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

Design and PSPICE Simulation of the local oscillator

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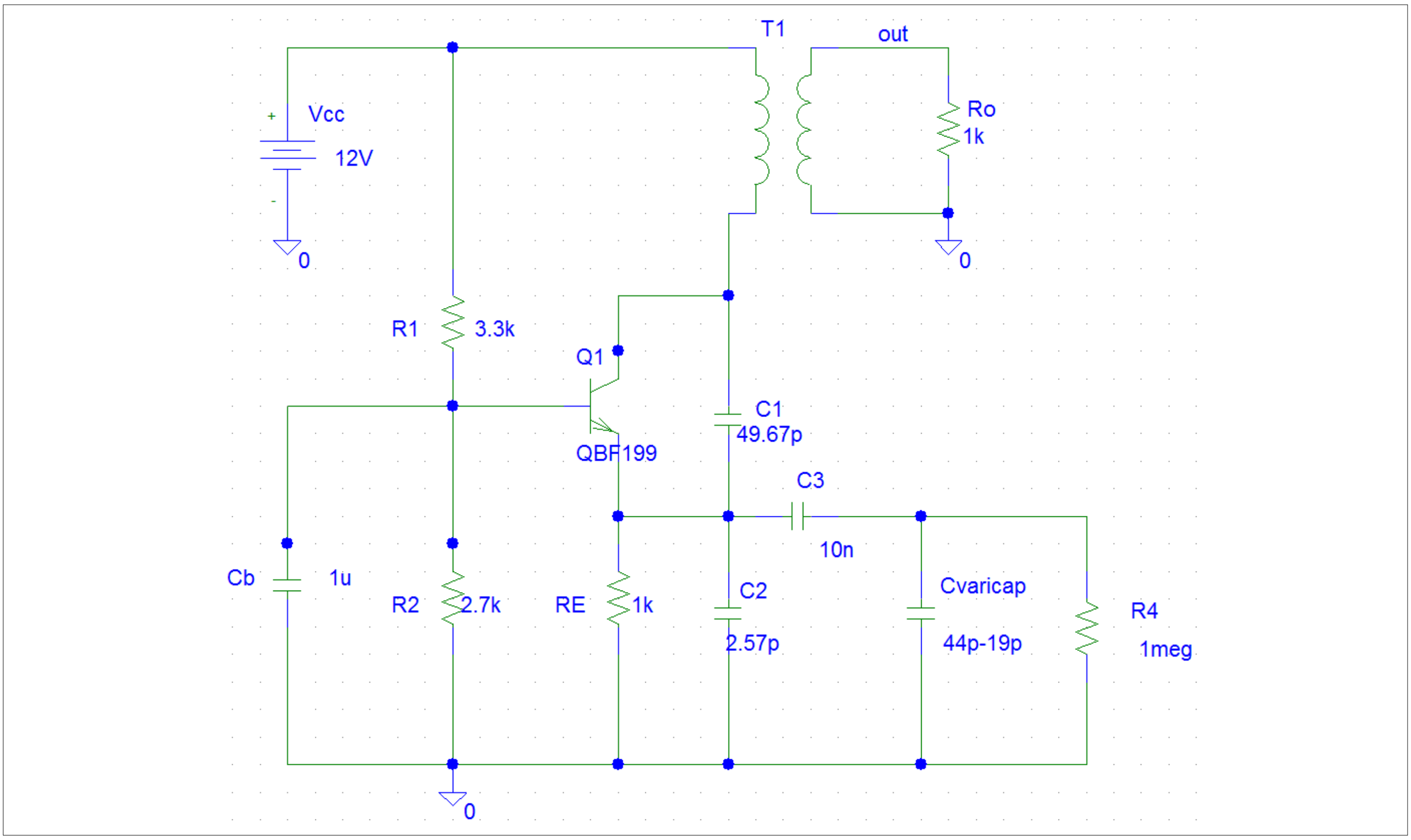
POINT A

Transform the tuned amplifier studied in the previous exercise in a voltage controlled Colpitts oscillator whose schematic is shown in Fig. 1. Note that the Varicap has been replaced by the capacitor CVaricap in order to simplify the simulation. In addition, resistor R4 has been inserted for avoiding a "floating" node at the connections between capacitors.



