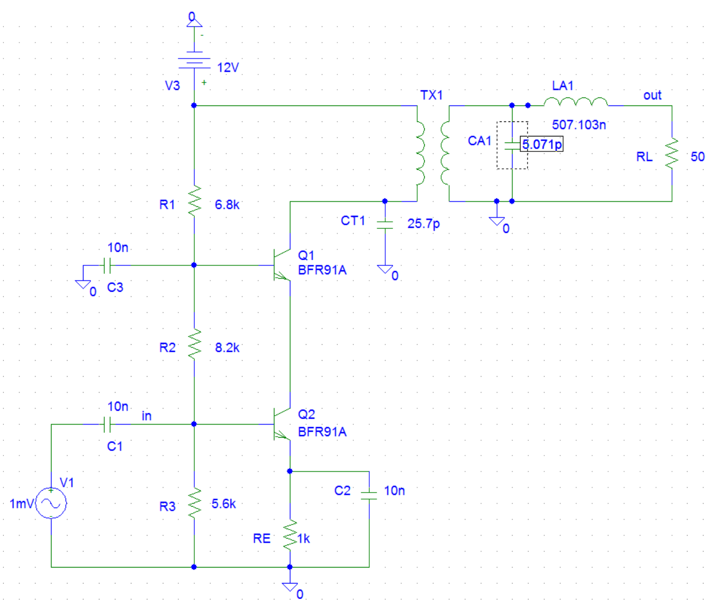


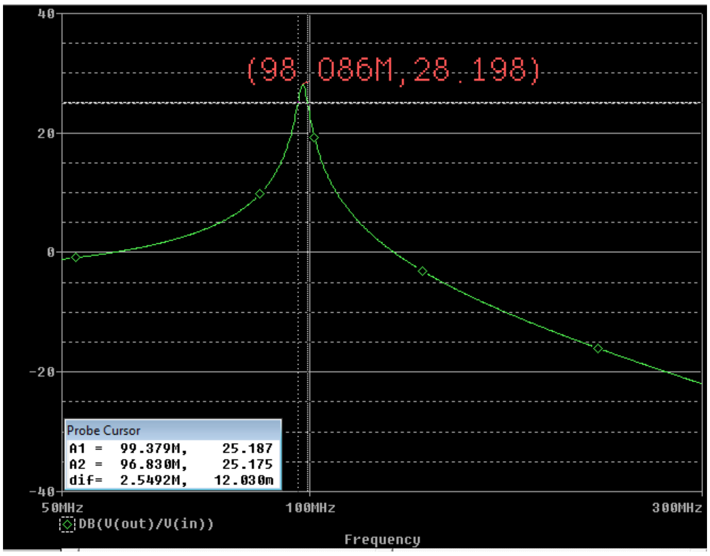
Maximum gain 23,84 dB at 98,086 MHz, Bandwidth 6,2 MHz, Q=15,82

You can note that the maximum gain is 24 dB. This behavior arise from approximations in expression of gain.

The influence of the output resistance should be inserted increasing the value of Rin (called Rs in the online tool).		
Executing several simulation you can obtain the following results		
Rs (Ohm)	**Gain (dB)**	**BW (MHz)**
731	23.80	6.20
1000	25.20	4.60
2000	**28.10**	**2.55**
5000	32.00	...
10000	35.10	0.56

Using configuration with 35dB of gain the bandwidth is too selective, for this reason the configuration with 28 dB is used in the following development.

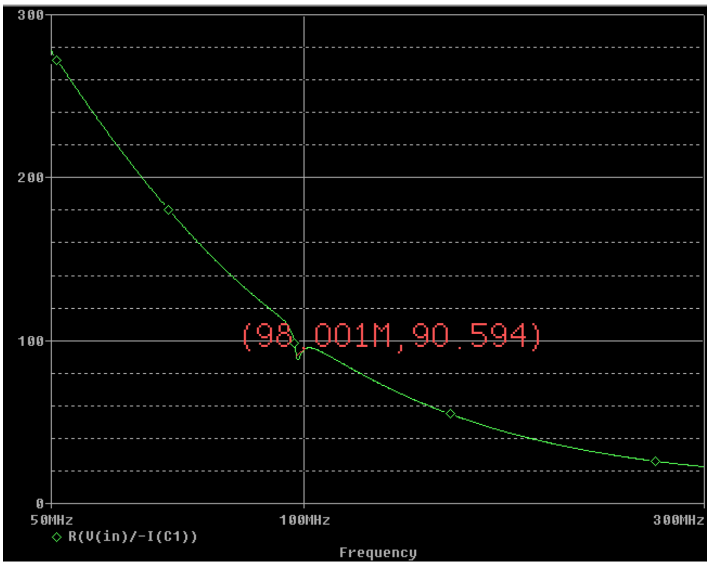




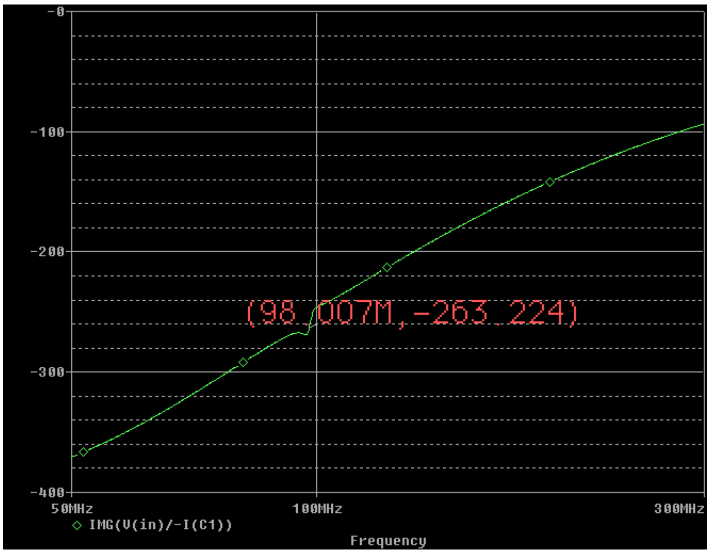
Maximum gain 28,2 dB at 98,086 MHz, Bandwidth 2.55 MHz, Q=38,46

POINT 4

After the design of the output matching network, determine the real and imaginary part of the input impedance of the circuit at the center frequency (98MHz).



