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D2.14 Public report on improved initial conditions for Harmonic Balance in solving free oscillatory problems

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Contents

1 Introduction

The task description of T2.3 is briefly summarized here. For distortion analysis of free-running oscillators getting a reasonable estimate for the initial conditions has proven to be a time-consuming business. To improve this situation, new algorithms to find the operating frequency of a free-running oscillator have been developed that drastically improves the speed and robustness of harmonic balance analysis for these cases. One algorithm uses available pole-zero analysis methods to determine the dominant poles of the system and hence finds a good initial estimate for the operating frequency. A different approach tries to find an initial frequency estimate from optimisation techniques. Combinations with time integration techniques are needed as well.

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2 HB Oscillator Analysis

A common way to solve free-running oscillator problems with the harmonic balance (HB) method is to use single, multiple, or multi-harmonic probes [1]. In the APLAC simulator [2] the probe element is called OscAProbe, which is actually a voltage source in series with a non-zero resistor, and it is usually connected to the output of an oscillator circuit.

The HB oscillator problem is solved by optimization. The optimization variables are the value of the probe voltage source at the fundamental frequency, V_{osc}, and the HB analysis fundamental frequency f_{osc}. The goal of the optimization is to have the HB fundamental spectral voltage over the probe element equal to V_{osc}, i.e., the current through the probe element is equal to zero.

The user is required to set initial values for V_{osc} and f_{osc}. A poor initial frequency or amplitude value can lead to unsuccessful optimization or will at least require a large number of optimization cycles to succeed. Therefore algorithms have been developed to provide better initial estimates for V_{osc} and f_{osc}.

3 Setting Initial Conditions for HB Analysis

The idea is to improve the initial estimates of V_{osc} and f_{osc} as follows:

- run an initial transient analysis over some specified interval,
- collect time-domain waveform data, i.e., the voltage over the probe element,
- extract improved values for V_{osc} and f_{osc} from the data using the two new implemented methods called “FFT” and “ZeroC”,
  - “FFT”: apply a FFT and search for the location (frequency) and value of the maximum amplitude peak and improve this estimate by parabolic interpolation

- "ZeroC": estimate the frequency based on zero-crossings (after removal of the average), and oscillation amplitude based on half of the maximum swing

- start the HB analysis based oscillator optimization using these improved values.

The algorithms have been implemented in the APLAC simulator. There are several parameters which can be used to control initial transient analysis and/or how the estimation of V_{osc} and f_{osc} is done.

4 Simulation Results

The following figures show the transient start-up and the HB waveform (result of the HB analysis based oscillator analysis) of two test circuits, Colpitts (Fig. 1) and vcoBi (Fig. 2).

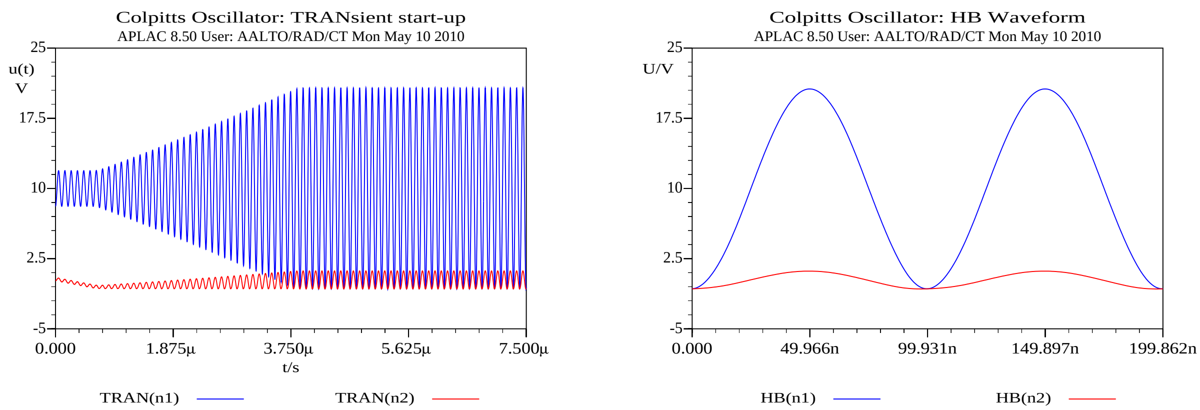

Figure 1: Colpitts Oscillator: Transient start-up (left) and HB waveform (right)