POINT B

Verify that the Barkausen condition on the loop gain is verified for the minimum and Fig. 1 Oscillatore di Colpitts maximum values of the Varicap capacitance. In particular, compute the product $A\beta$ *considering the value of A obtained from the simulations performed in the previous exercise. Moreover, compute* $\beta=\frac{C_1}{C_1+C_{eq}}$ *where* $C_{eq}\simeq C_2+C_{varicap}$ *, verify that for the two extreme values of CVaricap the product* $A\beta$ *is larger than 1.*

From previous simulations

$$A=g_m(r_0//R_0)=g_m\left(\frac{r_0R_0}{r_0+R_0}\right)\simeq 160{,}37$$

f_min

$$\beta=\frac{C_1}{C_1+C_{eq}}\simeq 0{,}48$$

$$|A\beta|\simeq 76{,}42\geq 1$$

Barkhausen condition is fullfilled

f_max

$$\beta=\frac{C_1}{C_1+C_{eq}}\simeq 0{,}66$$

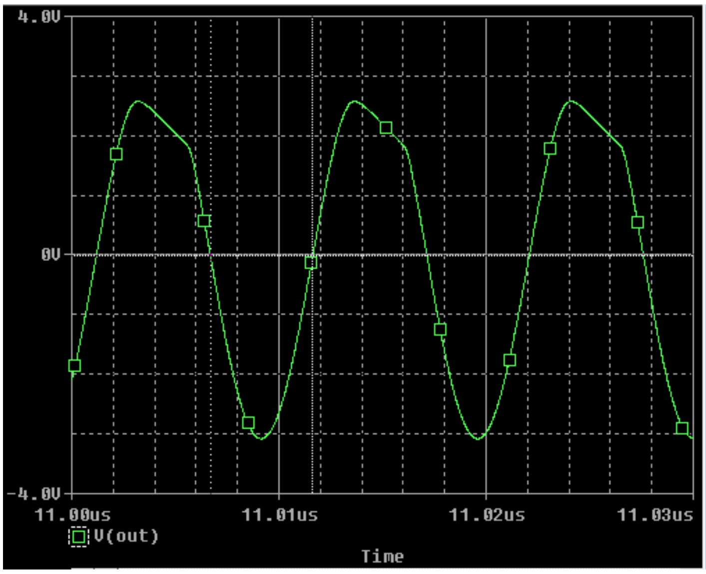
$$|A\beta|\simeq 105{,}87\geq 1$$

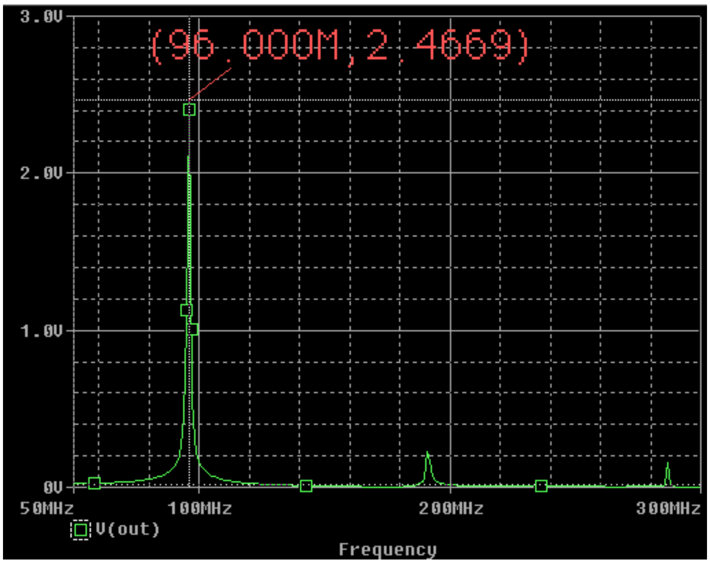
Barkhausen condition is fullfilled

POINT C

Perform the "Transient Analysis" of the circuit reported in Fig. 1. For permitting the oscillations to start use a non zero initial voltage condition on capacitor C1. For this purpose double click on C1 and set the parameter IC (Initial Conditions) to the desired value, for example 1V. Verify if the circuit oscillates at the frequency expected for the two values of CVaricap.

