

# **ADVANCING ATE SYSTEMS WITH PXI BASED POWER-OFF DIAGNOSTIC INSTRUMENT TECHNOLOGY**

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**Abstract - Typical military and aerospace power-on parametric or functional CCA tests reduce a failure to a cluster or ambiguity group of components. Adding PXI based power-off diagnostics validates detection and isolation of faulty components beyond the detailed parametric or functional testing and fault isolation of the test. Replacing the diagnostics portion of the test with power-off diagnostics allows reduced development time, enhanced fault isolation, while allowing the existing test to perform "Ready for Issue" verification. These existing tests assume that the defective Unit Under Test (UUT) can accept power. If the UUT can not accept power, the PXI based power-off diagnostics allows diagnosis of those UUTs. Automating probing during the diagnostics increases productivity and accuracy. This COTS PXI based approach maximizes the diagnostic capability while lowering ambiguity levels for component level faults as well as decrease the total cost of test development.**

## **INTRODUCTION**

Adding PCI eXtension for Instrumentation (PXI) based power-off diagnostics validates detection and isolation of faulty components on Circuit Card Assemblies (CCAs) beyond the detailed power-on parametric or functional testing and fault isolation of the test parametric testing and fault isolation of the functional test. The detailed diagnostic portion of the power-on test, should be either supplemented or replaced with Power-off Diagnostics to achieve better fault isolation and reduce costs This allows the power-on test to provide Go / No-Go and Ready For Issue (RFI) testing capabilities that it was designed to do.

## **SIGNATURE ANALYSIS**

PXI based power-off diagnostics is a troubleshooting technique that applies a sine wave stimulus to a component creating a voltage vs. current signature. The signature is displayed on a computer monitor for analysis. This technique allows a trained technician to locate damaged and marginal components. All signatures are made up of four basic components; resistance (any value from an open to a short), capacitance, inductance, and semi-conductance. Understanding the basic signatures simplifies the analysis of composite signatures. Voltage is displayed horizontally and current is displayed vertically.

