International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

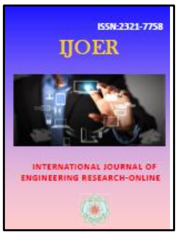
Vol.5., Issue.4, 2017
July-August

REVIEW ARTICLE

ISSN: 2321-7758

FAULT DETECTION IN ANALOG CIRCUITS USING NEURAL NETWORK: A REVIEW ON THE METHOD

DIVYA BISEN[1], YOGESH SHARMA[2]
[1]Student, Shri Shankracharya Institute of Technology and Management, CSVTU, Chhattisgarh, India
[2]Department of Electronics and Communication, Shri Shankracharya Institute of Technology and Management, CSVTU, Chhattisgarh, India



ABSTRACT

Analog fault detection is a complicated process and also a major problem in theory of circuits and thus it has been investigated by researchers in recent decade. Neural network is capable to classify fault and non-fault models of analog circuits by using various algorithms. So a comprehensive review on the different neural network based methods used for fault detection, classification and location in analog electronic circuits is presented in this study. This paper includes comparison and evaluation of the existing research over this area and reviewing it on the basis of various parameters like time constraint, efficiency, fault detection rate and performance. This paper also includes technical challenges in designing of such system and successful implementation for practical and real time application and also provides a valuable study of various algorithms.

I. INTRODUCTION

Fault detection in analog circuit is complicated due to limited access to internal nodes, non-linearity of output, insufficient fault models [1]. Fault is a basically a change in component value of the circuit with respect to the standard value which interrupts the normal circuit behaviour and leads to abnormal circuit performance. Fault is normally classified as: Hard fault and Soft fault [2]. Hard fault occurs due to open or close circuits and it stops the circuit functioning. While soft faults occur due to variation in values of circuit components, in case of such faults circuit still continues to work but leads to performance degradation. Soft faults are hard to detect and thus major research in this area involves soft fault detection in analog circuit. On the basis of simulation, fault diagnosis method is classifies as: simulation before test (SBT) and simulation after test (SAT). SBT eliminates on line simulation process and needs only one computational effort before test activity and thus it is more effective [6]. SBT uses fault dictionary approach for fault diagnosis, fault dictionary is prepared by simulating circuit at various faulty and non-faulty conditions.

Artificial neural network based approach for fault diagnosis is efficient because of its good learning ability, adaptability and robustness [3]. A neural network is an interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the neuron. The processing ability of the network is stored in the interunit connection strengths, or weights, obtained by a process of adaptation or learning from a set of training pattern. Different types of network topologies and learning algorithm is present to train the neural network for desired task. Neural network used for fault detection in many methods such as fault detection on the basis of parametric variation of components of circuit, fault dictionary based approach, utilising domain knowledge of circuit, etc. All such methods are discussed in this study.

II METHODS

1. Monte-Carlo simulation based method: A method for extracting soft faults or fault of analog circuit using neural network is presented in [4]. This method utilises the parametric behaviour of network like transfer impedance, driving point impedance, voltage gain and current gain under both faulty and non-faulty condition. Parametric behaviour of circuit under different condition gives the fault dictionary. Fault dictionary is prepared by taking Monte-Carlo simulation of each component of circuit under test (CUT) by varying component values under their tolerance limit of ±5%. Simulation result would be taken for numerous faulty conditions and a fault id is assigned for each condition. Proposed algorithm is examined through a second order sallenkey band pass filter. Two layer feedforward backpropagation neural networks is constructed for fault classification with input variables taken as magnitude and phase of four circuit parameters and output as binary equivalent of fault id. It is trained by the samples received from simulation process using Levenberg- Marquardt back propagation algorithm. It is the fastest back propagation algorithm but it requires more memory than other algorithm. Its validation performance is 0.10162 at epoch 48. Less number of measurements is needed to find the faulty element this method simplifies the testing procedure and reduces the testing cost.

2. Frequency domain classification and time domain testing based method: Neural network based approach for testing analog circuits with frequency domain classification and time domain testing in presented in [5]. It is based on designing training set of neural network by utilising domain knowledge of CUT. Training set is a representation of general set of response of circuit under both faulty and fault free condition. Data for training and testing set is collected from Pspice simulator and transient response of the circuit is used for this purpose and for classification frequency response of circuit is used. Monte-Carlo approach is used to generate responses for changes in component. Both single and multiple faults are induced in the circuit and their transient response is obtained. Biquadratic filter is used to perform the experimental results. Peak amplitude and shift in central frequency are the two parameters taken into consideration for classification with a tolerance of ±10%. Continuous pulse and a saturated ramp input is given to the circuit and its response is used for training of neural network. Transient response of the circuit is given as input to the neural network and output is defined to neural network under supervised learning. More than 90% fault detection is achieved using this method for hard and soft fault for both single and multiple faults. Advantage of this method is that no dc node voltages are needed for detecting shorts and opens in the circuit.