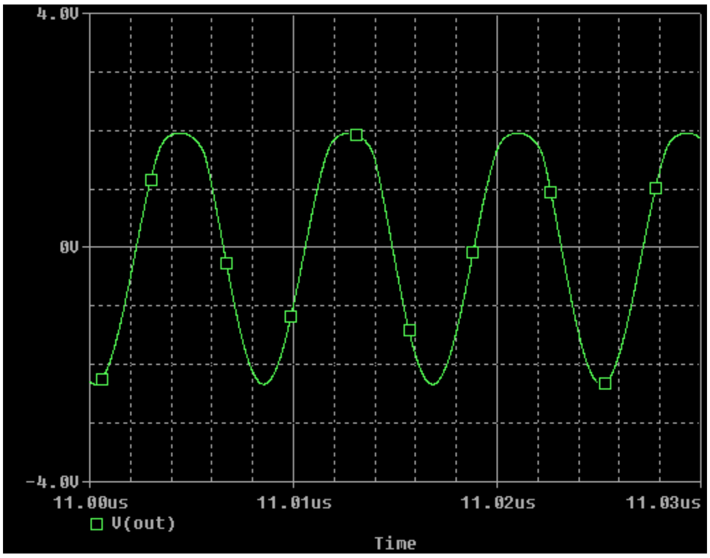
After several attempt, center frequency is equal to 96MHz when C_varicap = 44pF

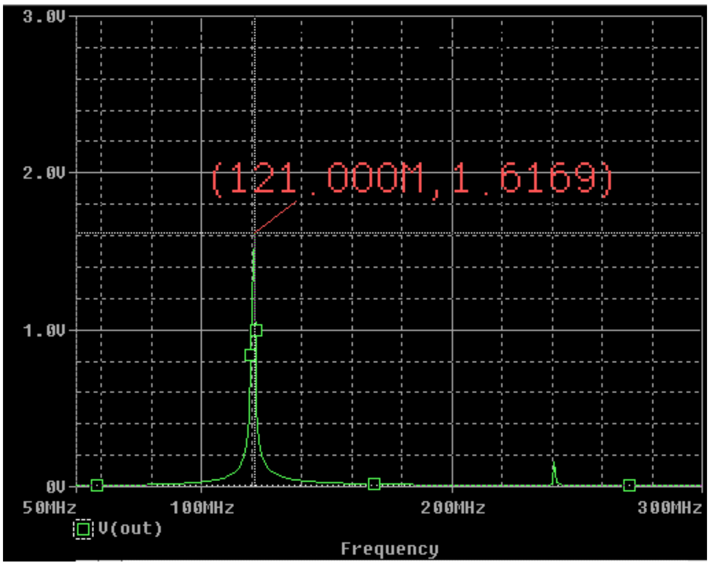




Oscillation frequency = 96 MHz
Vpeak=2,47V

After several attempt, center frequency is equal to 121MHz when C_varicap = 19pF

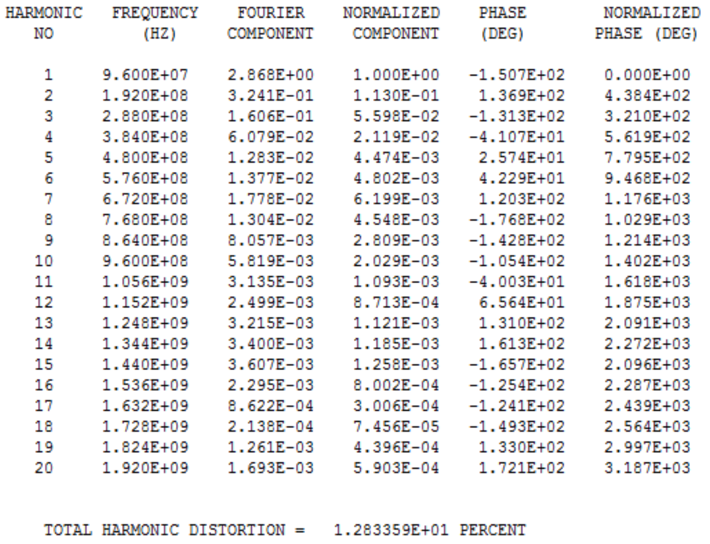




Oscillation frequency = 121 MHz
Vpeak=1,62V

POINT D

Activate the option “Fourier Analysis” of “Transient Analysis”. Determine the amplitude of the first 10 harmonics of the output signal and the related THD (Total Harmonic Distortion) for the two extreme values of CVaricap. N.B. For identifying the Center Frequency to be used in the “Fourier Analysis” perform a preliminary "Transient Analysis" on the circuit. In the probe module activate the function FFT on the voltage waveform and read the frequency of the first harmonic.



