

THE COMPARISON BETWEEN ORCAD AND MATLAB ON TOLERANCE ANALYSIS FOR ANALOG CIRCUIT

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Abstract-The paper presents the tolerance influence of circuit elements on the performance of the entire system. It is described the analysis of electric circuit with ORCAD software , and also with personal software .

Keywords: analysis tolerance circuit, Monte Carlo method,

1. INTRODUCTION

The distribution of parameter values from manufactured circuits is associated with the tolerance of circuit parameters. Thus, the tolerance defines an interval of possible values which the circuit parameters can be. An important observation is that in manufactured circuits the components can vary from their nominal value from 0.1% to more than 39%.

This means that the analysis of a circuit must be performed on a adequate interval of parameter values, close to nominal values. Such an analysis refers to a tolerance analysis. It implies combined effects of all component sensitivities from the analyzed circuit .By doing a tolerance analysis , the designers of circuits can be sure that a big quantity of manufactured circuits will comply with design specifications in spite of tolerance intervals.

2. TOLERANCE ANALYSIS OF ELECTRICAL CIRCUITS WITH ORCAD

From all the methods for tolerance analysis, the Monte Carlo analysis is the most powerful, and additionally

it gives us useful information's for tolerance designing.

Generally, the Monte Carlo analysis is a simulation of the real manufacturing process where the effect of random parameters value is set through calculation. Because it is a statistic method, it only estimates the effect of components tolerance.

Its name, Monte Carlo, doesn't come from specific methods of electronic circuits designing and it cannot be classified as one of them. It is used to describe a family of simulations techniques and experimental mathematics important for different types of disciplines.

These techniques are characterized by the use and manipulation of pseudo-random numbers in statistic experiments and they all obey very general theories and statistic education techniques.

Some interpretations of this method became relevant when they are applied in the particular context of electronic circuits tolerance analysis. One interpretation of Monte Carlo analysis is being like a first-test production of a circuit manufacturing, process which can be simulated directly with the help of generating random numbers and with circuit analysis.

A second interpretation of Monte Carlo analysis was already mentioned as a statistic exploration of the tolerance boundaries in components space. This perspective will prove useful to the interpretation and development of different tolerance designing methods. A third perspective of Monte Carlo analysis – being like a test experiment and the subject of statistic education – allows us for example to calculate the mistakes associated with varied Monte Carlo estimations of productivity.

Tolerance analysis deals with the estimation of statistic variation aspects of functioning between manufactured circuits, variations made by other statistic variation with nominal components identical. These variations of components have statistic variations in the processes in which the components are manufactured.

The design of circuits contains the positioning of the elements on the board, made by the circuit designer, types and nominal values of components and tolerances. For discrete components, the circuits are assembled on integrated circuits boards, the components are taken random from recipients. For integrated circuits, the components and the interconnection between them are manufactured concomitant in a series of processing phases: statistic variations leads to component parameter variations and from here to circuit performance variations. Thus, in both technologies circuit manufacturing can be represented as being a random selection of components, followed by circuit assembling.

If the performance of manufactured circuits are measured we will see a deviation from nominal values or from assumed values. The size of this deviation can be so large that some circuits fail to achieve the performance demanded by the client when they are tested. In this case the process productivity will be below 100%.

To reduce the risk of starting a production process with small productivity, it is better to obtain an estimate productivity before designing the entire circuit. A possible solution is to start with a test production. A small number of circuits is produced here and the efficiency of the test production is calculated as the number of manufactured circuits that comply to the design specifications divided to the number of bad circuits.

This real productivity is considered to be an estimation of the capability at full production capacity .The number of circuits made in the test production must be big enough to offer a correct estimation (otherwise the samples may give a bad estimation), and it must be smaller than the total number of necessary circuits for mass production so that this method to be an economical one.

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In the most cases, these test productions are very expensive and for integrated circuits, almost as expensive as mass production. So, that is why this method for productivity estimation is not so wide used .The designing phase must be used because the simulation gives us a view of the production.

The implementation of the tolerance analysis with ORCAD software

The Monte Carlo analysis is the best way to analyze a circuit from statistic point of view, to see the behavior of that circuit under variations of parameter values. The Monte Carlo analysis determines the circuit behavior when the parameter values are modified inside their tolerance domain. This analysis also calculates the productivity, when can be used in statistic analyses concerning mass production.

To apply this analysis the next steps must be followed

- the .MODEL functions must be edited for these components with the desired component variations

- the configuration of parameters under Monte Carlo analysis in dialog window Monte Carlo/Worst Case.
- Starting the analysis
- by using the option *Performance Analysis*, from the *Trace*, menu in the window *Probe*, we can see how the circuit is affected by component variation

.MC (Monte Carlo analysis)

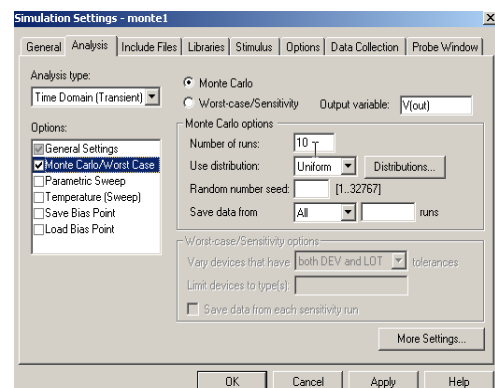
The **.MC** command starts a statistic analysis of the circuits so a numbers of runs are initiated depending on the selected type (DC, AC or transient).