3. Polynomial curve fitting based method: Neural network based fault diagnosis in analog electronic circuit using polynomial curve fitting is presented in [6]. It is a parametric fault diagnosis method in which a polynomial of suitable degree is fitted to the output frequency response of an analog circuit. Coefficient of polynomial attains different values under faulty and non-faulty conditions, using this feature back propagation neural network is designed to detect the parametric faults. Benchmark biquadratic filter circuit is used as circuit under test (CUT) to present the simulation results. Frequency response of CUT is plotted using bode plot of MULTISIM software and this frequency response is fitted with polynomial of suitable order. Coefficient of this polynomial represent circuit under fault and fault free condition and thus these coefficients are used to train the network for classification of faults. The methodology is shown below in figure 1.

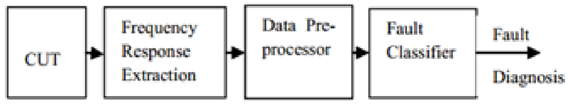


Figure 1: Block diagram for methodology of fault diagnosis

Parametric fault introduced in each component value are within the tolerance limit of ±1% to ±50%. Polynomial curve fitting is done by applying different frequency graphs to pre-processor to get the proper distinguishable feature. Polynomial curve fitting is done using curve fitting toolbox of MATLAB software. The NN toolbox of the MATLAB software is used to design the neural network architecture for fault classification by using fault dictionary approach. The network is trained with Levenberg Marquardt training algorithm and performance metric is taken as mean square error (MSE) and absolute error. This study indicates that this method is capable to diagnose single parametric faults of analog circuit in frequency domain.

4. Transient response based method: Neural network based fault detection in analog circuit using transient response of the circuit is given in [7]. This method is experimentally validated through Tuned Amplifier circuit. Data for training and testing set for neural network is collected from Pspice and MULTISIM simulator. Input voltage is kept fixed at 5V and output is taken by varying the frequency. Output of fault free circuit after simulation is compared with output of faulty circuit for detection of fault in circuit. Neural network is designed by using MATLAB software for fault diagnosis. It is a basic neural based method for fault detection and thus it may have poor performance and time constraint.

5. Sensitivity analysis and Monte-Carlo analysis based method: Parametric fault diagnosis of mixed signal analog circuit using neural network is presented in [8]. A benchmark R2R digital to analog circuit has been used as CUT for experimental validations. Methodology is categorised as circuit response measurement, fault classification and development of virtual instrument. Measurement of circuit response is done by simulating the circuit with MULTISIM software to get the simulated data and in real time the data is collected from data acquisition system of NIELVIS II board. Input data required for fault diagnosis process is collected by analysing the response data using sensitivity analysis of the CUT. Let the response of the circuit is 'y' with respect to the parameter of the component

'x', the sensitivity is denoted by s_y^x and it is defines as:

$$S_x^y = \lim_{\Delta x \to 0} \left\{ \frac{\frac{\Delta y}{y}}{\frac{\Delta x}{x}} \right\} = \frac{x}{y} \frac{\partial y}{\partial x} \quad \text{.........................(1)}$$

Fault models are taken by parametric variation of ±50% in the resistance value of CUT. Parametric behaviour of component is checked by performing 50 runs of Monte-Carlo analysis. Sensitivity of all resistance is calculated for each run of all the defined faults. Sensitivity analysis gives the optimum number of input combinations required for fault diagnosis. These input combinations are applied for each Monte-Carlo run of each defined fault model to get the output response of CUT. Fault classification is done by preparing fault dictionary and then the design of the artificial neural network. Fault dictionary is prepared by taking output responses for the different fault models. Total number of fault models, output responses and number of Monte-Carlo run decides the size of the fault dictionary. Multilayer artificial neural network (ANN) is designed in which input layer neurons are equal to number of output responses obtained from optimum number of inputs and number of output layer neurons are equal to number of fault models including non-faulty state of CUT. ANN is trained by using error back propagation training algorithm. Mean square error (MSE) has been taken as performance metric for artificial neural network and is given as:

$$\text{MSE} = \frac{1}{N} \sum_{n=1}^{N} (Tn - Yn)^2 \quad \text{....................(2)}$$

Where Tn and Yn are the target output and the output of the ANN.

