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COMPUTER AIDED FAILURE ANALYSIS

By R. S. Smith

Published December 1978

Final Report

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DP00613.

**Kansas City
Division**

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By R. S. Smith

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Final Report
R. S. Smith, Project Leader

Project Team:
W. C. Rutherford

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A computer aided failure analysis system has been developed to troubleshoot defects in electronic assemblies. Through a question and answer procedure, the system provides step-by-step corrections to guide a troubleshooter to the fault location. A diagnostic logic routine has been established for one product and the software necessary to store and implement the routine has been developed. The TSO terminal has been installed and the completed system is functional. A visual aid catalog has been developed for the current CAFA routine.

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SUMMARY

The manual processes commonly used to locate defects in electronic assemblies are often slow, inefficient, and costly. In addition to the actual failure analysis effort, a significant amount of engineering manpower must be used to train and assist troubleshooting personnel. When there is a change in personnel, the training must be repeated. The goal of this project was to develop an automated failure analysis process which will reduce the cost and eliminate some of the problems associated with present troubleshooting procedures.

A computer aided failure analysis (CAFA) system has been designed for use on this project. The CAFA system was developed for a specific application; however, the facilities and techniques are adaptable to many different product types.

The system approach is to store a diagnostic analysis program in a centralized computer and activate the program through time share operation (TSO) terminals located in the manufacturing area. Automated fault isolation is accomplished by question and answer communication between the computer and the troubleshooter. The computer asks questions about the test data and circuit performance to direct the troubleshooter to perform additional tests and checks. Ultimately, after guiding the troubleshooter through an analysis channel, the diagnostic program will decide on possible causes of failure. All statements and questions are presented to the user in English and all questions can be answered simply by typing a number into the TSO terminal.

With this CAFA system, a new or inexperienced troubleshooter should be able to analyze the failure quickly and accurately without direct engineering assistance. Engineering expertise will be provided through the computer.

A diagnostic logic routine has been established for one application and the computer software necessary to store and implement the diagnostic procedure has been developed. The completed system has been checked out on a TSO terminal and found to be totally functional.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to reduce the time and cost of troubleshooting electrical test failures during electronic assembly manufacturing processes. Present troubleshooting procedures needed to be improved in order to reduce the defect analysis time, the amount of engineering manpower required to train and assist troubleshooters, and the problems associated with personnel changes.

A computer aided failure analysis (CAFA) system has been developed. Although the development work was directed at solving problems associated with one specific product, it was intended that the guidelines and basic tools developed be used to troubleshoot many, if not all, of the electronic assemblies manufactured at the Bendix Kansas City Division.

PRIOR WORK

This is the final report on this project. A previous report presented the basic considerations and guidelines for the project and outlined a proposed design for a computer aided failure analysis system.

ACTIVITY

Basic Considerations

The basic components of a manual failure analysis system are illustrated in Figure 1. A typical troubleshooting procedure will consist of the following operations.

- An output from the test system indicates a failure.
- The operator, through deductive reasoning or consultation of manuals, schematics, or drawings, decides to perform a check of some kind.
- As the operator performs the check, another input from the equipment is received.
- Based on the input from this check, the operator initiates a second check and response cycle.

Figure 1. Troubleshooting System Block Diagram

The cycling continues until the operator determines the nature or location of the defect. The more complex the problem or product, the greater the number of checks and the greater the number of cycles.

There are a number of ways that failure analysis procedures can be improved.

- The failure indication can be more informative. Test data from the test system can be sequenced to direct the troubleshooter to a specific portion of the product.
- Diagnostic information can be presented in a less cumbersome and more usable form than written manuals.
- Diagnostic information can suggest what checks to perform and in what sequence.
- An expert's knowledge could reduce the number of check and response cycling.

Several related subjects are important in any consideration of the design of an automated failure analysis system. The intent of production testing is to check component reliability and

manufacturing processes rather than to evaluate the product design. Production test systems normally do not consider the problem of product repair and as a result tend to provide low diagnostic resolution. There are three fundamentally different testing techniques: substitution testing, comparison testing, and programmed response testing.² Programmed response is the most commonly used technique at Bendix Kansas City for acceptance testing of electronic assemblies. It has the advantage of providing quantitative information that can help physically locate a fault. The other two techniques usually are much simpler and less expensive to incorporate, but also provide less test and diagnostic data. The design of the troubleshooting system must be consistent with the product testing technique.

