# Use of Intelligent Mezzanine Carriers for Legacy Instrument Replacement in VXI Systems

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***Abstract*- Military and commercial Automated Test Equipment (ATE) users are facing significant problems keeping their ATE supportable for the life cycle of the products they are being used to test. Further, the cost of completely replacing the system is often insignificant compared to the cost of replicating and re-certifying the test program software. As a result, requirements have increasingly surfaced to replace legacy equipment in such a manner as to re-use existing test program software.**

**Familiar solutions such as one to one instrument replacement with an instrument from another manufacturer, complete redesign of the instrument with modern components, or software emulation using new instruments on a different platform have various issues with cost, implementation, and future migration. An approach using open standard mezzanine cards with platform specific carrier boards can provide an enormous selection of modern instruments from many different manufacturers, extensive reuse of legacy equipment and software, and a clear, easy migration path to existing and future platforms.**

**Most common ATE instruments exist in a mezzanine format and carriers can be found for VXI, PXI, PCI, and many other platforms. Carriers can be non-intelligent allowing direct access to the mezzanine modules by the host software, or intelligent allowing on-board firmware to further emulate the legacy instrument. Mezzanine modules can be mixed and matched on a single carrier to provide multiple functions in a single slot or to produce a multi-channel function. Embedded firmware can emulate other functions, such as a programming interface, that existed on the legacy instrument.**

## I. Introduction

Requirements for VXI test systems have begun to outlast the product life cycle of the instruments used in those systems. More and more often, companies are faced with maintaining, upgrading, or replacing legacy systems while attempting to salvage the millions of dollars invested in test software, fixtures, and instrumentation. This situation has created a unique need for legacy instrument replacement using new technologies while at the same time leveraging the companies' original investments and providing a clear migration path to new and future instrument standards.

## II. Test System Life Cycle

### *A. Keeping ATE Supportable*

One of the most significant problems facing military and some commercial ATE users today is how to keep their ATE supportable for the life cycle of the product or system it is used to test. A key example, where this is a major issue, is in ATE applications for major weapons systems. Often times in the past the ATE have been adaptations of commercial ATE or collections of commercial instruments that have lost their support, for a variety of reasons, long before the weapons system is out of production or has reached the end of its useful life. While this complaint has been most often heard with regard to commercial equipment, more and more it is becoming common place with regard to special equipment developed by defense contractors as well.

### *B. Life Cycle Cost*

The cost of a test solution falls into four basic categories: initial capital expenditure, support costs (spares, calibration, etc.), test program development and support, and fixtures. The initial cost of a test system can be anywhere between $50,000 and $1,000,000 and the total life cost can be as much as five to ten times that amount. A significant portion of this cost is in fixtures which can easily be over $100K; however, the largest portion of this cost is almost always test program support and development. A Test Program Set (TPS) of average complexity costs a minimum of $30K to develop and the average five year old functional tester has a minimum of ten test programs [1]. A typical life cost breakdown of an ATE system is shown in Figure 1;

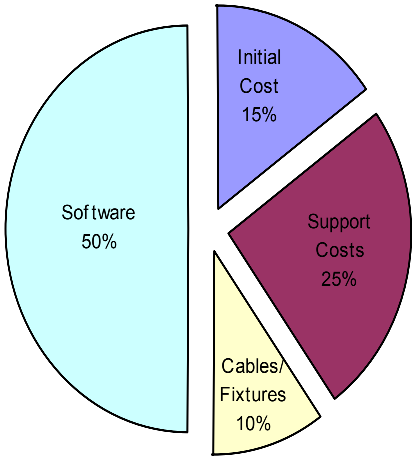


Figure 1. Typical ATE Life Cycle Costs

however, this breakdown varies widely depending on a number of factors, such as commercial versus military usage.

*C. Support Alternatives*

It has been shown by numerous papers given at this conference in the past that the cost of replacing the ATE, while appreciable, is often times insignificant when compared to the cost of replicating and re-certifying the test program sets. Hence, the ATE user is faced with two possibilities. Either replace the system at a very high cost due to replication of the test program software, or incur high upkeep costs for increasingly obsolete equipment that supports the original TPS software. Neither possibility is very attractive.

