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Literature Survey of Intermittent Failures and its Testing Measures

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ABSTRACT: In electronic and electrical circuits intermittent faults are of great concern as it is the main cause of NFF ('No fault Found') condition. Intermittent faults do not occur at regular intervals and they are not predictable as well. These failures can be severe at times and can become the cause of major damage significantly in case of avionics and transportation industries. The major causes behind the intermittent failures are loose broken or corroded wire/connectors, Cracked solder joint, unsoldered joints, Hairline crack in a printed circuit etc. In order to deal with these kinds of faults, clear understanding of root cause and available testing measures is important. The detail analysis of the problem and detection of the fault can be done using FMMEA (failure mode, mechanisms, and effects analysis) can be used. The testing measures available can be use of Pico-scope, TDR, IFD 2000 etc. In this paper, available literature regarding the most common intermittent faults is studied and reviewed. The causes and detection methods are overviewed.

KEYWORDS: Intermittent Faults, CTE mismatch, Non-intrusive fault diagnosis, FMMEA, IFD 2000.

I.INTRODUCTION

Most devices and systems contain embedded electronic modules for monitoring, control, and to enhance the functionality of cars, trains, ships and airplanes. The shrinking size and complexity of electronic circuits, with added redundancies, has led to difficulties in the maintenance of these modules. This becomes a challenge when faults are intermittent in nature [1].

Intermittent failures are sporadic failures that are not being easily repeatable because of their complicated behavioural patterns. These are also sometimes referred to as "soft" failures, since they do not manifest themselves all the time and disappear in an unpredictable manner. On the contrary hard failures are permanent in nature [2]. They also have specified codified standard methods to resolve or reduce the issues. Intermittent failures comes under the category of NFF (no fault found), which means that a failure was observed in the system, but when the device was tested for it, a failure mode could not be identified or the failure could not be duplicated even though they are recurrent. Many problems may occur due to intermittent faults like aircraft failures or train delays etc. Hence such faults have severe serious effects in the field of avionics, transportation etc. These errors can also be costly sometimes as mentioned by RoozbehBakshi et. al. in [2].For example, disruption in a voice command system of an airplane can be initially diagnosed as a component malfunction while after running test on components the intermittent failure happen again and further tests show that the reason is a loose connection. These extra tests impose additional costs, which account for a large portion of the maintenance budget. [2]. Thus the after effects of intermittent failure and NFF phenomena states the need for a detail study on the root causes of these failures.

II. CAUSES OF HARDWARE INTERMITTENT FAULTS

Hardware malfunctions may cause serious issues in electronic systems. It can be one of the many reasons of device failure very often. This section describes commonly observed causes of hardware failures. Wakil Syed Ahmad et. al. elaborated many faults in their paper on intermittent faults. They are enlisted as follows:

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1. Loose broken or corroded wire/connectors
2. Cracked solder joint , unsoldered joints
3. Hairline crack in a printed circuit

Repairing an intermittent fault may not be difficult but challenging to troubleshoot and it increases the maintenance cost of the product [1].

1. Loose broken or corroded wire/connectors

Intermittent failures in connectors or wires may happen due to variety of reasons like vibration, CTE mismatch, stress relaxation and movement of wiring harness due to effect of magnetic field. Due to this the contact resistance increases too much that device may get damaged. It may be intermittent for certain duration but can become a reason of permanent failure in later on lifecycle.

1.1 CTE mismatch

CTE is very important parameter in connection. It is the parameter that indicates the extent to which the material can expand when heated. Different substances expand differently. Thus CTE is important in connecting two different materials. The bonds between the wires get affected by the CTE mismatch on temperature variation. Once the temperature variation is stabilized, these wire bonds can be restored making it an intermittent fault. This may arise again upon temperature change. This type of faults can be either open circuit or short circuit. As per Osarumen O.Ogbomo et. al. results show that zinc-solder-silver joint having the highest CTE mismatch of 19.6 ppm exhibits the greatest damage while silver-solder-silver with no mismatch possesses the least damage [3].