Real part of input impedance = 90,59



Imaginary part of input impedance = -263,22

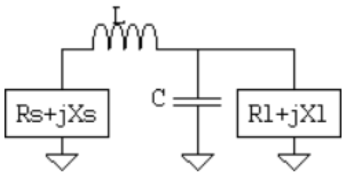
Calculate the values of the input matching network (L type) in order to have the maximum power transfer.

Source Resistance: 50 **Source Reactance:** 0

Load Resistance: 90.59 **Load Reactance:** -263

Desired Q: 3 **Frequency:** 98e6

LOWPASS Low-Hi MATCHING NETWORK

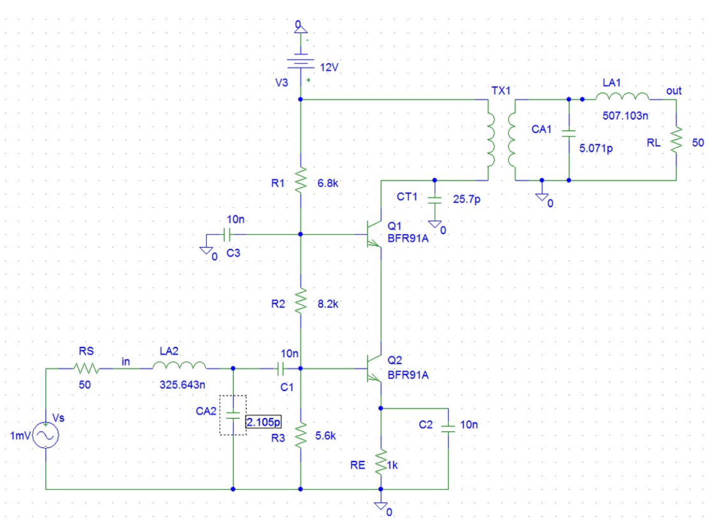


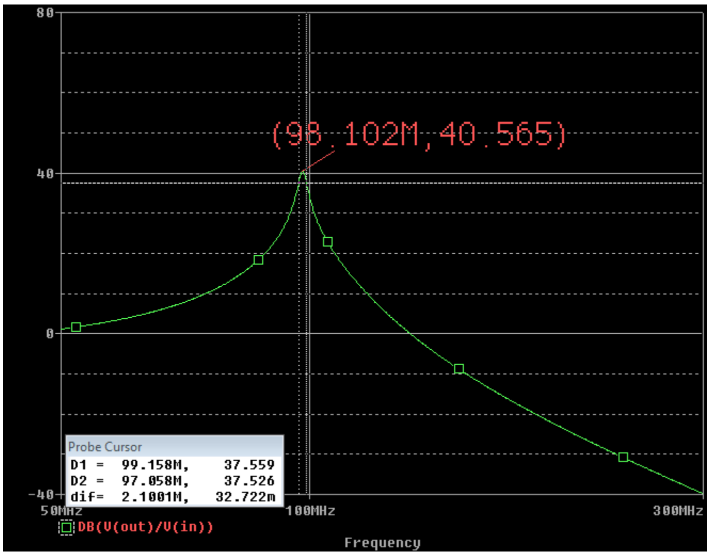
L Value: 325.6431 **nH**

C Value: 2.105062 **pF**

Q Value: 4.010309

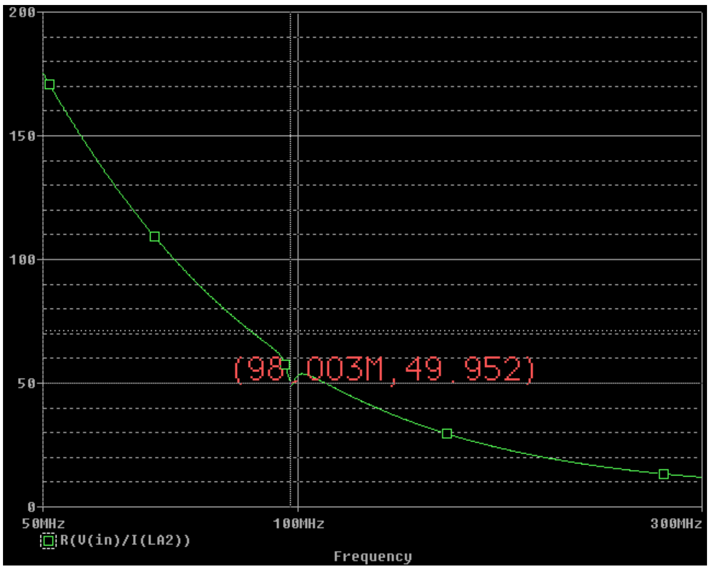
Insert the matching network in the circuit as in Fig. 4. Plot the frequency response of the amplifier in the range 50MHz – 300MHz and determine the resonance frequency, the maximum gain and the quality factor Q of the circuit.