More frequently, viable alternatives are becoming available that allow the user much greater flexibility in determining when or if he wishes to change, upgrade or replace his ATE. This paper will explore one of several techniques that have been developed and successfully implemented on a number of military ATE projects.

*D. Support Example*

In the 1970's Texas Instruments developed a line of minicomputer based ATE that ceased commercial production in 1982. These systems continue to support the F16 at Depot level, Sea SKUA missile production and support, and Tornado Radar depot and intermediate level support. In order to keep these systems viable, and deliver new stations to several current users, efforts have been made to create replacement instruments and peripherals that in each case run all TPS and diagnostic software unchanged, thereby preserving the customer's embedded investment in software and fixtures.

The combination of supporting this older technology equipment and development of new products for VXI and PXI based ATE applications has led several companies to embrace the use of open commercial standards for mezzanine cards that allow multiple functions to be placed in a single slot. This allows access to significant amounts of technology available from numerous vendors when addressing replacement issues. Of even greater significance, experience has led to the development of intelligent carriers which support numerous open standard mezzanine cards and more significantly allow functions such as translation software to be resident on each of these carriers. Examples of this approach along with significant characteristics follow.

## III. Replacement of Obsolete Instruments

The primary reason an ATE customer would need to upgrade or replace a test system is due to obsolescence of equipment in that system. The older a system gets the more likely it is that instruments within the system are no longer available or supported by the original manufacturer. Depending on the instrument, off-the-shelf replacements might be available; however it is generally the case that test program software has to be modified to support the new instrument.

*A. Applicable Instruments*

The list of obsolete instruments spans the entire spectrum of functionality found in legacy systems. Specialized functionality would, no-doubt, have a significant presence on such a list however it would also include a large number of standard ATE instruments such as oscilloscopes, counter-timers, DMM's, pulse generators, and arbitrary waveform generators. These standard ATE instruments lend themselves well for a mezzanine approach to replacement due to the large product base available on mezzanine modules.

Replacement of a specialized function usually requires significant non-recurring engineering (NRE) costs; however, a mezzanine approach is still beneficial for several reasons. One, it allows instant portability across multiple platforms. Two, it allows the designer to focus on the primary functionality of the instrument and not the interface, whether it be VXI, PXI, or another platform. Finally, it allows the designer to implement only the functions from the legacy instrument that do not already exist in a mezzanine format. For example, if replacing a specialized pulse generator, the designer may only need to design a pulse amplifier and integrate it with an existing commercially available pulse generator.

### B. Issues Involved

There are many issues to consider when selecting a new piece of test equipment as a replacement. Does the existing test system have the necessary power supplies to power the replacement piece of test equipment? Will the new instrument require new cables and fixtures to connect to the UUT or switching system? How will the speed and timing of the new instrument affect the test program sets? In many cases asynchronous delays are inserted into software to account for delays in the old instrument that do not exist in the new one. In addition, much of the timing is UUT driven and that timing has to be preserved. Other issues might include: long term support requirements of the system, phased migration plans to a new platform, and calibration requirements.

Obviously, the most important issue is matching the functional specifications between the old and new instruments. Can the new instrument make the measurement or provide a source with the required specifications? Perhaps equally important, however, is the reusability of the TPS's. As discussed earlier, TPS development and support is the biggest life-cycle cost for most ATE systems and can, therefore, be very expensive to replace.

### C. Replacement Approaches

There are several approaches one can take towards solving the problem of replacing an instrument with little or no affect on the TPS's. One option is to completely re-design the obsolete instrument using modern components. This approach would certainly involve very high NRE costs and should only be considered if no other options exist. Another option is the use of software emulation to make a new instrument look, to software, like the old instrument. This method usually involves capturing commands destined for the legacy instrument and translating as well as re-routing them for the new instrument. Racal Instruments, Inc. has developed a program called TILS specifically for this purpose [2]. Vektrex also has a product called Masquerade that takes this approach towards instrument replacement [3].

A third approach, which is the focus of this paper, uses open standard mezzanine modules on platform specific carriers. Of specific interest is the use of intelligent carriers containing on-board processing power that can enhance the capabilities of a standard non-intelligent mezzanine approach. The mezzanine approach has several advantages as highlighted throughout the remainder of this document.

