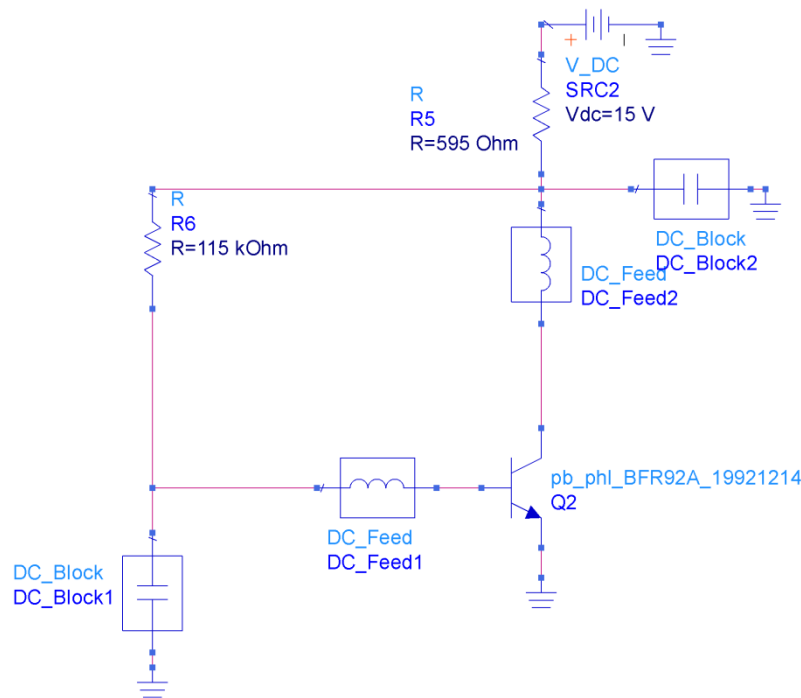


## ECE 3113

### SINGLE-ENDED ACTIVE MIXER DESIGN

#### Objective

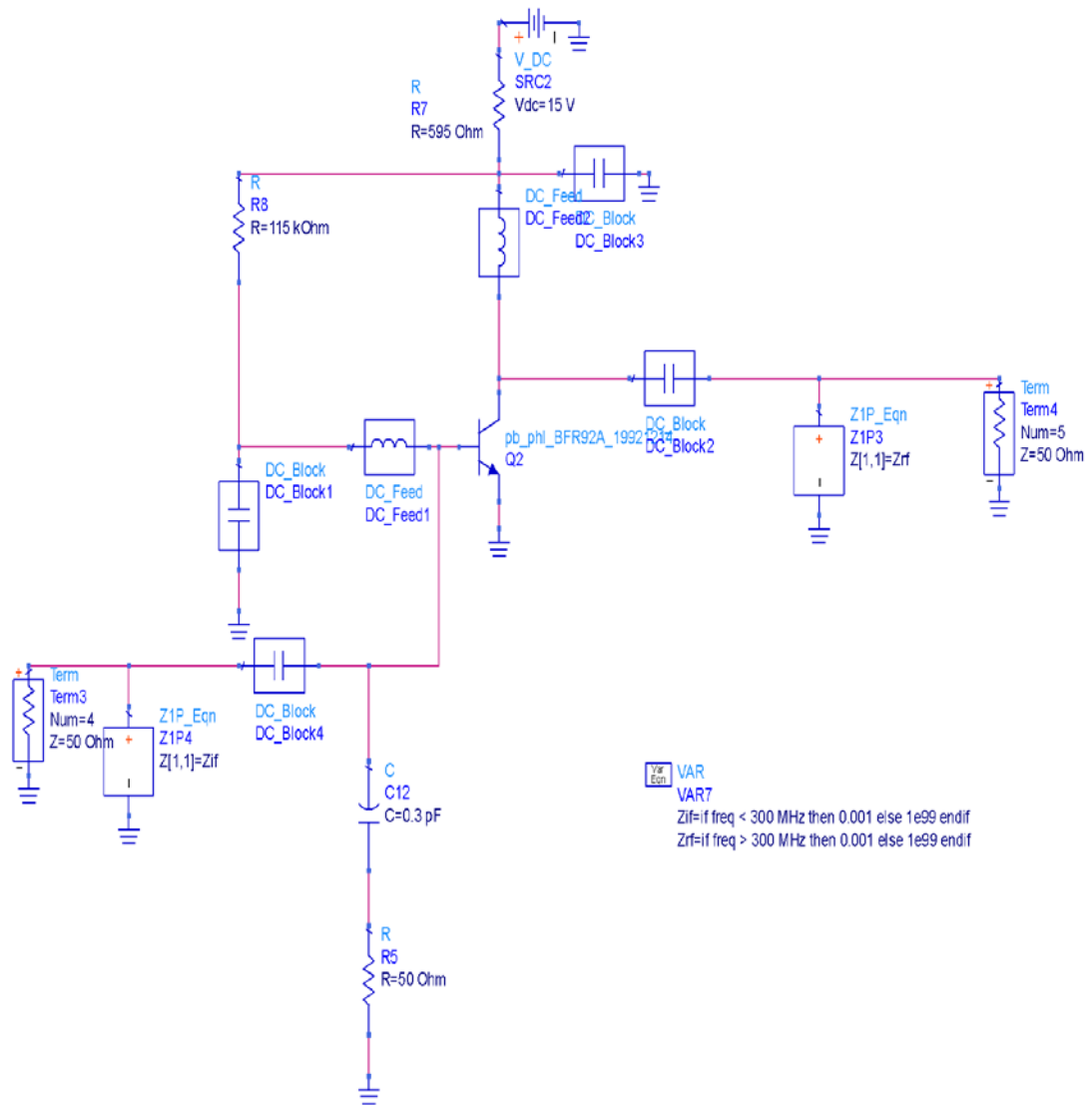
This project develops an active, single-ended mixer with the BFR92A npn transistor. Our goal is to down-convert a 2GHz RF input signal to a 200 MHz intermediate frequency (IF) with the help of a local oscillator (LO) signal at 200 MHz. For the mixer construction you should take the following biased amplifier design as a starting point, see below.