ANN is designed in MATLAB software. Virtual instrument is designed in LABVIEW software which contains a block diagram involving graphical code of fault diagnosis system and a front panel which contains displays of input, output and fault indicators and thus we get the fault in the display section. Novelty of this method is that it has been generalised by validating simulated as well as real time data.

6. Pseudorandom testing scheme based method: A different method for fault detection and diagnosis in analog integrated circuits using ANN is proposed in [9], this method uses a pseudorandom testing scheme. The property of the Gaussian white noise that its auto- correlation is a single Dirac-δ function is exploited in this research. Testing scheme proposed uses a pseudorandom noise as the input stimulus, thereby providing a good estimation of impulse response of CUT. This method utilises a fault model driven testing technique, which requires only simple output response measurement. The basic approach of the diagnosis method is to compare the CUT against the mathematical model of the fault free circuit, implemented using simple multilayer ANN. Overview of this testing strategy is shown in figure 2. The procedure of this methodology is divided in three stages: Signature generation, generation of residuals, detection and isolation of faults.

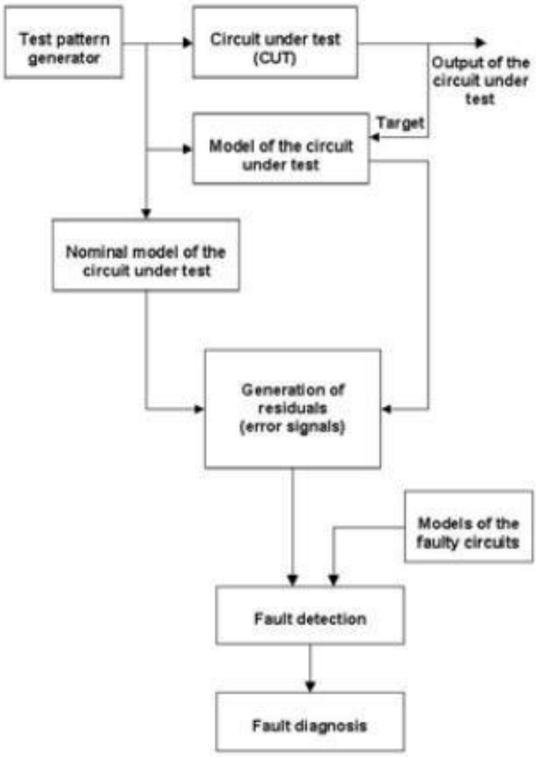


Figure 2: Overview of testing strategy

A CUT is simulated using the pseudo-random noise and the output response of the CUT forms the signature for fault class. For residual generation: nominal, actual and faulty CUT models are required. All the models are created using simple multilayer ANN consisting of one input layer, one or two hidden layer and one output layer. The ANN models are trained using BP algorithm to give the output responses under both faulty and fault free conditions. The difference between outputs of the nominal model and model of the actual CUT generates residual. Any fault in the circuit will change the signature of the residual. These residual signatures of the known fault condition of the circuit is known as fault signatures, these are first simulated and stored in a model bank for future use. Pseudorandom test stimulus provides a natural spread spectrum test signal, the test generation problem is completely eliminated and it can be used as universal stimulus for testing of analog ICs. The efficiency of this testing method relies on the proper choice of signatures and discrimination schemes to distinguish between the fault free and the faulty circuit in the dictionary.

7. **Hybrid evolutionary algorithm with neural network based method:** A hybrid evolutionary algorithm and neural network based method for fault detection in anlog circuit is presented in [10]. Back propagation (BP) algorithm of neural network has feature of rapid convergence on the local optima while genetic algorithm (GA) has powerful ability of searching global optimal solution. Hybrid of two algorithms will improve the evolving speed of neural network. Three amplifier state variable filter circuit is used as CUT to perform experimental validations. All the parameters of the circuit have assigned ±5% tolerance value for non-faulty case and ±50% tolerance value for faulty condition. The voltage transfer function of the CUT is given as:

$$VLPO = \frac{R2}{R5}\left[\frac{\frac{\frac{R2}{R5}}{R3C1R4C2}}{S2+\frac{\left(1+\frac{R2}{R5}+\frac{R2}{R1}\right)s}{\left(1+\frac{R7}{R6}\right)R3C1}+\frac{\frac{R2}{R5}}{R3C1R4C2}}\right] \quad \text{.................(3)}$$

By comparing equation (3) with the second order low pass filter transfer function, we will get the value of K, W0 and Q. Frequency f0 is approximately taken as 796 Hz. Now fault dictionary is prepared by getting the response of the circuit under numerous faulty and non- faulty conditions. Next step is to optimise neural network with GA algorithm. GA algorithm needs fitness function which can find neural network weights and chromosomes of GA are neural network weights. Now the final step is to design a neural network whose weight is optimised by GA algorithm. Four inputs to the neural network are VLPO, K, W0 and Q and outputs are the 9 parameters of CUT. 'Hyperbolic tangent sigmoid' and 'linear' functions have been selected as transfer function of hidden layers and output layers. This experiment is repeated with the different number of hidden layer and number of neurons in hidden layer. This method provides 86% of soft fault location rate.

