

The analysis and research of simulation test in Voltage Controlled Oscillator circuit

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Abstract. The Voltage Controlled Oscillator circuit had been analyzed in virtual test via NI Multisim 10.1 software. By changing the input DC voltage, the changing rule of the output waveform was observed, has read the cycle and calculate the frequency of the output waveform in conformity with the theoretical calculation results, it was concluded that the input DC voltage size has a linear relation with the output waveform frequency. When the input voltage was sawtooth wave, the output waveform frequency was varied with the sawtooth wave amplitude value change. It shows that the input voltage is either DC or sawtooth wave, the output waveform frequency is varied with the input voltage amplitude change, this further verified the working principle of voltage - frequency conversion circuit. When the NI Multisim10.1software is properly introduced electronic circuit experiment teaching, through the results of virtual simulation instance proves that it can improve the teaching effects of the circuit theory curriculum, and students can benefit a lot from the theory teaching and virtual experiment teaching.

Introduction

The function of voltage-frequency conversion circuit turns the input DC voltage into an output voltage which the frequency of it is proportional to the input voltage. It is also known as voltage-controlled oscillator circuit, referred to the voltage controlled oscillator circuit, called VCO. Generally outputs rectangular wave^[1-2]. Imagine if any physical quantity through the sensor is converted to electrical signals, after pretreatment it turns into a suitable voltage signal. Then controlling VCO, and using its output drive counter to make it record the number of rectangular wave in a certain time interval. Next using the digital to display, and finally getting the digital measuring instrument of this physical^[3]. As shown in Figure 1, it follows that the voltage-frequency conversion circuit is an analog/digital conversion circuit. Now VCO has been widely used in analog / digital signal conversion, FM, remote telemetry and other devices^[4]. The form of circuit has charge-balanced and reset type, in this paper only discuss charge balance voltage-controlled oscillator circuit which constituted by the voltage comparator.

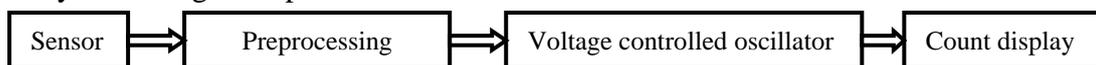


Fig.1 Block diagram of digital measuring instruments

The basic principle of the voltage controlled oscillator circuit which consist of voltage comparator

The voltage controlled oscillator circuit are two type of working principle of the charge balance and working principle of reset . Commonly used VCO is working principle of the charge balance.

Charge balance VCO usually composed by integrator and voltage comparator and its block diagram of principle is shown in figure 2 (a).The S is the electronic switch^[5-6], controlled by the output voltage u_O .

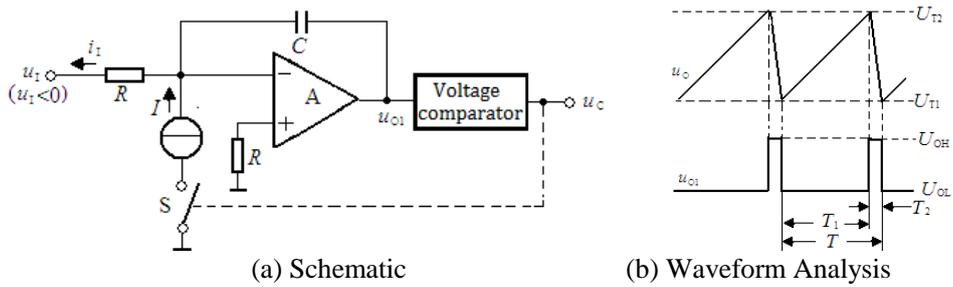


Fig. 2 Block diagram of the charge balance voltage controlled oscillator circuit.