1.2 Loose wires/connectors/components

Intermittent faults can also be caused by loose wires or connectors or components. It is also caused by loose conducting material. These loose connections can be detected by various methods including X ray, vibration and acoustic tests. These methods focus on the driving forces behind short circuiting. It also studies the effect of short circuits on component performance.

1.3 Stresses

The process of molding can cause stress which can in turn damage the wire bonds. But these faults are not visible as such hence they are categorized under intermittent faults. The best example of this is weakening of golden ball during the molding process.

1.4 Corrosion

Corrosion can occur at early stages of lifecycle of the electronic circuit. It degrades the electrical contact. Short circuiting happens due to corrosion. This increases the resistance of components. Therefore intermittent failures occur. Example of the failures due to corrosion is electrochemical migration between anode and cathode.

1.5 Vibration

Due to variations in temperature and vibration the conductive path between power supply board and power converter breaks. This results in spikes in the output of the system. This may damage the entire system if it occurs at initial stages.

2. Cracked solder joints

Generally solder joint crack occurs when heat stress is applied on it. The major causes of cracked joints are cold joints, overheated joints, dry soldering, solder starved joints, and joints with excessive solder materials, formation of solder bridge.

Now a days, lead free solder are also used for environment protection as lead is hazardous. But this may cause cracks if not used appropriately. The major reasons of such kind of soldering errors are manual errors. Soldering always needs skill, application of sufficiently heated soldering metal to the exact spot and the application of flux. Such kinds of cracked joints can cause open or short circuiting resulting in intermittent or permanent failures. Such type of errors can be easily handled.

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III. FMMEA (FAILURE MODE, MECHANISMS, AND EFFECTS ANALYSIS) METHODOLOGY

Refer fig. 1. It defines the process followed in FMMEA (failure mode, mechanisms, and effects analysis). FMMEA is physics-of-failure (PoF) based methodology for assessing the root cause failure mechanisms of a given product. FMMEA prioritizes the failure mechanisms based on their occurrence and severity in order to provide guidelines for determining the major parameters that must either be at least accounted for in the design or controlled.

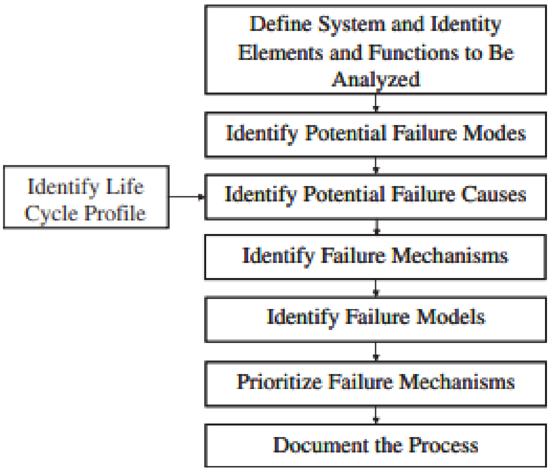

Fig.1: Flowchart of FMMEA methodology

FMMEA is the effective tool for life cycle management of products and devices. It is used to analyze the degradation tendency and failure mode, mechanism and effects in the lifecycle of the product. FMMEA has resulted in effective tool for monitoring and management of products like medical equipment, LED backlight systems etc. This method is used to detect failures in permanent as well as intermittent failures. Fig. 1 illustrates stepwise procedure followed in FMMEA. First step is design system, identify elements and functions to be analysed.

