Combining High Performance ICT with PXI Functional.

Michael Smith
Electrical Testing in the Production Line

• Incircuit test (ICT) is the established solution for electrical test because:
  • Ease of programming and use
  • Consistent results
  • Repeatable tests
  • Minimum training required for different products that are being tested.

• Functional test
  • Product and company specific and can also be unique.
  • Product test can be very extensive with multiple test cells
  • High Mix Manufacturing
    • Multiple test cells may only be used for short periods of time.
Development of computer controlled functional test

- General Purpose Instrument Bus (GPIB) or IEEE-488 instruments allowed for integration of instrument into ICT systems but long wire lengths, synchronization issues and slow communications mean this only had limited applications.

- GPIB based instruments are slowly being replaced by LAN eXtensions for Instrumentation (LXI) which resolves some of the issues with GPIB and retain some of the advantages.
Development of computer controlled functional test

- Since 1987 test systems have begun to take advantage of the integrated instruments.
- VME eXtensions for Instrumentation (VXI) bus was developed from the VME standard for Motorola 68000.
- Popular with the Automatic Test Companies:
  - GenRad and Teradyne who both developed testers based on this standard.
- Instruments Cards tend to be expensive:
  - compare to other instrument packages.
- Now seen as an old specification (1979):
  - based on 16(32)bit.
• PCI eXtensions for Instrumentation (PXI)
  • Introduced in 1997
  • Standard PC PCI bus structure.
  • Small size (Compact PCI)
    • 3U (100mm x 160mm) and 6U
  • Lower costs

• PXI has largely replaced VXI in automated test systems *
  • Automated test, particularly for military and aerospace, now relies heavily on PXI.

*Autotestcon September 2011
PXI - Tight Integration into Incircuit Test

- PXI is ideally suited to integrate into the ICT platform.

- Small size boards
- Windows PCI Hardware
- Windows Environment and Drivers
PXI Expansion Card

- PXI instruments cage with support for 4 x 3U PXI instruments.
- Relay matrix for:
  - direct connect
  - buffered (DC and AC)
  - switch connections to the UUT
PXI Expansion Card

• PXI Expansion Card can be fitted into the accessory slot
  • With no loss of system resources
• OR Take the place of 4 Driver Sensor pin cards.
• Two PXI Expansion cards can be fitted into one system.

• Support for a maximum of 8 x 3U PXI instrument cards.
• Boards are connected to the PCI Express controller in a PCI slot in the main system PC to become an extension of the PC.
• Provides direct short wire connection
  • High performance measurements to maintain signal integrity.
  • UUT Direct paths to PXI Expansion Board
    • less than 1.5 dB at 100 MHz*

• High performance switching matrix for distribution to key points on the UUT

• Access to the ICT system main analog bus for connection at any point on the UUT through the existing ICT fixtures bed of nails.

• Access to the IEEE-488 instrument connects on the back of the system
  • BNC to UUT - less than 3 dB at 80 MHz*

* 50 ohm Source and 50 ohm Detector
Tight Integration - Hardware

- The PXI Expansion Board is fully synchronization with both analog and digital subsystems.
- Complex digital vectors - synchronized with analog measurements
- Analogy input signals to the UUT can be read using digital sensors.
Tight Integration - Software

- Use Test Developers preferred solutions
  - National Instruments LabViews/CVI software
  - Microsoft Visual Studio
  - Any other programming language.
- Transportable to the system without having to rewritten!
- Take advantage of “best in class” for each application.
Tight Integration - Software

- Powerful Dynamic Programming Extension feature linked to the tester runtime.
- Tester runtime communicates with custom software applications:
  - Program status
  - Control variables can sent to the functional code
  - Measurement results can be returned to the test system.
PXI Expander Board - Summary