As you implement your design you should consult your textbook on p. 618 and adopt a similar approach.

#### Approach

- A) Model the RF input signal, block the LO path with a 50Ω series resistor and a series capacitor (see Fig. 10-47). For the cap you may choose 0.3pF.



B) Record the  $S_{11}$  at RF and build the RF matching network. Keep in mind that a shunt L of a matching network can replace one of the RFC.

**Note:** In ADS under the palette “Eqn Based-Linear” the Z-parameter network proves handy. It can be programmed such that the impedance is either “0” or “infinity” depending on the frequency. Inserted in shunt to the input or output of the device you can create ideal isolation conditions.



Since the RF frequency is 2 GHz, and the LO frequency is 1.8 GHz, the IF frequency should be 200 MHz for a down-converting mixer. At the RF input the  $Z_{if}$  is programmed to create a short-circuit at IF and an open-circuit at RF. For the output, the  $Z_{rf}$  is programmed to create a short-circuit at RF and an open-circuit at IF.

Setting the frequency to RF (2GHz), we get the following S-parameters.

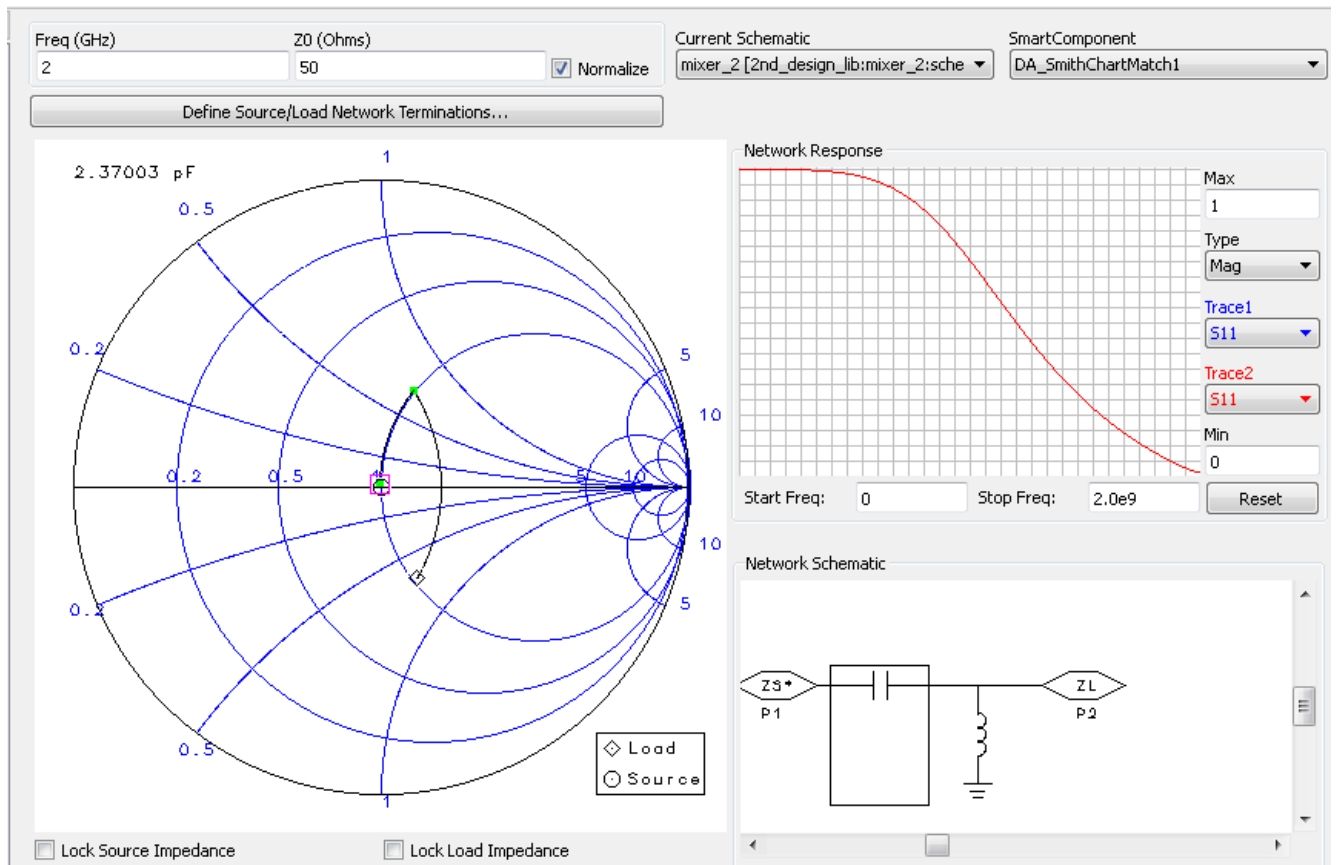
freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
2.000 GHz	0.313 / -71.453	6.258E-6 / 72.573	5.799E-5 / 59.361	1.000 / -180.000

Setting the frequency to IF (200MHz), we now get the following S-parameters.

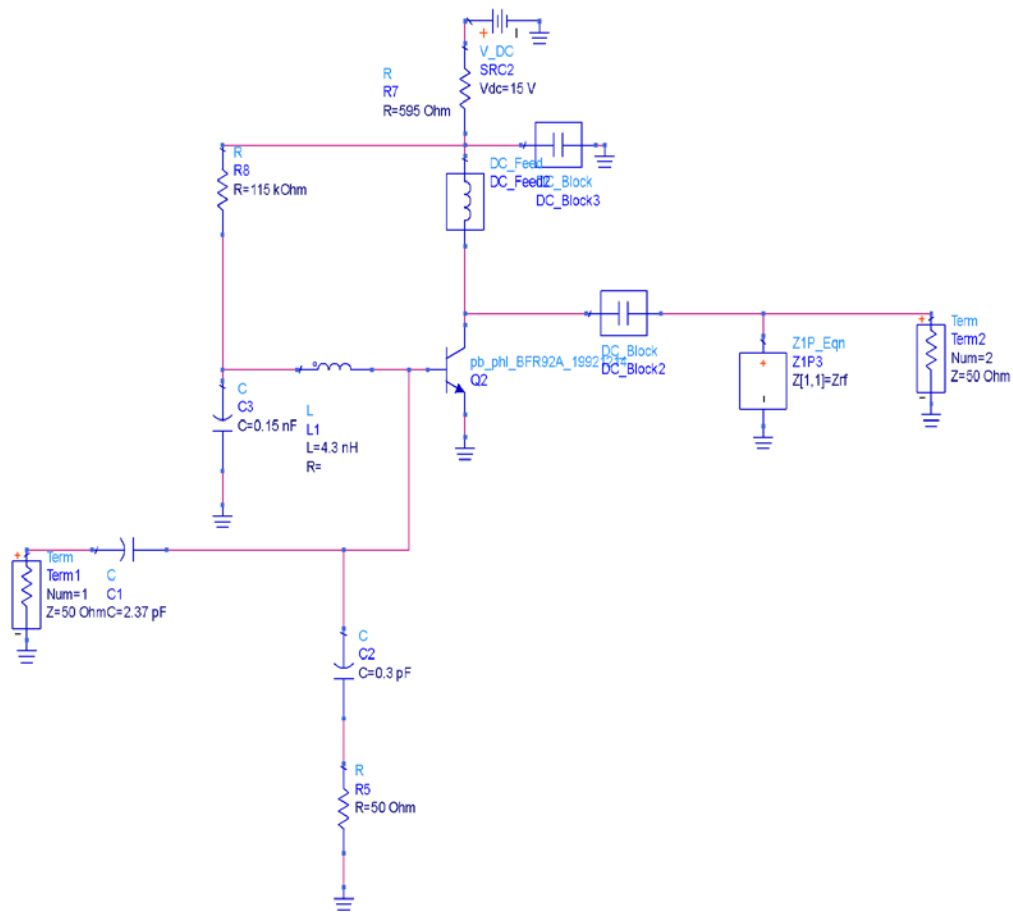
freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
200.0 MHz	1.000 / -180.000	9.214E-7 / 87.203	4.822E-4 / 139.550	0.972 / -4.460

