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Diagnosis Method for Analog Circuit Hard Fault and Soft Fault

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Abstract

Because the traditional BP neural network slow convergence speed, easily falling in local minimum and the learning process will appear oscillation phenomena. This paper introduces a tolerance analog circuit hard fault and soft fault diagnosis method based on adaptive learning rate and the additional momentum algorithm BP neural network. Firstly, tolerance analog circuit is simulated by OrCAD / Pspice circuit simulation software, accurately extracts fault waveform data by matlab program automatically. Secondly, using the adaptive learning rate and momentum BP algorithm to train neural network, and then applies it to analog circuit hard fault and soft fault diagnosis. With shorter training time, high precision and global convergence effectively reduces the misjudgment, missing, it can improve the accuracy of fault diagnosis and fast.

Keywords: *Tolerance Analog Circuit, Hard Fault, Soft Fault*

1. Introduction

Analog devices widely exist in military, communication, automatic control, instrumentation, mixed signal circuit, and chip system. The essence of the objective world determines the universality and irreplaceability of the signal analog circuit. With the development of large-scale integrated circuits, analog circuit complexity and the intensity increasing, the reliability requirements of the analog circuit are also stricter [1]. Therefore, analog circuit testing and fault diagnosis problem cannot be avoided, thus it is important to carry out research on related theories and methods.

With the development of the electronics industry, electronic equipment becomes more and more complex, the analog devices and circuit of it are indispensable. The theoretical analysis and practical application indicates that analog circuits of these devices are more prone to fault than digital circuits [2]. For this kind of equipment maintenance and maintenance is very complex, but it is indispensable to guarantee the normal operation of the system [3]. In addition, with the development of VLSI development and the increasing complexity of electronic devices, artificial traditional fault diagnosis methods are unable to meet the requirements, which forced the researchers' further exploration about the testing of new theory and method, in order to adapt to the social demand for the development of new test device.

In recent years, BP neural network is widely used in many fields and achieved good results [4, 5]. BP neural network has also exposed some inherent defects of itself: does not have global search capability; easy to fall into local minimum; convergence time is too long; the result is certain random [6]. In order to accelerate the learning speed of the network, to avoid falling into the local minimum, this paper used the adaptive learning rate and additional momentum algorithm to train the BP neural network. The trained BP neural network fault diagnosis system is applied to the analog circuit for detection and location the circuit fault. The circuits are modeled and simulated by OrCAD / PSpice software, analyzed and processed by MATLAB software. The simulation results show that the proposed method is effective.

2. Circuit Simulation

The fault waveform data extraction is the key of the analog circuit fault diagnosis.

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Meanwhile, fault waveform data extraction is also configured the basis of the sample set. How to extract the analog circuit fault waveform data effectively is the difficulty of circuit fault diagnosis and test. When designing analog circuit fault diagnosis system, the key to fault diagnosis is extracting the characteristics of circuit fault quickly and efficiently.

This paper presents a tolerance analog circuit fault waveform data extraction method. Firstly, tolerance analog circuit is simulated by OrCAD/Pspice circuit simulation software. Secondly, program in matlab automatically and accurately extracts fault waveform data. Lastly, the fault waveform data in binary form is stored in the matlab working space. The method can be used to solve communication problems in data between the two softwares. It realizes the fault waveform data extraction.

2.1. Simulation Software

OrCAD/PSpice is a powerful simulation software, has circuit simulation function, graph drawing the circuit powerful post-processing functions and components production function symbols, input graphically, automatic checking circuit, generating charts, simulation and calculation circuit [7]. It uses a very wide range, not only can be used for circuit analysis and optimization design, can also be used in computer aided teaching. It can not only analyze the characteristics of the circuit on the circuit of AC, DC, transient and other basic, but also can Monte Carlo statistical analysis, Worst Case Analysis, advanced analysis and design optimization. In addition, it can not only on the simulation analysis of analog circuit, digital circuit; digital-to-analog hybrid circuit can also be carried out computer simulation. Among them, the Probe module can not only display the results of signal waveform in after the simulation, but also can be some of the basic operation of waveform, including Fu Liye analysis, feature parameter extraction, analysis of circuit characteristics change with the parameters of the relationship between components.