Defining the system having failure is bit difficult as intermittent faults occur for temporary duration. Even the failure of one subsystem can affect the functionality of other subsystem. Hence in system where multiple subsystems are working together, it is tedious and critical job. Typically intermittent faults are recognised as NFF (No faults found). But exact identification of elements and functions needs some specially designed methods. Kirkland [4] suggests a variety of methods to detect intermittent failures in electronic devices, including signal looping, pattern looping, signal stepping, frequency deviation, pattern adjustment in critical areas, signal strength variation, current path duplication, measuring capacitance variations, V_{cc} adjustments, resistive or impedance rebounce, temperature change application, and noise dissimilarity testing. The examples of intermittent failures could be increased gate delays, degraded signals, increased leakage, and failing at high frequencies. For these usual occurring failure modes, a minimum set of conditions (like voltage drop threshold) needs to be set up to make the failure mode observable within a reasonable amount of time. It allows us to take preventive actions.

One more method for analysing intermittent faults is cause and effect diagram. It is also known as fishbone diagram. Example of this diagram is as shown in fig. 2. Several types of intermittent hardware failures of electronic assemblies are investigated, and their characteristics and mechanisms are explored. The case of the one solder joint intermittent failure case is shown in fig. 2[5]. It is one of the good methods to analyse the intermittent faults.

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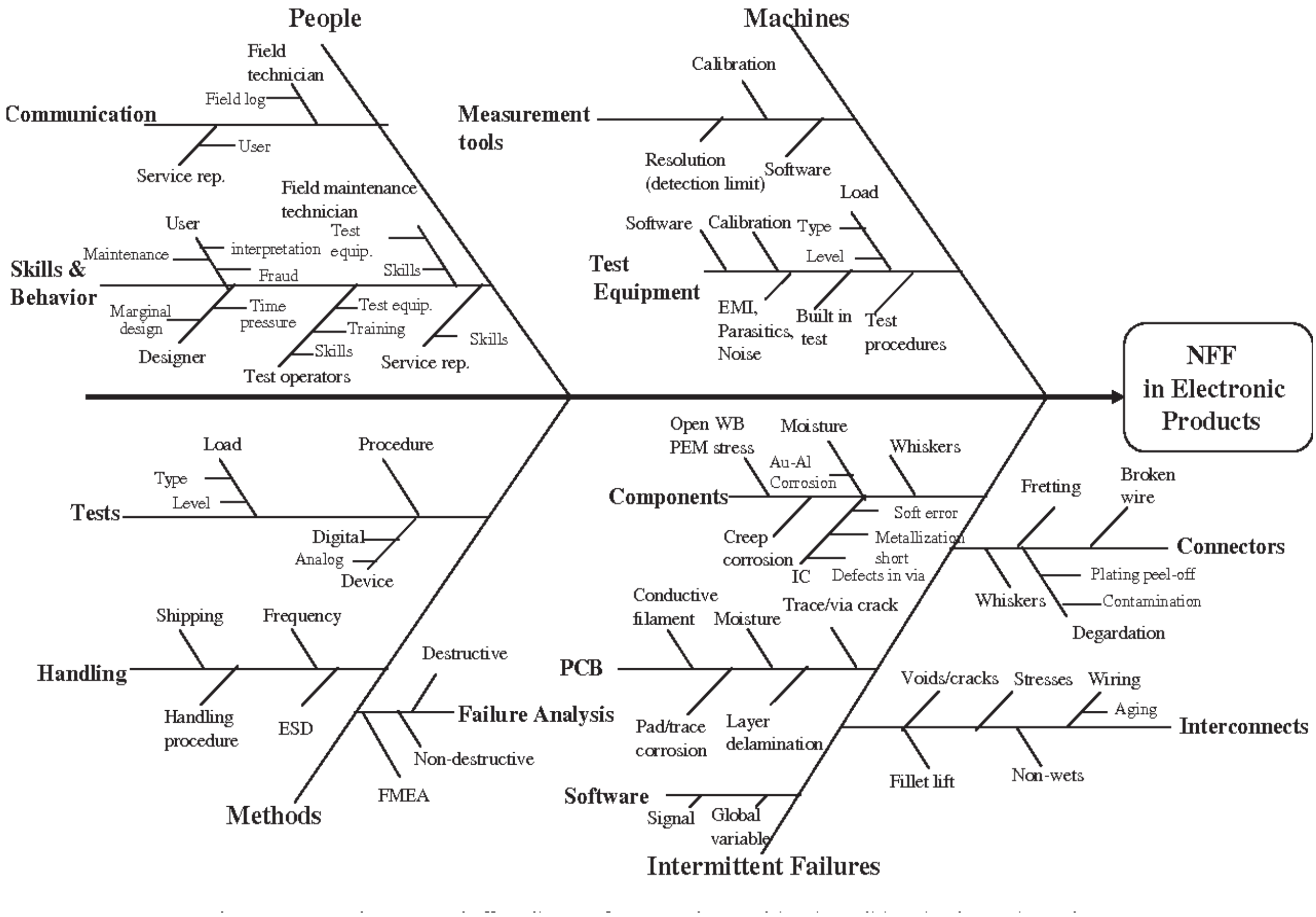