### D. Return on Investment (ROI)

Regardless of the instrument replacement approach taken, an excellent return on investment should be one of the primary goals. ROI of an ATE system is very hard to measure because the return is usually not tangible. The return comes in the form of low in-field failure rates, improved quality assurance, lower manufacturing and support costs, or simply, satisfied customers. When specifically discussing instrument replacement, the goal should be to salvage the existing returns provided by the system and minimize the investment necessary to do so. The number one objective must be to obtain a solution that is non-obtrusive to an existing proven test system. The ideal solution is a drop in replacement requiring no changes to cables, fixtures, or software. Realizing that, in a lot of cases, the ideal solution is not attainable, most approaches have been developed to minimize the total investment and make the transition to the new instrument as un-obtrusive as possible.

## IV. VXI MEZZANINES CARRIERS

VXI mezzanine carriers allow different functional instruments or multiple instances of the same instrument to be integrated into a single VXI module. A carrier contains all necessary logic to electrically and mechanically interface a mezzanine module to the VXIbus. VXI mezzanine carriers can be put into two basic categories, those that only provide a transparent or semi-transparent interface with no processor intelligence, and those which contain an intelligent processing capability.

### A. Non-Intelligent Carriers

Non-intelligent carriers provide the basic electrical and mechanical support for the mezzanine modules. Data is directly transferred to and from the mezzanine module without any manipulation by the carrier. Any required data interpretation and processing must be handled by the VXI host application. Some non-intelligent carriers allow access to the mezzanine modules through only one logical address, whereas others provide an independent logical address for each mezzanine. Both types of carriers allow control of the mezzanine module through the VXI bus; however, independent logical addresses make software driver development easier, because each mezzanine module is controlled as an individual VXI instrument. In some cases, the carrier is completely transparent to the user, even the manufacturer identification and module code of the mezzanine module is presented in the VXI ID and Device Type registers.

### B. Intelligent Carriers

Intelligent carriers provide more than just the basic electrical and mechanical support for the mezzanine modules. An intelligent carrier includes an embedded processor that can interact with the mezzanine modules directly and provide many useful integration, data interpretation, and data processing functions. An intelligent carrier will typically appear as a single VXI instrument (i.e., one logical address) and will contain its own set of control and status registers.

*C. Types of Mezzanines*

Mezzanine modules are available in a variety of formats. Hundreds of functions, such as D/A, A/D, digital I/O, motion control, waveform and pulse generation, counter/timer, and serial communication, are available in open-standard formats and are available from many different manufacturers. Some companies also provide VXI carriers in proprietary formats with mezzanine modules limited to those meeting the company's proprietary standards. The relative size of some of the available open-standard mezzanine modules is shown in Figure 2.

1) M-Modules. M-modules were developed by MEN Mikro Elektronik and became an ANSI standard in 1997 [4]. Today there are more than 150 different modules available from over 15 different manufacturers. The size of the M-module conveniently allows up to four single-wide instruments to be mounted in a single VXI slot. Additionally, modules may also be mounted in rear positions on some carriers, but do not have front I/O access. M-modules allow flexible front panel connections. Even though a 25-pin D-subminiature style connector is generally used where possible, the standard allows the use of other connectors such as SMA and combination COAX style D-subminiature connectors.

2) Industry Packs. The Industry Pack (IP) mezzanine format was first introduced by GreenSpring Computers. The format was approved as an ANSI standard in 1996 [5]. IP modules are heavily used by data acquisition and industrial control markets. There are more than 350 IP modules available from over 25 different manufactures. IP modules do not have a front panel; hence all I/O is routed through the carrier. This limits the use of IP modules in some applications; however, the large number of different types of available functions still makes IP modules a viable choice.

