THD Simulations in Analog Artist Environment using SpectreS

In this section, a brief introduction to THD (Total Harmonic Distortion) simulations in Analog Artist Environment of Cadence with SpectreS simulator is given. The circuit that is used as an example is the three-stage miller compensated operational amplifier. The test configuration is shown below.

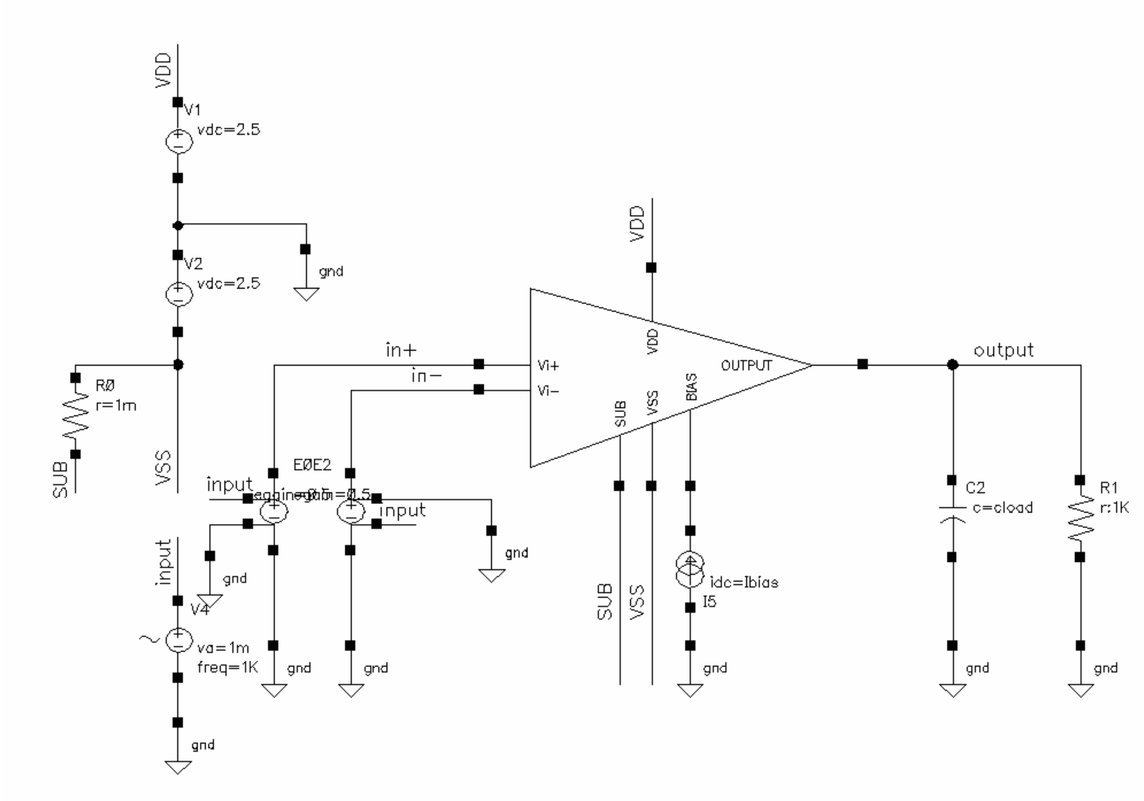
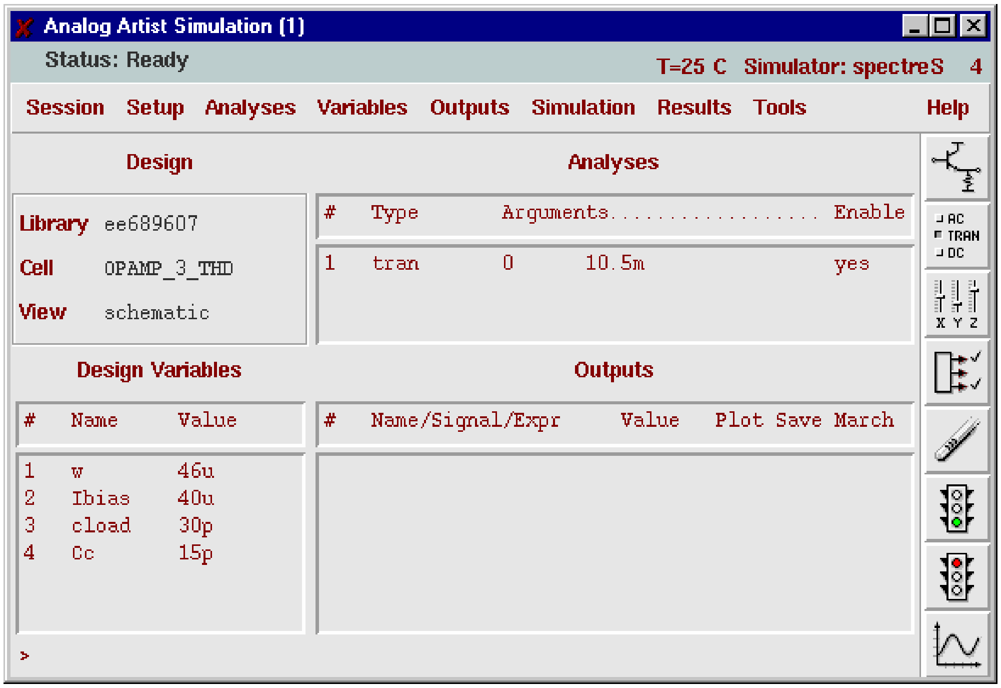