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HARMONIC   FREQUENCY    FOURIER    NORMALIZED    PHASE       NORMALIZED
   NO        (HZ)      COMPONENT    COMPONENT    (DEG)       PHASE (DEG)

    1     9.600E+07   2.868E+00   1.000E+00  -1.507E+02    0.000E+00
    2     1.920E+08   3.241E-01   1.130E-01   1.369E+02    4.384E+02
    3     2.880E+08   1.606E-01   5.598E-02  -1.313E+02    3.210E+02
    4     3.840E+08   6.079E-02   2.119E-02  -4.107E+01    5.619E+02
    5     4.800E+08   1.283E-02   4.474E-03   2.574E+01    7.795E+02
    6     5.760E+08   1.377E-02   4.802E-03   4.229E+01    9.468E+02
    7     6.720E+08   1.778E-02   6.199E-03   1.203E+02    1.176E+03
    8     7.680E+08   1.304E-02   4.548E-03  -1.768E+02    1.029E+03
    9     8.640E+08   8.057E-03   2.809E-03  -1.428E+02    1.214E+03
   10     9.600E+08   5.819E-03   2.029E-03  -1.054E+02    1.402E+03
   11     1.056E+09   3.135E-03   1.093E-03  -4.003E+01    1.618E+03
   12     1.152E+09   2.499E-03   8.713E-04   6.564E+01    1.875E+03
   13     1.248E+09   3.215E-03   1.121E-03   1.310E+02    2.091E+03
   14     1.344E+09   3.400E-03   1.185E-03   1.613E+02    2.272E+03
   15     1.440E+09   3.607E-03   1.258E-03  -1.657E+02    2.096E+03
   16     1.536E+09   2.295E-03   8.002E-04  -1.254E+02    2.287E+03
   17     1.632E+09   8.622E-04   3.006E-04  -1.241E+02    2.439E+03
   18     1.728E+09   2.138E-04   7.456E-05  -1.493E+02    2.564E+03
   19     1.824E+09   1.261E-03   4.396E-04   1.330E+02    2.997E+03
   20     1.920E+09   1.693E-03   5.903E-04   1.721E+02    3.187E+03


    TOTAL HARMONIC DISTORTION =   1.283359E+01 PERCENT
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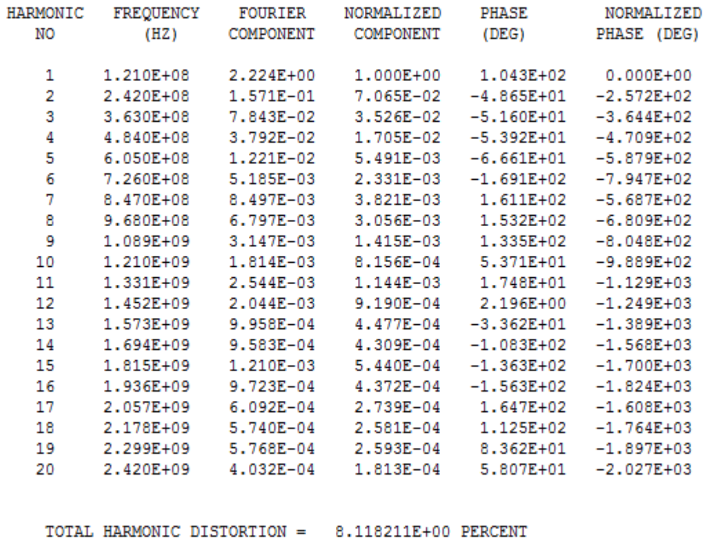
Cvaricap=44pF → oscillation frequency = 96 MHz
THD = 12,8%



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HARMONIC   FREQUENCY    FOURIER    NORMALIZED    PHASE       NORMALIZED
   NO        (HZ)      COMPONENT    COMPONENT    (DEG)       PHASE (DEG)

