How to Simulate IIP3 using SpectreRF?

Anuranjan Jha,
Columbia Integrated Systems Lab

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LOW FREQUENCY CASE: WHERE YOU DO NOT NEED 50 OHM SOURCE AND INPUT MATCHING.

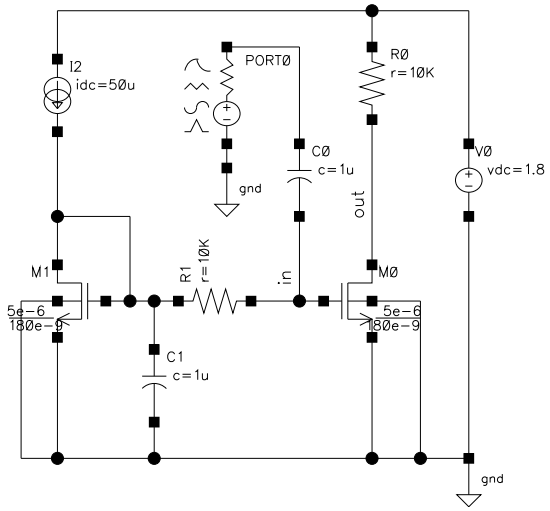
Let's begin with the simplest example — a common-source amplifier with resistive load with no degeneration and no input matching. We will deal in units of dBV.

Fig. 1(a) presents a test setup for measuring the IIP3 of my amplifier. First I set the two-tones needed for the test as 10 MHz and 12 MHz (see fig. 2(a) and 2(b)). The input is specified in terms of peak amplitude. Even though I am using a port in the simulation, it is not required *here*. In the results you will note that I have taken the V_{GS} voltage as my input reference. With ports, unless there is a perfect matching with its input resistance, the voltage you get from it is dependent on the load. For example, since the port is driving a capacitive load here, the voltage at the gate will be 40 mVpp for Vpk set to 20 mVpp in the port properties. I can now run pss to find the steady state response and then proceed to find the 3^{rd}-order amplitude in units of dBV. The pss results are shown in fig. 3. I tabulated the results for different V_{GS} cases and plotted them using MATLAB. The intercept point is shown in fig. 6(a). The IIP_3 for this Common-Source amplifier is about -7.5 dBV.

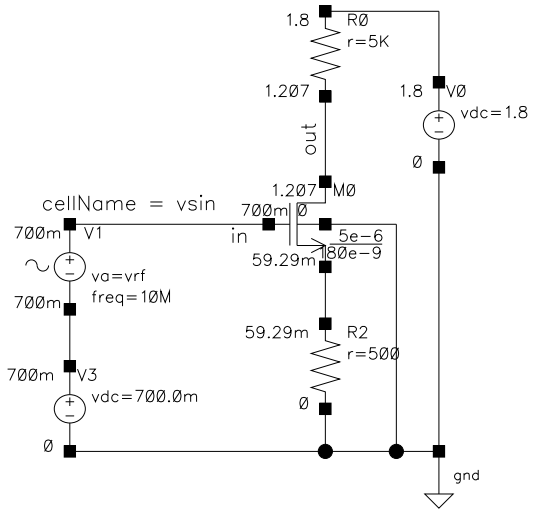
Next I simulated an amplifier with same nFET but with a source degeneration resistance of 500 Ω and load of 5 kΩ. Figs. 1(b), 4, 5 shows the test setup, the properties of the $vsin$ source used in the setup and the SpectreRF results when two-tone signals of amplitude 350 mV are applied, respectively. The $IIP3$ result is shown in fig. 6(b). It has improved to about -2.5 dBV.

The data and MATLAB code for Common-Source amplifier is attached below.

```
% Results of two-tone test of Common-Source Amplifier
% Circuit: /home/anu/cadence/ee6314_F05/CSampl

vrf =    [1 2 5 10 20 30 40 50 75 100 150]*1e-3;
in =     [-54.02 -48 -40.04 -34.02 -28 -24.48 -21.98 ...
          -20.04 -16.52 -14.02 -10.5];
out10M = [-36.54 -30.52 -22.57 -16.6 -10.79 -7.663 ...
          -5.99 -5.09 -4.064 -3.63 -3.262];
out8M  = [-127.8 -109.74 -85.9 -67.98 -50.28 -38.52 ...
          -28.71 -23.59 -18.3 -16.09 -14.35];
im3 = out10M - out8M;

inp =  [-54.02 -48 -40.04 -34.02 -28 -24.48 -21.98 ...
        -20.04 -16.52 -14.02 -10.5 -7.5];
int1 = out10M(1) + (inp-inp(1));
int3 = out8M(1) + 3*(inp-inp(1));


figure;
plot(in,out10M,'k-x','linewidth',2,'markersize',12); hold on;
plot(in,out8M,'k-o','linewidth',2,'markersize',12);
plot(inp,int1,'r-x','linewidth',2,'markersize',8);
```