Assuming $u_i < 0$, $I \gg |i_i|$, u_o 's high level is U_{OH} and u_o 's low level is U_{OL} . When $u_o = U_{OH}$, electronic switch S is closed. When $u_o = U_{OL}$, the electronic switch S is disconnected. If the initial state of the output voltage u_o in fig.2 is U_{OL} , electronic switch S is disconnected and the integrator will integrate the input current i_i . $i_i = u_i/R$, u_{o1} is gradually increased with time, and when u_{o1} increases to a certain value, u_o from U_{OL} jumps into U_{OH} to make the switch S closed, then the integrator doing integral computation on the difference between I and i_i . The difference between I and i_i approximate to I , and u_{o1} is decreased with time. Because $|I| \gg |i_i|$, the u_{o1} 's decline rate is far greater than the rate of increase. Therefore, the rate of decline is far greater than the rate of increase. When u_{o1} decreases to a certain value, u_o from U_{OH} jumps into U_{OL} , the circuit backs to initial state. The circuit repeats this process and produce self-excited oscillation, waveform shown in Figure 2 (b) below. Because $T_1 \gg T_2$, oscillation period can be considered as $T \approx T_1$. The larger value of u_i lets the T_1 smaller, and the frequency of oscillation higher. Thus achieving voltage-frequency converter, or achieving a voltage-controlled oscillator. Therefore, the voltage-frequency converter circuit is known as voltage-controlled oscillator circuit, same with below. Since the amount of charge which produced by the discharge(or reverse charge) of capacitor C which influenced from the current source I in a very short time, is equal to the amount of discharge produced by the charge of i_i in a long time. Therefore, such a circuit called a charge-balanced circuit. In a circuit which occurring sawtooth-wave, adjusting the resistance appropriately, will capable form a voltage controlled oscillator, shown in figure3. When $R_W \gg R_3$, the oscillation frequency f is shown in equation 1.

$$f = R_2 \times |u_i| / (2R_1 R_W U_Z C) \quad (1)$$

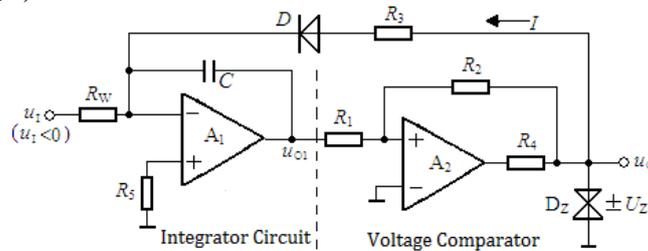


Fig.3 Sawtooth generator's evolution acts on Voltage-frequency conversion circuit.

Equation 1 illustrates the oscillation frequency f is controlled by the input voltage u_i , both of them appear linear relationship, concrete derivation refer to relevant books, not described in detail here.

Test simulation requirements and objectives of the charge balance voltage-controlled oscillator circuit

Build voltage controlled oscillator test circuit with charge balance type. The paper used the NI Multisim 10.1 simulation software of electronic circuit to test and analysis the voltage controlled oscillator for the type of charge balance. In accordance with the specific requirements of circuit parameters and components to build a VCO circuit, and according to the work principle of frequency-voltage conversion above described, mastered the structure and parameters of the test circuit layout simulation. Further virtual simulation of VCO circuit to observe the output waveform, read the output oscillation waveform cycle T and calculated the size of corresponding frequency f .

Fully grasp and understand the work principle and waveform characteristics of voltage-controlled oscillator circuit. On the basis of the sawtooth generator circuit, changing the position of potentiometer's sliding clamp. Forward integrating of integration circuit depends on the input voltage. Constituting the VCO circuit, using the work principle, related formulas and integrating circuit expression of hysteresis comparator to calculate the period T of output signal waveform and frequency f . Observing the frequency changed laws of the output oscillating waveform of u_o , which influenced by the amplitude variation of u_i , when input DC voltage was sawtooth signal.

Test Simulation of the voltage controlled oscillator circuit.

(1)Respectively measuring the output waveform's period and frequency when u_i 's amplitude equal -6 V and -3 V , observing the changes of u_{o1} 's and u_o 's waveform, then reading out the u_o 's period.

(2)Observing the features of waveform changes when u_i 's amplitude equal to the sawtooth which has the value of -3 V to -15 V , and calculating the relationship between the amplitude variation of u_i and frequency f of the output waveform.

Voltage controlled oscillator circuit's test simulation's purposes. In the paper, the test simulation of voltage controlled oscillator circuit has two purposes. First of all, mastering how the voltage-frequency converter circuit works. Secondly, researching the relationships between output waveform frequency f and input voltage u_i 's amplitude of voltage controlled oscillator circuit.

NI Multisim 10.1 Software's simulation test and analysis of voltage-controlled oscillator circuit

Set up charge balanced voltage-frequency conversion of the simulation test circuit. Set up charge balanced voltage-frequency conversion of the simulation test circuit as shown in figure 4. V_1 is input DC voltage, virtual voltage source. Hysteresis comparator is composed of voltage comparator U_2 and resistor R_1 , R_2 and R_4 , the high level and low level of output ,in theory ,is $+5.4\text{ V}$ and -5.4 V respectively. The integral circuit of sawtooth wave generator is composed of resistor R_3 , virtual diode D_1 , capacitor C_1 . In figure4, integrator is composed of R_6 and capacitor C_1 . Oscilloscope XSC1 observes the waveform of u_{o1} and u_o . Consider to the positive onset voltage of zener diode is $0.46 \sim 0.46\text{ V}$, the high level U_{OH} of output u_o is about 5.92 V , low level U_{OL} is about -5.98 V .

