Measuring S-Parameters of a Differential Mixer

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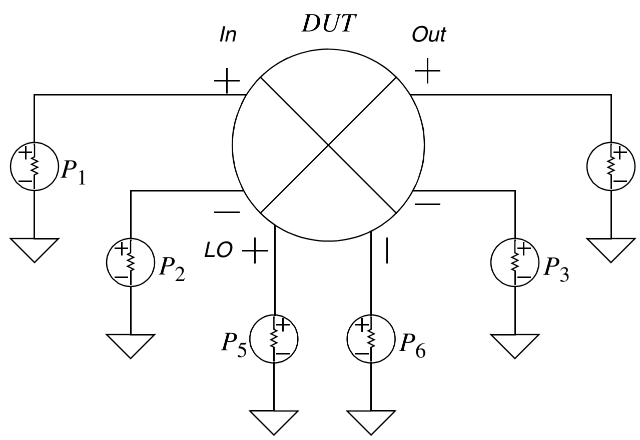
Gives the general outline of how to measure the *S*-parameters of a differential mixer with SpectreRF.

1.0 The Testbench

Consider a fully differential mixer with an input at 2.4 GHz, an output of 400 MHz, and an LO of 2 GHz. Assume that the mixer is constructed by simply combining two single ended mixers, each with port impedances of 50 Ω in parallel. In this way the differential impedance seen at each port of the combined circuit is 100 Ω, and the common-mode impedance is 25 Ω.

Consider the *S*-parameters of this mixer. Since the mixer is fully differential, the mixer has two balanced inputs and outputs. However, knowing the traditional 4-port *S*-parameters for the mixer, as measured by the testbench shown in Figure 1, are not very helpful

FIGURE 1. *Testbench for measuring 4-port S-parameters of a differential mixer (the LO ports, P5 and P6, are not active during S-parameter analysis). This is not the recommended approach for measuring S-parameters of a differential mixer.*



because they do not capture the differential nature of the circuit. Instead consider reformulating the *S*-parameters so that they are measured in terms of differential- and common-mode quantities [1,2].

Embed a fully differential mixer in the testbench shown in Figure 2. It consists of 3 pairs of ports. P_{id} and P_{ic} drive the input, P_{od} and P_{oc} drive the output, and P_{ld} and P_{lc} drive the LO (though the LO is driven by ports, these ports are not active during the *S*-parameter analysis). Ports P_{id}, P_{od} and P_{ld} are associated with differential signals and ports P_{ic}, P_{oc} and P_{lc} are associated with common-mode signals. Since the differential impedance seen at each port is 100 Ω, the reference resistance of ports P_{id}, P_{od} and P_{ld} should be 100 Ω. Similarly, the reference resistance of ports P_{ic}, P_{oc} and P_{lc} should be 25 Ω. B_i, B_o, and B_l are ideal baluns [3, 4], shown in Figure 3. They are used to convert the ground-referred signals associated with each port with the appropriate differential- and common-mode signals at the balanced inputs of the mixer.