(a)



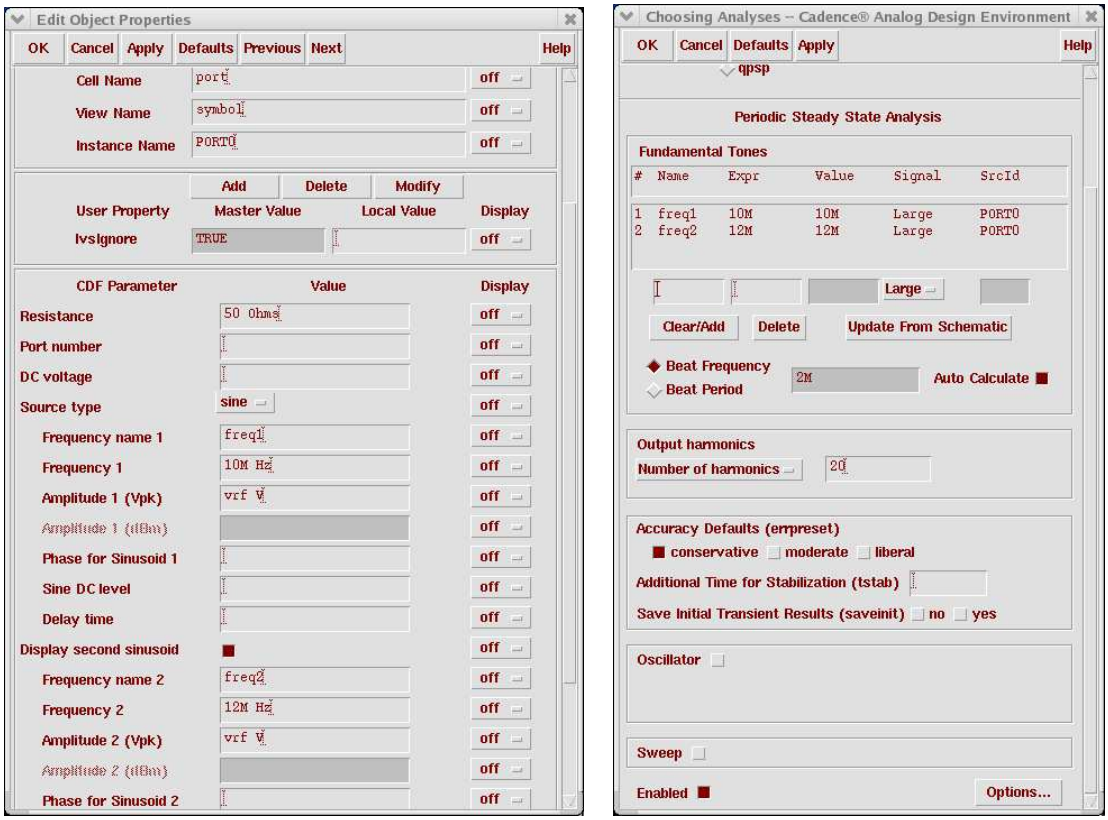
(b)

Fig. 1. Test setup for IIP3 measurement of (a) Common-Source Amplifier (b) Source-degenerated amplifier.

```
plot(inp,int3,'g-o','linewidth',2,'markersize',8); hold off;
set(gca,'ylim',[-175 15],'ytick',[-175:25:0],'fontsize',16);
L = legend('\omega_1','2\omega_1 - \omega_2');
set(L,'box','off','fontsize',16,'location','northwest');
xlabel('V_{gs}, dBV','fontsize',16);
ylabel('V_{out}, dBV','fontsize',16);
% Results in an IIP3 of -7.5 dBV
print -depsc CSamplIIP3.eps
```

RF CASE: WHERE YOU DO NEED 50 OHM SOURCE AND INPUT MATCHING.