MATLAB is the main face of scientific computing, visualization and interactive program design of high-tech software which is published by the American MathWorks company [8]. The numerical analysis, matrix computation and visualization, as well as the modeling and Simulation of nonlinear dynamic systems and many other powerful function were integrated in an easy-to-use Windows environment, It provides a comprehensive solution to many scientific fields and effective numerical calculation, and get rid of the traditional non interactive programming language editing modes to a great extent, represents the advanced level of the international scientific calculation software. It is widely used in the numerical calculation, graphics processing, symbolic computation, mathematical modeling, signal analysis, system identification, real-time control and dynamic simulation research. Because it has a powerful waveform signal analysis and processing functions, it can be employed together with OrCAD/Pspice software effectively, through which can maximize their respective strengths.

2.2. Circuit Fault Simulation

1. Circuit fault simulation process

Circuit fault simulation process as is shown in Figure 1, simulation generated fault waveform data are saved in text form for matlab extraction.

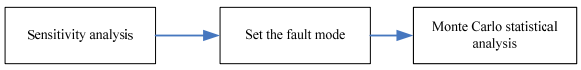

Figure 1. Circuit Fault Simulation Process

2. Sensitivity analysis

Under normal circumstances, the slight change of the circuit component values will change the characteristics of certain aspects of the circuit. The sensitivity is used to measure the change of physical quantities. Electrical network function T with respect to the rate of change of a parameter X is its specific definition. Sensitivity is represented by the symbol S_X^T.

$$S_X^T = \frac{\partial T}{\partial X} \quad (1)$$

Where T is a circuit network function (output variables), such as input impedance, output impedance, the transfer function, and the output voltage (or current). X is the component values or influences certain physical parameters of the component values, such as temperature. Tolerance analog circuit sensitivity analysis process is as follows.

(1) Use the PSpice-AA parameter library element to draw tolerance analog circuit diagram.

(2)Set the analysis parameters; call PSpice simulation tolerance analog circuit characteristics.

(3) Determine the tolerance analog circuit characteristic function.

(4) Inspection tolerance analog circuit characteristic function simulation results.

(5) Call PSpice10.5-AA, call for tolerance analog circuit parameters.

(6) To run the Sensitivity tool for sensitivity analysis.

(7) According to the degree of influence of each parameter on the output signal, determine the diagnosable components.

3. Set fault mode

There are two types of analog circuit fault.

(1) Soft fault

It is caused by deviation from the normal tolerance range of the component, also called the offset fault. Which is characterized by non-structural damage, there are an infinite number of possible fault state number, and easily mixed with tolerance;

(2) Hard fault

It is caused by open or shorted; including open, shorted and line-to-line short-circuit. The characteristics of this kind of fault is the extreme element changes or structural damage, the number of fault state may form is limited.

According to foreign literature statistics [9], probabilities of fault are: hard fault is 80%-90%; soft fault is 10%-20%. 50%-60% is resistance open-circuit, capacitance short-circuits, diode short-circuits, and triode short-circuits. The other is the capacitor open-circuit, diode open-circuit, triode open-circuit.

4. Monte Carlo analysis

Tolerance analog circuits Monte Carlo analysis process is as follows.

(1) Use the PSpice-breakout parameter library element drawing tolerance analog circuit diagram.

(2) Set analysis parameters.

(3) Set the element falut model, called Monte Carlo analysis.

(4) The fault data stored in text form, return to third step.

2.3. Matlab Extract Fault Waveform Data

Matlab software can be programmed directly in the command window and can also create M-files to be programmed. It can make the program seem simple and easy to modify and maintain. Matlab software provides a series of low-level I/O functions in order to be able to read and write arbitrary binary or formatted ASCII file [10]. Such as: fopen ( ) function, fclose ( ) function, textread ( ) function, num2str ( ) function and str2double ( ) function.