PSO optimised neural network based method: PSO-optimized modular neural network trained by OWO-HWO algorithm for fault location in analog circuits is presented in [11]. In this study, an active filter circuit is used as the CUT and is simulated in both fault-free and faulty conditions. A modular neural network based method is proposed for soft fault diagnosis of the CUT. To optimize the structure of neural network modules, particle swarm optimization (PSO) algorithm is used to determine the number of hidden layer nodes of neural network modules. Instead of conventional output weight optimization–backpropagation (OWO-BP) algorithm, hidden weight optimization (OWO-HWO) training algorithm is employed to improve convergence speed in training of the neural network module. Experimental results show that the PSO-optimized modular neural network model which is trained by the OWO-HWO algorithm offers higher correct fault location rate in analog circuit fault diagnosis application as compared to the classic and monolithic investigated neural models.

III. CONCLUSION

This paper has presented a brief study of various neural network methods for fault diagnosis in analog circuits. Fault dictionary based methods are mostly used and they are easy to implement. [4,7,8,10,11]. Some of the method utilises component variation of the CUT under faulty and non-faulty condition to prepare the fault dictionary [4,8]. Neural networks can easily model fault dictionary to detect faults in analog circuitry. Hybrid methods are also implemented [10,11] to improve the circuit performance and decrease the time constraint. Real time circuit is also analysed for fault detection [8].

This study helps to evaluate various methodologies in this series in terms of set of desirable characteristics and it reveals the strength and weakness of various approaches. This paper gives a clear observation that no single method has all the desirable features a diagnostic system to possess. It is our view that some of these methods can complement one another resulting in better diagnostic systems. Integrating these complementary features is one way to develop hybrid systems that could overcome the limitations of individual solution strategies. All the study concludes that ANN plays a vital role in analog circuit fault detection.

REFERENCES

[1]. Deng, Y., He, Y., Sun, Y.(2010). Fault diagnosis of analog circuits with tolerances using artificial neural networks. IEEE Design &Test of Computers, (pp. 292–295).

[2]. Kondagunturi, R., Bradley, E., Maggard, K., Stroud, C. (1999). Benchmark circuits for analog and mixedsignal testing. In: Southeastcon’99 Proc. IEEE, 217-220.

[3]. M. A. El-Gamal and M. D. A. Mohamed, Ensembles of Neural Networks for Fault Diagnosis in Analog Circuits, Journal of Electronic Testing: Theory and Application 23 (2007), pp 323-339.

[4]. A. Kavithamani & V. Manikandan & N. Devarajan, “Soft Fault Classification of Analog Circuits Using Network Parameters and Neural Networks”,Springer Science+Business Media New York 2013, 11 April 2013, pp 237-240.

[5]. Palaniswamy, Arun, Anura Jayasumana, and Yashwant K. Malaiya. "A Neural Network based Approach for Testing Analog Circuits with Frequency Domain Classification and Time Domain Testing." Proc. IEEE Int'l System Test Diagnosis Workshop, 1999.

[6]. Kumar, Ashwani, and A. P. Singh. "Neural network based fault diagnosis in analog electronic circuit using polynomial curve fitting." International Journal of Computer Applications 61.16 (2013).

[7]. Mohd Ayub Khan, Divya Rawat, Mahima Singh, Meghna Acharya, Monika Garg, ” FAULT DETECTION IN ANALOG CIRCUIT USING NEURAL NETWORK”, IJARSE, Vol. No.4,Issue 05, May 2015.

[8]. Narula, Ashwani Kumar, and Amar Partap Singh. "Fault Diagnosis of Mixed-Signal Analog Circuit using Artificial Neural Networks." International Journal of Intelligent Systems and Applications 7.7 (2015): 11.

[9]. Jahangiri, Mahdieh, and Farhad Razaghian. "Fault detection in analogue circuits using hybrid evolutionary algorithm and neural network." Analog Integrated Circuits and Signal Processing 80.3 (2014): 551-556.

[10]. Sheikhan, Mansour, and Amir Ali Sha’bani. "PSO-optimized modular neural network trained by OWO-HWO algorithm for fault location in analog circuits." Neural Computing and Applications 23.2 (2013): 519-530.