Study on Simulation of Gate Circuit Self-excited Multivibrator

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Abstract. Simulation in circuit design is increasingly used in recent years, because it can not only optimize design, reduce experiment consumption, but also improve design efficiency. However, when gate circuit self-excited multivibrator is simulated using EWB, the result of simulation experiment is wrong and is inconsistent with the one of real circuit experiment at all. Why does this phenomenon happen? In this paper, a simulation experiment was made and the reason of wrong simulation experiment result was analyzed. At last, a solution method of simulation experiment was pointed out. This simulation experiment shows, in some special condition, little things can lead to a large difference.

Introduction

Gate circuit self-excited multivibrator is a king of simplest and most important pulse generating circuits in electronics. Because of its simpler structure and less components consumption than other circuits, it is widely used in some instruments. When we design a multivibrator circuit with a given frequency, simulation is generally used to aid design. Simulation can not only optimize design, reduce experiment consumption, but also improve design efficiency. However, when gate circuit self-excited multivibrator is simulated, the result is not right at all. The period of the output signal is much less than that of theory calculation. Why does this mistake happen and how to solve this problem? The following study pointed out the wrong phenomenon, analyzed the reason of the mistake, and put forward a method to solve the problem.

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Circuits of Self-excited Multivibrator

There are many kinds of self-excited multivibrator circuits. Two typical and simple circuits are respectively unsymmetrical gate circuit self-excited multivibrator shown in Figure 1 and symmetrical one shown in Figure 2 [1].

![Figure 1. Unsymmetrical self-excited multivibrator.](image1)
![Figure 2. Symmetrical self-excited multivibrator.](image2)
In the two simulation circuits above, the default threshold voltage for the logic gates is set as 2.5V, which is half of the power source voltage. According to charge and discharge of RC circuits in the above figures, the constant time $\tau$ can be described as following function.

$$\tau = RC$$  \hspace{1cm} (1)

In the above two circuits, the capacitor of each circuit charge and discharge alternately from -5V to +5V, so the period of output vibrating signal can be calculated easily. It is about 2.2ms.

**Wrong Results of Simulating**

When the circuits of Figure 1 and Figure 2 are simulated using EWB, Figure 3 and Figure 4 show that the periods of the output signals are both 20ns rather than 2.2ms. In the waveform figures, the upper curve is the signal waveform of the first channel, and the lower one is the signal waveform of the second channel. Periods of the output signal are not right obviously. They are much less than the theory calculation result. We can see from the circuits, B should have an inverse state of A; and C should have an inverse one of B. However, in the simulation experiment, the signals’ states of points A, B and C are always the same.

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**Figure 3.** Unsymmetrical multivibrator and its wrong vibration signal.

**Figure 4.** Symmetrical multivibrator and its wrong vibration signal.

**Reason Analysis of Wrong Simulation Result**

In Figure 1 and Figure 2, the default propagation delay time of the not gate is 10ns. From Figure 3 and Figure 4, we can see that the periods of the output signals are just two times of propagation delay time of the gate and they have nothing to do with R and C in circuits.
In these two simulation circuits, the simulation system set every not gate’s default initial state as “0”. At the initial moment of simulation running, the state of points A, B and C are “000”. At this moment, the capacitors can not be charged. Because of gate’s response time, after propagation delay time, these points’ state is changed to “111”. After another propagation delay time, the state is changed to “000” again. So the states alternate between “000” and “111”. The voltage across RC is always 0, so the capacitors can not be charged and discharged. The delay times that states change from “000” to “111” and change from “000” to “111” are both a propagation delay time 10ns. Two times change is just a cycle, so the vibration period is 20ns. At this moment, because the vibration frequency is very high, the capacitors can be regarded as short circuit. Accordingly, the wrong results just come into being. Because of the wrong initial states of circuit components, and ideal computer simulation, the above change courses abide by the rule of circuit simulation too. Simulation experiment runs with different regulation from real experiment. So simulation experiment leads to the above wrong result.

**Improvement of the Simulation Experiment**

According to the above analysis, the wrong simulation is caused by wrong initial states and ideal simulation. If the circuits are given reasonable initial states, the simulation result will be rectified. For example, change the “not gate” in Figure 1 to a “not and gate”, the circuit in Figure 1 is amended to Figure 5. When we simulate this circuit, switch [K] is lay right firstly, the state of point A is set as “0”, so point B is set as ‘1’and point C is set as “0”. Three points A, B and C are set an initial state“010”. This initial state is accordant with real experiment. When the switch turn left, the left “not and gate” can be regarded as “not gate”. As is introduced in textbook, at this moment, the capacitor will be charged and discharged alternately, then the signal vibrates in right period. The signal of improved circuit in Figure 5 is shown in Figure 6. The period is just the same as the one which accords with theory calculation, and approximately equal to the result of real experiment too. The improvement experiment further testified the correctness of the above reason analysis. The error mainly comes from the different threshold voltage between simulation gate and real gate.

![Figure 5. Unsymmetrical multivibrator circuit improvement.](image)

![Figure 6. Right vibration signal generated by unsymmetrical multivibrator.](image)
In the same way, the circuit in Figure 2 is amended to the circuit in Figure 7. It can also generate right period vibrating signal which is shown in Figure 8. The simulation result is right too.

![Figure 7. Symmetrical multivibrator circuit improvement.](image1)

![Figure 8. Right vibration signal generated by symmetrical multivibrator.](image2)

Summary

It can be seen from the above analysis of the two kinds of gate circuit self-excited multivibrators, neither circuit can be simulated rightly. The reason that causes this mistake is the wrong simulation model and ideal simulation. Simulation experiment has some difference from real circuit experiment. If some of the improvement measurements are made, the simulation can be done rightly. The simulation experiment shows, in some special condition, little things can make a big difference; even hairlike difference can lead to utter mistake[2]. So more details must be taken into account when we make simulation experiments.

References

[1] Yan Shi, Fundamental of Digital Electronics Technology, 5th ed., Higher Education Press, Beijing, 2006.

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