Method of Fault Diagnosis based on Granular Reasoning and Directional Graphic of Fault Propagation

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Abstract. The directional graphic of fault propagation is established based on the clock circuit of the broadcasting station and granular reasoning method and directional graphic of fault propagation are unified. The sample sets of the fault are obtained according to the circuit simulation and analysis, after that the sample sets of the fault decision is transformed into decision table which reflects the relation of faults and symptoms, then the decision table is transformed into the corresponding granular based, consequently fault source that most likely occurrence to fault is found by searching granular based and computing the most similarity.

1. Introduction

Communication station is one of the main means to guarantee mobile communication and diversify of communication support mission. With the upgrading of modern electronic technology and the application of high and new technology, the performance of radio equipment has been greatly improved which makes the complexity improved accordingly. As the key part of radio, the security and reliability is very important of circuit. The difficulty of fault detection and diagnosis on the fault circuit of the radio station is getting more and more difficult, especially with a large number of test points, to confirm reasonable test points and make analysis [1] are particularly important in the troubleshooting and maintenance of communication equipment.

In this paper, circuit model is established by circuit simulation tools, fault Settings, and the output of the analog circuit fault condition, to record of working state of all nodes, and through the signal flow analysis to establish directional graphic of fault propagation, and search for the relationship of connection between each element and the path of signal propagation along the connecting unit, using granular reasoning method for internal rule, backward reasoning to find possible source of fault, which could not only solve the problem of shortage of maintenance experience of the new station, but also provides a new method of fault diagnosis for electronic equipment. Paper.
2. The concept of Directional Graphic of Fault Propagation based on Granular Reasoning

2.1. Directional Graphic of Fault Propagation
The Directional Graphic of Fault Propagation abstracts the various elements of a specific system into the nodes in the graph, and abstracts the relation of fault propagation of elements into the directed edge which connecting two nodes, thus transforming the fault propagation model of a specific system into a Directional Graphic of Fault Propagation. With a mathematical model [2]:

\[ G = \{V, E\} \]

Directional Graphic of G with node-sets \( V = \{v_1, v_2, \cdots, v_i, \cdots, v_n\} \) and directional edge-sets \( E = \{e_{ij}\} (i \neq j) \). \( v_i \) Represents the node; \( e_{ij} \) represents the directional edge between nodes, the arrow shows \( v_i \) directs to \( v_j \).

2.2. Directional Graphic of Fault Propagation based on granula
With the analysis of the Directional Graphic of Fault Propagation, we can obtain that whether the fault source has an impact on the components at the same level, but the specific connection between the fault source and the fault phenomenon cannot be analyzed. Granular reasoning is mainly used to process uncertain, inaccurate and incomplete information, mine massive and massive data, discover hidden knowledge and reveal potential rules [3].

In this paper, the nodes in the directed graph model of fault propagation are described by granular formalization, and the fault sample set is obtained by experiment and analysis. Then the decision table is transformed into the corresponding granulary. Finally, the maximum similarity is calculated by searching the granulary to find the most likely fault source.

Decision table:

\( DT = (U, C \cup D) \) as the decision table, U as a whole domain, C as conditional attributes, node-sets Directional Graphic is the C in decision table, the node state of three kinds of deviation of positive and negative deviation and normal, which is corresponding the properties of conditional attribute values with "1", "1", "0", D as decision attribute, what happens to all nodes in the Directional Graphic of fault for the D in the decision table, with the Numbers 1, 2, 3, etc.

The decision table is transformed into a granulary by taking the conditional attributes of the decision table as the conditional grains of the granulary and the decision attributes as the decision grains of the granulary.

\[ G = \{G_1, G_2, \cdots, G_i, \cdots, G_n\} \], \( G_i \) stands for each granula in the granulary, i represents the order in the granulary, and n represents the number of granula in the granulary, \( G_i = (C(\land), \{i\}, D) \), (\( C(\land), \{i\} \)) as the conditional granula, \( C(\land) \) represents the intersection of added attributes in the decision table, \( \{i\} \) represents the sequence number of the granula in the decision table, D represents the decision granula.