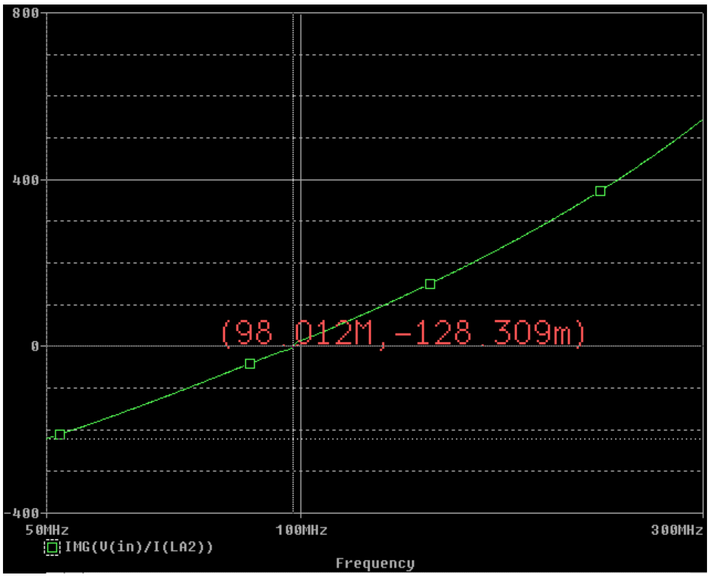


Maximum gain 40,56 dB at 98,102 MHz, Bandwidth 2,1 MHz, Q=46,72

Plot the real and imaginary parts of the input impedance of the amplifier.



Real part of input impedance with input MN = 49,95



Imaginary part of input impedance with input MN = -0,128

Comment on the results.

It is possible to note that using the output matching network based upon Rs=2000, it was necessary to change the input L matching network.

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POINT 5, 6

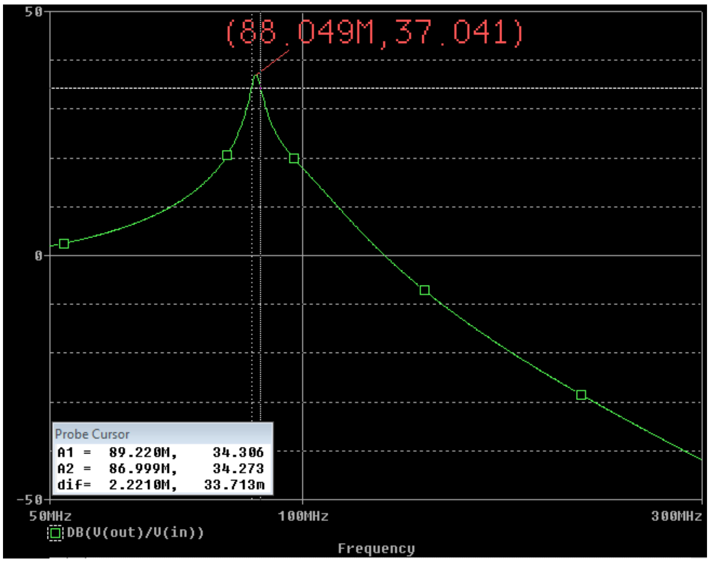
In order to increase the circuit selectivity, insert the input transformer TX2 with an input inductance of 100nH and an unitary transformation ratio together with the capacitor CT2.
Compute the values of the capacitance CT1 and capacitance CT2 in order to have the minimum and maximum resonance frequencies at 88MHz and 108MHz.

Resonant frequency = 88 MHz
CT1_max=CT2_max=33,3 pF

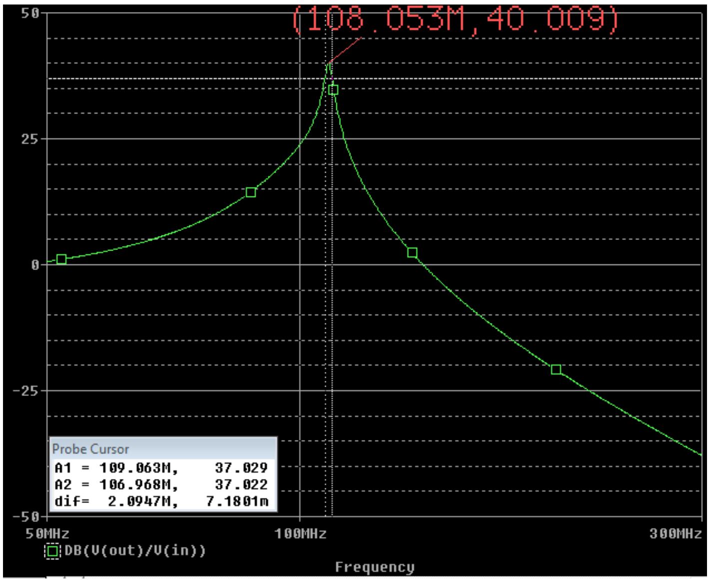
Resonant frequency = 108 MHz
CT1_min=CT2_min=20,1pF

POINT 7

Simulate the circuit obtained and determine the gain at 88MHz and 108MHz, respectively.