FIGURE 2. *Testbench for a fully differential mixer.*

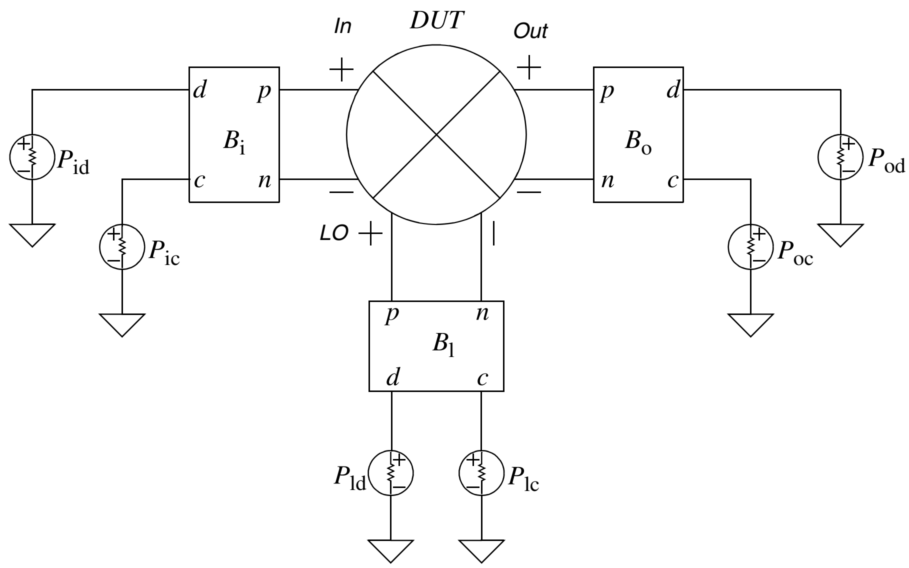


FIGURE 3. *Ideal balun.*

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simulator lang=spectre

subckt balun (d c p n)
    T1 (d 0 p c) transformer n1=2
    T2 (d 0 c n) transformer n1=2
ends balun
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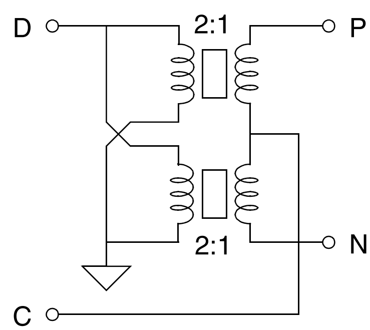

2.0 The Analysis

Use Spectre®RF's[1] periodic *S*-parameter, or PSP, analysis to compute the *S*-parameters of this mixer. To do so, first set the *type* parameter for the input and output ports (P_{id}, P_{ic} P_{od} and P_{oc}) to *dc* and configure ports the LO ports (P_{ld} and P_{lc}) to produce the LO signal. Since the LO is differential, generally P_{ld} is configured to produce either a sine or square wave, in this case at 2 GHz, and P_{lc} is configured to produce a DC bias.

The PSP analysis uses the idea of virtual port, where each virtual port is the combination of a physical port and a sideband index. Assume, for the moment, that only the dif-

1. Spectre is a registered trademark of Cadence Design Systems.

ferential *S*-parameters involving the input and output are of interest. In this case, denote virtual port 1 (the input port) to represent P_{id} at the upper sideband of the LO fundamental (sideband 1) and denote virtual port 2 (the output port) to represent P_{od} at baseband (sideband 0). In this way, s_{11} represents the differential reflection coefficient of the mixer's input, s_{21} represents the differential gain, s_{12} represents the differential reverse transmission, and s_{22} represents the differential reflection coefficient at the output. Perform the PSP analysis with the frequency sweep centered about 400 MHz to get the desired results.

If the common-mode *S*-parameters are also of interest, one can add additional virtual ports to represent the common mode quantities. Currently, Artist limits users to three virtual ports, so one cannot add both the input and output common-mode ports. Instead, consider just the common-mode input port P_{oc} at baseband (sideband 0) as virtual port 3 (the auxiliary port). Then, s_{11}, s_{21}, s_{12}, and s_{22} have the same meaning as above, and s_{31} represents the differential- to common-mode gain.

2.1 If You Have Questions

If you have questions about what you have just read, feel free to post them on the *Forum* section of *The Designer's Guide Community* website. Do so by going to *www.designers-guide.org/Forum*.

References

[1] David Bockelman and William Eisenstadt. Combined differential and common-mode scattering paramters: theory and simulation. *IEEE Transactions on Microwave Theory and Techniques*, vol. 43, no. 7, July 1995, pp. 1530-1539.

[2] David Bockelman and William Eisenstadt. Combined differential and common-mode analysis of power splitters and combiners. *IEEE Transactions on Microwave Theory and Techniques*, vol. 43, no. 11, November 1995, pp. 2627-2632.

[3] Kenneth S. Kundert. *The Designer's Guide to SPICE and Spectre*. Kluwer Academic Publishers, 1995.

[4] Ken Kundert. *A Test Bench for Differential Circuits*. Available from *www.designers-guide.org*.