- Compliant with PXI Specification Revision 2.2
- Supports 5V or Universal voltage PXI instruments
- Supports up to four 3U PXI Peripheral Modules per board
- Supports up to two PXI Expansion Boards per tester
  - 8 PXI instruments total
- Board can be plugged into a Accessory slot or Pin Board slots
- Relay switched signals to the UUT with current capacity of 2 Amps
- 100MHz bandwidth signals through Direct Connect signals
  - High signal isolation « -40dB @ 100MHz
TestStation PXI Expander Board – Summary

- Switched and un-switched ground pins
- Four high performance unity gain linear amplifiers
- Direct cable access
  - eight IEEE-488 BNC ports at rear of system
- Connection to ICA
  - Arbitrary Waveform Generator output signal
  - Trigger Digital Multi-meter instrument
- Eight analog channel connections to the system backplane and scanner matrix
- Four maskable trigger pulses are available for synchronization with digital bursts
- Sixteen switched analog I/O lines plus 16 direct analog signal lines available at the receiver interface
- Does not support Star Trigger bus
Advantages of Integrating PXI into ICT

- There are significant cost advantages in the integration of functional test into the ICT test stage in both low and high volume environments.
  - Operator
  - Automatic Board Handling
  - Fixture and tooling
  - Overheads
  - Diagnostic, Repair, Scrap
  - Final Product Quality
Saving Operator Costs

- High mix environments use manual labor rather than automatic handlers for loading and unloading UUT.
  - Therefore the combined test cells will save at least one operator per shift
- ICT operator normally need little additional training when add functional tests.
  - The savings can be major if a separate function test station is required for every board manufactured.
- Reduced test stage also helps with quality!
  - Reducing operator handling helps reduce damage to boards.
Automatic Board Handling

- The high volume manufacturing environment are normally fully automated with handling systems on both ICT systems and any/all functional test systems in the production line.

- Combining functional test into ICT, would save the cost of:-
  - Functional test system
  - Board handler
  - Functional diagnostic loop
Fixture and Tooling

• One Fixture is cheaper than Two
  • less storage space
  • less handling
  • less maintenance than two fixtures combined.

• High volume environment with board handling is better suited for combined ICT, Functional and BScan
  • Better control over the board height for selective access to the UUT.

• Multi-height probing for limited functional/Boundary Scan access can add cost!
  • BUT still less than the fixtures required for both the ICT and Functional test system
Overhead Savings

- Less floor space required.
- Increase system utilization.
- Reduced capital investment.
- Better used of production equipment inventory.
- Reduced overall maintenance costs.
- Reduced calibration requirements.
- Less power required for systems and environmental controls.
- Lower Integration and maintenance costs of factory MES/ERP systems.
Diagnostic, Repair, Scrap and Final Product Quality

- Standard look and feel
  - Reduce costs in diagnosis and repair
- Early defect detection preventing excessive rework.
  - Improved overall quality
- Transfer of the tests from the standalone test system
  - Defect coverage will remain the same
  - Thus quality will not be affected
- Combining ICT and functional into the same system will have a major savings that can be calculate using the standard DPMO model.
DPMO Model - Test Capability

- Assumes inline Image Inspection as well as ICT and Functional test.

<table>
<thead>
<tr>
<th></th>
<th>Imaging</th>
<th>ICT</th>
<th>Functional</th>
<th>System</th>
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</thead>
<tbody>
<tr>
<td>Test Access</td>
<td>99%</td>
<td>90%</td>
<td>70%</td>
<td>80%</td>
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<tr>
<td>Fault Coverage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural</td>
<td>50%</td>
<td>95%</td>
<td>90%</td>
<td>60%</td>
</tr>
<tr>
<td>Electrical</td>
<td>0%</td>
<td>85%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td>Test Coverage</td>
<td>50%</td>
<td>86%</td>
<td>63%</td>
<td>48%</td>
</tr>
<tr>
<td>Structural</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>0%</td>
<td>77%</td>
<td>67%</td>
<td>79%</td>
</tr>
<tr>
<td>Test Coverage</td>
<td>41%</td>
<td>84%</td>
<td>64%</td>
<td>53%</td>
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<tr>
<td>False Fail Rate [ppm]</td>
<td>500</td>
<td>50</td>
<td>5</td>
<td>2</td>
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# DPMO - Assumptions