Maximum gain 37,04 dB at 88,049MHz
Bandwidth 2,22 MHz
Q=39,66

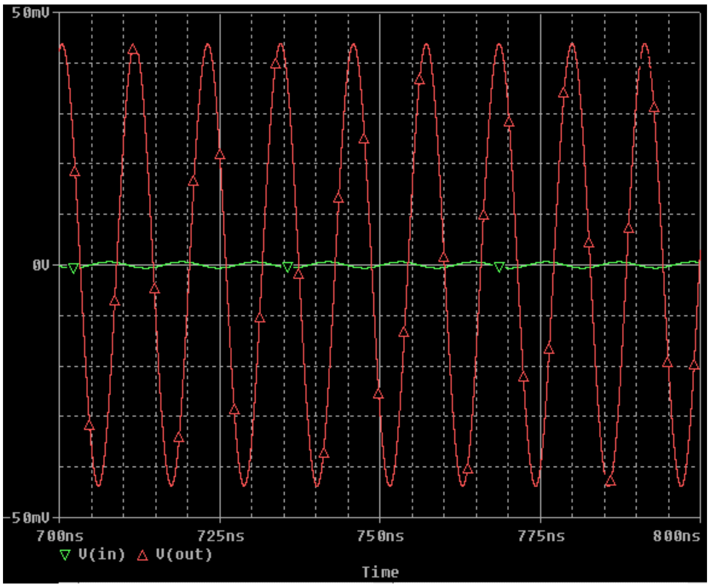


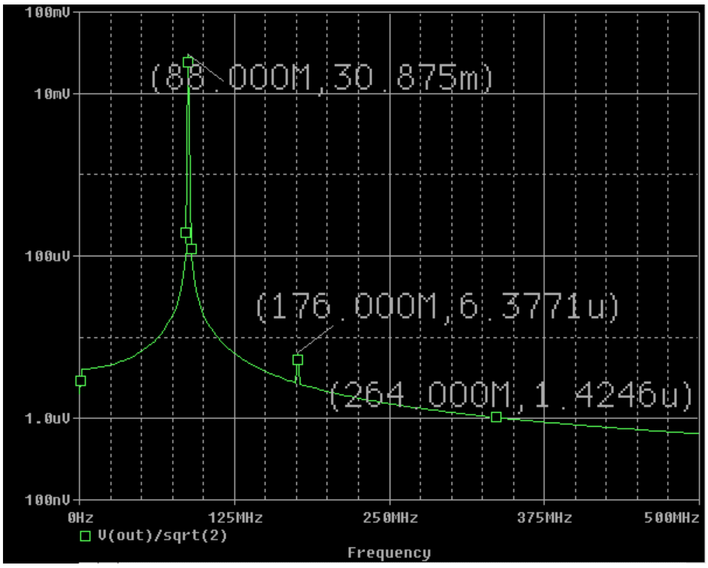
Maximum gain 40 dB at 108,053 MHz
Bandwidth 2,09 MHz
Q=51,7

POINT 8

Perform a transient analysis on the circuit designed. Impose a sinusoidal input generator with amplitude of 1mV and frequency 88MHz. Moreover, set the value of the capacitances in order to get the resonance at 88MHz. Display the input and output voltages. Measure the distortion of the amplifier.

frequency=88MHz, amplitude=1mV



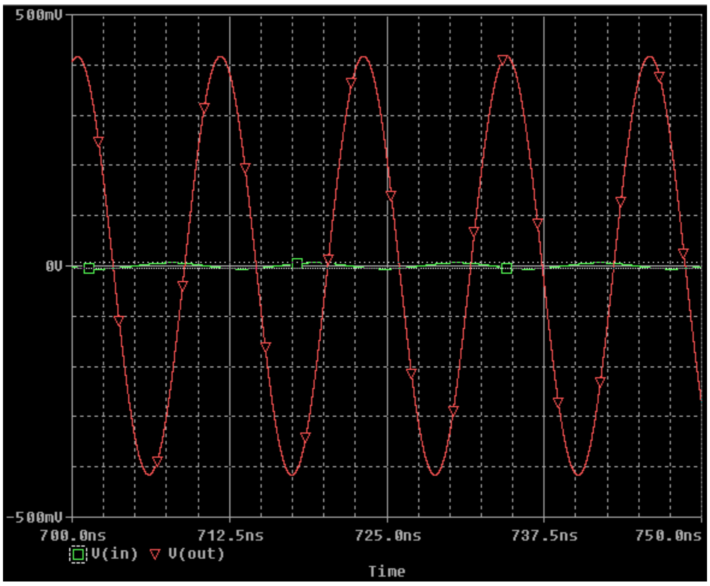


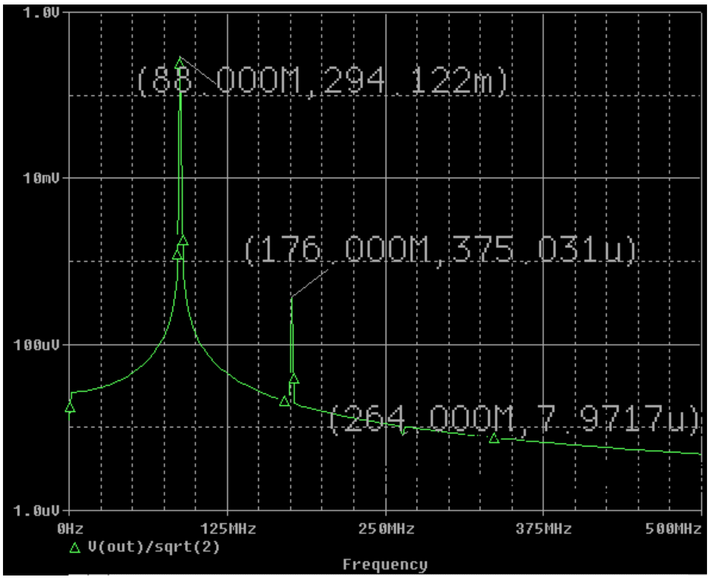
Vin_peak=0,618 mV
Vout_peak=43,9 mV
Linear gain = 71,03
db gain = 37,02

Vrms at first harmonic =30,875mV
Vrms at second harmonic =6,377uV
Vrms at third harmonic =1,425uV
THD=0,021%

Repeat the analysis with an input signal of 10mV.