    1     1.210E+08   2.224E+00   1.000E+00   1.043E+02    0.000E+00
    2     2.420E+08   1.571E-01   7.065E-02  -4.865E+01   -2.572E+02
    3     3.630E+08   7.843E-02   3.526E-02  -5.160E+01   -3.644E+02
    4     4.840E+08   3.792E-02   1.705E-02  -5.392E+01   -4.709E+02
    5     6.050E+08   1.221E-02   5.491E-03  -6.661E+01   -5.879E+02
    6     7.260E+08   5.185E-03   2.331E-03  -1.691E+02   -7.947E+02
    7     8.470E+08   8.497E-03   3.821E-03   1.611E+02   -5.687E+02
    8     9.680E+08   6.797E-03   3.056E-03   1.532E+02   -6.809E+02
    9     1.089E+09   3.147E-03   1.415E-03   1.335E+02   -8.048E+02
   10     1.210E+09   1.814E-03   8.156E-04   5.371E+01   -9.889E+02
   11     1.331E+09   2.544E-03   1.144E-03   1.748E+01   -1.129E+03
   12     1.452E+09   2.044E-03   9.190E-04   2.196E+00   -1.249E+03
   13     1.573E+09   9.958E-04   4.477E-04  -3.362E+01   -1.389E+03
   14     1.694E+09   9.583E-04   4.309E-04  -1.083E+02   -1.568E+03
   15     1.815E+09   1.210E-03   5.440E-04  -1.363E+02   -1.700E+03
   16     1.936E+09   9.723E-04   4.372E-04  -1.563E+02   -1.824E+03
   17     2.057E+09   6.092E-04   2.739E-04   1.647E+02   -1.608E+03
   18     2.178E+09   5.740E-04   2.581E-04   1.125E+02   -1.764E+03
   19     2.299E+09   5.768E-04   2.593E-04   8.362E+01   -1.897E+03
   20     2.420E+09   4.032E-04   1.813E-04   5.807E+01   -2.027E+03


    TOTAL HARMONIC DISTORTION =   8.118211E+00 PERCENT
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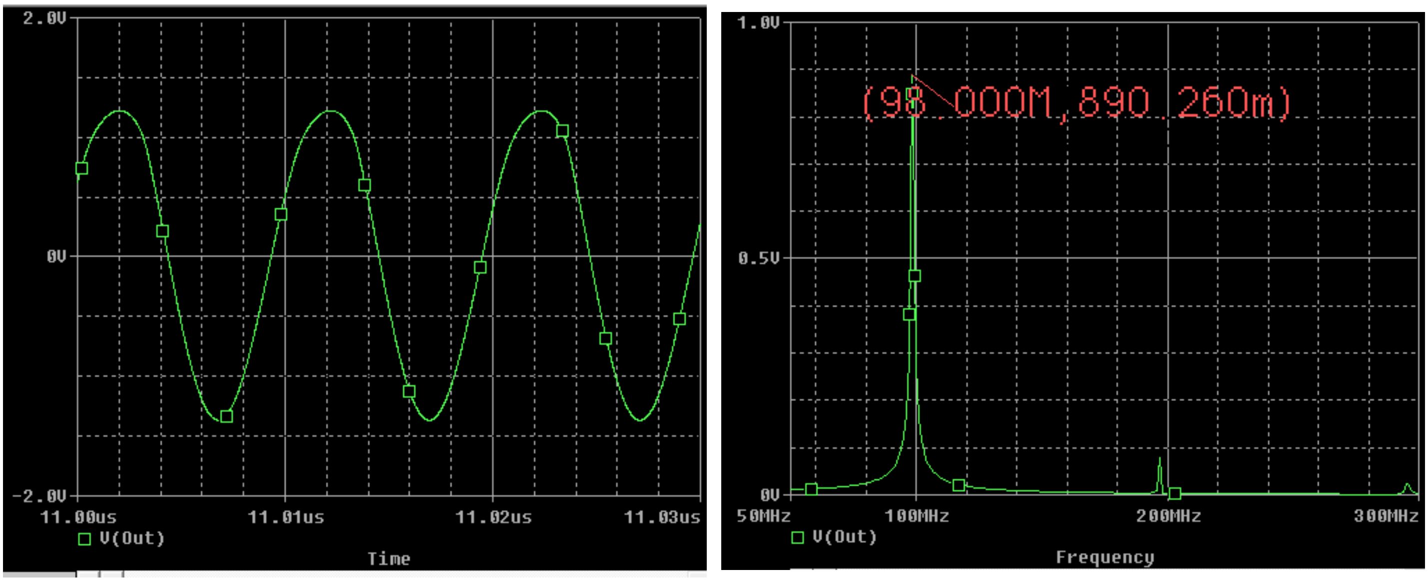
Cvaricap=19pF → oscillation frequency = 96 MHz
THD = 8%