In order to improve troubleshooting procedures, it is important to be able to predict the kinds of defects the product will experience during production. A review of the production history of typical electronic products reveals 80 percent of the test failures were the result of assembly errors and defective components, 12 percent were the result of tester and testing problems, and 8 percent were the result of design problems. The majority of the design and tester problems usually occur early in production and once resolved do not reoccur.

There are two basic approaches to automated fault isolation--fault signatures and nodal status.³

Fault Signatures

The fault signature method uses the failure pattern at the external connections of the test unit for identifying faults. Fault signature tables or dictionaries are generated to correlate with failure modes of specific defects. When a device fails a test sequence, the fault signature dictionary is scanned to locate a fault pattern that matches the test data of the failing unit. Fault table storage and scanning is performed by the computer. The success of this approach is dependent upon the ability to obtain a unique signature for each fault. It is also possible to have probabilistic statements when exact signature matches do not exist. As the complexity of the product or test sequence increases, the quantity of data in the fault signature tables can become astronomical. For example, the test sequence of one Bendix product can theoretically have approximately 37×10^{49} unique fault signatures.

Nodal Status

The nodal status method of fault isolation uses the status of each electrical node to guide the operator through the failing unit to the location of the defect. This method could be described as the automation of the manual process that technicians have

historically used in troubleshooting. This method can be implemented by various techniques: split half, first failure indication, failure symptom category, and so on. With this fault isolation method, a structure file and logic tree is stored in the computer and activated by an input and response dialogue between the computer and the operator.

System Design

The following general guidelines were established for design of a computer aided failure analysis (CAFA) system.

- Emphasis should be placed on the resolution of test failures caused by assembly errors and defective components. The computerized mathematical analysis of design errors and worst-case tolerance buildup, for example, should not be required very often once a product is in production.
- The CAFA system should be flexible enough to adapt to different types of electronic assemblies.
- Operation of the CAFA system should be such that production troubleshooters will not need extensive new skills or training.

An automated failure analysis system has been designed and an initial application program established for one product. The system is a computerized method of applying the engineers knowledge of circuit operation and test requirements to analyzing a product failure without the engineer actually being present.

When a product failure occurs, the troubleshooter communicates with a computer program to analyze the failure. The computer asks questions about the test data and directs the troubleshooter to perform additional tests. It gives specific information on where and how to make these test measurements and describes what a "good" measurement or waveform looks like.

The CAFA system is general in application since the facilities and computer techniques are adaptable to many different types of product. Specific programs, however, must be established for each product using the system. The amount of detail, accuracy, and style of a particular analysis program will depend upon the engineering input.

Iteration Technique

As previously described, the two classical iterative approaches to automated fault isolation have been fault signatures and nodal status. The electronic products and test systems at Bendix suggest that a combination of these two fault isolation approaches would be the most effective. It is desirable to get as much

diagnostic information as possible from the original test data of the failing unit; however, it is usually necessary to perform additional checks to locate the fault.

The logic routine (iteration technique) devised for one product (a timer) uses the original test data of the failing unit to first classify the failure into a failure category. The logic routine then continues to draw information from the test data to direct the operator within a channel of the failure category. When required, the logic routine specifies that additional nodal checks are to be performed. Based on the results of these nodal checks, the logic routine continues to direct the user through an analysis channel until the cause of failure is determined. Figure 2 is a simplified block diagram of this logic routine approach.

Computer Hardware

The facilities of the Mezzanine Data Acquisition System (MEZZDAS) are used as the hardware basis for the CAFA system. The analysis program is stored in the central computer and the user (troubleshooter) communicates with the computer by using a TSO terminal. Figure 3 illustrates how the CAFA system is contained within the MEZZDAS hardware. The decision to use this system was based on the following facts.

- No new main-frame computer equipment need be purchased. In some cases it might be necessary to add equipment, such as a CRT terminal for a particular CAFA system, but this equipment expense is minor compared to the cost of a completely new computer system.
- The concept of multiple program storage in one central computer significantly reduces the amount of new software development required for CAFA programs of new or additional products.
- The structure of the MEZZDAS system allows access to a particular failure analysis program from more than one location. For example, the failure analysis program for one product could be activated from either the laboratory or the manufacturing facility.
- With this system approach, automated failure analysis is not tied to a particular product tester or manufacturing area. As a result, there should be minimal problems associated with such things as tester calibration and facility changes.