Fig 2: fishbone diagram for NFF in electronic faults[5]

Similarly in literature many models are found regarding the investigation of intermittent faults.

The potential failure is the way in which the failure can occur. It may consist of the manner in which the item fails to perform as expected or it performs the functions but does not meet its goals. Failure modes are closely related to the functional and performance requirements of the product. Failure cause is defined as the process that initiates the failure and can help to identify the failure mechanism driving the failure mode. Failure mechanisms are the processes by which a specific combination of physical, electrical, chemical, and mechanical stresses induces failures. Failure effect is the effect that the failure has on the entire product or system. [6].

IV. TESTING MEASURES FOR INTERMITTENT FAULTS

There are many test measures available for detection of intermittent failures. Few of them which are widely used are as explained below.

4.1. The use of Pico-scope

Intermittent faults created by normal wear and tress may get worsen with time. They can convert temporary failure into permanent failure. The Pico-scope is the PC based oscilloscope. It can be used for testing intermittent faults. It has three modes of operation namely scope, persistence and spectrum mode. Through persistence mode, intermittent fault data is collected and diagnosed [1]. Fig. 3 shows the experimental setup for Picoscope.

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Fig.3: Experimental setup for use of Picoscope

4.2. Reflectrometry

Reflectrometry methods are divided into Time Domain Reflectrometry (TDR), Frequency Domain Reflectrometry (FDR), Sequence Time domain Reflectrometry (STDR), Spread Spectrum Time Domain Reflectrometry (SSTDR), Joint Time Domain Reflectrometry (JTDR) and Noise Domain Reflectrometry (NDR). Among these methods, NDR, STDR, SSTDR, and JTFDR are capable for online diagnosis. preservation [9].

4.2.1. Time Domain Reflectometry

Time Domain Reflectometry (TDR) is an electronic instrument to diagnose faults in electrical conductors. TDRs transmit a short duration pulse into the circuit which is reflected if there is any damage within the connection or wiring. The reflected signal is generated due to an impedance mismatch; if no change in impedance is encountered then the injected signal will be absorbed in far end. Fig. 3 shows the basic operation of TDR.

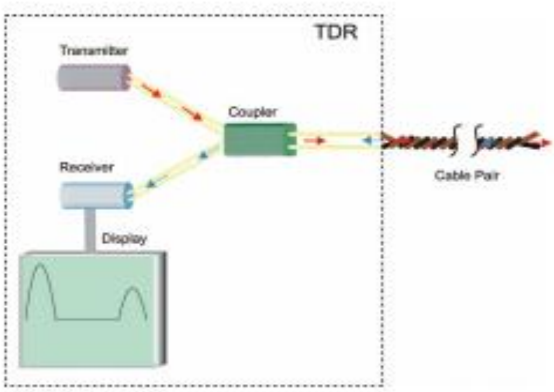

Fig. 3: Basic operation of time domain Reflectometry

Two side by side conductor separated by an insulator has characteristic impedance between them. If distance change then characteristic impedance changes. It has direct relationship. TDR makes use of simple transmission line principles

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and pulse reflection principles. The TDR transmits high frequency electrical pulses that travel through the cable until a change in characteristic impedance is encountered. Depending on the nature of the impedance change either all or part of the transmitted pulse will reflect back to the TDR. The change in the characteristic impedance can be positive or negative. Positive change indicates increase in the characteristic impedance and negative one shows decrement.