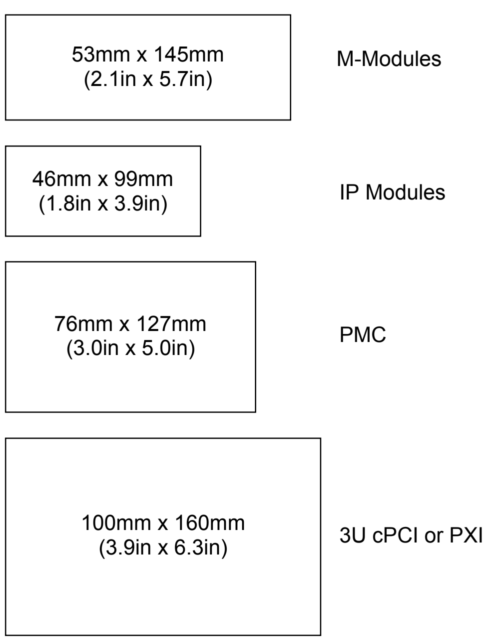


Figure 2. Relative size of various mezzanine modules

3) PMC Modules. The PCI Mezzanine Card (PMC) standard originated from the Bus Architecture Standards Committee of the IEEE Computer Society (CMC Mezzanine IEEE P1386). PMC modules are well suited for high performance I/O applications, such as high speed serial and parallel busses due to its use of the slave/master PCI bus [6].

4) Compact PCI and PXI Modules. Compact PCI or PXI modules are generally not considered mezzanine modules; however, they can be treated as such with respect to the VXI bus. Many manufacturers of high-end instruments, such as digitizers, have chosen the cPCI/PXI format as the platform of choice for new instrument developments. Allowing these new instruments to be used in a VXI system offers many obvious advantages [7] [8].

5) Other Mezzanine Modules. In addition, to the mezzanine formats already discussed, there are other mezzanine formats available that offer there own unique advantages, such as PC-MIP and PC Cards.

## V. Replacement Using Intelligent Carriers

Intelligent mezzanine carriers provide an enormous amount of flexibility that facilitates replacement of legacy instrumentation. The processing power of an intelligent carrier can help integrate multiple mezzanine modules into a single instrument and can emulate functionality that existed on the legacy instrument being replaced. On-board software can tie multiple modules of different functionality together to look like a single VXI instrument or multiple instruments of the same functionality together to look like a single multi-channel instrument. Further, software can implement a programming interface that emulates the legacy instrument or provide additional functionality such as data analysis or data compression. The capabilities are summarized in Figure 3.

*A. Functional Integration*

With the enormous amount of instruments available in several different mezzanine formats, a seemingly unlimited number of combinations of functions are available to integrate into a single VXI instrument. A simple example would be to combine a few digital and analog I/O modules on an intelligent carrier to create a single VXI multi-function I/O module.

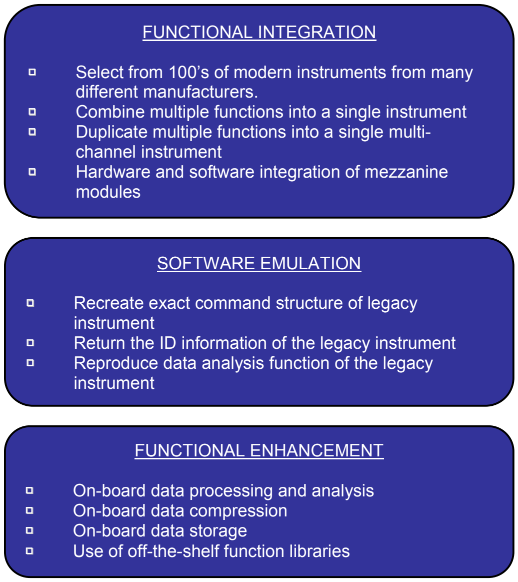


Figure 3. Capabilities of intelligent carriers for Legacy instrument replacement

In some cases, the separate mezzanine functions must interface to each other at a hardware level beyond what is provided by the carrier. In this case, peripheral connectors provided by the mezzanine modules or cables hidden inside the shield of the integrated unit can provide this interface.

For example, a MA204 50MHz Pulse Generator M-module integrated with a M206 Pulse Amplifier M-module provides a replacement for a Tri-Phenix Digital Pulse Generator. This requires a single cable from the MA204's output to the M206's input as shown in Figure 4. On-board software can provide the functional integration of the modules by grouping the modules under a single logical address and a single programming interface. Mezzanines of the same function can also be combined to create a multi-channel device. For example, four MA204's can be combined to create a four channel 50 MHz function generator that is capable of replacing the Agilent 81110 function generator.