Fig. 1 THD simulation setup.

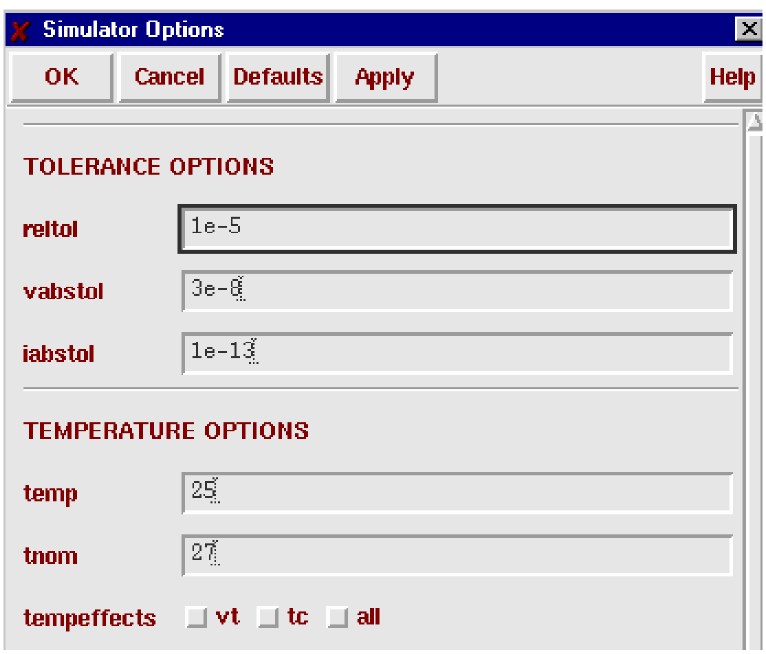
THD figure of the circuit is obtained using transient simulation. In order to be able to get accurate results, one should be careful about the settings of the transient simulation. The maximum time step should be low enough to account for the highest frequency component of the signal. The details about the settings can be obtained from the "openbook" in the eesun system. Typing *openbook* in a command line in eesun is enough to reach the menu of the "openbook". Then, you may search for THD and/or DFT. It is also possible to reach the openbook within Cadence. Clicking on the help button on a window opens the corresponding section of the openbook.

It is recommended that a transient simulation be run for slightly more than ten cycles of the input signal to obtain accurate THD figures. Note that the input frequency is set as 1kHz in the test configuration. Therefore, we run the simulation up to 10.5 milliseconds. The design variables are the widths of the driver transistors of the input differential pair, the bias current of the opamp, the load capacitance and the miller compensation capacitance, as shown on the Analog Artist Simulation window given below. Some of these variables are associated with the other simulations.

