MATEC Web of Conferences **232**, 04013 (2018) https://doi.org/10.1051/matecconf/201823204013
EITCE 2018

VI Curve Test Based On Discrete Excitation Signals

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Abstract: In-Circuit Test System is an instrument that uses the VI curve test to diagnose circuit faults. Generally, continuous signals such as sine wave, triangle wave and square wave are used as the VI curve test excitation source. There are some problems in the synchronization of the analysis. In this paper, we study a VI curve test based on discrete excitation signal, analyze the problems arising from continuous signal testing, and propose a continuous signal discretization circuit scheme. The feasibility and practicability of this method are proved by Matlab simulation and experiment.

1 Introduction

VI curve test is a kind of circuit fault diagnosis technology for power failure test. Its principle is to apply a scanning signal with a certain frequency and amplitude between the pin of the device under test and the ground (or other pin) when the circuit board is not powered (usually apply a sinusoidal signal), the port correspondingly produces an impedance change, which is displayed on the voltage-current coordinate system to form a VI curve[1-2]. The VI curve of common components has a specific variation law, so the shape of the VI curve can reflect the electrical characteristics of the test node. Comparing the VI curve of the circuit under test with the VI curve of the normal circuit can determine whether the circuit is faulty or even locate the faulty component[3]. During the test, because of the impedance test, there is no large current on the testing board, so the test is safer[4]. Moreover, it has strong versatility, and thus has become one of the hot issues in the field of circuit fault diagnosis[5].

VI curve test usually uses continuous signal as excitation source[6]. Its amplitude and sampling time are difficult to control. The circuit node is associated with many electronic components'pins, such as input pins and output pins. If the current through the output pin is too large or the test time is too long, the temperature of the PN junction exceeds the limit, it will cause damage to the PN junction or melt the baseline[7-8]. If the current through the output pin is too small or the test time is too short, the fault will not be detected. At the same time, using continuous signal as the excitation for VI curve test, it is very hard to keep the sampling and excitation strictly synchronized, so the method is less repeatable and accurate in the application[9]. In this paper, we use discrete signal instead of continuous signal as the excitation source. Replace the continuous signal with a series of discrete pulse signals whose amplitude and pulse width can be adjusted. It not only realizes the synchronization of excitation and response, but also improves the test security, which can well solve the original problems in the VI curve test.

2 Research ideas

The continuous signal is split into a series of pulse signals through the circuit. Taking a sinusoidal signal as an example, a discrete signal as shown in Figure 1 is obtained.

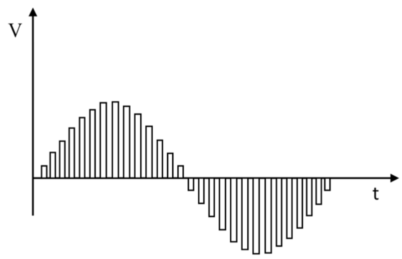

Figure 1. Discrete sinusoidal signal

The amplitude and pulse width of the pulse signal can be adjusted in real time through the circuit, which can well compensate for the lack of testing with continuous signal. And in order to prevent components from being damaged during the test, it is necessary to strictly control the current through the component and the test time. Therefore, in the test, refer to the safety tolerance of the rear drive technology[10], the current is set within 10 mA , and the test time is less than 16ms to ensure the safety of the components associated with the node under test. When a general pulse signal is input into a circuit, the impulse response generated cannot be used as the basis for fault diagnosis. However, using the discrete signal as the excitation not only tests the impulse response characteristics of the circuit, but also reflects the response of the sinusoidal signal excitation in the macro cycle, which is equivalent to a composite response test of the circuit. This composite test not only avoids the

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complicated discretization process, but also has the advantage of discrete signals.

In this paper, a circuit board general detect system based on VI curve test (referred to as general detect system) is designed. Discrete signal is used instead of continuous signal as the excitation source of VI curve test. The system schematic diagram is shown in Figure 2.