frequency=88MHz, amplitude=10mV



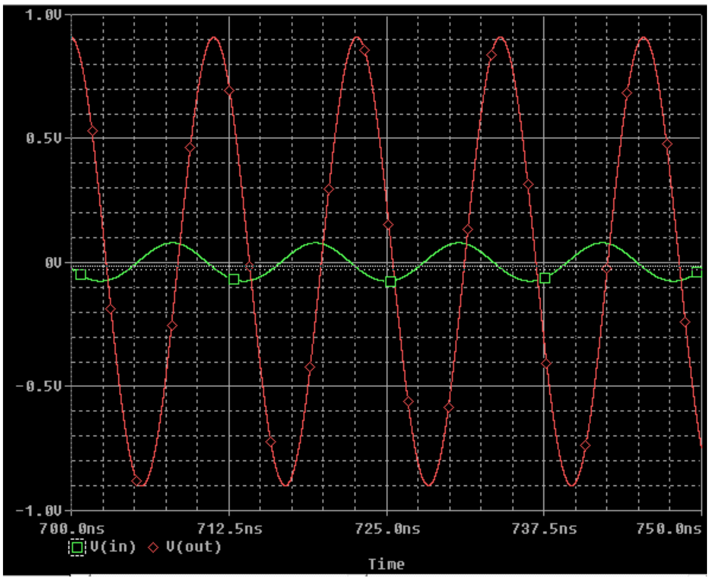


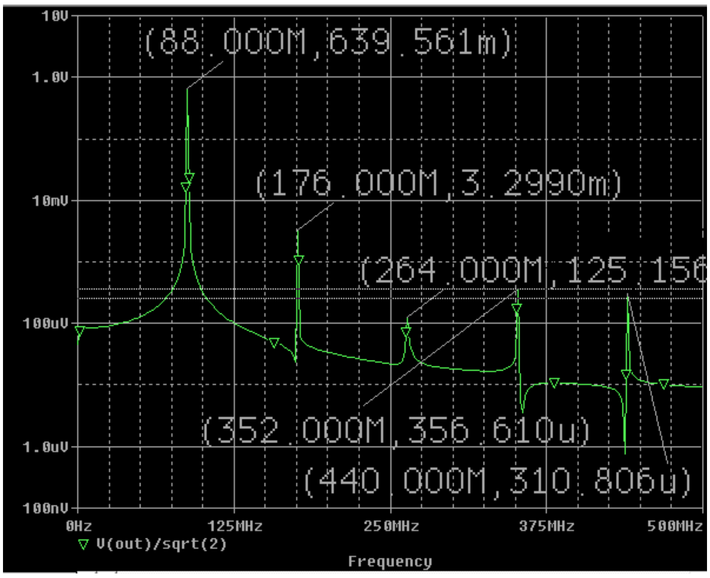
Vin_peak=6,24 mV
Vout_peak=418,05 mV
Linear gain = 66,99
db gain = 36,52

Vrms at first harmonic = 294,122mV
Vrms at second harmonic = 375,031uV
Vrms at third harmonic = 7,972uV
THD=0,127%

Repeat the analysis with an input signal of 100mV.

frequency=88MHz, amplitude=100mV



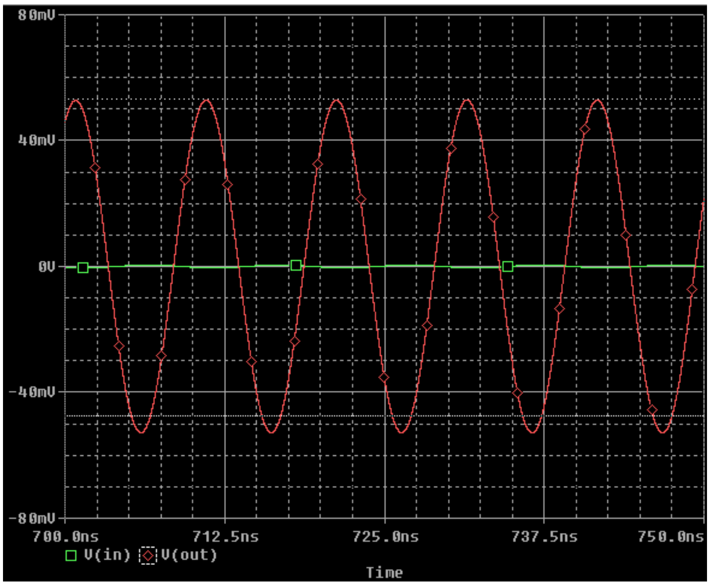


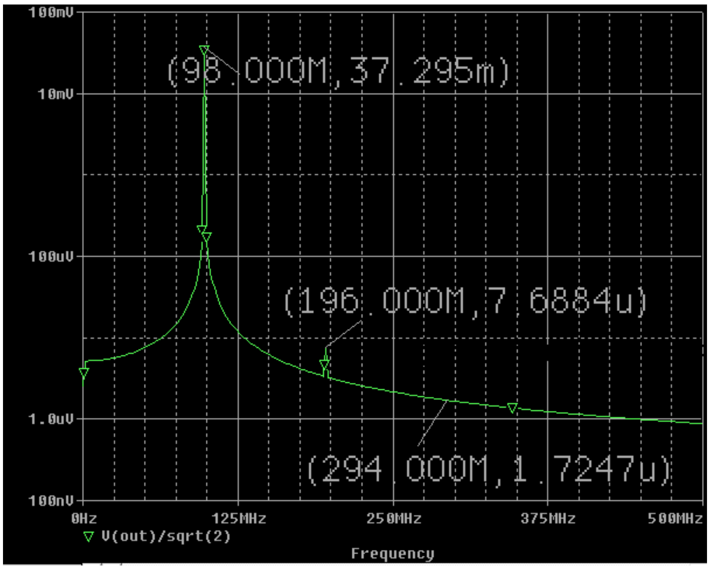
Vin_peak=79,70 mV
Vout_peak=910,80 mV
Linear gain = 11,43
db gain = 21,16

