Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 22 (2014) 71 – 75
www.elsevier.com/locate/procedia

3rd International Conference on Through-life Engineering Services

# Study on Intermittent Faults and Electrical Continuity

Wakil Syed Ahmad[a], Suresh Perinpanayagam[b,*], Ian Jennions[b], Samir Khan[a]

[a] EPSRC Centre for Innovative Manufacturing in Through-life Engineering Services, Cranfield University, MK 43 0AL, UK
[b] Integrated Vehicle Health Management Centre, Cranfield University, MK43 0QF, UK

* Corresponding author. Tel.: +44 (0) 1234 75 0111 x2356;. E-mail address: suresh.nayagam@cranfield.ac.uk

**Abstract**

Intermittent faults in electrical/electronic interconnections are recognised as one of the major sources of No Fault Found (NFF) events. These can be caused due to surface corrosion (e.g. oxidation of pins or fretting wear), bent pins, debris within the female connector, or incorrect installation during initial manufacture and assembly. Unless such issues are narrowed down to a specific root cause, any corrective actions or troubleshooting will be difficult to carry out, and hence its resolution may not make its way into future designs of the system. This leads to further susceptibility to NFF. Intermittent behaviour is often a clear sign of a partially damaged connector, or a connector undergoing a particular degradation mechanism, with the level of intermittency being further aggravated through process variation of harsh environments and parametric faults. In order to further our understanding of the relationship between degradation, operating conditions, intermittent behaviour within the subject, an experimental investigations have been carried out.

This paper is a work in progress paper that illustrates a test regime that has been used to stimulate intermittence in electronic connectors whilst subjected to vibration, using both a traditional oscilloscope and bespoke intermittent fault detection equipment, in order to capture an intermittent signature. The results of these experiments provide an insight into the limitations of test equipment and requirements for future intermittent fault detection techniques.


Peer-review under responsibility of the Programme Chair of the 3rd InternationalThrough-life Engineering Conference

*Keywords:* Intermittent Faults; No Fault Found; Testability; Fault Diagnosis; Test Equipment

## 1 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. Intermittent faults are a growing problem in electronics equipment (especially for aircraft and other vehicle industry) due to thermal, vibration, moisture and other stresses. A variety of intermittent fault causes include:

- Loose or corroded wire
- Cracked solder joint
- Corroded connector contact
- Loose crimp connection
- Hairline crack in a printed circuit.
- Broken wire
- Unsoldered joint

Repairing an intermittent fault may not be difficult but challenging to troubleshoot and it increases the maintenance cost of the product. Further to the literature study, correspondence with industrial partners showed that wire harnesses and connectors are the main issues for intermittence. Often the solution to the problem is to employ maintenance tools which are specially designed to detect them. There is a need to monitor all electrical paths with the capability to capture very short duration discontinuity.


Peer-review under responsibility of the Programme Chair of the 3rd InternationalThrough-life Engineering Conference
doi:10.1016/j.procir.2014.07.015