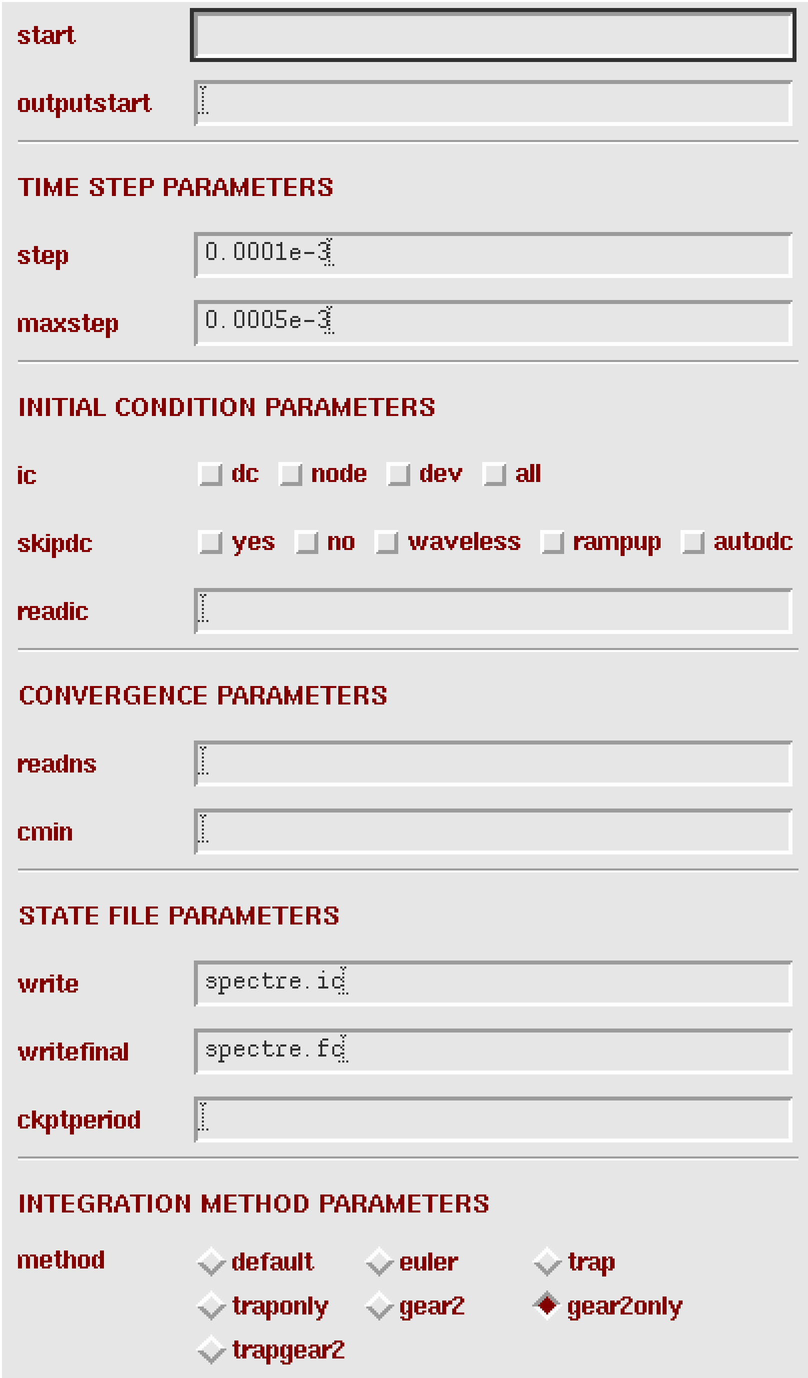


For the sake of the accuracy of the simulation results, it is suggested that the following tolerance parameter values are used throughout the simulations. The menu shown below can be reached at

Simulation -> Options -> Analog.



In the options section of the transient simulation window that can be reached from the “Choosing Analyses” menu, the time step parameters are set as shown below.



Note that the integration method is set as “gear2only”. Once all the parameters are set as shown above, the simulation is run. In order to get the THD figure, one should use the calculator window. After the transient output waveform is selected from the schematic view, “thd” function from the “special functions” section of the calculator window should be chosen. As a consequence, the Total Harmonic Distortion” window shown below pops up. It is recommended that only the last cycle be taken into account for the THD calculation. Therefore, we use the time period from 9milliseconds to 10 milliseconds.

Number of samples is taken high enough to account for the high harmonics properly. After the “OK” button is clicked, the THD expression appears in the calculator. Then, the THD value can be plotted clicking the “erplot” button of the calculator. The value in the plot given below is the THD figure in percent of the opamp for an input voltage signal of 2mV_{pp} at f=1kHz. The x axis in the plot can be ignored.