Vrms at first harmonic = 693,561mV
Vrms at second harmonic = 3,299mV
Vrms at third harmonic = 125,156uV
Vrms at fourth harmonic = 356,61uV
Vrms at fifth harmonic = 310,806uV
THD=0,48%

Impose a sinusoidal input generator with amplitude of 1mV and frequency 98MHz. Moreover, set the value of the capacitances in order to get the resonance at 98MHz. Display the input and output voltages. Measure the distortion of the amplifier.

frequency=98MHz, amplitude=1mV



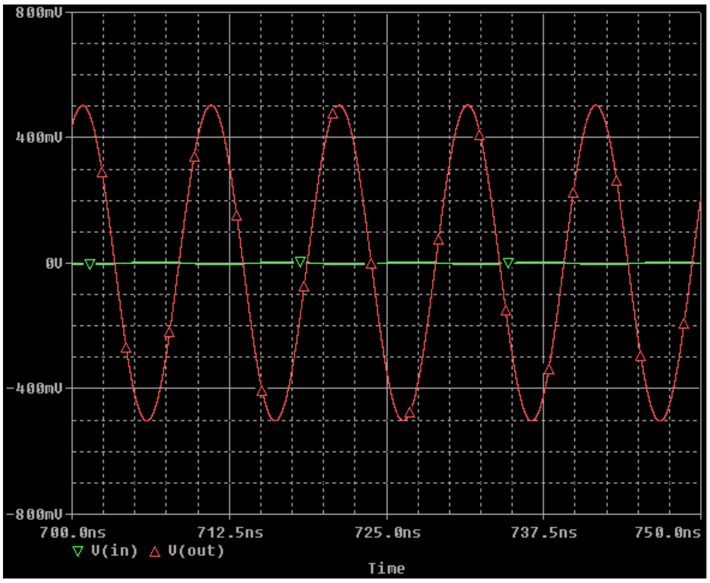


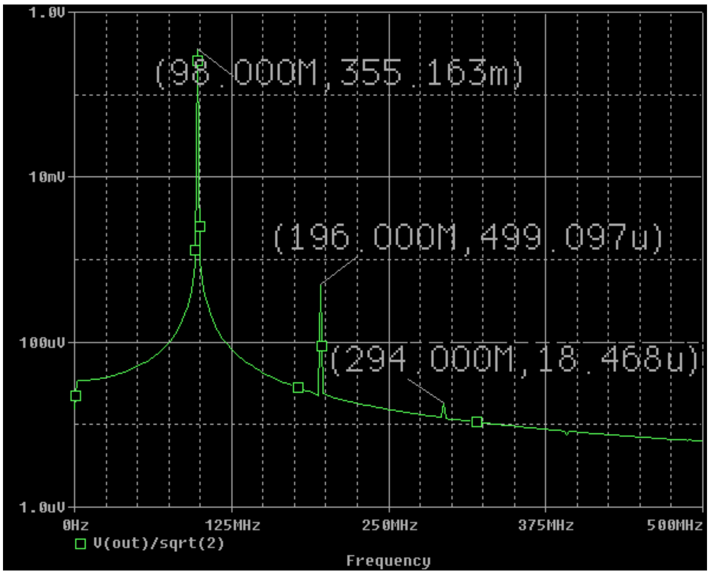
Vin_peak=0,499 mV
Vout_peak=53,089 mV
Linear gain = 106,39
db gain = 40,54

Vrms at first harmonic =37,295mV
Vrms at second harmonic =7,688uV
Vrms at third harmonic =1,725uV
THD=0,021%

Repeat the analysis with an input signal of 10mV.