Figure 2. Logic Routine Block Diagram

Figure 3. CAFA System Block Diagram

Computer Software

The software for this system is designed to require minimum input from the user. The failure analysis procedure consists of a question and answer session between the computer and the troubleshooter. All questions are presented in English and can be answered by simply typing a number into the terminal.

The software package consists of three separate but interactive parts. Part A (Figure 4) contains the wording of the statements and questions presented to the user. Part B (Figure 5) establishes the logic tree of the iteration procedure. Part C performs the input/output operations and the interconnection of Part A and Part B. The user will see and interact only with Part A of the program. Part C of the software package will be essentially the same for any CAFA file; however, each product will require unique Part A/Part B software.

Figure 6 is an example of a complete troubleshooting sequence. This example demonstrates the nature of the conversation between the computer and troubleshooter and shows that very little input is required from the troubleshooter. It should be pointed out that this particular troubleshooting sequence was chosen as an

0501
WHICH ONE OF THE FOLLOWING IS THE REASON FOR FAILURE?(1)DOES NOT FIRE,(2)FIRE
TIME SLIGHTLY OUT OF LIMITS,(3)FIRE TIME GROSSLY OUT OF TOLERANCE
0502
DURING RUNDOWN, WHAT IS THE CONDITION OF TIMEW READ,PIN 13?(1)THERE IS NO
SIGNAL,(2)SIGNAL PRESENT BUT INDICATES ALL ONES OR 7F8US,(3)SIGNAL NORMAL.
0503
DURING RUNDOWN,IS THERE PROPER VOLTAGE ON VCC,PIN 17(1)YES,(2)NO.
0504
IS THERE AN OUTPUT FROM THE SPECIAL SWITCH DURING RUNDOWN(BRD 3-PIN 344
CLAMPED LOW AND BRD 3-PIN 341 CLAMPED HIGH)?(1)YES,(2)NO.
0505
THE SPECIAL SWITCH CIRCUITRY IS DEFECTIVE. MOST LIKELY CANDIDATES FOR FAILURE
ARE Q301,Q302,Q303,Q304 OR Q305. CHECK THAT POLARITY OF CR312/CR315 IS OK.
0506
IS THERE A PROPER CLOCK OUTPUT AT PIN 327 OF BRD 3,FIGURE 11?(1)YES,(2)NO.
0507
MOST UNUSUAL. POSSIBLY PIN 19 OF U204 IS SHORTED TO GND.
0508
DURING RUNDOWN IS THE COLLECTOR OF Q206 CLAMPED LOW,BRD 2-PIN 335?(1)YES,(2)NO.
0509
DURING RUNDOWN,IS PIN 16 OF U204 CLAMPED LOW?(1)YES,(2)NO.
0510
DOES PIN 9 OF U204 REMAIN HIGH DURING RUNDOWN?(1)YES,(2)NO
0511
MOST LIKELY,U204 OR ITS TRANSISTOR(PINS 9 TO 10) IS DEFECTIVE.
0512
POSSIBLE CAUSES OF FAILURE ARE (A)OPEN VR202/R252/R227,(B)R227 SELECTED WRONG,
(C)R 231/R228/R230 SHORTED,(D) VCC TOO LOW,SELECT CATEGORY 6 TO ANALYZE
FAILURE.
0513
DOES PIN 19-U204(BRD 2-PIN 333)REMAIN HIGH DURING RUNDOWN?(1)YES,(2)NO
0514
DOES PIN 18 OF U204 REMAIN HIGH DURING RUNDOWN?(1)YES,(2)NO

Figure 4. Software, Part A

example because it is exceptionally short. Most failure analysis sequences will require more question and answer events and involve additional checks and tests on the product.

There are five noteworthy features of the software package.

- No special typing or programming skills are required of the system user (troubleshooter).
- Very limited knowledge of computer programming is required for a product engineer to establish a CAFA file for new product.
- The software design is adaptable to many different types of products and test systems.
- The software is adaptable to different types of iteration procedures.

0001010002000300040005000600070008000900100011009000910020003000400050009700

0100010101160127013201590163

01010102010301130114

GO TO STATEMENT 0104 FOR ANSWER 1

01029999

GO TO STATEMENT 0104 FOR ANSWER 3

01030104010701040107010901110112

GO TO STATEMENT 0109 FOR ANSWER 5

010401050106

GO TO STATEMENT 0107 FOR ANSWER 2

01059999

01069999

010701080106

01089999

010901050110

STATEMENT 0110

01109999

GO TO END OF PROGRAM (STATEMENT 9999)

01119999

01129999

01139999

011401159999

01159999

011601170115

Figure 5. Software, Part B

WELCOME TO FAILURE ANALYSTS

THERE ARE THIRTEEN CATEGORIES OF TESTS

AN FCA/FINAL UNIT MAY FAIL ONE OR MORE OF THE FIRST NINE CATEGORIES.