Similarity
\[ G \text{ And } G' \text{ are two granulas, } G' \text{ is similar to } G \text{ at least with } p \text{ degree, notes as Clp}(G', G) , p \in [0,1], \]

define \( p; p = \frac{\text{card}(G' \ominus G)}{\text{card}(G)} \) \( (G \neq \Phi) \)

The symbol( \( \ominus \) ) means that the two grains are congruent; card represents the total number of elements in the set; \( \frac{\text{card}(G' \ominus G)}{\text{card}(G)} \) represents the ratio of the elements with the same elements between \( G' \) and \( G \) in total number of elements in the set of \( G \).

The reasoning method is to compare the condition of the granula composed of fault data with the condition of each granula in the granulary.
3. Model establishing of Directional Graphic of Fault Propagation of circuit Fault based on Granular Reasoning

3.1. Preconditions of establishing Directional Graphic of Fault Propagation
The fault propagation directed graph describes the connection relationship of fault units. The model is established on the following preconditions:
(1) The fault has transitivity;
(2) For a component with multiple inputs, a component fault is considered as long as one of the input faults; the element is in normal condition if and only if all inputs are normal.

3.2. Establishing Directional Graphic of Fault Propagation
Clock signal is the key part of the whole high speed circuit, which provides the standard for each module. The quality of clock signal directly affects the accuracy of circuit logic.

3.2.1. Clock circuit signal flow [4]. The clock circuit consists of four parts: thermostatic crystal oscillator (OCXO), FPGA, VCXO oscillator and output buffer. The output of VCXO is divided into two channels, one of which is sent to the intermediate frequency digital processing module via buffer. Another route is sent to the FPGA as clock reference. The frequency of OCXO is divided into three channels, the first channel is sent to the frequency hopping module through the buffer. The second channel is sent to the digital audio interface module and digital signal processing module through the buffer. The third channel is sent to the internal discriminator as the frequency reference of VCXO. The internal discriminator obtains a voltage control terminal of phase difference voltage output to VCXO.

![Figure 1. Flowchart of clock circuit signals](image)

3.2.2. Directional Graphic of Fault Propagation based on granula. According to the signal process of the clock circuit, the node represents the circuit element and the grain is formalized, and the directed edge represents the transmission path between the elements. Then the fault propagation relationship based on the grain can be represented by the directed graph:
3.3. Granulary

The circuit is analyzed by means of spice and the model is established. Test the circuit and measure the signal of each node by adding various excitation signals, such as intermediate frequency input and local vibration input, so as to check whether the whole system is working normally.

Another purpose of circuit simulation is to set up the circuit model, simulate the output of the circuit and record its working state. The clock circuit is mainly output frequency, so the frequency of each point is selected as the parameter for measurement. Point D provides the frequency output of voltage control point E for point E, so the voltage is selected as the parameter. The variables were artificially set with all parameters as variables, and the relational variables were placed in the first row and first column of the influence relational table. The column variables were artificially deflected to find the row variables that had influence on them. The increasing variable was represented by "+1" and the decreasing variable by "-1". Every positive variable is pulled, and the influence relation is written in the corresponding table to obtain the influence relation table.

Through spice software simulation, the cause-effect relationship between the two variables was analysed, and the relationship between fault and symptom was obtained:

| Fault sources | Fa  | Fb  | Fc  | Vd  | Fe  | Ff  | Fg  |
|---------------|-----|-----|-----|-----|-----|-----|-----|
| OCXO          | +1  | +1  | +1  | -1  | -1  | -1  | -1  |
| MC74HC390     | -1  | -1  | -1  | -1  | -1  | -1  | -1  |
| MC74HC4060-1  | 0   | +1  | -1  | -1  | -1  | -1  | -1  |
| CD4046        | 0   | 0   | +1  | -1  | -1  | -1  | -1  |
| VCXO          | 0   | 0   | 0   | +1  | +1  | +1  | +1  |
| MC74AC74      | 0   | 0   | 0   | 0   | +1  | +1  | +1  |
| MC74HC4060-2  | 0   | 0   | 0   | 0   | 0   | +1  | +1  |
Granularity: $G = (G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{14})$;

$G_1 = ((F_e(1) \land F_4(1) \land F_3(1) \land V_d(1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{1\}), OCXO);$

$G_2 = ((F_e(-1) \land F_4(-1) \land F_3(-1) \land V_d(-1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{2\}), OCXO);$

