Next Generation Test System Architectures for Depot and O-Level Test

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Abstract—For over 30 years, ATE has been a key resource and tool for the maintenance and repair of electronic systems, subsystems and board level assemblies deployed on a wide range of military-aerospace systems. ATE has been relied upon to maintain and support electronic assemblies for avionics, weapons systems, and communication systems. In addition, repair logistics and the “up-time” demands for these systems have resulted in the need for repair / support strategies that shorten the repair loop. For the U.S. Marine Corp, the need to minimize this repair loop is acute and has resulted in the adoption of a maintenance / repair strategy that employs Depot – level test capabilities which can also be deployed at the field or O-level. This paper discusses how next generation test architectures can address this on-going requirement for portability, performance and cost effective test solutions which address both Depot and O-level test needs.

Keywords — depot level test; digital test; TETS; Viper/T; O-level test; ATE; TPS migration; PXI; LXI

I. BACKGROUND

Beginning in the mid-1990s, the USMC developed an electronics support strategy that focused on providing repair and diagnostics test capability in a depot level or field environment. Based on these requirements, the Third Echelon Test System (TETS), developed by ManTech (Figure 1) provided a transportable electronics test system that could be used at both repair shop and in field forward applications.

Figure 1 – TETS

Expanded capabilities and requirements to support USMC electronics systems resulted in the development of the Virtual Instrument Portable Equipment Repair/Test (VIPER/T) system, a VXI-based system designed and manufactured by Astronics DME. (Figure 2)

Figure 2 – VIPER/T

II. REQUIREMENTS - NEXT GENERATION ARCHITECTURES

The on-going need to support the repair and diagnosis of electronic assemblies at both the depot and field or O-level, coupled with the requirement to support existing test programs yields a demanding set of requirements for next generation test systems. Specifically, these requirements include:

- Significantly smaller footprint and corresponding weight
- Improved reliability with lower total power dissipation
- Retain TETS and VIPER/T legacy test capabilities and provision for new / next generation test needs

In addition, a next generation test platform needs to address new and emerging electronics systems and communication technologies. As an example, modern communication systems require test instrumentation and systems that can support both analog and digital modulation technologies as well as address new communication systems that operate at frequencies up to
26 GHz. These test needs require the use of flexible and cost effective instrumentation solutions.

Next generation test systems must also be capable of offering lower total life cycle costs - doing more with less is the message being delivered throughout the armed forces and improved test system effectiveness and efficiency is a key attribute for any new test platform. Key attributes to help achieve lower life cycle costs include:

- Improved TPS execution time – The specific design and implementation of a TPS can have a significant influence on execution time however instrumentation and the test systems’ instrument control bus(s) can also have a significant effect on overall test execution time.
- System availability or up time – the more reliable and available the system is, the less need there is for multiple systems and spares, lowering overall test system life cycle costs.
- Legacy TPS support and migration – the need to support and migrate legacy test programs to a next generation platform can be a major cost factor, easily surpassing the acquisition costs of the test system hardware. Consequently, any new test platform or architecture with a requirement to support legacy TPS’ must effectively and efficiently address test migration. Being able to accomplish this goal with minimal labor investment is essential to achieving a low cost solution.

III. IMPLEMENTATION – A NEXT GENERATION Depot AND O-LEVEL TEST ARCHITECTURE

At first glance, meeting these requirements would appear to be a very difficult task. However, today’s test system platforms and instrumentation offer the capabilities needed to meet these requirements. Beginning with the TETS system and subsequently the VIPER/T which are largely based on the VXI card modular architecture, these systems offered the required flexibility and technical capabilities for depot and O-level test support when they were initially fielded over 10 year ago.

However, for current and next generation test needs, the card modular PXI standard offers several key features and benefits that meet the needs for complex test systems such as VIPER/T. Compared to VXI and other instrument standards, PXI offers:

- High “functional density”
- A compact footprint
- A wide range of baseband, analog and RF products including high performance digital subsystems

The term “functional density” refers to the required space or volume needed to support a specific instrument function. As demonstrated by VXI and subsequently by PXI, card modular instrument vendors have demonstrated the ability to achieve high levels of instrument functionality and density on a single card, resulting in high levels of “functional density” compared to “box” implementations. As an example, Figure 3 details how the size or functional density of a 6.5 digit DMM compares for a box, VXI and PXI version of the same basic instrument.