### B. *Software Emulation*

The biggest advantage of using an intelligent carrier to replace a legacy instrument is the capability to emulate software functions existing on the instrument that, as in most cases, can not be found on a mezzanine module. The primary utilization of this capability is to emulate a programming interface. The exact command structure of a legacy instrument can be re-created on the replacement module even to the point that it responds with the old instrument's ID information. For example, we can take a modern instrument like a cPCI digitizer (see Figure 5) and emulate a command structure such that it looks exactly like an obsolete Tektronix VXI oscilloscope to the test system software. This way, little if any changes need to be made to existing test programs, thus leveraging prior investments in test system software.

Firmware utilities existing on the carrier will manage the VXI interface allowing commands to be received via the VXI word serial protocol. The firmware can then be instructed to pass commands on to a user application also running on the embedded processor. In the digitizer example above, the user application will simply take the old Tektronix command and translate it into a command understood by the new cPCI digitizer. Further, since the application will have control of the VXI registers, identification information can be written to the VXI ID and Device Type registers so that software cannot tell the difference between the legacy instrument and the replacement.

### C. *Functional Enhancement*

In addition to emulating the command structure of an instrument, it may be necessary to re-create other functionality such as data analysis functions or a peripheral communications bus. In the latter case, a simple digital I/O mezzanine module and a firmware based control process can emulate a simple slow speed parallel bus interface. More advanced interfaces can be emulated using the various communications mezzanine modules found on the open market. Data analysis capabilities are inherent with the processing power of an intelligent carrier. Many available software libraries include data analysis functions that exceed the capabilities found in older instruments.

The processing power of an intelligent carrier also facilitates further functional enhancement of the mezzanine modules. In addition to data analysis functions, data processing routines such as waveform math functions can be added to the instrument. Again many available software libraries include such functions. Data compression can be performed on-board the carrier and some mezzanines, in particular PMC modules, can easily facilitate data storage

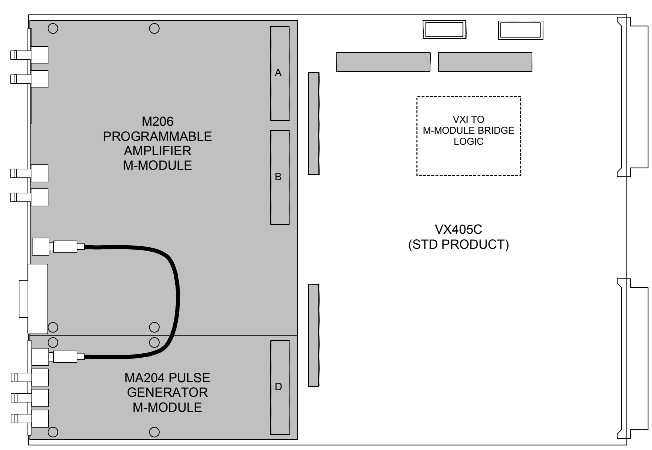


Figure 4. Example of the functional integration of a pulse generator using a non-intelligent VXI M-module carrier

Figure 5. Example of a VXI Oscilloscope using a PXI Digitizer on an intelligent VXI to cPCI/PXI carrier

devices such as hard disk drives or flash memory. Thus, data can be collected, processed, compressed, and stored on-board the instrument limiting the amount of data that must be transferred over the VXI bus.

## VI. CONCLUSION

The approach of using intelligent mezzanine carriers for instrument replacement in VXI has emerged recently as a viable alternative to solutions that sometimes require further investments, such as system fixtures and software support and development. The concept grew out of necessity to provide long term support for aging ATE systems and out of continued success of non-intelligent mezzanine carriers in VXI systems.

The enormous amount of instruments available coupled with the flexibility provided by on-board processing makes intelligent mezzanine carriers an attractive solution to the growing need in the ATE market for VXI instrument replacements. As more and more VXI instruments become obsolete the market for VXI instrument replacement will grow and as more and more mezzanine modules become available on the open market the mezzanine approach will continue to gain momentum as an attractive solution.

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