Syntax **.MC** <#runs value> <analysis> <output variable> <function> [option]*
 + [SEED=value] <#runs value>

The first run uses nominal values for all components. The next runs use variations of simulation model parameters, variations specified by the tolerances DEV and LOT of each simulation model **.MODEL**.

The Monte Carlo analysis is very useful when the designers want a real imagine of what is going to happen with the project in mass production conditions , for example when the entire range of components used in assembly line has a tolerance .

Fig. 1 ORCAD interface



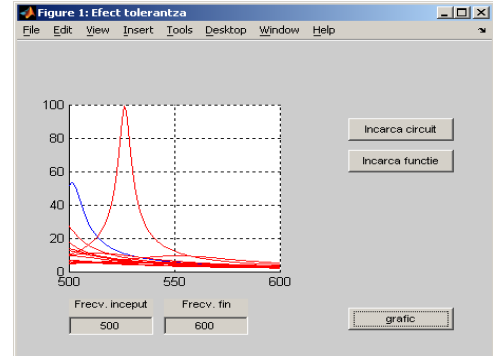
3. MATLAB SOFTWARE FOR TOLERANCE ANALYSIS

It was developed an application in Matlab which shows in a graphic the contribution of circuit elements tolerance to the value of a transfer function (voltage amplifier, transfer impedance etc.). Because for each circuit element is mentioned the tolerance interval, the program chooses at every run a random value, from that interval, and calculates again the transfer function.

To run the application are necessary the next steps:

- the file with the circuit description is loaded (similar with Spice files)
- the transfer function is loaded in symbolic form (like text lines)
- the frequency range is selected
- the application presents the effects of the tolerance on the circuit function

Fig. 2 Application interface



4. EXAMPLE OF ANALYSED CIRCUIT

Passed band filter Sallen and Key

This filter is well known and described in the theory of active filters. The nominal values of the components are:

$$R1=15800; R2=5110; R3=2610; R4=3320; R5=13300; C1=1e-7; C2=C1;$$

For input data we chose a 2 % tolerance for the resistors and 10 % for the capacitors.

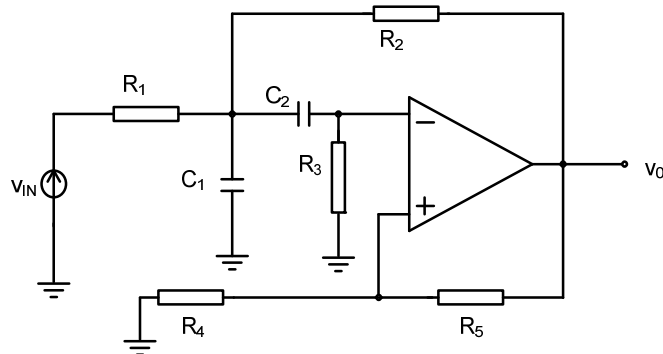


Fig. 3 Sallen and Key filter

The output voltage forms obtained with ORCAD is presented in figure 4 and in figure 5 the result obtained with Matlab.

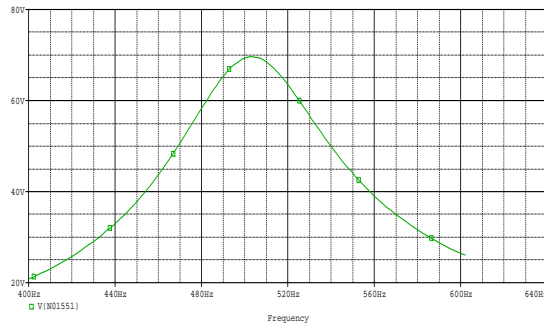


Fig. 4 Output voltage obtained with ORCAD.

From this graphic we can see the value of the middle frequency which is 500 Hz , and the form of output voltage variation.

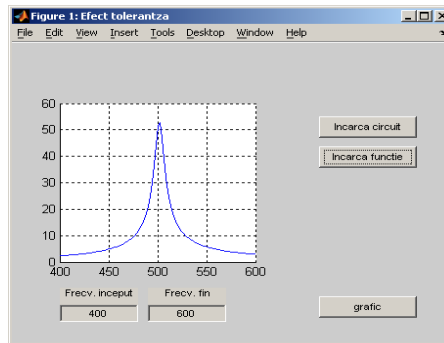


Fig. 5 Output voltage obtained with MATLAB.