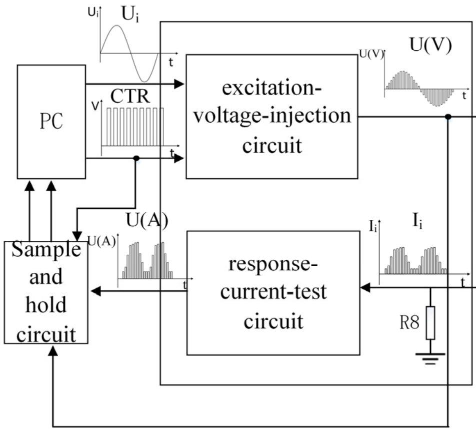

Figure 2. General detect system

The general detect system includes a PC, an excitation-voltage-injection circuit, a response-current-test circuit, and a sample-and-hold circuit.

The PC sends a continuous periodic signal (Ui) to the excitation-voltage-injection circuit through the PWM module. Under the control signal (CTR), the continuous signal is discretized by the excitation-voltage-injection circuit, where Ui determines the amplitude of the excitation signal. The CTR determines the pulse width of the excitation signal, thereby achieving amplitude modulation and widening of the excitation signal. The discrete excitation signal (U(V)) is injected into one node of the circuit under test, and the output current response (Ii) output from the other node is converted into a voltage signal (U(A)) by the response-current-test circuit and sent to the sampling. The circuit is sampled. Under the control of CTR, the sample-and-hold circuit samples U(A). Since the CTR is uniformly sent by the PC, the discretization process of the continuous signal and the sampling and maintaining of the sampled signal are strictly synchronized. Finally, a discrete excitation signal and a VI curve that is strictly synchronized with the response can be obtained.

3 Principle analysis

3.1 Discrete method

Taking a sinusoidal signal as an example, the PC outputs a sinusoidal signal with the expression: $f(t) = A\sin(\omega_0 t + \varphi)$. The expression of the CTR is:

$\delta_T(t) = \sum_{k\to-\infty}^{+\infty} \delta(t-kT)$, Under the control of the CTR, the excitation-voltage-injection circuit discretizes the continuous signal *f(t)*. According to the sampling theorem, the discrete signal is expressed as:

$$f_s(t) = f(t)\delta_T(t) = f(t)\sum_{k\to-\infty}^{+\infty}\delta(t-kT)$$
$$= \sum_{k\to-\infty}^{+\infty} f(t)\delta(t-kT) = \sum_{k\to-\infty}^{+\infty} f(kt)\delta(t-kT) \tag{1}$$

In order to simplify the final calculation of the circuit output response, a Laplace transform is performed on the discrete signal $f_s(t)$ to convert the time domain to the frequency domain:

$$F_s(s) = L[f_s(t)] = L[\sum_{k\to-\infty}^{+\infty} f(t)\delta(t-kT)]$$
$$= \sum_{k\to-\infty}^{+\infty}\{f(t)L[\delta(t-kT)]\} = \sum_{k\to-\infty}^{+\infty} f(kt)e^{-ksT} \tag{2}$$

Taking the first-order parallel Resistance-Capacitance Circuit shown in Figure 3 as the object to be tested, the circuit transfer function can be expressed as:

$$H(s) = \frac{R\times\frac{1}{sC}}{R+\frac{1}{sC}} = \frac{R}{RsC+1} \tag{3}$$

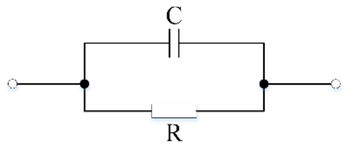

Figure 3. First-order RC parallel circuit

Then the response of the circuit output can be expressed as:

$$Y(s) = F_s(s)\times H(s) = \sum_{k\to-\infty}^{+\infty} f(kT)e^{-ksT}\frac{R}{RsC+1}$$
$$= A\sum_{k\to-\infty}^{+\infty}\sin(\omega_0 kt+\varphi)e^{-ksT}\frac{R}{RsC+1} \tag{4}$$

Transform the response into a time domain by performing a Laplace inverse transformation:

$$y = AR\sin(\omega_0 t+\varphi) - AR\sin(\omega_0 t+\varphi)\frac{R}{e^{t/RC}}$$
$$= AR\sin(\omega_0 t+\varphi)\ (1-\frac{1}{e^{t/RC}}) \tag{5}$$

The curve is fitted to the sampling points in the response current and the excitation voltage, and the relationship between the excitation and the response is plotted in the voltage-current coordinate system, which is the VI curve of the circuit under test.

https://doi.org/10.1051/matecconf/201823204013

3.2 Simulation

The discretization process of continuous signals is simulated based on Matlab. The continuous signal *f(t)=sin(2πt)* output from the PC.