CATEGORIES 10 THROUGH 13 PERTAIN TO THE INDIVIDUAL PRINTED WIRING ASSEMBLIES

CATEGORY	NAME	PRODUCT SPEC. TEST NUMBER
1	IMPEDANCE	1.2, 3.4A, 5A, 9, 10, 11, F
2	DATA PULSE	4B---1, 5H---1, 6H---1, 7G---1, 8A---H
3	VIBRATION	4J, 5J, 6J, 7J, 8J, 11A, 12A, 13A, 14A, 15A, 16AH, 17AH, 18A, 19A, 27A, 28A, 29A, 30A, 31A, 32A, 33A, 25A, 26A
4	PWR. SUPPLY	6AK, 7AK, 12B, 13B, 14B, 15B, 16B, 19B, 2AB
5	RISE TIME	12E, 13E, 14E, 15E, 16C, 17C, 27D, 28D, 33D, 3AC, 25C
6	OPTION SEL.	12CD, 13CD, 14CD, 15CD, 16EF, 17EF, 30DE, 32AC, 13BC, 11BC
7	NOISE	12F, 13F, 14F, 15F, 16D, 17D, 27C, 28CF, 29A, 30B, 31B, 33F, 25B, 26B
8	OUTPUT PULSE	12GH, 13GH, 14GH, 15GH, 19CDE, 19CDE, 23H, 33FG
9	SPECIAL	20A, 21A, 22A, 23A, 24A, 27H, 29C, 32D, 34A
10	PWA 1	
11	PWA 2	
12	PWA 3	
13	PWA 4	

WHICH OF THE FOLLOWING BEST DESCRIBES THE FAILURE MODE OF THIS UNIT?

- (1) CAT 1, (2) CAT 2, (3) CAT 3, (4) CAT 4, (5) CAT 5, (6) CAT 6, (7) CAT 7, (8) CAT 8, (9) CAT 9, (10) CAT 5 AND 6, (11) CAT 3, 5 AND 6, (12) CAT 5 AND 7, (13) CAT 2 AND 3, (14) CAT 10 - PWA 1, (15) CAT 11 - PWA 2, (16) CAT 12 - PWA 3, (17) CAT 13 - PWA 4, (18) NONE OF THESE

① ————— OPERATOR INPUT

WHICH ONE OF THE FOLLOWING DOES THE UNIT FAIL? (1) TEST 1, 2 OR 3, (2) TEST 4A AND/OR 5A, (3) TEST 9, (4) TEST 10, (5) TEST 11DE, (6) SOME COMBINATION OF 1 THROUGH 5

① ————— OPERATOR INPUT

DOES THE UNIT FAIL? (1) TEST 1 ONLY, (2) TEST 2 ONLY, (3) TEST 3 ONLY, (4) A COMBINATION OF TESTS 1, 2 AND 3

① ————— OPERATOR INPUT

Figure 6. Troubleshooting Sequence

- Changes to the logic tree and statement file are made by changing cards in a card deck. The program cannot be altered by a user from the TSO terminal.

Visual Aid Catalog

At various appropriate points in the troubleshooting question and answer sequence, the CAFA routine refers the user to a figure showing the correct waveform at an indicated point (Figure 7). Based on the presented waveform, the user decides whether or not the unit undergoing failure analysis is functioning correctly. The answer to the waveform question determines the sequence followed in the logic tree (Figure 5) of the CAFA routine.

These waveform figures are arranged in a Visual Aid Catalog (VAC) which could be in one of three forms.

- VAC waveforms could be stored and displayed on the TSO terminal. This would require a minimal programming effort by the product engineer. A disadvantage is the inability of the TSO terminal to present a fairly accurate plot.
- VAC waveforms could be stored and displayed on a microfiche card, but this would require an additional piece of equipment--a microfiche viewer.
- VAC waveforms could be displayed in a booklet.

The waveforms are now displayed in a booklet. Each page of the booklet refers to a figure number and also shows the user where to place the oscilloscope probe to determine if the waveform in the failing unit is identical to the one displayed in the catalog. The VAC booklet could easily be converted to microfiche.