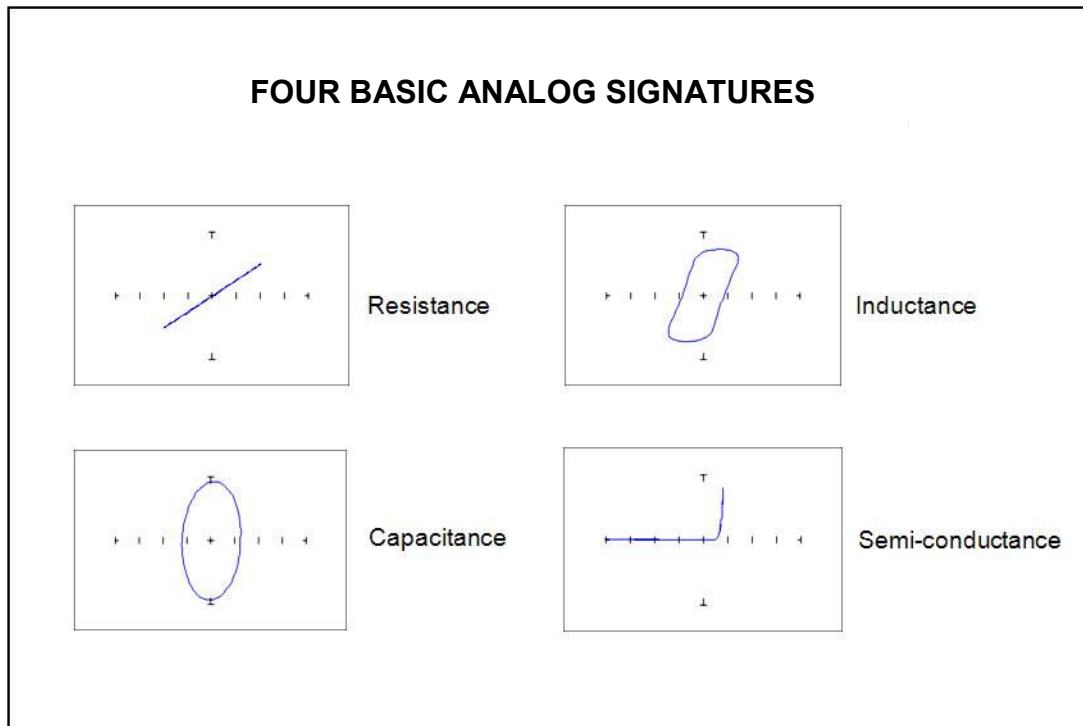


Figure 1. Typical Analog Signatures

An open circuit draws no current so it is represented by a horizontal line. A short circuit draws maximum current so it is displayed as a vertical line. Resistors have a constant voltage/current ratio causing a linear diagonal signature with the angle of slope being directly proportional to the resistance value. Capacitors and inductors cause a phase shift between voltage and current producing a circle or elliptical signature directly proportional to the amount of capacitance or inductance. Diodes, the simplest semi-conductive device, allow current to flow in one direction and not the other. These signatures are displayed by a horizontal line that goes vertical just after the center axis of the display.

Complex or composite signatures are combinations of the four basic signatures. Integrated circuits are made up of transistors (which are a combination of diodes), resistors, and capacitors. The signatures displayed by ICs are composite signatures. These devices have built-in protection circuits which allow current to flow in both directions displaying a signature that is vertical in the bottom half, then horizontal, then vertical in the top half. These signatures are typically called "chair patterns". Common zener diodes will display a chair pattern that has a vertical break-over point at .6 volts (the conducting voltage of a silicon device) and a second break-over point at the rated voltage for the zener diode. Variations of this signature found in integrated circuits (ICs) are due to resistive and capacitive elements. CMOS integrated circuits are built with capacitors causing their signatures to display a loop in the "back" of the chair pattern.

Leakage current is indicated by curvature of the linear portions and the rounding of corners in the diode or chair pattern. Gaps in the signature indicate that the current path is being interrupted. Resistive (diagonal) portions of a signature not found in a good device indicate damage to the component. Capacitive signatures that flutter, vary in size, and change shape indicate a possible problem in the dielectric.

Integrated circuits of the same type (e.g. 7404) but differing in manufacturer can display slight differences because of the various ways in which the components are constructed. This is a normal condition and should not be confused with a device failure. PXI based power-off diagnostics employ software based

multiple signature storage and merge features that can compensate for this by allowing the computer to store several serialized signature sets to compare against.

The final decision of determining the failed components is performed by test personnel trained to interpret signature differences. This training can be accomplished in a couple of days.

## **INTRODUCTION TO PXI**

PXI (PCI eXtension for Instrumentation) has been developed and introduced by National Instruments in 1997/98. Today the PXI System Alliance, a group of now more than 60 companies, is the governing body over the PXI specification [2].

PXI is based on the Compact PCI (cPCI) specification [3], defined in the mid 1990s. Both feature the same electrical characteristics as PCI, with a throughput of 132Mbyte/sec (up to 256Mbyte/sec at 66MHz).

PXI is a high-performance, low-cost platform for test & measurement and automation systems. Manufacturing Test (e.g. Aerospace, Automotive, Military, Telecom, and Consumer Electronics), Industrial Test and Automation are the main applications for PXI today.[1]

PCI eXtensions for Instrumentation (PXI) is the open, multi-vendor standard for measurement and automation that delivers more than 10 times the performance of older measurement and automation architectures. With PXI, you automatically benefit from the low cost, ease of use, modularity, and flexibility of PC technology.[4]

PXI provides a robust industry standard platform for the implementation of Power-off Diagnostics. The compact size and wide variety of test equipment cards allow Power-off Diagnostics to be combined with other test instruments used for RFI testing.

## **REDUCING AMBIGUITY GROUPS**

Typical military and aerospace power-on Circuit Card Assembly (CCA) tests reduce a failure to a cluster or ambiguity group of components. Adding PXI based power-off diagnostics using Signature Analysis (SA) validates detection and isolation of faulty components beyond the detailed power-on parametric or functional testing and fault isolation. This allows the technician to evaluate the health of each component in that cluster, preventing unnecessary removal of healthy components.

Lockheed Martin Information Systems has performed a study to extend the Consolidated Automated Support System (CASS) Test Program Sets (TPS) fault isolation capabilities using Power-off Diagnostics for the purpose of evaluating the addition of a CASS Diagnostic Asset to the CASS production baseline. This study included a capabilities demonstration, a cost/benefit analysis, and an evaluation of alternate implementations of testing Shop Replaceable Assemblies (SRAs).