Think about it... Coming up...



(a) (b)

Fig. 2. (a) Properties of the port used in the test setup of fig. 1(a) (b) PSS analysis form.

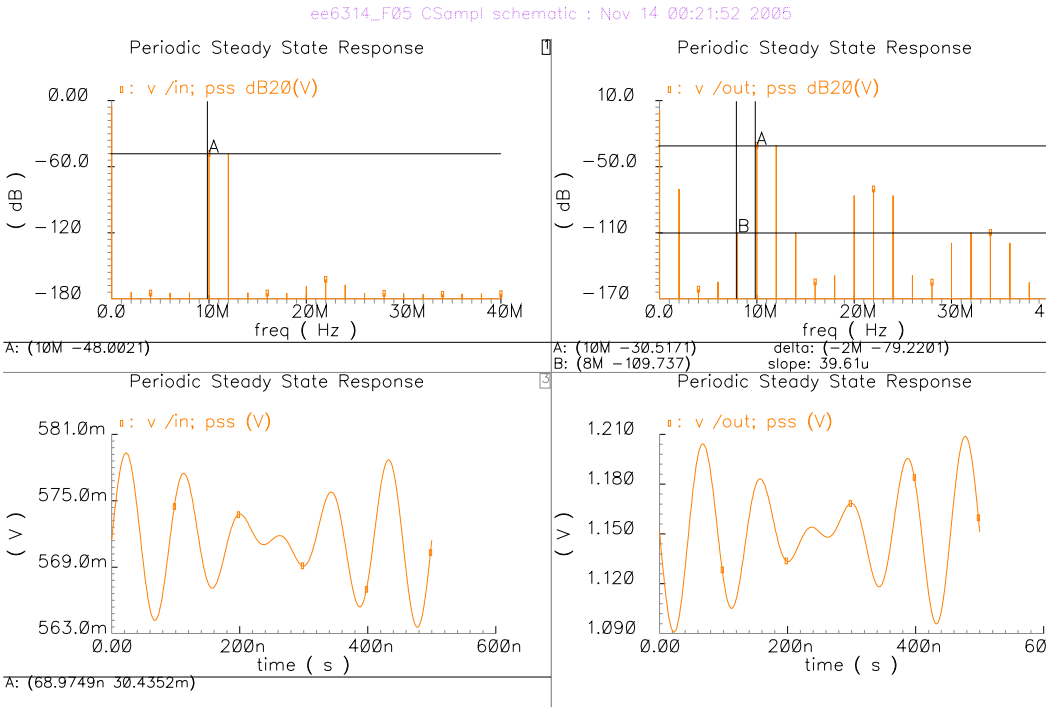


Fig. 3. SpectreRF results for smallest applied V_{GS}.

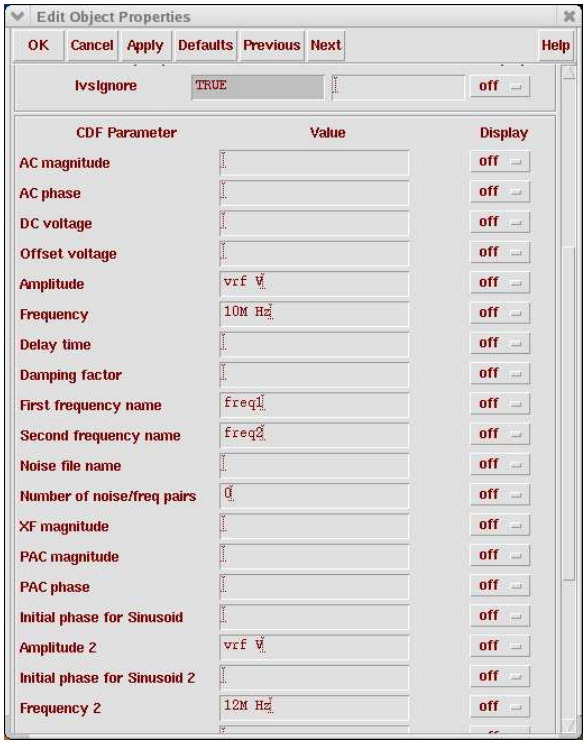


Fig. 4. Properties of the $vsin$ source used in the test setup.