According to the sampling theorem, the sampling frequency fs=1000, the number of sampling points N=1000, and the sampling time t1=(0:N-1)/fs are set to discretize the continuous signal. The resulting discrete signal is shown in Figure 4.

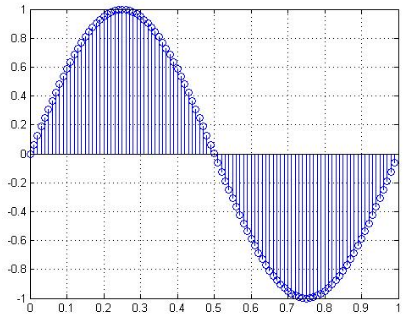

Figure 4. Discretized signal image

Set the resistance R=100Ω and the capacitance C=100μF in the circuit to be tested. According to the obtained current response and the discrete signal, the VI curve of the circuit is drawn, as shown in Figure 5. It can be seen that the VI curve of the circuit to be tested is a slanted elliptical shape.

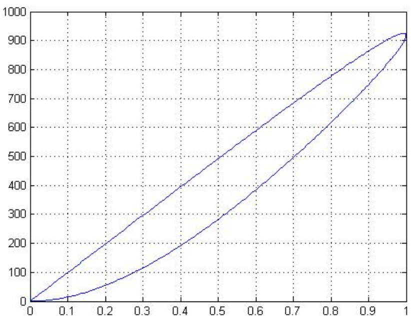

Figure 5. Matlab simulation image

The first-order parallel Resistance-Capacitance Circuit was measured using an in-circuit tester, and the resulting VI curve image is shown in Figure 6.

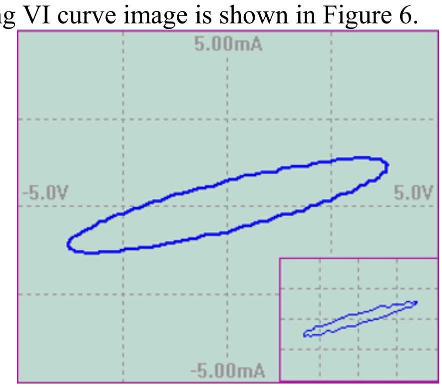

Figure 6. RC parallel circuit image in an inline tester

It can be seen that the shape of the simulation curve (Figure 5) is consistent with the measured VI curve (Figure 6). It can be proved by Matlab simulation that the VI curve of the complete feature can be obtained by the VI curve test with discretized signal as the excitation.

4 Experience

In order to verify the feasibility of the theory, capacitors and circuit boards are respectively used as the object to be tested for fault diagnosis.

4.1 Component test

In order to verify the feasibility of the theory, capacitors and circuit boards are respectively used as the object to be tested for fault diagnosis.

Capacitor with a capacitance of 50 μF is used as the object to be tested. For comparison, the general detect system separately collects the VI curves of the normal capacitance and the fault capacitance, as shown in Figure 7.

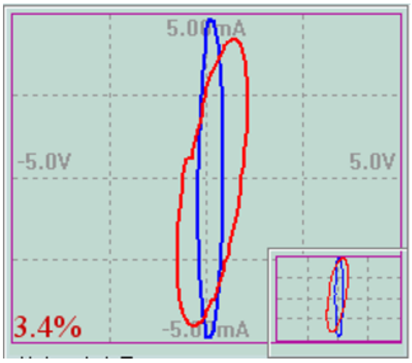

Figure 7. Capacitance test results

The blue curve in the figure represents the test result of the normal component, and the red curve represents the test result of the faulty component.