When using function generator XFG1 generated sawtooth input signal, the rest of the components and parameters is like figure 4, the test circuit as shown in figure 5.

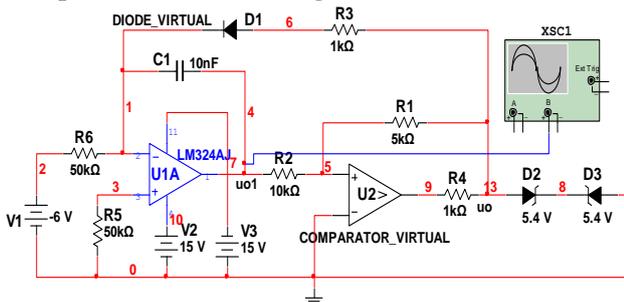


Fig. 4 VCO circuit test of u_i when the input DC voltage is -6 V or -3 V .

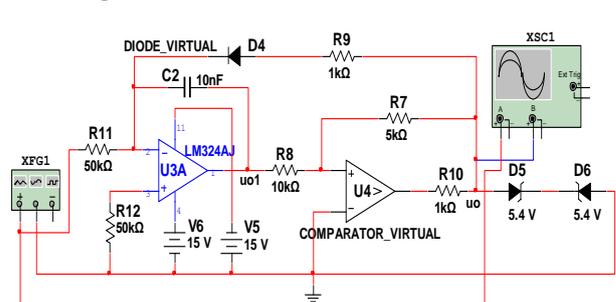


Fig. 5 VCO tests circuit when inputting a sawtooth wave signal.

Test and observation of waveform changes of every circuit output

In order to observe sawtooth wave of u_{o1} and wave of u_o the period T and the relationship between the frequency f , virtual test waveform and its change rule of circuit u_{o1} and u_o , and illustrate VCO circuit output waveform frequency and the relationship between the input voltage range.

(1) When input DC voltage $u_i = -6\text{ V}$, observe waveform of u_{o1} as shown in figure 6, show the waveform of u_{o1} with a red line. When input DC voltage $u_i = -3\text{ V}$, observe the waveform of u_o as shown in figure 7, shows the waveform of u_o with a blue line.

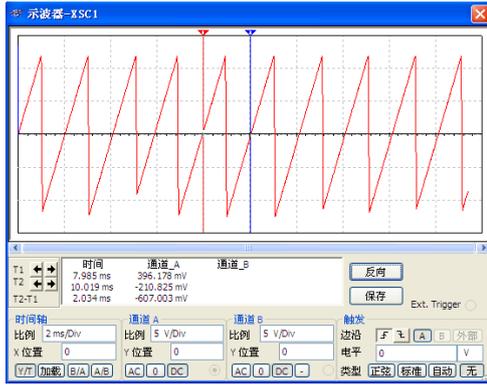


Fig. 6 Waveform of u_{O1} when $u_1=-6V$.

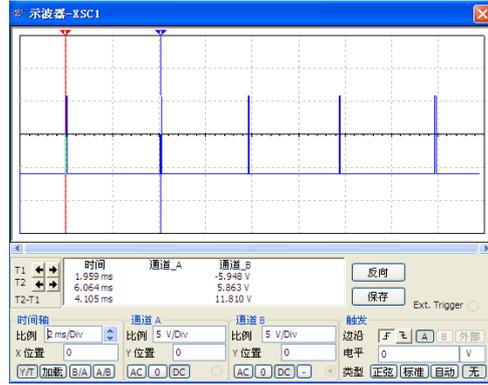


Fig. 7 Waveform of u_O when $u_1=-3V$.

(2) When using the function generator XFG1 to generate sawtooth wave as the signals u_1 , observe u_{O1} and u_O waveform is shown in figure 8, the red line shows the function generator to generate the input u_{O1} sawtooth wave, the blue line shows the output u_O and density pulse waveform.