Using ORCAD we realized a Monte Carlo analysis for this circuit. The results obtained for 10 runs considering the variations of component tolerances is the next one:

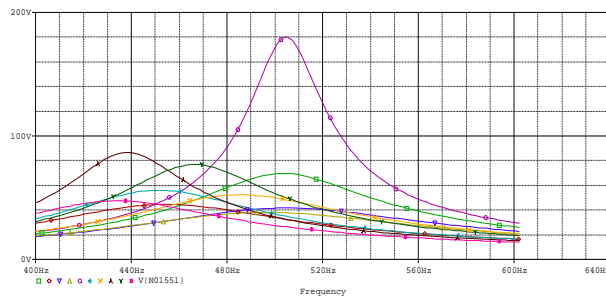


Fig. 6 Monte Carlo analysis obtained with ORCAD.

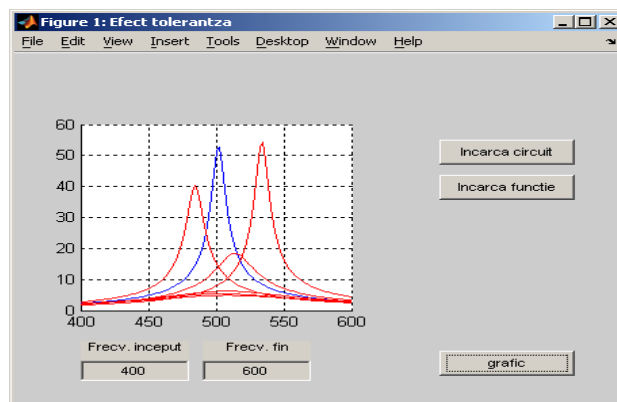
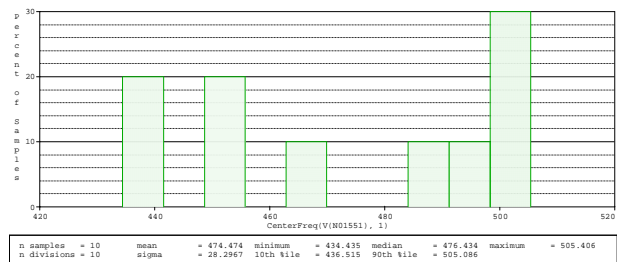


Fig. 7 Monte Carlo analysis obtained with MATLAB.

In figure 6 and 7 we observe the effects of component tolerances on the exit characteristic for Sallen and Key filter.

Next, we will make a performance analysis of this circuit, the results will be represented as a histogram. The histogram presents under Gaussian distribution the middle frequencies value for the ten runs for the analyzed filter. On the x axis of the histogram is represented the frequency, and on the y axis is represented in percent the number of obtained frequencies.

Fig. 8 Histograme for 10 runs.



After the performance analysis the program gives us the minimum, medium, maximum values of f_0 frequency and the value of the root sum square σ . The working time was relatively short for 10 runs, about 1 s, but this time will become bigger with the increase of the number of runs. In figure 9 is represented the histogram obtained for 3216 runs.

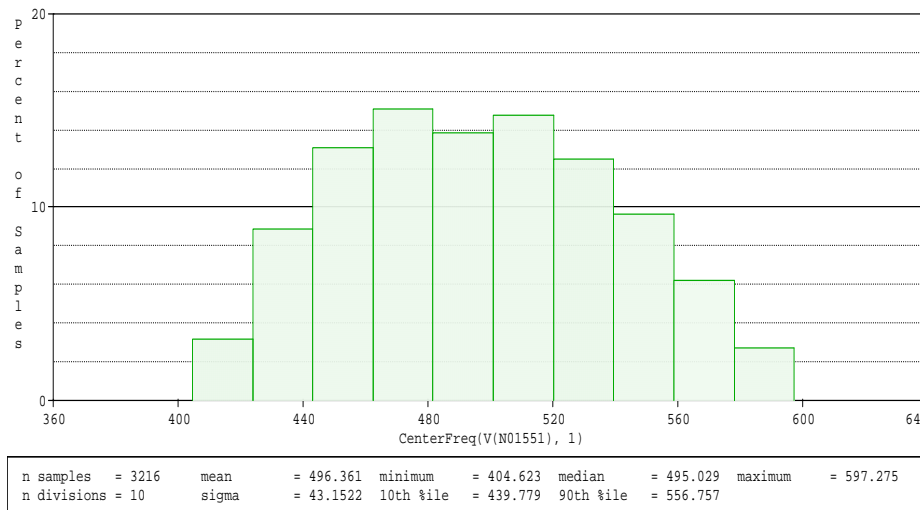


Fig. 9 Histograme for 3216 runs.

In this case we notice the Gaussian form of placement of the values for middle frequencies.

CONCLUSION

We can also notice an improvement of values, the obtained results are better and closer to the real ones with the increase in the number of runs .In this case, 3216 runs, the working time was 189 s, which is quite big. Another disadvantage is the limited number of runs on ORCAD software, while for Matlab the number of runs much more bigger.

The advantage when working with ORCAD is the easy way to implement the circuit.

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