Reflectometry methods show good results in cable fault diagnosis but they are contact techniques that require a detection device connected to the test cable for sending an incident signal and receiving the reflected signal. To deploy these contact cable diagnosis approaches, the existing cable system needs to be disconnected to enable the connection of detection device. This would greatly increase the complexity and cost of deployment and maintenance. To address the limitations of contact approaches, it is desirable to develop non-intrusive cable fault diagnostic approaches. Non-intrusive means to not puncture or remove the protective conducting sheath surrounding the cable, which is ideal from the perspective of safety and infrastructural.[9]

4.3. The direct testing solution

Universal Synaptics has developed and patented the direct testing solution named as IFD-2000[8] (Intermittent fault detector). It uses a super sensitive, electronic, bio-sensing neural network to monitor each and every circuit simultaneously.It is the mixture of analog and digital technology. It has the ability to monitor thousands of test line continuously and simultaneously. As it has no limiting test rates, almost all the intermittent faults are tracked. IFD 2000 is the computer based analyser which contains massively parallel analog hardware neural network to perform real time data reduction. It makes use of sensor fusion techniques. Digital circuitry is used for high speed latching of events and for computer interfacing. The single unit of **IFD-2000** is able to monitor 256 single ended lines or 512 double ended connections simultaneously. The major functions performed by this device are ***intermittentfault detection*** and ***signature analysis***.

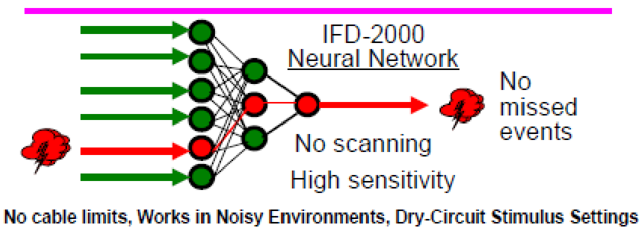

Fig. 4 IFD 2000 working scenario

This function is used by randomly occurring real time faults. There are two selectable modes namely automatic and program. In automatic mode heuristic reasoned is used to monitor the test progress and adjust the stimuli and sensitivity levels accordingly. In program mode these values are set by operator.

4.4 Carrier signal approach for intermittent fault detection

Some carrier signal is continuously populated to the system under test (typically wire). Thus it gets affected by the intermittent failures if any. The distortions in the output of the signal indicate presence of the faults. The difference between the obtained and expected results shows the status of the wire. For this purpose simple modulation scheme like FSk will also be suitable according to Charles Kim [7] as per his paper on intermittent faults. Practically this approach can be used in two ways. The first one is single transmitter and single receiver configuration (STSR). In the STSR, the detection and location of the fault are the same when a fault is detected; the location is the dedicated circuit itself. Second way is multiple transmitters and a single receiver (MTSR) configuration. It can be applied to the circuit which branches into many sub circuits. In this configuration, each transmitter is installed at the end of a sub circuit where load is installed, and the receiver is positioned at the end of the main circuit so that the receiver can receive
data streams from all transmitters. Well configured protocol and transmitter identification, and collision avoidance and arbitration enable this configuration possible.

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V. CONCLUSION

The paper describes the causes and testing measures available in the literature. It has been seen that interconnects suffer more than other components for intermittent faults in electrical / electronic circuits. The FMMEA methodology provides the systematic and complete approach to reach towards the failure part. There are various tools available for detection of intermittent faults. The tools available for detection of intermittent faults are described. After the overall literature survey in this domain it can be concluded that IFD 2000 developed by Universal Synaptics is the most promising tool to detect the intermittent faults.

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