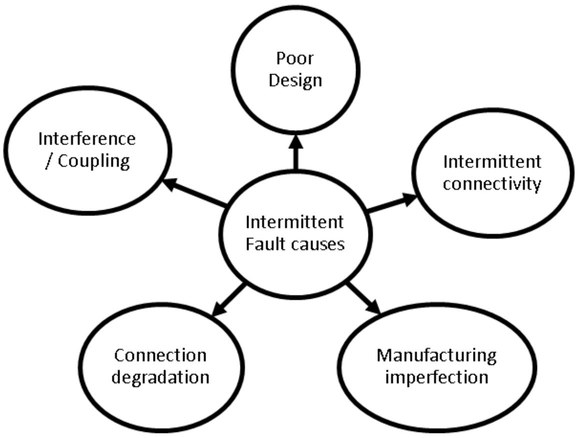



Figure 1. Major causes of intermittent faults in electronic circuits

## 2 Intermittent Fault Causes and Classification

The key issue with all intermittent faults is that if the fault is not present at the time of testing, then it will be impossible to isolate. Even though root cause of fault may be difficult to find some common causes of intermittent faults can be analysed from past experience (Kirkland, 2011) as show in Figure 1. With any product, be it mechanical, electrical or a combination of both, there is always the potential for faults that may only manifest themselves in a service environment. Despite attempts to contain these early life failures using a combination of thermal and vibration screening during manufacture, the potential for intermittent faults remains. Intermittent faults, within a product can often be characterised by the repeated removal of a particular product for the same symptom, each rejection resulting in a NFF classification following workshop test. The different types of intermittent faults causes have been portioned according to three main disciplines components, design, and connectivity.

Majority of intermittent faults within electronic systems are caused by interconnections, component, and marginal design (H. Qi, 2008). The different causes of intermittent faults are illustrated in the figure 1. Fault in any of these can manifest themselves as intermittent failure at the product level. Wiring and interconnect systems have become a major area of research and development from aerospace to defence equipment (B.G. Moffat, 2008). The amount of wiring has tremendously increased in modern vehicles because of onboard electronic /electrical devices.

The two basic problems that can occur in wires / wire harnesses are open and shorts circuits. Intermittent are usually caused by some mechanical change like temperature, vibration, moisture and physical stress that temporarily changes the electrical characteristics of device under test.

H.Qi et al in their research of intermittent failure in electronics product has illustrated that 80% of intermittent faults are due to loose / contaminated inter-connections.

Connectors and wire harnesses subject to harsh environments may experience vibration resulting in fretting corrosion and degradation in contact resistance over time. Connector degradation causes intermittent failure due to impedance mismatch.

Many authors have taken investigation into intermittent faults. Abbort et al. and Murrell et al. detect intermittent behaviour using counters and Hubner et-al. measure the contact resistance during intermittent fault behaviour. P.Lall et-al. has investigated connectors for automobiles subject to vibration. F.Loete et-al has done experiment to detect the degradation in the connectors. A.E. Ginart et-al. has presented on-line methodology for detecting intermittent disconnection failures. Y.Lei with Y.Yuan and J. Zhao have used model base approach to monitor the CAN bus for intermittent connections.

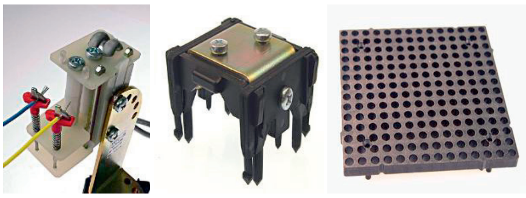
Abbott et-al. (Abbott & K.Schreiber, 1981) (Abbott, March 1984) defines a contact voltage-drop of threshold between 0.2V to 0.5V as intermittent fault. Murrel et-al (S.R. Murrell, 1997) used a 10 mA constant current source with an open circuit voltage of 1V and defined the intermittence as any event exceeding a contact resistance of 10 Ω. The classical contact theory has been applied by Skinner to evaluate several possible short duration intermittent failures in open or high resistance caused by mechanical motion (Skinner, 1975 current version 2003). A. Lee has described that fretting corrosion increases the contact resistance and this cause earlier and more frequent discontinuities (A.Lee, 1987). Fretting is a major cause of contact deterioration and failure and is a main cause of intermittence or short duration discontinuities (C. Maul, 2001).

Connector's degradation causes electrical failure during or prior to vehicle operation, P.Lall et-al simulated connector's degradation in vibration test profile and used in-situ resistance spectroscopy (P.Lall & R.Lowe, 2012 ). Y.Lei et al have presented model base intermittent connection detection for Controller Area Network (CAN), he used maximum likelihood estimation based model for intermittent events (Y.Lei, 2013). F.Loete et al have used frequency domain reflectrometry for connector's degradation monitor (F.Loete, 2012). They also described other literature for wire harness and connector degradation. They have simulated degradation monitor with DC contact resistance and impedance spectrometry at 1MHz.