In conjunction with the high functional density of PXI, PXI’s card modular architecture offers the ability to decrease the overall size of a test system. With a maximally configured 19 inch rack supporting up to 20 PXI slots, (19 peripheral and one controller), a compact system footprint can be achieved. In addition, with the flexibility to combine both 3U and 6U PXI cards in a single chassis (Figure 4), system designers have the option to exploit the capabilities associated with 6U cards while retaining a small system footprint.

IV. EXAMPLE SYSTEM – THE COBRA/T PLATFORM

A prototype system, the Common Off-the-Shelf Benchtop Rapidly deployed Advanced / Tester (COBRA/T) has been developed as an IR&D effort for the purpose of demonstrating how the current VIPER/T and TETS platforms can be downsized while retaining and even expanding the current capabilities of the VIPER/T. The system emulates the current VIPER/T functionality, employs cPCI, PXI, PXI Express and LXI instrument standards and offers the following capabilities:

1. A PXI-based, performance digital I/O subsystem supporting 50 MHz data rates, offering 144 channels with per pin timing capability. The digital subsystem
provides equivalent functionality to the existing TETS and VIPER/T test systems while offering much lower power dissipation and improved thermal management.

2. An LXI switch subsystem offering switching capabilities to 26.5 GHz and full compatibility with VIPER/T and TETS

3. An LXI DMM offering capabilities compliant with the VIPER/T and TETS systems

4. A cPCI waveform / arbitrary generator with expanded capabilities, and compliant for both VIPER/T and TETS systems

5. A cPCI digitizing oscilloscope providing enhanced performance, but still compliant with VIPER/T and TETS systems

6. PXI-based RF measurement instrumentation offering capabilities compliant with the VIPER/T and TETS systems with the added ability to operate at frequencies up to 26.5 GHz and supporting both digital and analog modulation schemes.

7. Support for modern computer bus interfaces such as 10 Gigabit Ethernet and USB 3.0

8. Multiple DC Power Supplies for UUT power. Eight (8) programmable power supplies with compatible voltages and currents for VIPER/T and TETS systems.

Figure 5 details the COBRA/T system.

When compared to the existing TETS and VIPER/T systems, the new platform features:

1. A more compact footprint - the system requires less space/weight (two transit cases and one storage case) versus three or four (TETS) transit cases and two storage cases. Much of this reduction in size and weight can be attributed to the extensive use of cPCI / PXI /and LXI instrumentation versus the use of VXI instrumentation.

2. Synthetic instrumentation which offers RF stimulus and analysis capabilities to 26.5 GHz and supports CW, Pulse, and Modulation (analog and digital) modes. In addition, with a wide IF bandwidth of 160 MHz, the RF instrumentation is capable of supporting the latest generation of communication technologies including frequency hopping, spread spectrum, Bluetooth, and OFDM capabilities. The use of synthetic RF instrumentation has been a key factor in downsizing the test system’s footprint while providing expanded test capabilities that can address next generation RF communication technologies.

3. Improved Digital I/O performance: The existing TETS digital subsystem is based on VXI and offers a 25 MHz data rate, 32 kbits of memory per channel with a limited programming range for digital levels from -2 to +5 volts. For the COBRA/T, a high performance PXI digital subsystem (Figure 6) was selected which offers a higher data rate - 50 MHz instead of 25 MHz; more channel memory (256 kbits); wider programmable voltage levels, -11 to +15 V, and equivalent functionality to the current digital subsystem simplifying TPS migration and re-hosting of test programs.

4. Power saving digital instrument architecture: The digital subsystem offers significantly lower power dissipation and greatly improved thermal management compared to the existing digital subsystem. As detailed by Manor in the paper “Implementing a High Performance Digital Sub-System Using the PXI Architecture”, Autotestcon 2010; by actively controlling the VCC and VEE rails of the digital boards, it is possible to minimize overall power dissipation for the digital subsystem for a given set of programmed drive Hi / drive Lo levels. In addition, by properly architceting the digital subsystem it is possible to totally disable the board’s pin electronics between bursts while retaining the board’s digital states – resulting in significant power savings and much lower thermal dissipation. Compared to the
VXI digital subsystem, which dissipates on the order of 600 watts continuously, the PXI system with no pin electronics active, dissipates < 150 watts for 144 digital channels.