POINT E

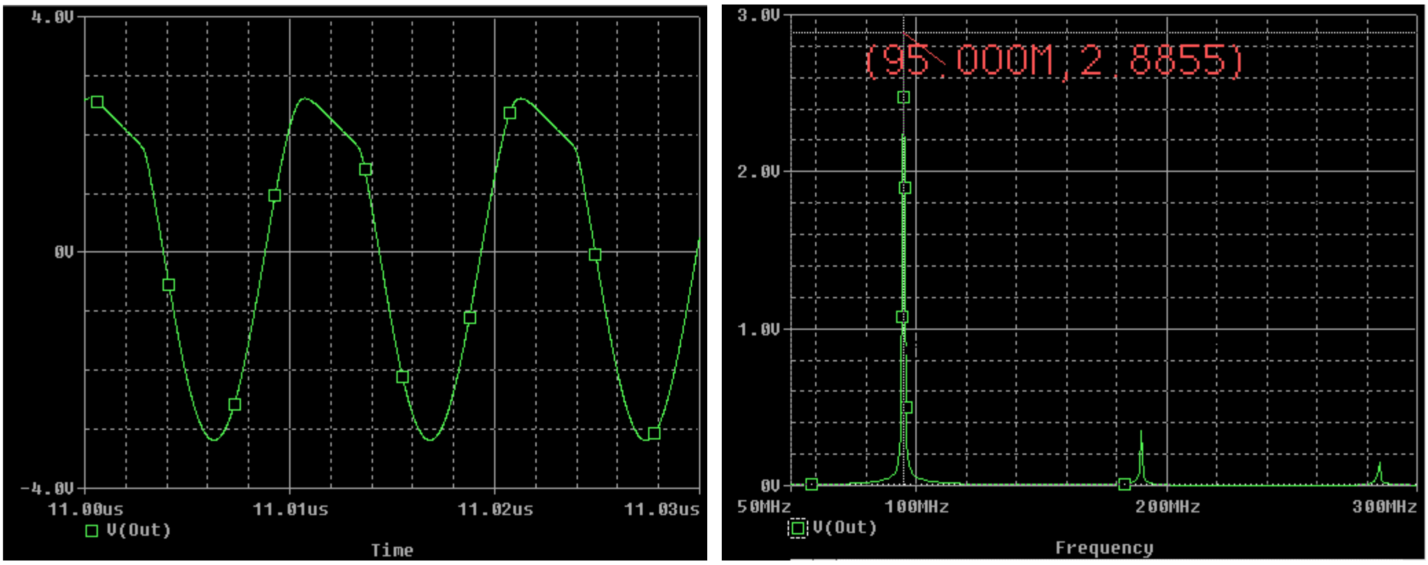
Repeat points c and d for Ro=100 and Ro=10.000. Comment on the results.