## 3 Experimental Setup

A test rig which repeatedly produces intermittence under vibration has been made of wire and spring connector. The oscilloscope, Pico-scope (PC based oscilloscope) and Copernicus's N-Compass equipment are used to capture the intermittence. In this initial investigation one wire and one connector has been used but this could be extended to multi test points.

Experimental setup details: A spring hook is used to hold the wire in such a way that the wire connection can be vibrated under the external vibration as shown in Figure 2a. All the components of connector kit that includes the assembly to attach on the shaker are shown in Figure 2b and 2c.



a) Hook assembly b) Bracket c) Grid tile

Figure 1 Components of intermittent fault generator

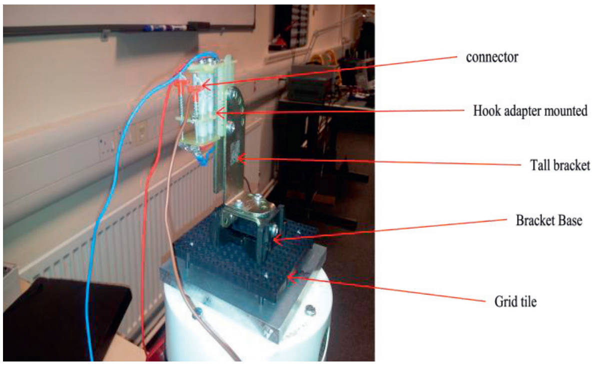



Figure 2. Intermittent demonstrator/generator

The connector assembly is attached to the bracket (Figure 2b) and is locked into grid tile (Figure 2c). The grid is attached to the shaker to apply variable vibrations on spring connector for analysis as shown in Figure 3. The full setup, with shaker, spring connector circuit and N-compass intermittent diagnosing equipment, is show in Figure 4.


Figure 3. Experimental setup to monitor intermittence using n-compass

## 4 Results

### *4.1 Oscilloscope*

A digital oscilloscope of 4 G bits/S sampling frequency with 200 M Hz bandwidth has been used to monitor the intermittent transients for this experiment. The connector is given a 20 Hz vibrations stress by feeding the pulse from the signal generator to shaker amplifier. First we have done measurement by using an oscilloscope as shown in Figure 4.

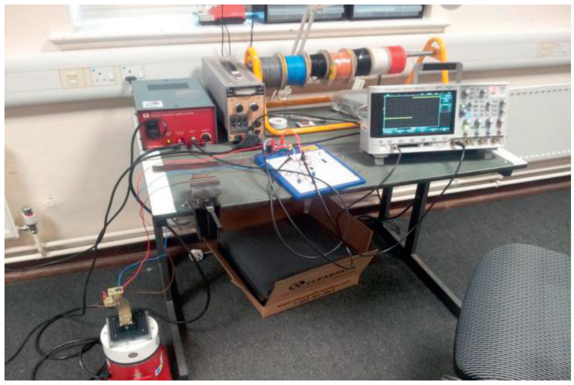


Figure 4. Experimental setup to monitor intermittence using oscilloscope

A 20 Hz and 2 volts peak to peak square pulse has been applied as stimulus to the circuit and its output is observed as shown in Figure 6. The oscilloscope fails to capture the intermittency despite little spikes that could be due to noise.

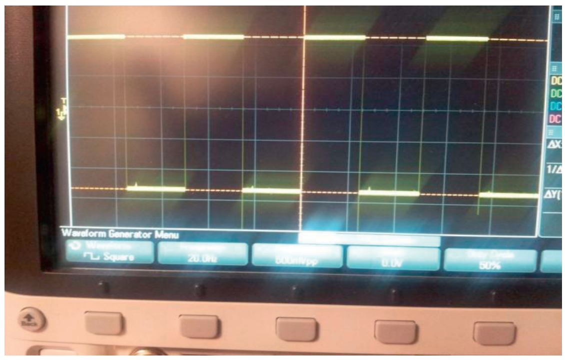



Figure 5. Oscilloscope to monitor intermittence

### *4.2 N-Compass*

Universal Synaptic equipment is specially designed to capture electronic intermittent faults in electronic circuits and it is called N-Compass. N-Compass has the ability to monitor 256 channels simultaneously when circuit is not in operation.