Building the input matching network we need to match to

$$\Gamma_{in} = S_{11} = 0.313 / -71.453$$



Thus, a shunt inductor of 4.3 nH and a series capacitor of 2.37 pF will accomplish matching. However, we can also replace the DC\_feed1 and DC\_block1 with the capacitor, inductor combination. The extra  $C_3 = 0.15$  nF is dimensioned such that it provides a short at IF. The following schematic makes clear the configuration.

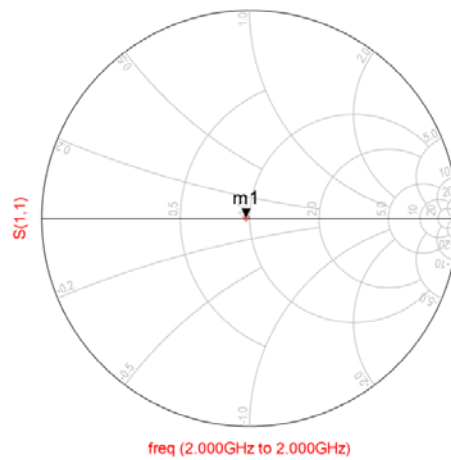


The good matching is documented by observing the S11 parameter.

```

m1
freq=2.000GHz
S(1,1)=0.018 / 166.125
impedance = Z0 * (0.965 + j0.008)

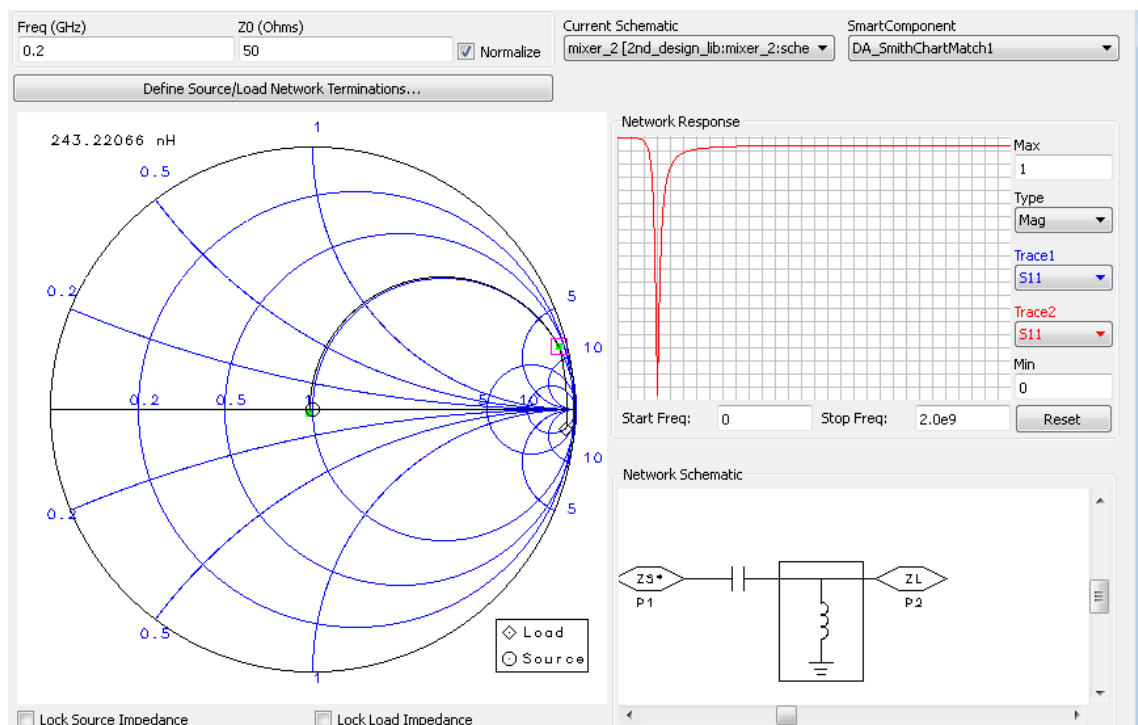
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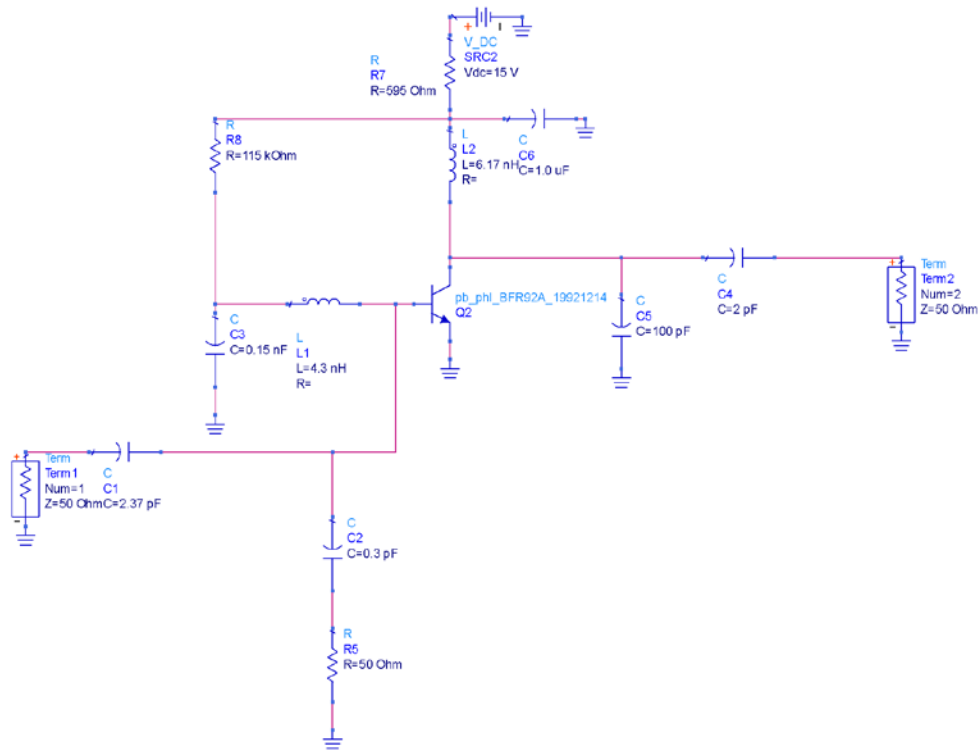
C) At IF record  $S_{22}$  and build the output matching network. Again, explore ways to combine the matching network with blocking capacitors and/or RFCs.