Combined with the matlab syntax of sequential structure, loop structure, branch structure and control statements, we can use the above functions to do some of the more complex operations in order to achieve text file extraction. Fault waveform data extraction program flow chart is shown in Figure 2.

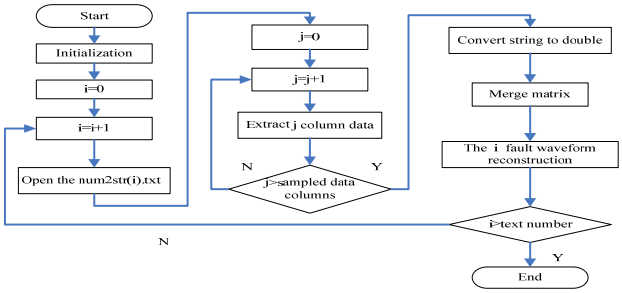

Figure 2. Fault Waveform Data Extraction Program Flow Chart

3. BP Neural Network

BP network structure is similar to the multilayer perception. It is a multi-layer feed forward neural network [11]. BP neural network model is shown in Figure 3. The neural network has a strong nonlinear mapping ability, fault tolerance and generalization ability. The Kolmogorov theorem can be learned with a single hidden layer perception can map all continuous functions. Therefore in this paper a single hidden layer BP neural network was chosen for analog circuit fault diagnosis.

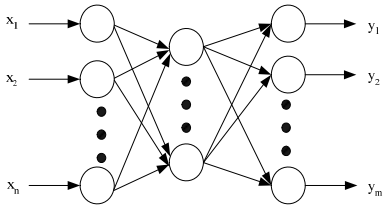

Figure 3. BP Neural Network Model

The neural network learning algorithm uses the back propagation algorithm [12]. The learning process of the BP algorithm is composed of the signal forward propagation and the error back-propagation. Forward propagation, the input sample is passed from the input layer, each hidden layer after layer processing, transmitted to the output layer. If the actual output and the expected output layer do not match, transferred to the stage of the error back-propagation. Error back propagation is the output error in some form through the hidden layer to the input layer back propagation, and the error is assigned to all units in each layer, the error signal as a correction unit weight basis. Forward propagation and error back propagation of layers weight adjustment process is network learning and training process. This process has been to errors of network output is reduced to an acceptable level, or to the preset times of learning.

BP neural network is trained in batch mode. It is adaptive learning rate and the additional momentum BP algorithm to adjust the network weights.

The formula is as follows:

$$\Delta w(n+1) = (1-mc)\eta(n)\frac{\partial E(n)}{\partial w(n)} + mc\Delta w(n) \tag{2}$$

$$\eta(n+1) = \begin{cases} \alpha\eta(n) & E(n+1) \prec E(n) \\ \beta\eta(n) & E(n+1) \succ E(n) \end{cases} \tag{3}$$

$$\eta(n) = \eta(n+1) \tag{4}$$

mc is momentum coefficient. $\eta(n)$ is the adaptive learning rate. α , β is learning rate and adjustment coefficient respectively.

4. Simulation

Circuit as shown in Figure 4, it is composed of 2 resistors, 3 capacitors and 1 inductance components RLC band-pass filter circuit. The parameter values are shown in Figure 2. Resistance tolerance is 5%. Inductance and capacitance tolerance is 6%, 5%respectively. The circuit is carried to Sensitivity analysis using Orcad10.5 sensitivity tool. Therefore R_1-50%, C_2 open circuit and C_3+50% are selected as the fault. Including normal, the circuit is a total of four modes.