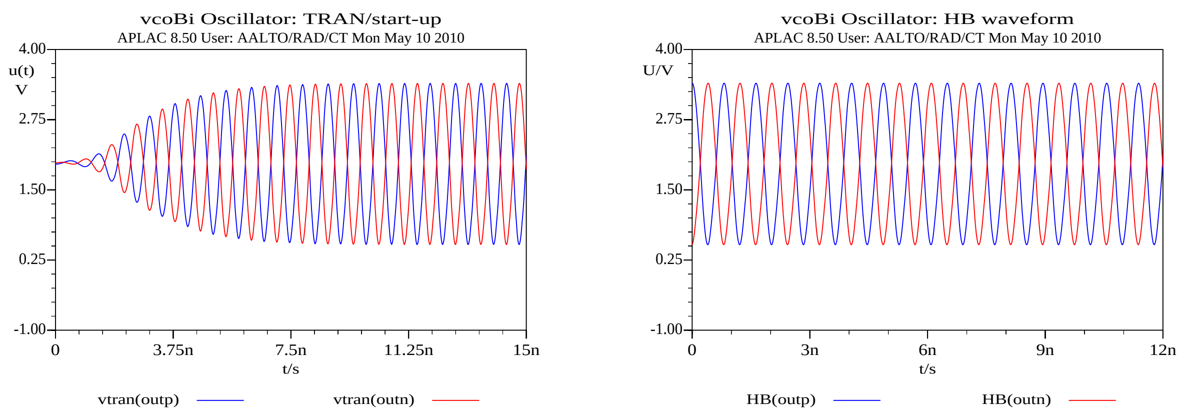

Figure 2: vcoBi Oscillator: Transient start-up (left) and HB waveform (right)

Table 1 shows more detailed analysis results for Colpitts, vcoBi, Pierce and VHF oscillator circuits. Columns "Circuit", "Method", "HBITER", "CPU", and "Speedup" show the name of the circuit, the used analysis method (algorithm), the total number of HB iterations, CPU-time in seconds, and the speed-up factor, respectively. A HB iteration in the APLAC simulator involves steps in an optimization loop: solve a driven oscillator problem by Newton Raphson, and update V_{osc} and f_{osc} for the next optimization loop. The analysis algorithm "old" refers to the default settings of the simulator, and "FFT" and "ZeroC" refer to the new implemented methods. The speedup factor has been computed are a ratio of the CPU-times of the simulated case and the reference simulation – faster simulation than the reference simulation gives a speedup factor higher than one. In case of "FFT" and "ZeroC" methods, the CPU-time includes also the time of the initial transient simulation.

Circuit	Method	HBITER	CPU	Speedup
Colpitts	old	1756	0.58	1.0
	FFT	1529	0.54	1.1
	ZeroC	1153	0.38	1.5
vcoBi	old	738	1.98	1.0
	FFT	312	0.80	2.5
	ZeroC	31	0.08	24.8
Pierce	old	779	0.27	1.0
	FFT	593	0.22	1.2
	ZeroC	452	0.14	1.9
VHF	old	50	0.01	1.0
	FFT	43	0.02	0.5
	ZeroC	31	0.02	0.5

Table 1: Detailed analysis results in case of Colpitts, vcoBi, Pierce and VHF oscillator circuits

In general, the usage of either "FFT" or "ZeroC" based estimate for the initial values improve the efficiency and enhance the robustness of the oscillator optimization analysis. Optimization methods are, however, quite sensitive to the initial values, and depending on the values of analysis and/or optimization parameters, the optimization algorithm does not always benefit for the improved initial values. This is partly due to the nonlinear behaviour of the current through the probe element as a function of the supplied voltage (see Lampe [3–5]). Also the number of zero crossings needed to estimate the frequency can be higher than 2. The first item can be improved by applying vector extrapolation techniques before completing the actual zerocrossing process. Also a more robust Newton-iteration method improves things (these are part of the NXP contribution, not yet described in this report).

5 Conclusions

In this report we have described new methods ("FFT" and "ZeroC") that have been developed during the project. Both of these methods have been implemented in the industrial, commercially available APLAC simulator during H1/2010 and will later be available to designers using AWR (and APLAC) software. These new features have been tested on a large set of industrial problems, and the results have been good: faster convergence and improved robustness of the new approaches are greatly improving the quality of the HB based oscillator analysis. The methods implemented during this project also enable further research and improvements for the algorithms once we have more feedback based on real design problems.

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References

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