For the output matching network the S-parameter at 200 MHz is:

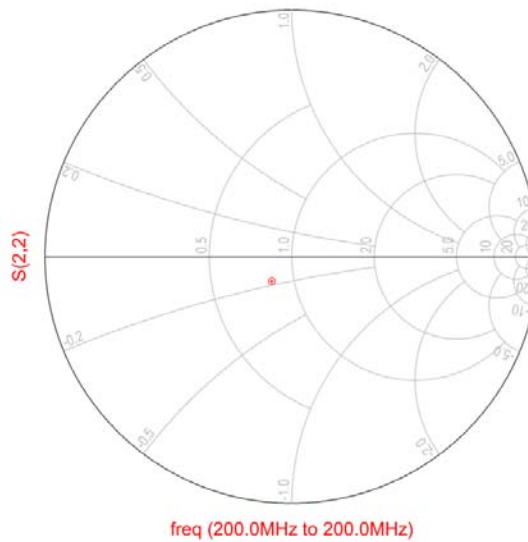
$$\Gamma_{out} = S_{22} = 0.972 / -4.46$$



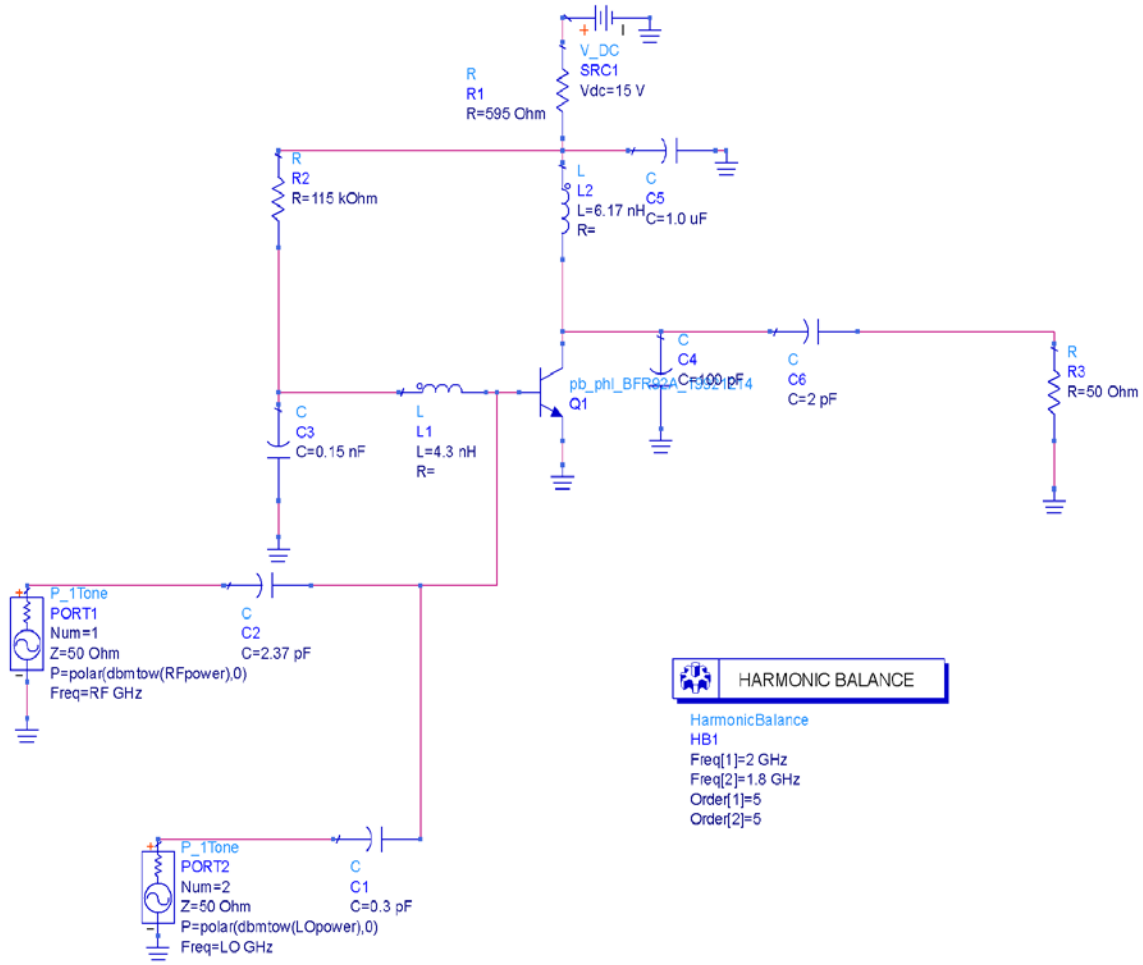
At the output, the shunt inductor does not short the RF signal feed-through. We therefore build an equivalent LC parallel circuit. At 200 MHz, the values are 6.17 nH and 100 pF, respectively. This combination allows us also to replace the RFC, as the schematic below shows.



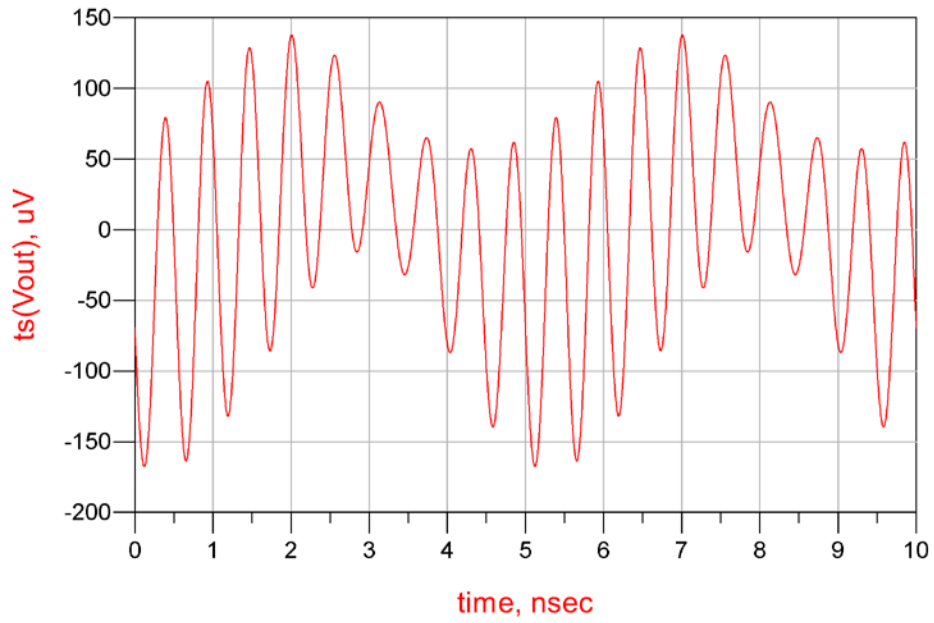
