An Advanced Automatic Electronic Diagnosis System

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ABSTRACT

Every complex system is liable to faults and failures. In the most general terms, a fault is any change in a system that prevents it from operating in the proper manner. Here, the diagnosis of catastrophic defects in complex digital circuits. In fact, today the technical diagnosis is great challenge for design engineers because diagnostic problems are generally under determinate. It is also a deductive process with one set of data creating, in general, unlimited number of hypotheses among which one should try to get the solution. So the diagnosis methods are based on proprietary knowledge and personal experience, although they were built into integrated diagnostic equipment. The approach proposed here is an alternative to existing solutions, and it is expected to encompass all phases of the diagnostic process: symptom detection, hypotheses generation, and hypotheses discrimination.

Keywords : *Fault diagnosis, Fuzzy Logic, ANN, P-Spice, MATLAB.*

I. INTRODUCTION

DIAGNOSIS can be defined as the task of identifying the cause of a fault that is manifested by some observed behavior. Then there are some methods of determining what fault has occurred is required. This is most often considered to be a two stage process: firstly the fact that fault has occurred must be recognized - what is referred to as fault detection. Secondly, the nature should be determined such that appropriate remedial action may be initiated.

Besides the human expert that is usually performing the diagnostic project, one needs tools that will help, and what is most desired, will perform diagnosis automatically. Such tools are a great challenge to design engineers that pertains to the fact that the diagnostic problem is generally under determinate. Thus, as mentioned earlier, this is why the methods applied in large companies and small services were generally based on experience, and proprietary knowledge.

Many methods are available for fault diagnosis. They include:

- Time series analysis - use history data to predict future events
- Fuzzy logic methods - fuzzy diagnosis matrix, clustering, evaluation, segmentation and learning
- Neural networks - system adaptation by self learning
- Multisource & multisensor data fusion - combination of numeric, logic, linguistic information
- Case-based reasoning - heuristic method using experience and history data
- Probability reasoning - Bayesian networks, Fisher's discrimination functions
- Hybrid method - combination of above methods
- Electronic Diagnosis System

And many more technologies, that are coming up in this field.

II. PROCEDURE FOR FAULT DIAGNOSIS

Fault diagnosis is generally categorized into two main types as mentioned below:

Circuit Partitioning (Effect Cause- Diagnosis)

- Identifying fault-free or possibly-faulty portions.
- Identifying suspect components, logic blocks, interconnects.

Model Based Diagnosis (Cause Effect-Diagnosis)

- Assuming one or more specific fault models.
- Comparing behavior to fault simulations.

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A. Circuit Partitioning

This employs the method of separating the known good areas of the circuit from the comparatively weaker ones. This will automatically reduce the chances of failure and if not so, it will surely help in the faster diagnosis of the fault that has occurred. Here the reasoning is based on observed behaviour and expected functions. The drawback of this system lies herein that the system is not very accurate and precise, and it does not indicate any defect mechanism.

B. Cause Effect Mechanism

If the first one was the effect cause mechanism, this one is the reverse methodology, which incorporates the starting from possible causes to compare the observed effects. A simulator is used to predict behavior of the circuit in the presence of various faults in such case. This method leads to our project idea, that is of the Electronic Diagnosis System. The major advantage of it is that it implicates a mechanism as well as a location. The drawback of it would be that the system can be fooed by the un-modelled defects, or the defects that have not been accounted for in the process of fault detection. The illustration below can very well describe the methodology involved.

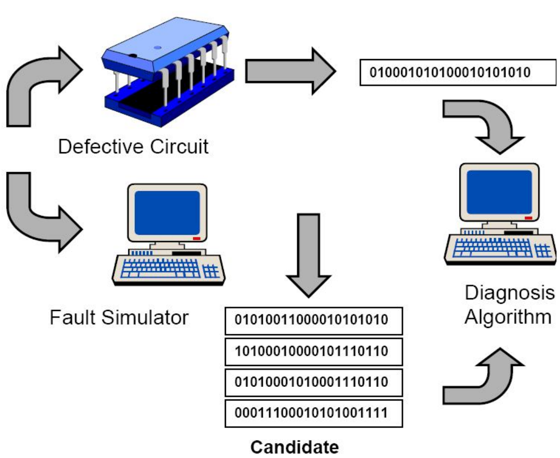

Fig.1 Cause-Effect Methodology of fault diagnosis

III. THE TOOLS EMPLOYED

We have basically used an upcoming field of study, i.e., neural networks for the Implementation of Electronic Diagnosis System for Fault Detection. For the accomplishment of which, we have used MATLAB 7.0 and for the analysis of the Example circuitry, we have used PSpice Simulation software.