$G_3 = ((F_e(0) \land F_4(1) \land F_3(1) \land V_d(1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{3\}), MC74HC390);$

$G_4 = ((F_e(0) \land F_4(-1) \land F_3(-1) \land V_d(-1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{4\}), MC74HC390);$

$G_5 = ((F_e(0) \land F_4(0) \land F_3(1) \land V_d(-1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{5\}), MC74HC4060-1);$

$G_6 = ((F_e(0) \land F_4(0) \land F_3(-1) \land V_d(-1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{6\}), MC74HC4060-1);$

$G_7 = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{7\}), CD4046);$

$G_8 = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(-1) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{7\}), CD4046);$

$G_9 = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{9\}), VCXO);$

$G_{10} = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(1) \land F_{g}(1) \land F_{g}(1), \{10\}), VCXO);$

$G_{11} = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(0) \land F_{e}(1) \land F_{g}(1), \{11\}), MC74AC74);$

$G_{12} = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(0) \land F_{e}(1) \land F_{g}(1), \{12\}), MC74AC74);$

$G_{13} = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(0) \land F_{e}(0) \land F_{g}(1), \{13\}), MC74HC4060-2);$

$G_{14} = ((F_e(0) \land F_4(0) \land F_3(0) \land V_d(0) \land F_{e}(0) \land F_{e}(0) \land F_{g}(0), \{14\}), MC74HC4060 - 2)$

4. Case of fault analysis

Fault description: when the radio station starts up, it cannot send and receive signals, and the function of sending and receiving displays does not show the working status. After inspection, the clock input signal of digital audio interface module, digital signal processing module and intermediate frequency digital processing module is abnormal, while the clock input signal of FM module is normal. Compare the fault value of measuring point with normal value:

|    | Fa  | Fe   | Ff   | Fg |
|----|-----|------|------|----|
| Normal value | 25.6M | 32.768 M | 16.384M | 16k |
| Measure value | 25.6M | 16.384M | 8.192M | 8k |
| Variation trend | 0 | -1 | -1 | -1 |

Conditional granular

$G' = (F_e(0) \land F_4(-1) \land F_3(-1) \land F_{g}(1))$

Compare with granular:

$p_1 = \text{card}(G' \otimes G_1) / \text{card}(G_1), p_2 = \text{card}(G' \otimes G_2) / \text{card}(G_2), p_3 = \text{card}(G' \otimes G_3) / \text{card}(G_3), p_4 = \text{card}(G' \otimes G_4) / \text{card}(G_4), p_5 = \text{card}(G' \otimes G_5) / \text{card}(G_5), p_6 = \text{card}(G' \otimes G_6) / \text{card}(G_6), p_7 = \text{card}(G' \otimes G_7) / \text{card}(G_7), p_8 = \text{card}(G' \otimes G_8) / \text{card}(G_8), p_9 = \text{card}(G' \otimes G_9) / \text{card}(G_9), p_{10} = \text{card}(G' \otimes G_{10}) / \text{card}(G_{10}), p_{11} = \text{card}(G' \otimes G_{11}) / \text{card}(G_{11}), p_{12} = \text{card}(G' \otimes G_{12}) / \text{card}(G_{12}), p_{13} = \text{card}(G' \otimes G_{13}) / \text{card}(G_{13}), p_{14} = \text{card}(G' \otimes G_{14}) / \text{card}(G_{14})$

Analysis: the maximum similarity was 4/7, so the possible failures were MC74HC390, MC74HC4060-1 and CD4046. Another data $F_e$ is collected. If the data of point C is normal, the CD4046 fails. If point
C is fault data, then MC74HC390 and Mc74hc4060-1 may fail, and data Fb will continue to be collected. If Fb value is normal, then Mc74hc4060-1 will fail. Fb value abnormal, then MC74HC390 fails.

5. Conclusion
This paper mainly studies the application of fault diagnosis technology combining fault propagation directed graph and grain reasoning method in fault diagnosis of communication radio station. Practice show that failure propagation digraph can intuitive effective description of fault propagation path, grain of reasoning method of grain of library search maximum similarity calculation, so as to find the most possible fault source, diagnosis of a relatively short time for digital circuit fault diagnosis and fault data processing provides an effective method and means.

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