Legacy TPSs are often limited in their ability to isolate faults at the SRA level. Depending on the TPS, it may only be possible to isolate faults to groups of components, or even groups of SRAs. Fault isolation capability can also be restricted by the TPS, which can be incomplete or outdated through SRA revisions.[6]

As part of the CASS modernization effort there is a need to support third party SRA (Shop Replaceable Assembly) node level diagnostic assets presently used by the Navy. Through integration of these assets, overall test efficiency, and CASS functionality can be enhanced. A single TPS processor can be used to interactively test a WRA (Weapons Replaceable Assembly) down to the SRA component level. SRA fault ambiguity groups identified using present TPSs and fixtures can be further diminished using SRA node level test assets.[6]

The Dry Run, Demonstration and follow up SA diagnostics show that when using a signature database that is built on a single board revision, SA is a tool that will reliably detect faults. Some analysis of signatures is required to fully use the SA capabilities.[6]

Multiple revisions of the same SRA/CCA may require different diagnostic procedures. This gets very expensive when developing a traditional TPS, but less expensive with Power-off Diagnostics. A signature database is created for each specific revision of a SRA. The database should contain signatures from at least three known good sample SRAs of the same revision. This is to allow the database to encompass normal component variations.

## REPLACING POWER-ON DIAGNOSTICS

Most TPSs include both RFI and diagnostic testing. It is estimated that over half of the development time is for diagnostics. Replacing the diagnostics portion of the power-on parametric or functional test with power-off diagnostics allows reduced development time, enhanced fault isolation, while allowing the parametric or functional testing to perform "Ready for Issue" verification.

Over the lifecycle of the TPS, the investment in adding guided probe component signature analysis diagnostics as an augmentation to the CASS product will be offset by savings realized through decreased technician test time, decreased repair time, lower repair part inventory costs and lower scrap rates on SRAs due to repair damage incidents. Since an OTPS services several SRAs, the cost advantage of a single SRA implementation is multiplied when all SRAs in the TPSs are serviced similarly with the CASS station common guided probe component signature analysis tools. Further cost benefits will be realized as additional TPSs employ the tools common to a CASS station or a CASS station installation that has been modified to process with Component Signature Analysis.[6]

The Navy Module Test and Repair (MTR) Program develops and provides electrical/electronic module test and repair capabilities to organizational (O-level) and intermediate (I-level) maintenance facilities for both ashore and afloat commands. It also serves as the In-Service Engineering Agent (ISEA) for various MTR equipment, develops and provides technical manuals on CD ROM, develops Gold Disks for circuit card assemblies, certifies Gold Disk Developers and developer sites, provides for the maintenance and operation of MTR facilities, provides technical assistance and guidance for all aspects of the MTR Program and is the Gold Disk Verification Agent for all DOD activities.

The Gold Disk MTR program uses Power-off Diagnostics as the main tool for finding component faults. The September, 2004 MTR report cites that there are 308 work centers. These work centers reported from April 1<sup>st</sup>, 1996 through June 30<sup>th</sup>, 2004 the following activities:[8]

Table 1. MTR Program Results

<b>Activity</b>	<b>Results</b>
Repairs Submitted	95,850
Repairs Started	95,510
Repairs Not Started	330
Repairs In Progress	448
Repairs Closed	84,358
Repairs Cancelled	2,272
Repairs Rejected	8,418
CASREPs averted/corrected	6,171
Tested with no fault evident	13,015
Repairs Documented	36,986
Repair module Cost Avoidance	\$267,131,161.29
Piece part cost	\$3,843,135.51
<b>Net Cost Avoidance</b>	<b>\$263,288,025.78</b>

The cost of development of a TPS for a moderately complex SRA has been estimated at 2000 man hours. Of that, 30% of the hours (600 man hours) are allocated to fault insertion testing, first article test and the development of the test strategy document. Regardless of the test method, these tests and this document are deliverables. Thus the comparable traditional TPS development net cost is 1,400 man hours. The cost of developing a TPS compatible with the component signature analysis strategy is approximately 25% of the traditional TPS development net cost (350 man hours).[6]

## **DIAGNOSING CCAs THAT CANNOT EXCEPT POWER**

These power-on tests assume that the defective Unit Under Test (UUT) can accept power. If the UUT can not accept power, the PXI based power-off diagnostics allows diagnosis of those UUTs.