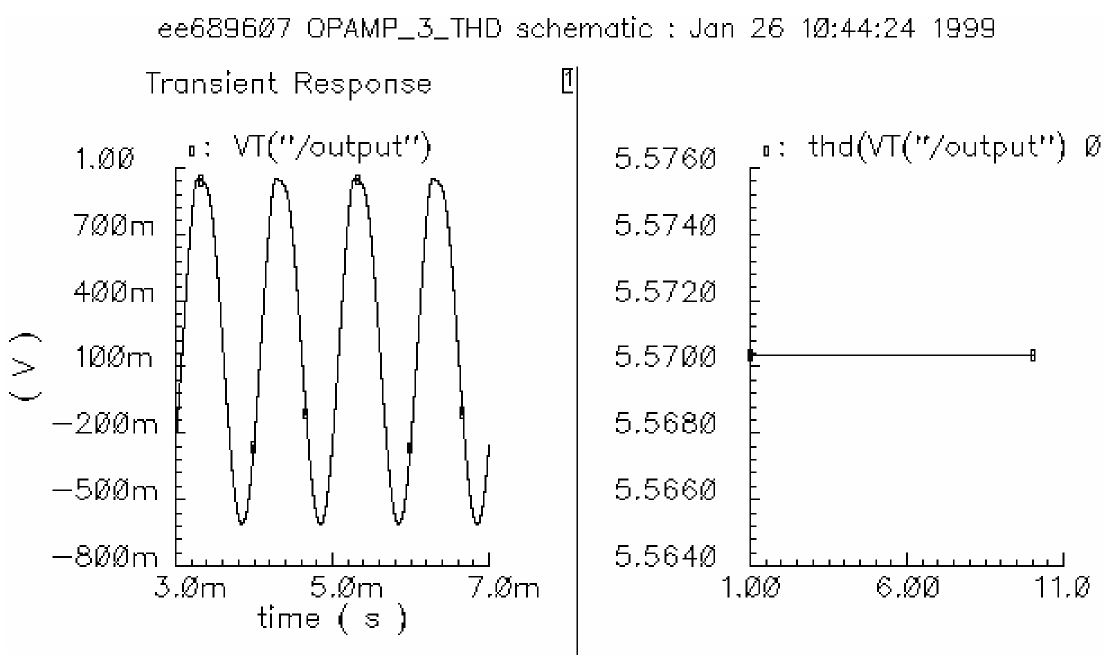
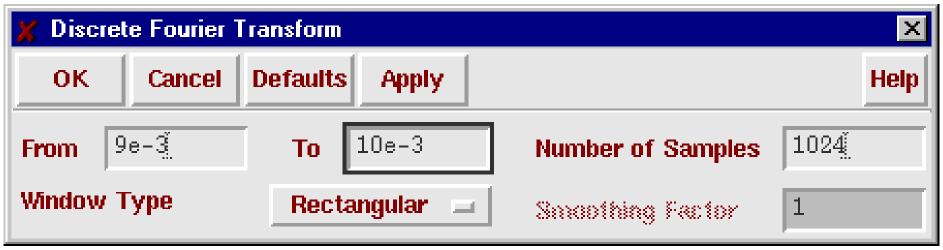


Fig. 2 Output voltage of the opamp and the corresponding THD for V_{in}=2mV_{pp} at f=1kHz.

Another way of getting the THD figure is through the use of the “dft” function. This function is also reached from the “special functions” section of the calculator window. As it is seen on the window given in the following page, the same settings as those of the total harmonic distortion function are used.



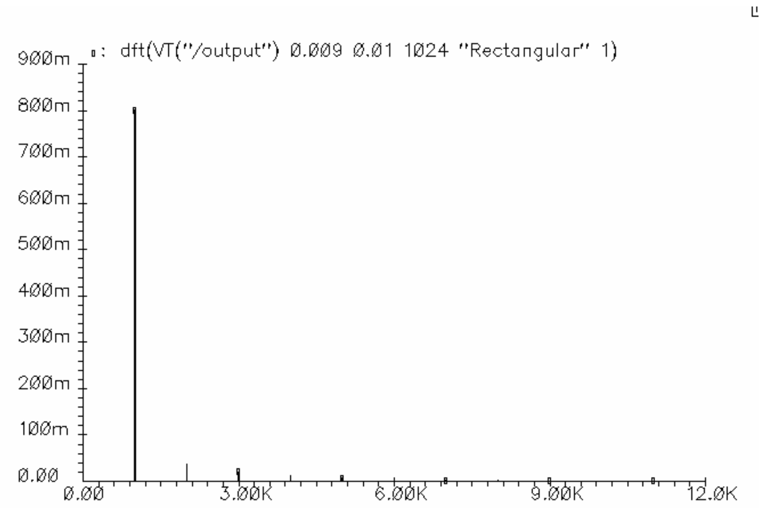


Fig. 3 Frequency Spectrum of the output voltage of the opamp.