ACCOMPLISHMENTS

A diagnostic logic routine using the MEZZDAS facilities has been established for one product. The computer software necessary to store and implement this routine on a computer has been developed. The TSO terminal has been declared operational and ready for CAFA use. A visual aid catalog has been developed for the current CAFA routine and is also ready for use.

WELCOME !!! FAILURE ANALYSIS FOR THE TIMER - GROUP 260

THERE ARE NINE CATEGORIES OF TESTS PERFORMED ON A TIMER. A UNIT MAY FAIL ONE OR MORE OF THESE CATEGORIES.

CATEGORY	NAME	PRODUCT SPEC	TEST NUMBER
1	IMPEDANCE	1, 2, 3, 4A, 5A, 9, 10, 11DC	
2	DATA PULSE	4B---I, 5B---I, 6B---I, 7B---I, 8A---H	
3	VERIFICATION	4J, 5J, 6J, 7J, 8I, 11A, 12A, 13A, 14A, 15A, 16AB, 17AB, 18A, 19A, 27A, 28A, 29A, 30A, 31A, 32A, 33A	
4	PWR SUPPLY	6A, 7A, 12B, 13B, 14B, 15B, 18B, 19B, 28B	
5	FIRE TIME	12E, 13E, 14E, 15E, 16C, 17C, 27D, 28D, 33D, 30C	
6	OPTION SEL	12CD, 13CD, 14CD, 15CD, 16EF, 17EF, 30DE, 32DC, 33BC	
7	NOISE	12F, 13F, 14F, 15F, 16BD, 17BD, 27C, 28CE, 29D, 30B, 31B, 33E	
8	OUTPUT PULSE	12GH, 13GH, 14GH, 15GH, 18CE, 19CE, 31DE, 33FG	
9	SPECIAL	20A, 21A, 22A, 23A, 24A, 27B, 29C, 31C, 32D, 34A	

WHICH OF THE FOLLOWING BEST DESCRIBES THE FAILURE MODE OF THIS UNIT?

(1) CAT 1, (2) CAT 2, (3) CAT 3, (4) CAT 4, (5) CAT 5, (6) CAT 6, (7) CAT 7, (8) CAT 8, (9) CAT 9, (10) CAT 5 AND 6, (11) CAT 3, 5 AND 6, (12) CAT 5 AND 7, (13) CAT 2 AND 3, (14) NONE OF THESE

ANSWER WAS (3)

DOES THE UNIT FAIL FIRE TIME AND/OR OPTION SELECT IN ADDITION TO VERIFICATION,

(1) YES, (2) NO

ANSWER WAS (2)

WHY DOES THE UNIT FAIL VERIFICATION BECAUSE (1) IT ALWAYS VERIFIES 77777, (2) IT ALWAYS VERIFIES 0000, (3) IT VERIFIES AN INCORRECT CODE OTHER THAN 77777/00000

ANSWER WAS (1)

WHEN UNIT VERIFIES 77777, IS THERE (1) NO DATA REPLY PULSE AT PIN 9, OR (2) AN INCORRECTLY SHAPED OR POSITIONED REPLY PULSE ON PIN 9. SEE FIGURE 10

ANSWER WAS (1)

IS THERE CORRECT BASE DRIVE TO Q205, FIGURE 2, DURING DATA SET? (1) YES, (2) NO

ANSWER WAS (1)

POSSIBLE CAUSES OF FAILURE ARE (A) R225 WRONG VALUE, (B) Q205 DEFECTIVE, (C) C207 OR C202 LEAKY OR SHORTED, (D) CR203 LEAKY, (4) CR204 HIGH FORWARD VOLTAGE/REVERSED

BASED ON THE INFORMATION SUPPLIED TO THE DIAGNOSTIC PROGRAM, THIS IS THE COMPLETION OF FAILURE ANALYSIS. IF THIS HAS NOT RESULTED IN A POSITIVE FAULT LOCATION, ONE OR MORE OF THE FOLLOWING ACTIONS SHOULD BE TAKEN

(A) REPEAT FAULT DIAGNOSIS USING DIFFERENT FAILURE CATEGORY.

(B) TROUBLESHOOT USING MANUAL PROCESSES.

(1) CONTACT ENGINEERING FOR ASSISTANCE

VISUAL AID CATALOG FIGURE REFERENCE

Figure 7. Software, Figure Reference

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ELECTRICAL: Failure Analysis

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