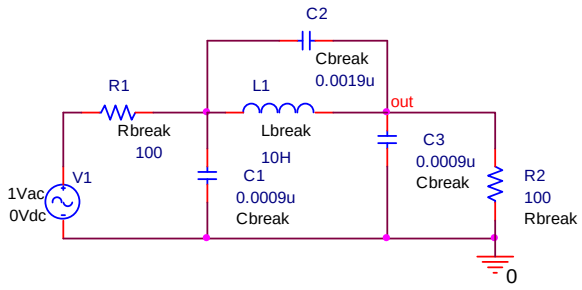

Figure 4. RLC Band-pass Filter Circuit

Then for each mode to do the 100 times Monte Carlo analysis, the output waveform is shown in Figure 5, Figure 6, Figure 7 and Figure 8. Every time, Monte Carlo analysis completes, and the output waveform will be stored in the form of data in the text. Finally, automatically extract fault waveform data using matlab programming approach. Reconstruction fault waveform using the extraction data. Reconstruction of the waveform is shown in Figure 9, Figure 10, Figure 11 and Figure 12.

Fault sample data is data preprocessing, constructed sample set. The desired outputs respectively are normal state (00), R_1-50% (01), C_2 open circuit (10) and C_3+50% (11). BP neural network was used for RLC band-pass filter circuit fault diagnosis. BP neural network parameters are set to: the output neuron number is 2, the number of hidden neurons in 40, hidden layer neuron transfer function using tansig, output layer neurons of the transfer function using logsig, expected error 0.001, the number of training for the 1000 epochs, with adaptive learning rate and additional momentum BP algorithm.