And the S22 parameter shows the wellness of the matching.



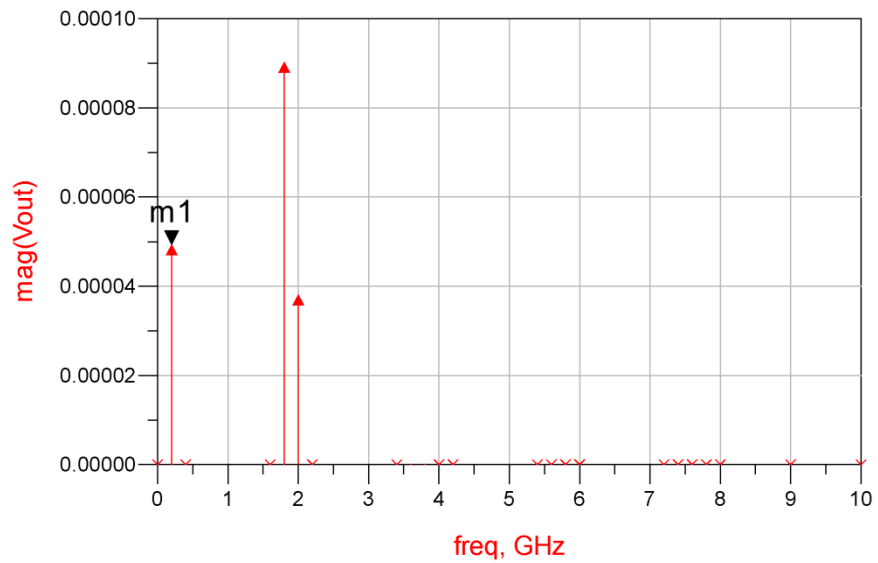
D) Simulate your design with the harmonic balance controller. Set the RF input power and LO power to -30dBm and 0dBm, respectively. Plot the output voltage as a function of time and in a separate graph show the spectral tones up to 5 harmonics.



The time domain for output voltage



Spectrum for output voltage



m1
freq=200.0MHz
mag(Vout)=4.924E-5