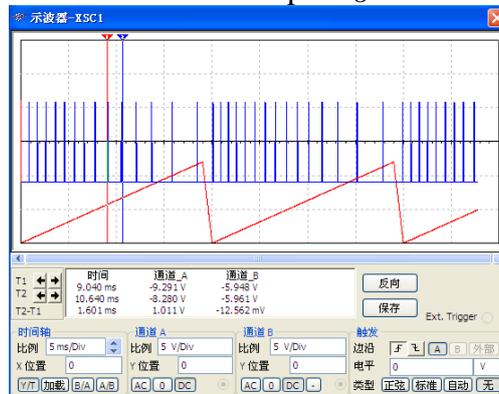


Fig. 8 Waveform of u_{O1} and u_O when input is sawtooth.

Test and analysis of the results of the simulation.

(1) When using simulation test circuit in figure 4, observe the waveform of u_{O1} as shown in figure 6 when $u_1=-6V$. The reading between two data pointer is the sawtooth wave period T , $T=1.601ms$, frequency $f=491.64$ Hz, mobile data pointer readable output voltage amplitude of u_O about $\pm 5.95V$, as shown in table 1. Using the table 1, calculated the frequency $f=504.2$ Hz, show that the simulation waveform cycle of reading test results agreed with theoretical calculation cycle or frequency.

(2) When the simulation test circuit $u_1=-3V$ in figure 4 and the waveform of u_O is as shown as that in figure 7, the reading between two data pointer is the pulse wave period T , $T=4.105$ ms, frequency $f=243.61$ Hz, mobile data pointer readable output voltage u_O amplitude is $\pm 5.95V$, as shown in table 1. Using the Table 1, calculated the frequency of $f=245.82$ Hz, show that the simulation waveform cycle of reading test results agreed with theoretical calculation cycle or frequency.

Table 1 Voltage-controlled oscillation circuit with different input voltage oscillation frequency and the output voltage amplitude

u_1 / V	u_O or u_{O1} cycle T / ms	u_O or u_{O1} frequency f / Hz	output voltage u_O amplitude / V
-6	2.034	491.64	5.951
-3	4.105	245.82	5.954

(3) Use sawtooth wave signal generated by function generator XFG as the input u_1 , waveform of u_{O1} and u_O is shown as figure 8, using two readings between data pointer is the pulse wave period T reading, $T=1.601$ ms, frequency $f=624.61$ Hz. u_O amplitude is still about $\pm 5.95V$. Change the input signal amplitude of u_1 , the waveform frequency of u_O also follow changes.

(4) The figure 6 shows that when the input voltage $u_1 = -6 V$, output the frequency of voltage u_{O1} and u_O , waveform frequency is 491.64 Hz. When the input voltage $u_1 = -3 V$, frequency, $f=243.61$ Hz, which frequency is about the half when $u_1 = -6 V$, this suggests that the voltage controlled oscillation circuit output waveform frequency and the input signal amplitude proportional relation, consistent with the theoretical calculation and analysis.

(5) When the sawtooth wave produced by the function generator was used as u_i , change the the amplitude of u_i , frequency changes. This shows that when $u_i = -3V \sim -15V$ of sawtooth wave, amplitude of u_o is $\pm 5.95V$, changing with amplitude and frequency of u_i , density and pulse wave.

Conclusions

When VCO using the input DC voltage source as input, changing the size of DC voltage amplitude of u_i , the frequency of the output waveform u_{O1} and u_o with amplitude of u_i change size, and voltage-controlled oscillation circuit output waveform frequency f is proportional to the input signal amplitude of u_i . Sawtooth wave produced by the function generator and when used as the input signal is u_i , change the sawtooth wave amplitude value size $-3V \sim -15V$, the frequency of the output waveform changes the amplitude of u_i , and the output voltage u_o is about $\pm 5.95V$, output waveform for the density and pulse wave. This verified that the result of using electronic circuit NI Multisim10.1 simulation software to virtual test voltage- frequency conversion circuit is correct. By analysing the virtual simulation of VCO circuit, using the oscilloscope observation circuit test point of each output voltage waveform changes, to find the relationship between output frequency f and the amplitude of u_i , further understand and master the principle of VCO, understand different analysis method and processing method of the circuit in software. Predictably introduce the simulation software to electricity class teaching, and it is the inevitable trend of teaching development. The continuous development of simulation software will continue to promote teaching method improvement, the NI Multisim 10.1 simulation experiment and traditional experiment teaching organically^[7], complement each other, give full play to the advantages of various test methods^[8], lets the student in the teaching of theory and experiment more benefit.

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