Assignment 6

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Topics in Electronics I
Simulation of Radio Frequency Circuits

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The goal of this assignment is to train the student on the generalization of the HB technique from the single-tone to the multi-tone excitation. The target circuit used for this purpose is the doubly-balanced mixer circuit shown in Figure 1.

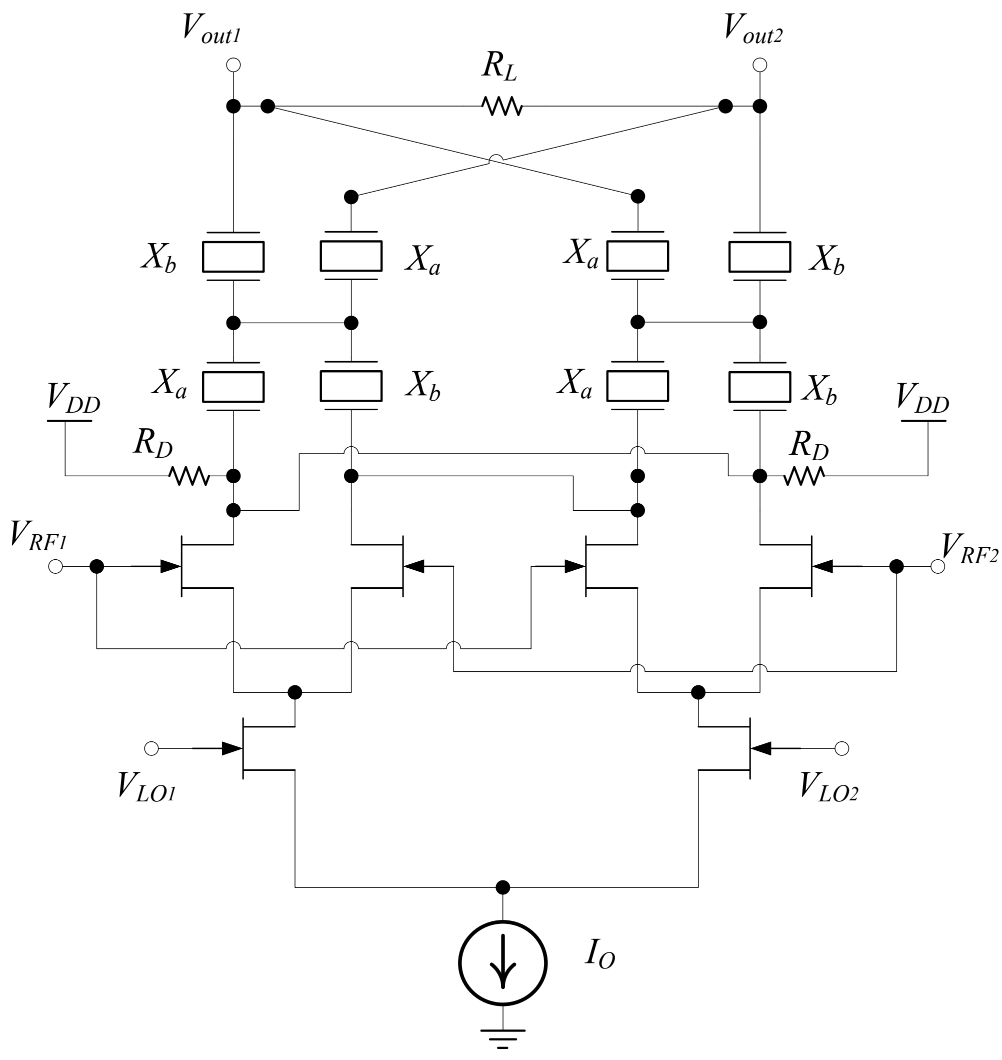

Figure 1: The circuit schematic

This circuit is simulated by two sources of two different frequencies. The first source is the output of some local oscillator, whose waveform is given by

$$v_{\text{LO1}}(t) = -v_{\text{LO2}}(t) = 0.125 \times \sin\left(2 \times \pi \times 10^9 \times t\right) \tag{1}$$

and the second source is the waveform of some RF frequency given by

$$v_{\text{RF1}}(t) = -v_{\text{RF2}}(t) = 0.0125 \times \sin\left(2 \times \pi \times 900 \times 10^6 \times t\right) \tag{2}$$

The output of the circuit is a differential output taken between the nodes out1 and out2, i.e.,

$$v_o(t) = v_{\text{out1}}(t) - v_{\text{out2}}(t)$$

.

Thus, it can be observed that that input sources exciting the mixer is have two distinct tones

$$\begin{aligned} \omega_1 &= 2\pi \times 1\text{GHz} \\ \omega_2 &= 2\pi \times 0.9\text{GHz} \end{aligned}$$

Hence, the response of the circuit will contain frequencies at multiples, and combinations of multiples, of ω_1 and ω_2, i.e., with frequencies λ, where $\lambda = \pm m \times \omega_1 \pm n \times \omega_2$ with $m, n = 0, 1, 2, 3, \cdots$

The circuit is designed to filter out (dampen) all the components at the output nodes except for the component at the difference between the frequencies, i.e. at $\omega_1 - \omega_2 = 2\pi \times 100$MHz, i.e. the component for which $m = 1 and n = -1$.

Part (a)

Draw a sketch for two-dimensional grid showing the the box-truncated frequency spectrum for $K_1 = 3$, and $K_2 = 5$.

Part (b)

Assume that a two-tone HB technique is used to compute the steady-state response of this circuit, and let a box truncation scheme with truncation indices $K_1 = 2, K_2 = 2$, be employed to truncate the frequency spectrum of the response.

List the set of *unique* frequencies obtained through the box truncation scheme, starting with the DC frequency.

Part (c)

Using *the same frequency ordering you listed in the previous part* , write down only the **non-zero** entries of the HB right-side vector $\bar{\boldsymbol{B}}$ ordered in Harmonic-major/node-minor.

To do this, create a two-column table, where the first column indicates the index of a non-zero entry in $\bar{\boldsymbol{B}}$ while the second column provides the corresponding numerical value of that entry.

Hints A good suggestion in answering this part is to do it using the HiSPICE interface. You can use the HiSPICE interface to know the entry index in the source vector $\boldsymbol{b}(t)$ that corresponds to the input RF source, by calling the function `mna_get_var_index_type`, using the `'current'` option, as shown next,

```
[vrf1_current_index,vrf1_type] =
mna_get_mna_var_index_type(my_circuit_struct.circuit_id,...
                                              'Vrf1')
```

This will give the position in $\boldsymbol{b}(t)$ corresponding to the current of the source `Vrf1`, which is the one responsible for $\omega_2 = 2\pi \times 0.9$ GHz. You can do the same thing for the other sources (e.g. $v_{\text{LO1}}(t)$) to find the index of their currents, which will correspond to $\omega_1 = 2\pi \times 1$GHz in the case of $v_{\text{LO1}}(t)$. Using these two, and the box truncated frequencies, you can find out the entries of $\bar{\boldsymbol{B}}$.

Part (d)

Assume that the technique of Artifical Frequency Mapping is being used to perform a two-tone HB simulation, create a table showing the actual frequency spectrum and its corresponding artficial frequency spectrum. Use the ordering of the actual frequency spectrum that you developed in part (a) to list the frequency components of the actual spectrum.

Part (e)

Provide in a clear and consie manner the permutation matrix that is used to reorder the components of the original spectrum into the artifical one.

IMPORTANT INSTRUCTIONS. What you need to submit

You are required to submit only one PDF file showing your responses to the above parts.