5. Higher instrument bus speeds with the use of PXI and PXI Express, providing the necessary bus bandwidth to support a synthetic instrument architecture as well as improving overall test system performance and TPS execution.

6. Use of standard communication bus protocols (i.e. USB 3.0 and 10 Gigabit Ethernet) for instrument control providing higher performance and lower cost solutions for instrument connectivity when compared to custom control bus solutions such as VXI/MXI and Express Card I/O.

V. TPS MIGRATION

A key requirement associated with any new system or platform that is replacing a legacy test system is the need to support existing test programs and fixtures. As detailed by Carey and Dewey in the paper “Modernizing Legacy Automated Test Systems for DoD Depots”, Autotestcon 2010, the costs associated with TPS conversions can easily exceed the initial capital cost of the system, making it essential that the overall capabilities of the replacement system closely map into the legacy system’s capabilities and that associated migration tools allow rapid program conversions to help mitigate overall costs of a test system upgrade. Good TPS migration tools minimize the need to “tweak” or re-write test programs with fully “automatic” program conversion with no code changes offering the ideal solution.

The next generation TETS / VIPER/T platform has been architected to support existing test programs and fixtures. The COBRA/T platform’s test interface accepts existing test fixtures and replicates existing test instrumentation and switching capabilities. Figure 7 details the fixture compatibility offered by the COBRA/T platform.

As shown in Figure 8, the migration tools provide the ability to convert binary digital files (.dtb files) to a binary format that is compatible with the COBRA/T digital subsystem via the use of the XML intermediate file format. Additionally, tools have been developed that allow LASAR .tap files to be converted into digital bursts for the new digital subsystem. For guided probe applications, this latter strategy is the preferred methodology.

To prove out the effectiveness of these conversion tools and the capabilities of the COBRA/T system, a test case was developed using an existing TPS that was developed for a Time Space Matrix CCA (Figure 9).
The UUT required 102 dynamic digital channels and included dynamic bi-directional read/write sequences. Using the .dtb conversion tools, converted bursts were created to support a go/no-go test of the UUT. The resulting conversion required no manual “tweaking” of the digital test program. To confirm the robustness of this conversion process, additional testing with other UUTs will be conducted. Initial results indicate that the conversion methodology, coupled with the functionality of the PXI digital subsystem offers a digital subsystem with comparable performance to the legacy digital subsystem and is an efficient TPS conversion process.

VI. SUMMARY

The development of this demonstration test platform, the COBRA/T, has shown that by employing modern T&M instrument standards, a depot/field deployable test system can be developed that offers several key benefits:

➢ Smaller system size and weight: Compared to the VIPER/T this platform offers approximately 50% smaller size and 50% less weight. Clearly, these benefits are key attributes for a system that is transportable and deployed in field locations.

➢ New generation instrumentation and architectures such as synthetic instruments offer the flexibility and a lower cost solution to address current and emerging communication technologies and standards.

➢ Lower power dissipation: Compared to the current VIPER/T at idle, this platform offers a power reduction of greater than 50% which translates into not only lower operational costs but lower internal operating temperatures resulting in increased overall system reliability and up time.

➢ Lower recurring acquisition costs: The use of the PXI architecture provides the opportunity to significantly lower the acquisition cost of test systems. For comparable instrument functions, PXI instrumentation can be 50% less than a VXI version of the same instrument and for some high end instruments such as digital cards, the per channel cost for PXI vs VXI can be 60% less. Additionally, the infrastructure costs for items such as PXI chassis will be less compared to VXI. Clearly, the use of PXI can be a major factor in decreasing test system acquisition costs.

By building on the technical and economic benefits of PXI, coupled with migration tools to preserve the existing investment in TPS’, a next generation TETS / VIPER/T platform can be constructed that offers improved performance and lower total life-cycle costs while still providing the support for legacy test programs and products.

VII. REFERENCES