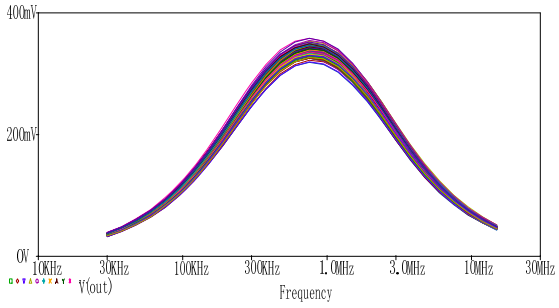

Figure 5. Normal Waveform

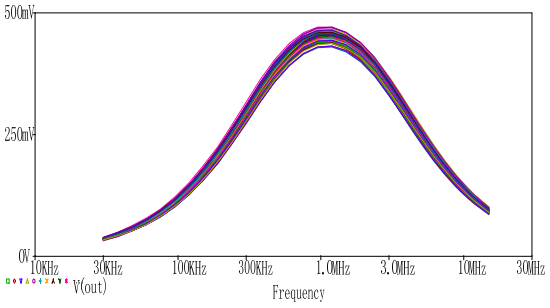

Figure 6. R_1-50% Waveform

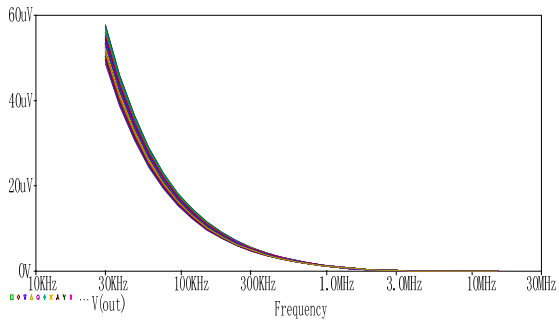

Figure 7. C_2 Open Circuit Waveform

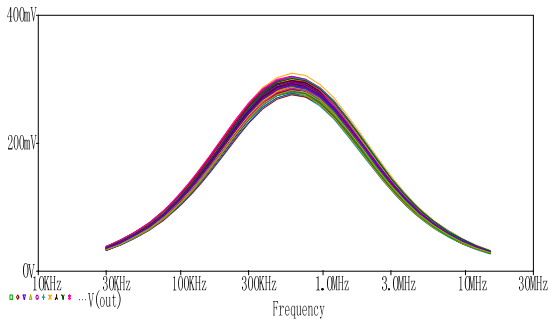

Figure 8. C_3+50% Waveform

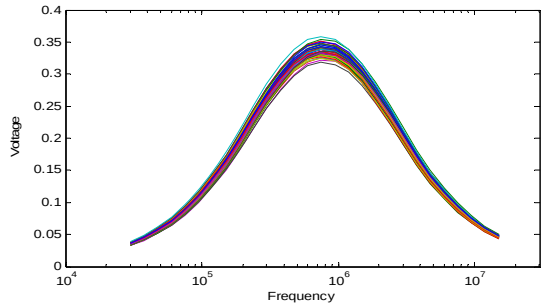

Figure 9. Normal Waveform of Reconstruction

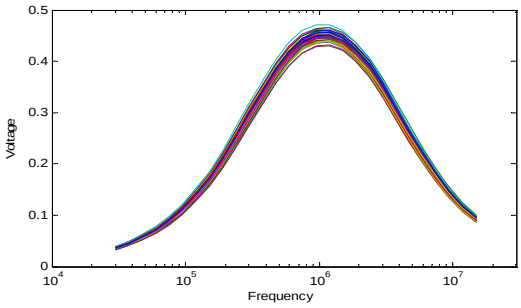

Figure 10. R_1-50% Waveform of Eeconstruction

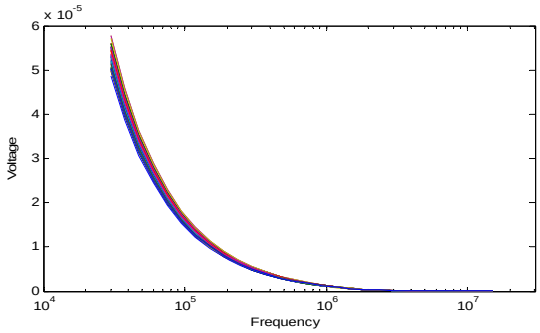

Figure11. C_2 Open Circuit Waveform of Reconstruction

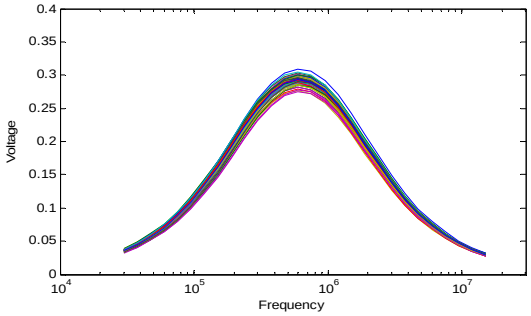

Figure12. C_3+50%Waveform of Reconstruction

To train the BP neural network. Figure 13 is the BP neural network training error curve. Figure 14 is linear regression. Each fault state of each select 10 groups of test samples (different from the training sample) to test the trained BP neural network. The average error of test sample diagnosis results is 0.0036.When the threshold is the 0.15, neural network's diagnosis correct rate is 100%,can accurately identify the circuits of 5 kinds of fault types.

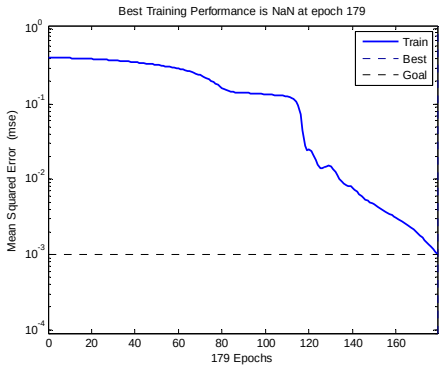

Figure 13. The Training Error Curve

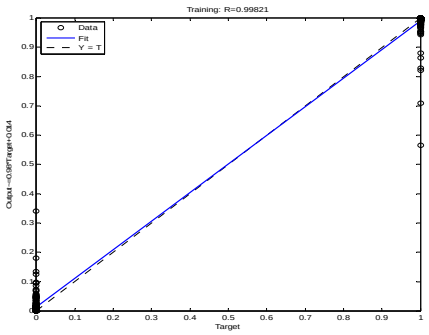

Figure 14. The Linear Regression

5. Conclusion

This paper uses the application of neural network in fault simulation of hard circuit and soft fault diagnosis as the main line, profoundly studies fault feature extraction and fault diagnosis method for analog circuits. Through the analog circuit diagnosis example, the

principle of this method and realization are introduced in details. This simulation experiment indicates that this method can fast and effectively check hard faults of analog circuits and soft fault diagnosis, and of course has a good application prospect.

Acknowledgements

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