frequency=98MHz, amplitude=10mV



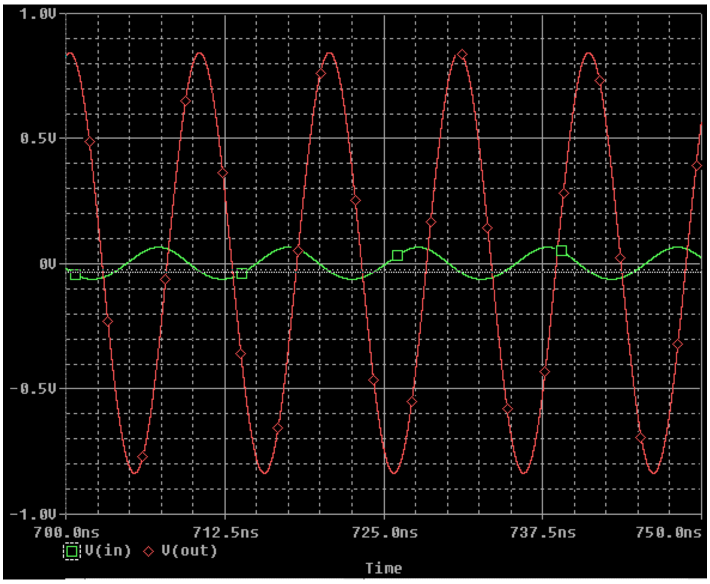


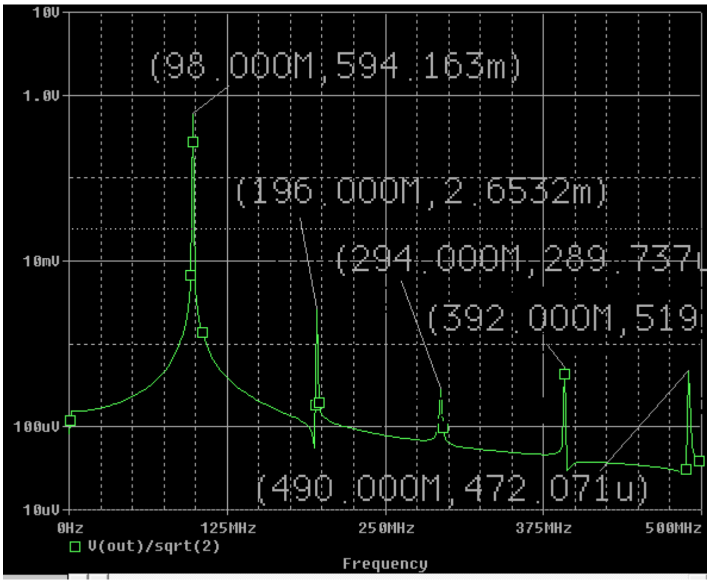
Vin_peak=4,90 mV
Vout_peak=504,934mV
Linear gain = 103,05
db gain = 40,26

Vrms at first harmonic = 355,163mV
Vrms at second harmonic = 499,097uV
Vrms at third harmonic = 18,468uV
THD=0,14%

Repeat the analysis with an input signal of 100mV.

frequency=98MHz, amplitude=100mV





Vin_peak=66,486 mV
Vout_peak=846,205 mV
Linear gain = 12,73
db gain = 22,09

Vrms at first harmonic = 594,163mV
Vrms at second harmonic = 2,653mV
Vrms at third harmonic = 289,737uV
Vrms at fourth harmonic = 519,377uV
Vrms at fifth harmonic = 477,071uV
THD=0,46%

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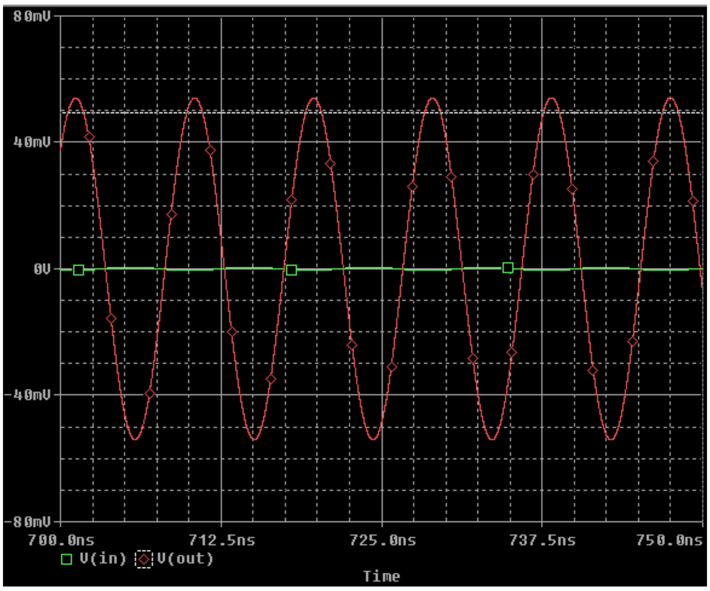
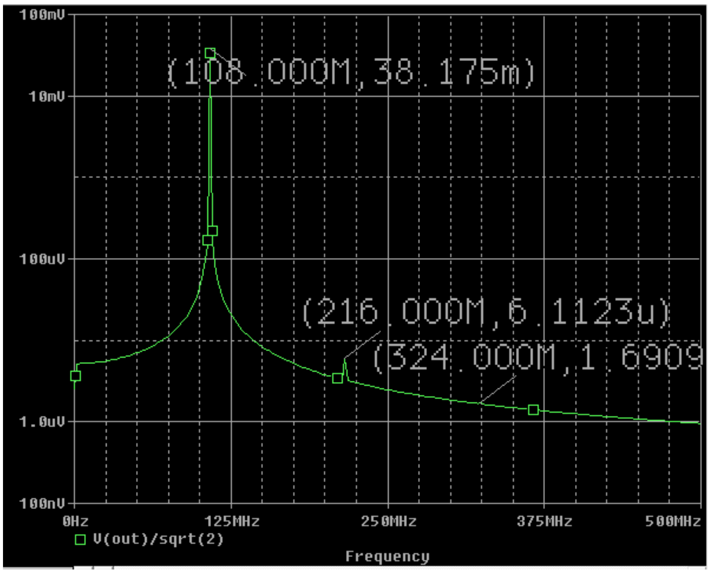
Impose a sinusoidal input generator with amplitude of 1mV and frequency 108MHz. Moreover, set the value of the capacitances in order to get the resonance at 108MHz. Display the input and output voltages. Measure the distortion of the amplifier.

