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RESEARCH ARTICLE OPEN ACCESS

Simulations of a typical CMOS amplifier circuit using the Monte Carlo method

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ABSTRACT
In the present paper of Microelectronics, some simulations of a typical circuit of amplification, using a CMOS transistor, through the computational tools were performed. At that time, PSPICE® was used, where it was possible to observe the results, which are detailed in this work. The imperfections of the component due to manufacturing processes were obtained from simulations using the Monte Carlo method. The circuit operating point, mean and standard deviation were obtained and the influence of the threshold voltage Vth was analyzed.
***Keywords*:** Monte Carlo simulation, analog electronics, amplifiers, instrumentation, manufacturing processes

I. INTRODUCTION

The modeling of circuits, in microelectronics, is an essential step in the elaboration of a project, due, mainly, to the high cost employed in the manufacturing processes. In this way, we find in this work with a simple circuit, but with large applications, being the best known polarization configuration by means of a voltage divider. Used mainly in the amplification of small signals.

Therefore, we used the PSPICE® simulator, where the circuit was described and the simulations performed, including the Monte Carlo simulation, which takes into account the uncertainties of the values of the related physical quantities. These uncertainties, which are inherent in the manufacturing processes, but still need to be taken into consideration before a real integrated circuit design.

The importance of the computational simulation can be realized, and in the work will be shown in detail the main tools used and the results achieved.

II. DESCRIPTION OF THE CIRCUIT

The simulated circuit can be presented in Fig 01, and details, in addition to the schematic configuration, the values of the elements associated to the transistor. The knots of the circuit are also visible:

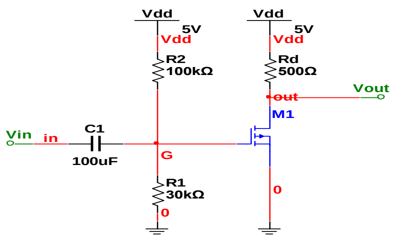

Fig.1. Schematic diagram of the analyzed Circuit

Another information, not present in the diagram, is the characteristics of the transistor being: W = 15µ and L = 0.5µ. Recalling that the transistor model adopted was the model ami05.mod.In SPICE® language the circuit can be described according to the descriptions below:

R2	**dd**	**g**	**100K**		
R1	**g**	**0**	**30K**		
Rd	**dd**	**out**	**500**		
C1	**in**	**g**	**100u**		
MN1	**out**	**g**	**0**	**0**	**n**
	w=15u	**L=0.5u**			
Vdd	**dd**	**0**	**5v**		
Vin	**in**	**0**	**AC 1**		

This configuration of voltage divider polarization provides greater independence of the currents that circulate through the transistor, an important fact, mainly because the amplification values of the transistors are more inaccurate and quite sensitive to the increase in temperature. In some references, this factor is placed as a β factor [1].

The capacitor placed between the input voltage Vin and the node g is used to separate the possible DC levels from Vin (the capacitor behaves as an open circuit for the DC voltages). This configuration has an operating point, which will be described next..

III. OPERATING POINT

The first paragraph under each heading or subheading should be flush left, and subsequent paragraphs should have a five-space indentation. A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

According to Boylestad, in amplification with transistors, the current and the DC voltage resulting from the polarization, establish an operating point in the characteristic curves, which defines the region that will be used in the amplification of the signal. As this point is usually fixed in the curve, it is given the name of point Q, which comes from the term quiescent point, which means rest, or stable [1].

To find the point of operation it is necessary to observe how the voltages Vds and Ids behave, and these values depend essentially on the values of the resistors R1 and R2.

Although calculations to find the operating point are not complicated, they can become long and laborious in more complex circuits, which increases the risk of errors throughout the process.

In this first step, the values of the resistors are considered constant (R1 = 30 kΩ and R2 = 100 kΩ), and then the simulation with ELDO® will be used, through the **[.op].** As a result of the simulation, we have the value of Ids = 75.55 mA.

IV. INFLUENCE OF THE DIVIDER IN POLARIZATION

As previously commented, the polarization depends essentially on the values of R1 and R2. By changing the values of these resistors, the operating point is also changed. Thus, even small variations in R1 and R2 may promote small variations in the current Ids.