In repair situations it is often necessary to test the board without power applied due to uncertainty as to the nature of the failure. When this condition occurs it is necessary to use nondestructive test equipment to safely examine component signatures and validate good from bad. Safely testing a board in this mode will result in a higher rate of repair and faster turn around for customers in the field.

## **LIMITATIONS**

PXI based power-off diagnostics do not perform "Ready For Issue" (RFI) testing. They simply help determine which components to replace before RFI tests are performed.

This power-off technique cannot see inside of an IC. It looks at the quality of the IC pin circuits. Most IC failures are caused by an external event that damages these internal circuits.

PXI based power-off diagnostics is not a go / no-go test. No measurements are made. Signatures are generated that can be compared with software and ultimately human interpretation determines which components to replace.

## **AUTOMATING GUIDED PROBING**

Automating probing during the diagnostics increases productivity and accuracy.

Manual probing of circuit cards is inherently error prone and can result in erroneous identification of components, as faulty. As a result, retest is required and test station throughput is reduced.[7]

Robotic Probing provided at least 10:1 improvement in probing time over manual probing. In addition, it eliminated the need for documentation to locate probe points and it reliably made contact without error. [7]

When probing is required during power-on or power-off tests adding robotics allows probing of points on fine pitch ICs and other components without expensive fixtures.

## **SAMPLE PXI SYSTEM WITH POWER-OFF DIAGNOSTICS**

In a sample PXI based ATE system described below, Power-off Diagnostics augments the functional test capabilities with diagnostic testing. Its capabilities are further enhanced with automated guided probing.

For discussion purposes, the ATE system shall include a Power-off Diagnostics card, frame grabber, boundary scan controller, relay matrix, oscilloscope, Digital Multi-meter (DMM), Arbitrary waveform Generator (ARB), Power Supply, Spectrum Analyzer and Digital IO card. All of these cards are implemented into an 18 slot rack with an embedded computer running Microsoft Windows XP and National Instruments LabView. An automated probing station is connected to the frame grabber, Power-off Diagnostics card and the embedded computer serial port. The Power-off Diagnostic signature databases are generated and comparison signatures stored using Huntron Workstation Software. The functional test sequence as well as most of the modules used for functional test are controlled by LabView which also manages power-up and power-down sequences.

The Unit-Under-Test (UUT) is a typical CCA with analog and digital circuitry. There are two basic approaches to testing the CCA.

The first is to test the CCA with Power-off Diagnostics, replace faulty components and then use the functional test to perform RFI testing.

The second approach is to use the functional test to reduce the ambiguity group to a number a components and then only test those components with Power-off Diagnostics. Replace the faulty components and then retest with the functional test for RFI certification.

Power-off diagnostics require that the Unit-Under-Test not have voltage present. This means power must be removed from the CCA and the CCA discharged between functional and Power-off Diagnostics.

The functional test modules, such as scopes, DMMs, or ARBs are used to evaluate the CCA at functional speed.

An ATE system of this type can be utilized in prototype verification, manufacturing test and even repair and/or field service.

The automated probe can be disconnected from the Power-off Diagnostic card and connected to the functional test cards. The automated probe can be moved to any X-Y-coordinate on the CCA and make contact with test points or pins throughout the functional test to gain test access and to improve test coverage.

The Camera on the automated probing station can be used to read part numbers, check component placement, evaluate color codes on devices, check illumination of LED's, read LCD displays, etc.

## **CONCLUSIONS**

This COTS PXI based approach maximizes the diagnostic capability while lowering ambiguity levels for component level faults as well as decreasing the total cost of test development. Power-off diagnostics can be used to enhance existing parametric or functional diagnostics or used in place of these diagnostics in new TPS development.

This proposed approach provides significant improvement in the time to develop the component level diagnostics thereby accelerating the delivery of a complete TPS. In addition, the accuracy of the test to the component level would be far greater than is possible today.

Power-off diagnostics are a technically sound and economically competitive approach. When high-performance PXI is not an option, other integration options such as off-line USB, rack mount USB and VXI are available.

## REFERENCES

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