frequency=*108MHz*, amplitude=1mV

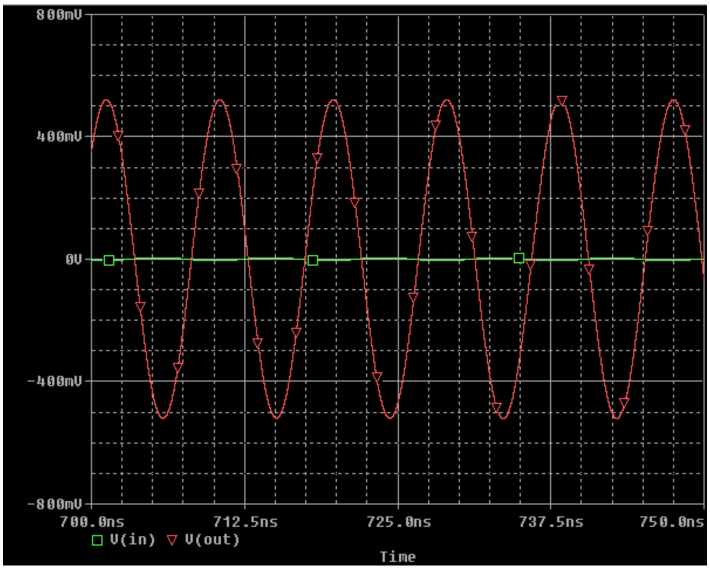


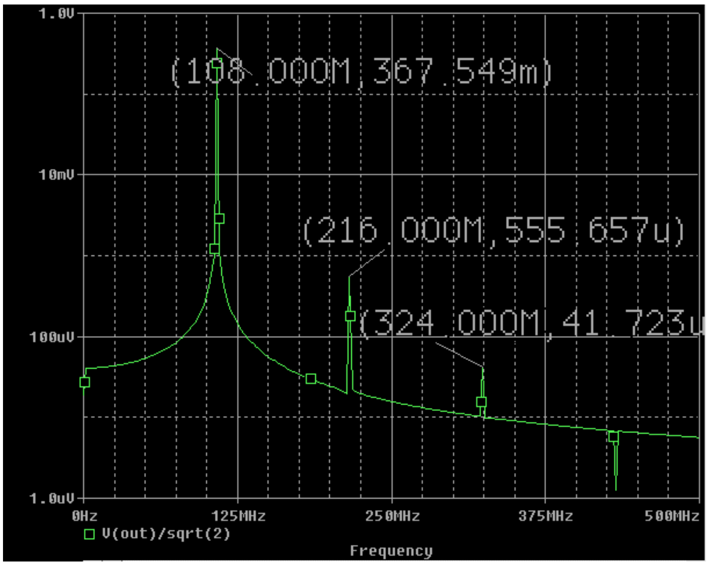


Vin_peak=0,542 mV
Vout_peak=54,308 mV
Linear gain = 100,20
db gain = 40,02

Vrms at first harmonic =38,175mV
Vrms at second harmonic =6,112uV
Vrms at third harmonic =1,691uV
THD=0,017%

frequency=*108MHz*, amplitude=10mV

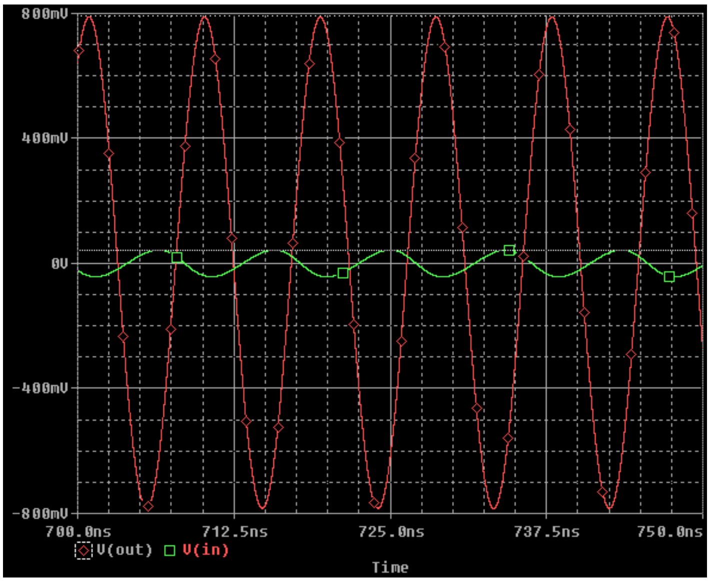




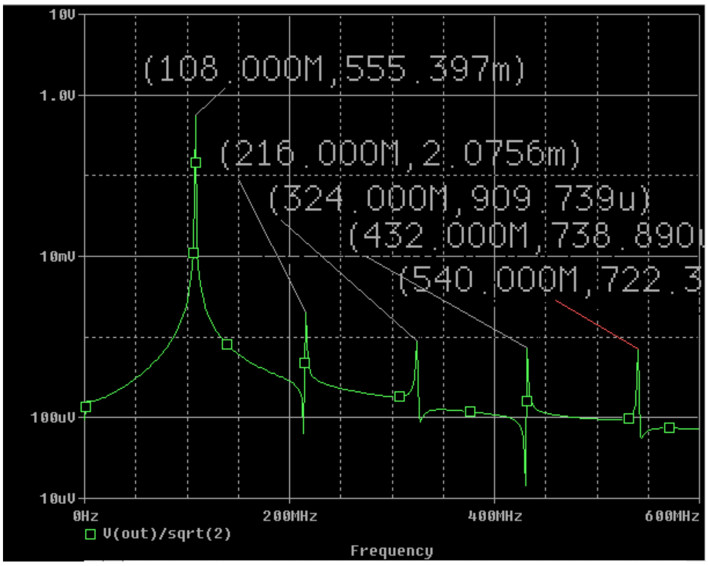
Vin_peak=5,296 mV
Vout_peak=522,538 mV
Linear gain = 100,20
db gain = 40,02

Vrms at first harmonic =367,549 mV
Vrms at second harmonic =555,657 uV
Vrms at third harmonic =41,723 uV
THD=0,15%

frequency=*108MHz*, amplitude=100mV



Vin_peak=43,793 mV
Vout_peak=792,726 mV
Linear gain = 98,67
db gain = 25,15



Vrms at first harmonic = 555,397 mV
Vrms at second harmonic = 2,076 mV
Vrms at third harmonic = 909,739 uV
Vrms at fourth harmonic = 738,890 uV
Vrms at fifth harmonic = 722,387 uV
THD=0,45%

POINT 9

Extract CP 1dB , IIP3 and OIP3 from data obtained in the previous step for the frequency 88MHz.