The following text gives an overview of the above stated technologies i.e.

- MATLAB 7.0
- PSpice Simulation software
- Artificial Neural Networks

IV. CREATION AND CONCEPT OF FAULT DICTIONARY

A. Choice of Circuitry

The circuitry has been chosen keeping in mind its size and complexity, that would be suitable as a case study. The chosen case is of an operational (differential) amplifier which consists of current mirrors, amplifiers and widlar current sources. As can be seen from the circuit diagram (Appendix I), it has 26 nodes, which have been denoted by numbers stating from 1 to 26. The circuit has 11 resistors, a capacitor, and 24 transistors, of which 2 are multi collector ones.

These components are shown in figure. The input and output nodes are also denoted in the figure, and are also marked along with the other components. The 26 nodes, thus marked are later used for simulation and observation.

This circuit satisfied our need of the case study, as it is genuinely large, well designed, and an operational circuitry.

A neural network system trained for a case of 26 nodes will serve a purpose for cases which lie within the limits of 26 nodes, and using this as a precedent, a similar network can easily be trained in the future. Therefore, a circuit consisting of 26 nodes, will suit our purpose of fulfilling the requirement as a case study.

B. Simulation of the circuit

The circuit has been simulated using the PSpice full version that is 15.7, as the ADlite edition could not support a large a number of transistors. The coding or net list for the circuit has been added below

The simulation gave us the result which has been appended in the Appendix-II. The original, fault free voltages were obtained, which formed the basic requirement for the creation of fault dictionary. These node voltages acted as the initial training voltages for the ANN system,. To be developed at a further stage

C. Creation of Fault Dictionary

The fault dictionary has to consist of all the possible faults that can occur in the system. All the components are mentioned in a list, alongside is mentioned their every possible fault. The simulation has to be done every time we introduce a fault, to see the corresponding changes in the obtained node voltages at each of the 26 nodes.

ERROR CODE	ELEMENTS	FAULTS				
	RESISTORS		1	2	3	4
0000001	R1	SC	0	0	14.412	-0.5444
0000010		OC	0	0	14.412	-0.5442
0000011	R2	SC	0	0	14.412	-0.5443
0000100		OC	0	0	14.412	-0.5444
0000101	R3	SC	0	0	14.412	-0.5445
0000110		OC	0	0	14.412	-0.5444
0000111	R4	SC	0	0	14.305	-0.6424
0001000		OC	0	0	14.735	-0.1808
0001001	R5	SC	0	0	14.736	-0.1567
0001010		OC	0	0	14.736	-0.1632
0001011	R6	SC	0	0	14.412	-0.5444
0001100		OC	0	0	14.412	-0.5444
0001101	R7	SC	0	0	14.412	-0.5444
0001110		OC	0	0	14.412	-0.5444
0001111	R8	SC	0	0	14.412	-0.5444
0010000		OC	0	0	14.412	-0.5444
0010001	R9	SC	0	0	14.412	-0.5443
0010010		OC	0	0	14.412	-0.5444
0010011	R10	SC	0	0	14.412	-0.5444
0010100		OC	0	0	14.412	-0.5444
0010101	R11	SC	0	0	14.412	-0.5444
0010110		OC	0	0	14.412	-0.5444

Fig. 2 A section of the fault dictionary

Therefore, in our case study, with a total of 76 possible faults for all the components, the circuit has to be simulated 76 times, to obtain the faulty voltages at every node, in case of any fault. Every fault is given a unique code which is to be generated, when that particular fault occurs. The fault code assigned to each fault is also mentioned alongside the component name. Thus a input matrix is formed, which is required to be fed into the ANN system for fault detection. A section of the fault dictionary has been shown here, for better understanding of the process involved. The entire fault dictionary is appended in the Appendix.

V. THE ELECTRONIC DIAGNOSIS SYSTEM

We have used an ANN of 24-5-5-7 architecture, i.e. we have used a total of 4 layers:

- 1 Input Layer
- 2 Hidden Layers
- 1 Output Layer

The Process:

1) The fault dictionary of the given circuit is created.
2) The artificial neural network is then trained by using the node voltages for all possible faults as the Input to the ANN and the corresponding expected binary fault code as the Target.
3) The output layer of the ANN depending on the applied values at the input and present condition of weights, generates some random 7-bit binary code.
4) This output of ANN is compared with the actual desired Target and error between the two is calculated.
5) This error is then backpropagated to the previous layers and depending on the value of error, the values of weights between all the adjacent layers are updated. the weights are updated so as to minimise the value of error between Target & the actual Output.
6) This process is then repeated automatically by the ANN to adapt itself with a set of weights which provide minimum or zero error condition.
7) The faulty circuit is then simulated using any simulation software and the voltages at all the nodes are determined.
8) The obtained node voltages are fed to the input layer as the inputs.
9) The input layer processes the input signal levels by using the weights of the interconnections between the input layer and the first hidden layer, as per the transfer function decided.
10) These processed signals are then fed to the second hidden layer which further processes the signals using the interconnections weights and the transfer function of the hidden layer transfer function.
11) These signals are then fed to the output layer having hard-limit-symmetrical transfer function where the outputs of second hidden layer are classified into either binary '0' or binary '1'.
12) This sequence of 7 bit binary code is then looked up in the Fault Dictionary and the corresponding fault is then easily determined.

The inputs obtained from the fault dictionary were fed to the ANN and the plot of the inputs was obtained using MATLAB. This plot is as follows:

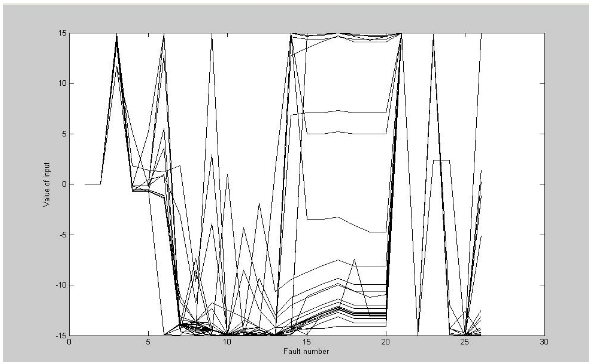

Fig. 3 Plots of the Input

The target vector, which was also obtained from the fault dictionary, was represented in the form of plot. This was found in MATLAB to be as:

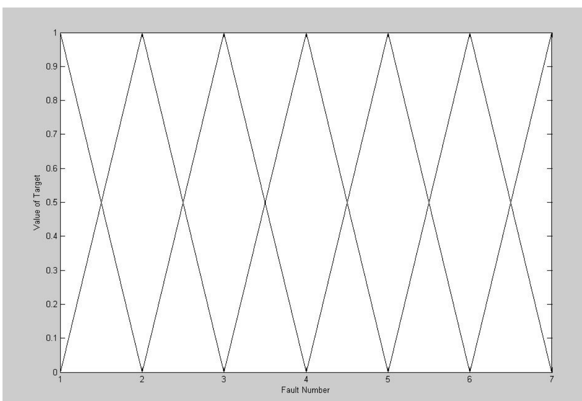

Fig. 4 Target Vector

On the initial simulation of the ANN with the inputs and the Network condition following plot as obtained:

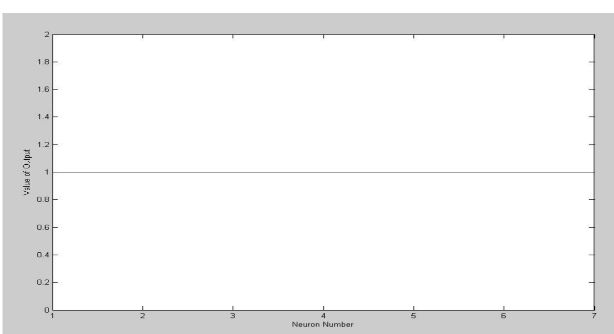

Fig. 5 Simulation of the ANN with the inputs

VI. CONCLUSION

The system defined earlier adopts a fault diagnosis methodology that is very systematic, hence detection of faults is easier than the conventional approach.The system, for its operation, requires minimum human interference and thus provides accurate results. The human factor causing variations in output for different working conditions is minimised. It is very quick in operation and provides result in a small fraction of time taken by the conventional system for the same circuit. This system is highly reliable and the chances of its failures are minimum. Thus it is expected to provide the stated degree of performance excellence under the stated conditions.

The system has a wider domain since a single EDS system can be used for diagnosing faults in a number of circuits.

APPENDIX

The table showing the original node voltages after simulation through PSpice.

Node Number	Node Voltages (V)
1	0.0000
2	0.0000
3	14.4120
4	-.5444
5	-14.4450
6	-1.1091
7	-13.8940
8	-13.8940
9	-14.4460
10	-14.9920
11	-14.9920
12	-.5444
13	-14.9990
14	-14.9020
15	14.7530
16	14.7530
17	14.9930
18	14.7370
19	14.7370
20	14.7370
21	15.0000
22	-15.0000
23	14.3080
24	-14.3330
25	-15.0000
26	14.9890

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