Ro=100 Ohm instead of 1000 Ohm as in point C



Oscillation frequency = 98 MHz
Vpeak=0,89V
THD=6,27%

Ro=10000 Ohm instead of 1000 Ohm as in point C



Oscillation frequency = 95 MHz
Vpeak=2,88 V
THD=14,41%

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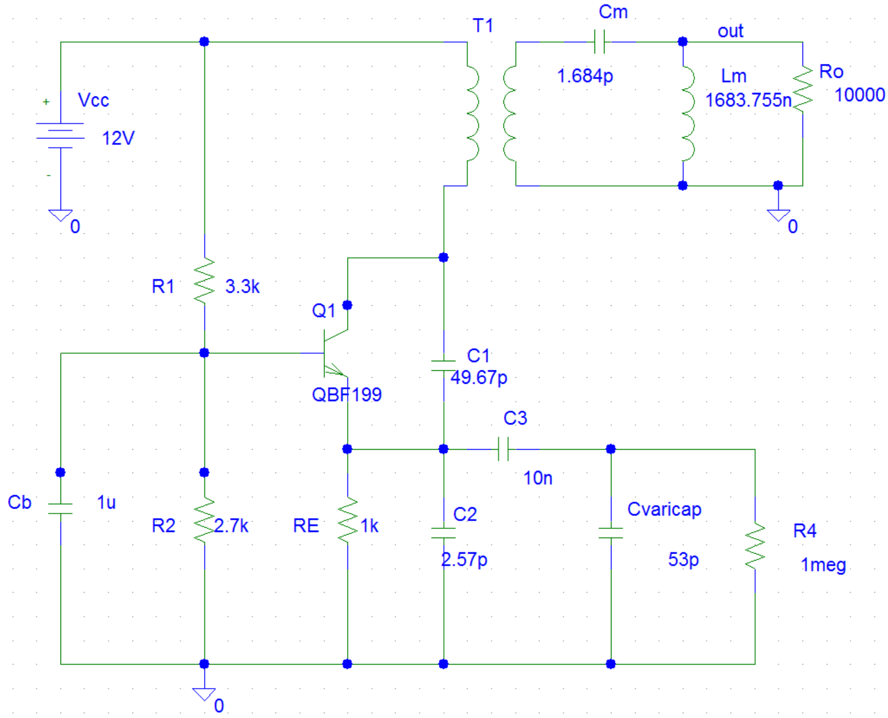
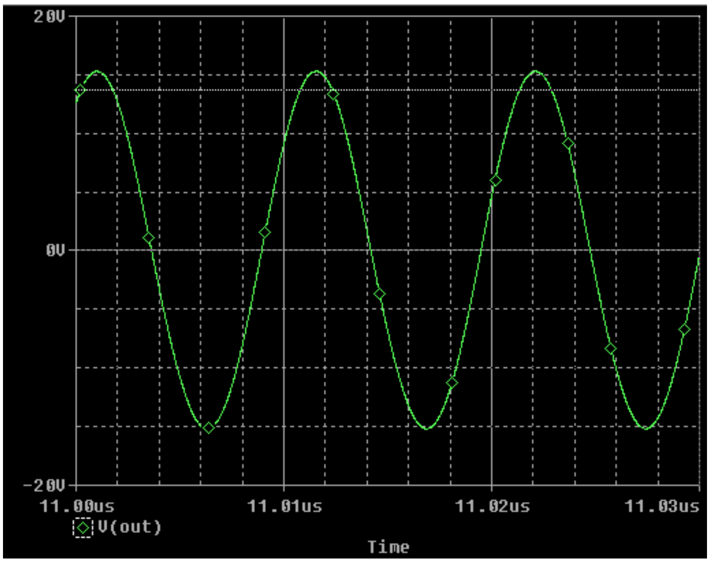
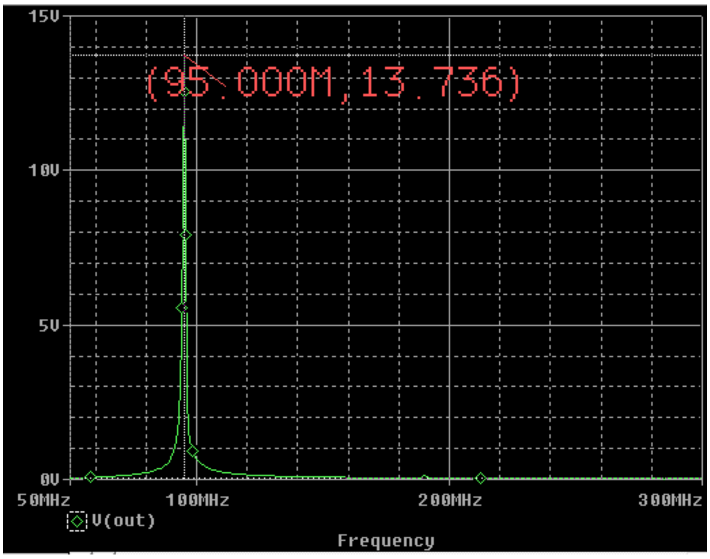
POINT F

Acting on the loop gain $A\beta$ *, find out a way to reduce the distortion in one of the case previously analyzed.*

Considering last case in point E, it is possible to reduce distortion inserting a matching network to adapt output.







Oscillation frequency = 95 MHz

Vpeak=13,74 V

THD=0,95%