It can capture nano second transients and latch them as intermittent fault. It has a variable threshold to set the trigger points for intermittent transients of intermittence triggers.

We have only used one point for this experiment to demonstrate single connection intermittence.

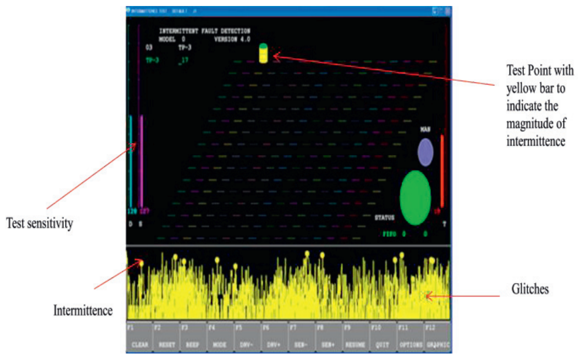



Figure 6. N-Compass displaying intermittence in the circuit

The complete circuit for this experiment can be seen in the Figure 4. The vibrating connector's circuit is connected to the N-compass through interface card and pin configuration is defined in the N-Compass software.

The repeatedly intermittency with yellow glitches / noisy signals with dotted heads can be seen in Figure 7. The yellow dotted heads on some spikes indicates the intermittency in the circuit. The horizontal dotted lines indicate the all possible test points in Figure 7 of N-compass display. The only used single test point that can be seen on first top horizontal row at third place from left with green cap with yellow small bar that indicates the magnitude of intermittency at that test point. The vertical bars on either side indicate the sensitivity level for intermittency. The yellow intermittent signals in the display of Figure 7 are not linear but are all latched transition displayed without time scale.

### *4.3 Picoscope*

The picoscope is a PC base oscilloscope/ spectrum analyser. It has three modes of operation called scope, persistence and spectrum mode. Persistence mode is very useful for getting intermittent fault data. In this mode it displays the less dense and more frequent data in different colours. The software display of picoscope in persistence mode is shown in Figure 8. Blue transient data shows the less frequent/dense data where as red colour indicates the dense and more frequent data.

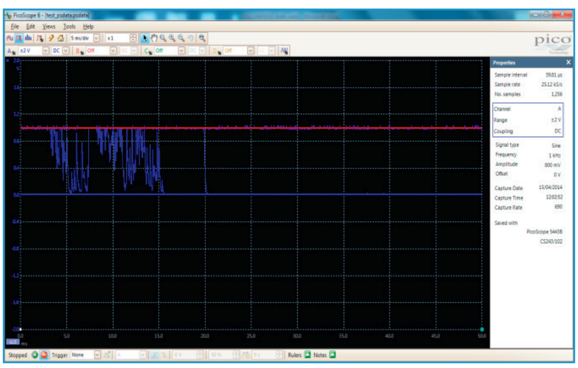


Figure 7. Picoscope persistence mode

Figure 8 shows the persistence mode using various colour-coding or shading to distinguish frequent and infrequent data. One can arrange for previously used data to fade away after a specified time or to remain on the display until you erase it. Persistence mode has two advantages: it allows the scope to capture waveforms faster than it can update the display, and it makes it easier to spot transient / intermittent events.

The red colour indicates the densest areas of data where the majority of the waveforms are located. The coolest colours i.e. blue indicate transient events such as glitches and jitter.

The capture rate depends on the scope settings but is usually many thousands of waveforms per second. The display rate is typically 10 to 20 updates per second in this mode, although this is of little importance because each waveform persists for a long time on the display. In fact, with the persistence time set to infinity, you can leave picoscope running overnight and still be sure of catching glitches.


Figure 8. Persistence display mode

Persistence mode has allowed us to see transient data, that was practically invisible in real-time mode, and gives us a qualitative display of its rate of recurrence as shown in the Figure 8.