The plot obtained using the dft function is given above. It is possible to read the voltage levels of the harmonics of the output voltage signal from the plot, which is a representation of the frequency spectrum of the signal. Then, it is quite straightforward to calculate the THD of the signal. Remember that the THD is a measure of the percentage of the signal power due to the unwanted harmonics with respect to the fundamental signal power. A lower THD figure corresponds to a purer fundamental signal.

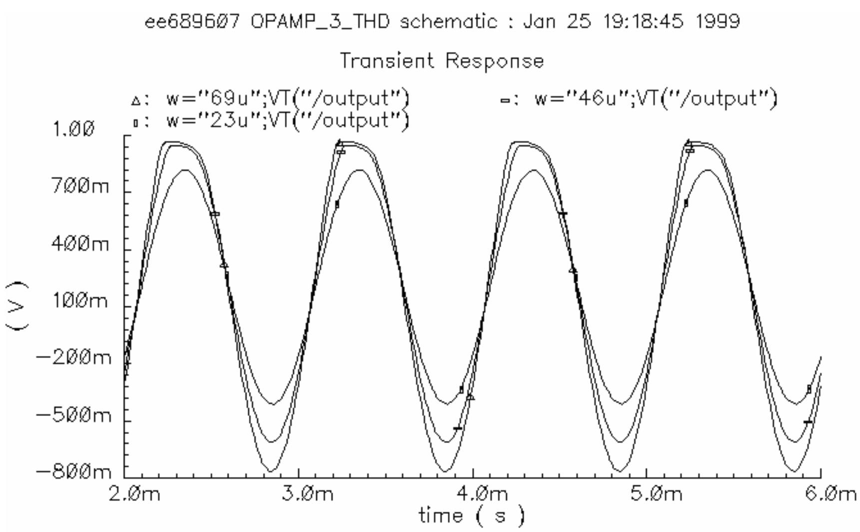


Fig. 4 Output transient waveforms of the opamp obtained from a parametric simulation.

We should note that one should be very cautious in interpreting the results obtained from the dft and thd functions as both of them are very prone to errors. It is a good practice to view the transient waveforms together with the results from these functions to check the accuracy of the results roughly.

Figs. 4-5 show the plots obtained from a parametric simulation. The width of the driver transistors of the input differential pair is taken as a parameter. The transient output waveforms are given in Fig.4 and the corresponding THD figures are given in Fig.5. The x-axis in Fig.5 is the width of the transistors. The results from the two plots can easily be correlated.

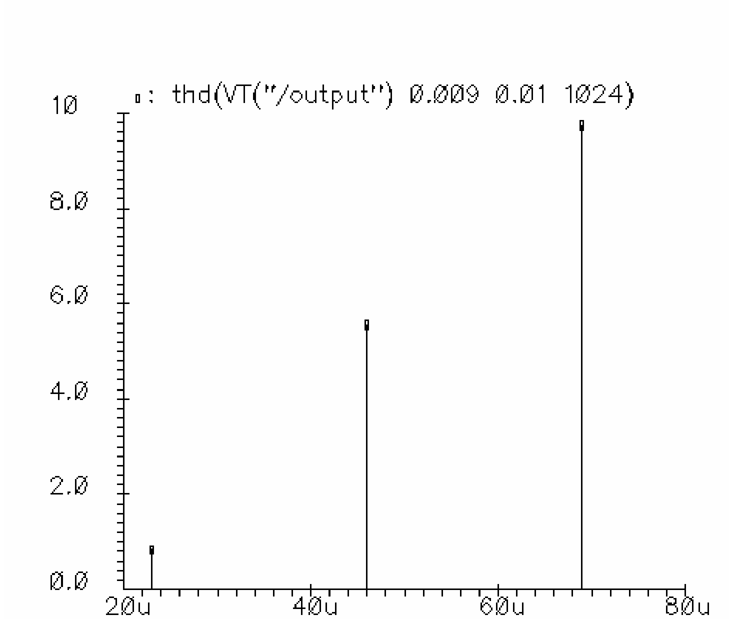


Fig. 5 THD figures of the opamp obtained from a parametric simulation.