4.2 Circuit board test

Taking the circuit board of a certain type of vibration sensor as the test object, Figure 8 and Figure 9 show its physical map and schematic:

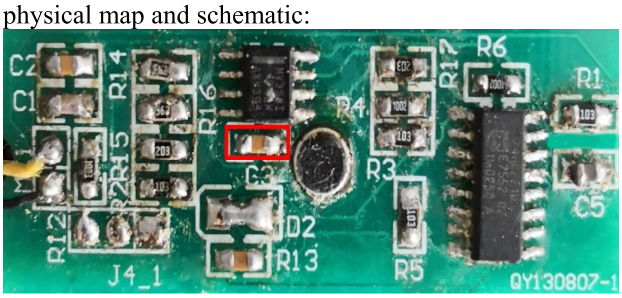

Figure 8. Physical map of the vibration sensor

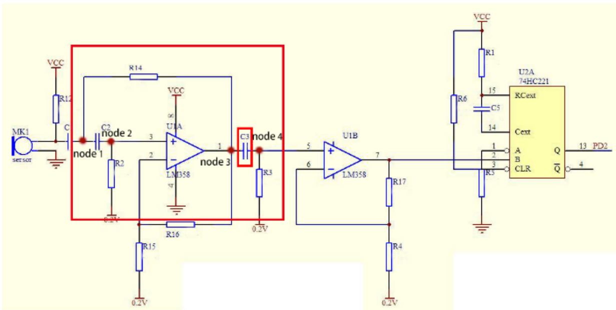

Figure 9. schematic of the vibration sensor

The board was tested using a general detect system with 4 nodes in the red rectangle of Figure 9. First, the VI curves between any nodes are collected in the test range in the normal circuit board. Then the component C3 on the board is removed, the open circuit fault is generated, and the VI curve image of the circuit board card is collected in the same manner. The VI curve comparison image is shown in Figure 10. The blue curve in the figure represents the normal circuit board, while the red curve represents the fault circuit board of the C3 open circuit.

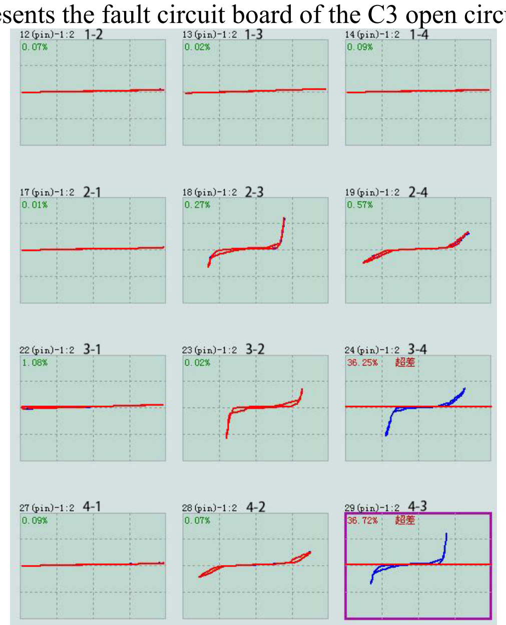

Figure 10. VI curve alignment image

Through image comparison, it can be found that only the VI curve between node 3 and node 4 in the circuit board to be tested is different from that of the normal circuit board, and the VI curves between the remaining nodes are completely coincident with the normal circuit board. In this way, it can be determined the fault problem occurs between node 3 and node 4, while the component associated with the two nodes has only capacitive element C3. Therefore, C3 is the faulty component, and the circuit board to be tested has a fault problem.

Through experimentation, the feasibility and practicability of the VI curve test method using discrete signals as excitation can be verified.

5 Conclusions

This paper studies a VI curve test method based on discrete signals as excitation. Compared with continuous signals, the advantages of discrete signals are mainly reflected in the following aspects:

(1)As a discrete signal of excitation, it complies with the safety tolerance of the rear drive technology, does not cause damage to the device under test, and ensures the safety of the VI curve test;

(2)Discrete continuous signals through the circuit can avoid complex mathematical operations;

(3)The CTR simultaneously controls the excitation-voltage-injection circuit and the sample-and-hold circuit to ensure strict synchronization of sampling and excitation, so that the obtained VI test data has good repeatability.

The feasibility and practicability of the VI curve test method based on discrete signal as excitation is verified by Matlab simulation and experiment of components and circuit boards. The method has applied for invention patents. In the next step, it will continue its engineering application research in circuit fault diagnosis, in order to realize circuit general fault diagnosis without drawings and data.

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