**Production and process information for product:** High Volume

<table>
<thead>
<tr>
<th>Board Assumptions</th>
<th>High Volume</th>
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<tbody>
<tr>
<td>Number of Solder Joints</td>
<td>4000</td>
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<tr>
<td>Number of Components</td>
<td>1000</td>
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<tr>
<td>Annual Production Volume</td>
<td>250000 [boards/year]</td>
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<tr>
<td>Value of Board If/When Scrapped</td>
<td>200 [$]</td>
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<tr>
<td>Total Opportunities for Error</td>
<td>5000</td>
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<tr>
<td>Board DPMO</td>
<td>370</td>
</tr>
</tbody>
</table>

**Repair Assumptions**

| Repair Yield                                  | 85% [%]     |
| # of Repair Cycles Permitted                  | 5           |
| Scrap Rate                                    | 0.0076%     |

**Defect Rate Assumptions (Process Capability)**

<table>
<thead>
<tr>
<th>Defect Rate Assumptions</th>
<th>High Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical DPMO</td>
<td>250 [ppmC]</td>
</tr>
<tr>
<td>Structural DPMO</td>
<td>400 [ppmJ]</td>
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<tr>
<td># of Structural Defects/Board</td>
<td>1.6</td>
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<tr>
<td># of Electrical Defects/Board</td>
<td>0.25</td>
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</table>
**DPMO - Assumptions**

- Testing with both ICT and separate functional test

<table>
<thead>
<tr>
<th>Debug/Diagnosis and Repair Costs</th>
<th>Imaging</th>
<th>ICT</th>
<th>FT</th>
<th>System</th>
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</thead>
<tbody>
<tr>
<td>Hourly Labor Cost of Verification/Diagnosis</td>
<td>$65</td>
<td>$65</td>
<td>$85</td>
<td>$85</td>
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<tr>
<td>Hourly Labor Cost of Repair</td>
<td>$50</td>
<td>$50</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>Time to Verification /Diagnose One Defect</td>
<td>1</td>
<td>5</td>
<td>60</td>
<td>120</td>
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<tr>
<td>Time to Repair One Defect</td>
<td>15</td>
<td>15</td>
<td>30</td>
<td>60</td>
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<td>Cost to Debug/Diagnose One Defect</td>
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<td>$5.42</td>
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<td>$170.00</td>
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<td>Cost to Repair One Defect</td>
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<td>$25.00</td>
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<td>ReTest Cost</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$1.00</td>
<td>$2.00</td>
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</table>

- Combined ICT and Functional
By combining the two functions into one then the saving at this stage can reduce costs by $2.5M while still keeping the final quality.

In reality the product quality will increase due to reduced handling and early defect detection.
Summary – Advantages of PXI Integration

- Reduced fixture and tooling costs,
- Lower handling costs,
- Reduced development costs,
- Fewer test operators,
- Greater system utilization.
- Cost saving in diagnostics, repair and scrap
- Overall reduction in the cost of test and manufacture with no loss of quality!
References

• More information can be found on the following web sites on the follow topics:-
  • History of GPIB(IEEE-488) - http://zone.ni.com/devzone/cda/tut/p/id/3419
  • VXI - http://www.vxibus.org/
  • PXI - http://www.pxisa.org/
  • LXI - http://www.lxistandard.org/
Definitions

- PCI: Peripheral Component Interconnect
- PXI: PCI eXtensions for Instrumentation
- VME: Versa Module European
- VXI: VME eXtensions for Instrumentation
- LAN: Local Area Network
- LXI: LAN eXtensions for Instrumentation
- ICT: Incircuit Test
- UUT: Unit Under Test
- GPIB: General Purpose Instrument Bus
- IEEE: The Institute of Electrical and Electronics Engineers
- DPMO: Defects per Million Opportunities
Thank you!