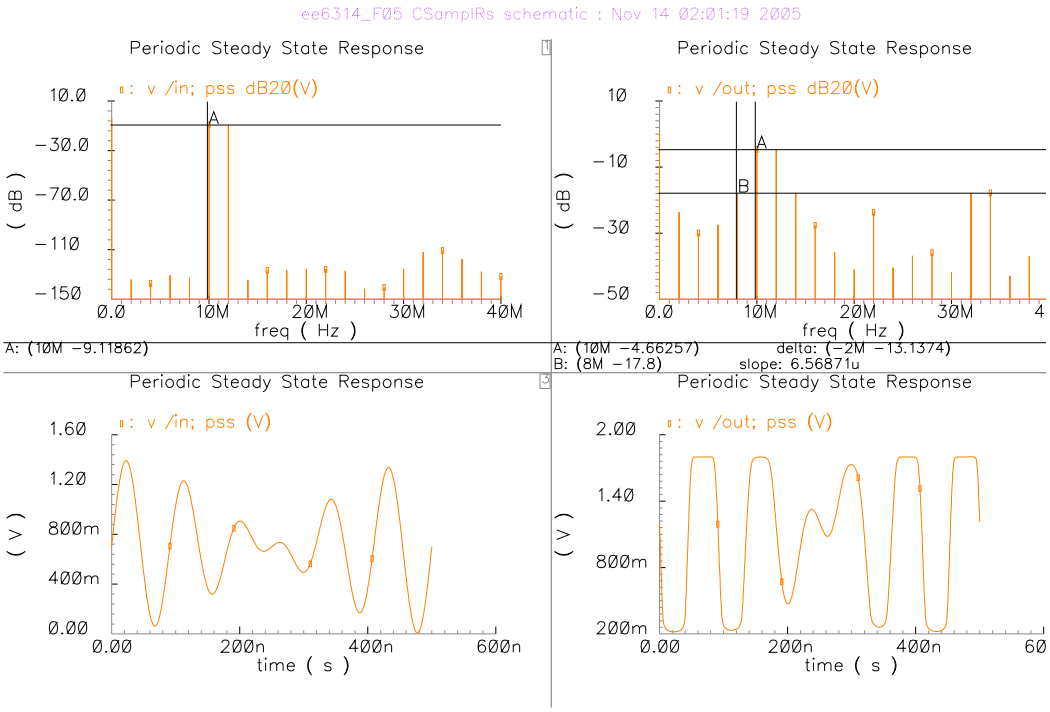
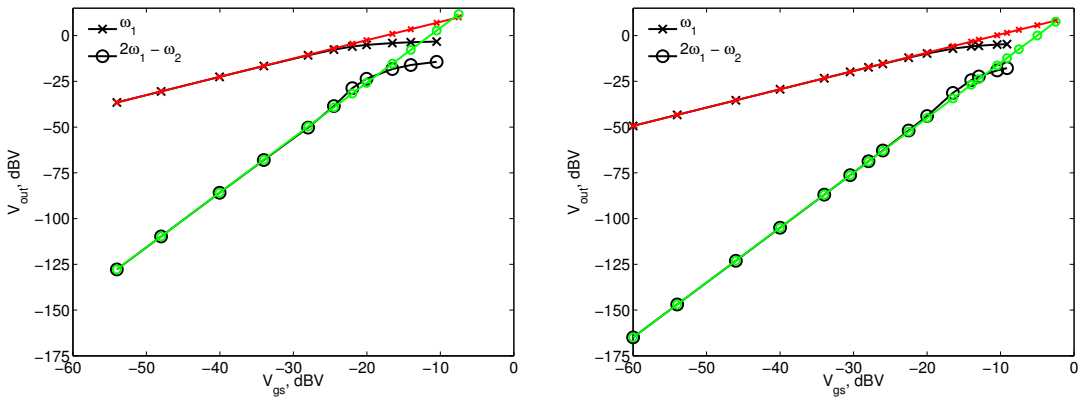


Fig. 5. SpectreRF results for largest applied V_{GS} for fig. 1(b)



(a) (b)

Fig. 6. IIP_3 comparison for (a) Common-Source amplifier and (b) Source degenerated amplifier.