It is well known that the values of the resistors are not exact, since the manufacturing process is not perfect. Given this, we can note that variations due to imperfections can be taken into account when dealing with microelectronics projects.

In this case, we can deal with this problem from a Monte Carlo simulation. The Monte Carlo method (MMC) is a statistical method used in stochastic simulations with several applications in areas such as physics, mathematics and biology [2]. The Monte Carlo method has been used for a long time as a way of obtaining numerical approximations of complex functions. This method typically involves generating observations of some probability distribution and using the sample obtained to approximate the function of interest.

According to Hammerseley [3] the name "Monte Carlo" arose during the Manhattan project in World War II. In the design and construction of the atomic bomb, Ulam, von Neumann and Fermi considered the possibility of using the method, which involved the direct simulation of probabilistic problems related to the neutron diffusion coefficient in certain materials. Although it had attracted the attention of these scientists in 1948, the logic of the method had been known for some time.

In summary, the higher the number of samples analyzed, the closer to the actual (or average) values the results will be. And consequently, the lower the standard deviation found. For our circuit, we will make the values of the resistors R1 and R2 have a variation of 10%, simulating an imprecision of 10%, due to the manufacturing process.

For the Monte Carlo simulation, a sample of 1000 units was defined. At the end of the simulation, we analyzed the values of Ids:

.MC 1000
.Extract Label= "Ids" i (rd)

The results of the simulation can be seen below. The sample was analyzed from a total of 1000. Recalling that the larger the number of samples, the lower the standard deviation and the closer the average will be to the nominal / actual value.

Rage [5.1626 E-4 1.0419 E-3]
Valor Nominal = 7.5515 E-4
Average Value = 7.5791 E-4
δ = 1.0905 E-4
δ = 1.0908 E-4

V. INFLUENCES OF VTH

Although the uncertainties in the resistivity values in the resistors are common due to fabrication, these are not the only elements of the circuits that can suffer this kind of variation. Elements such as capacitors and even transistors can also suffer from the "imperfect" manufacturing process and are therefore susceptible to this type of uncertainty.

Recalling that the transistor is simulated following a pre-established model, with tens (and sometimes hundreds) of diverse variables. In order to simulate these variations, it is necessary to modify the variables in the transistor model itself, which in this case will be the Vth.

Proceeding to file ami.05.mod, it was determined that the Vth should have a Gaussian variation, of standard deviation equal to 5% in the value of the threshold voltage Vth0.

For analysis, the EZwave® was used, with the frequency response, by means of a log scale, similar to a Bode diagram. The result of this analysis can be observed in Fig 02, which details the behavior of the circuit in front of this variation in the transistor.

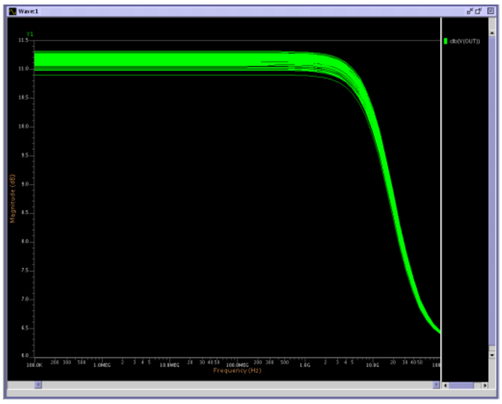

Fig.2. Frequency response

VI. CONCLUSION

Once again we can see the importance of computational tools in microelectronics projects. One can also see, through these simulations, how the uncertainties of values, inserted through manufacturing processes, can not be overlooked, especially in micrometric (and even nanometric) mechanisms such as microelectronic circuits. The presentation to new mathematical tools such as Monte Carlo simulation and the Gaussian distribution inserted in Vth provided an increase in the range of possibilities in statistical analysis of the circuits.

Finally, it can be concluded that the simulations can not only be a representation of the idealized, but an approximation of the real, the imperfect. The more real features (such as imperfections) are inserted in the computational process, the more efficient the design and simulation process, and consequently the pre-fabrication process [4]

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