## 5 Conclusions

The first two sections described the root causes and their classification of intermittent faults. It has been seen that interconnects suffer more than other components for intermittent faults in electrical / electronic circuits.

Third section described the experimental setup to capture an intermittent fault using traditional and special equipment. Then results are presented that shows the traditional equipment like oscilloscope is not able to capture intermittent transients. To capture glitches and nano second transient/intermittent events we used latching continuity neural network based Copernicus N-compass and deep memory scope like pico-scope in persistence mode where it display less and more frequent data in different colours.

It is clear from this paper that there is a need to develop better equipment to capture intermittent and transient faults as n-compass and pico-scope are not able to display in frequency and other modes to predict system health or degradation. These also not allow us to download intermittent data for further investigation.

## 6 References


[1] A.Lee, e. a. (1987). Fretting Corrosion of Tin-Plated Copper Alloy. IEEE Trans. on Components,Hybrids, and Manufacturing Technology.

[2] Abbott, W. (March 1984). Time Distribution of Intermittents Versus Contact Resistance for Tin-Tin Connector Interfaces During Low Amplitude Motion. IEEE Trans. Comp., Hybrids, Manufact. Technol., (pp. 107-111).

[3] Abbott, W., & K.Schreiber. (1981). Dynamic Contact Resistance of Gold Tin and Palladium Connector Interfaces During Low Amplitude Motion. Proc. Holm Conf. on Electrical Contacts.

[4] B.G. Moffat, E. A.-a. (2008). Failure Mechanisms of Legacy Aircraft Wiring and Interconnects. Dielectrrics and Electrical Insulation; IEEE Transactions , 15, 808-822.

[5] C. Maul, J. a. (2001). Intermittent Phenomena in Electrical Connectors. IEEE Transaction on Component and Packing Technologies , 24 (3), 370-377.

[6] F.Loete, C. (2012). Diagnostic of Connector's degradation level by Frequency Domain Reflectometry. Electrical Contacts (Holm), IEEE 58th Holm Conference on , (pp. 1-4). Portland, OR .

[7] H. Qi, S. G. (2008). No-Fault Found and Intermittent Failures in Electronic Products.

[8] Kirkland, L. (2011). When should intermittent failure detection routines be part of the legacy re-host TPS? . Baltimore, MD : Autotestcon, IEEE.

[9] P.Lall, P., & R.Lowe, K. G. (2012 ). Leading Indicators for Prognostic Health Management of Electrical Connectors Subjected to Random Vibration. Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), 2012 13th IEEE Intersociety Conference on , (pp. 632-638). San Diego, CA .

[10] S. Hannel, S. P. (2001). The Fretty Sliding Transition as a Criterion for Electrical Contact Performance. Wear , 49, 761-770.

[11] S.R. Murrell, S. (1997). Intermittence Detection in Fretting Corrosion Studies of Electrical Contacts. Electrical Contacts, 1997., Proceedings of the Forty-Third IEEE Holm Conference on , (pp. 1-6). Philadelphia, PA, USA .

[12] Skinner, D. (1975 current version 2003). Intermittent Opens in Electrical Contacts Caused by Mechanically Induced Contact Motion. Parts, Hybrids, and Packaging, IEEE Transactions on , 11 (1), 72-76.

[13] Y.Lei, Y. J. (2013). Model Base Detection and Monitoring of the Intermittent Connections for CAN Network. Industrial Electronics, IEEE Transactions on (99).

# Study on intermittent faults and electrical continuity

Ahmada, Wakil Syed

2014-10-31



Wakil Syed Ahmad, Suresh Perinpanayagam, Ian Jennions, Samir Khan, Study on intermittent faults and electrical continuity. 3rd International Conference in Through-life Engineering Services, 4-5 November 2013, Cranfield, UK. Procedia CIRP, Volume 22, 2014, Pages 71-75

http://dx.doi.org/10.1016/j.procir.2014.07.015