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# : Making the Case for IVI

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## INTRODUCTION

The Interchangeable Virtual Instrument (IVI) Foundation was formed in 1998 with a charter to simplify test system development and maintenance by standardizing instrument driver technology. Towards that end, the IVI Foundation composed a series of specifications to facilitate the development of IVI instrument drivers. Many instrument manufacturers already have a range of IVI drivers accompanying their instrument products and more manufacturers are moving to adopt IVI. In addition, the LXI (LAN eXtensions for Instruments) Consortium has selected IVI as the driver technology for its important instrument platform. Yet, misinformation and confusion about IVI abound. Instrument manufacturers unfamiliar with IVI, struggle to compose compelling arguments justifying an investment in IVI. Subcontractors grapple with IVI driver requirements cropping up in project specifications. As most of the key participants in IVI are themselves competing instrument manufacturers, market posturing all too often clouds the IVI messaging throughout the industry.

This paper presents an objective, comprehensive examination of the benefits of IVI driver technology. This paper will further explain why there truly are few, if any, compelling reasons to consider any kind of instrument driver *other* than an IVI driver.

## WHAT IS IVI?

The IVI standard is grouped into three technology areas; 1) a set of instrument class specifications; 2) a collection of architecture specifications; and 3) a library of shared software components.[1]

The **class specifications**, or instrument classes, define several types of traditional instruments such as DMMs, function generators, and spectrum analyzers. Each class specification precisely lays out the required functionality of an instrument class along with

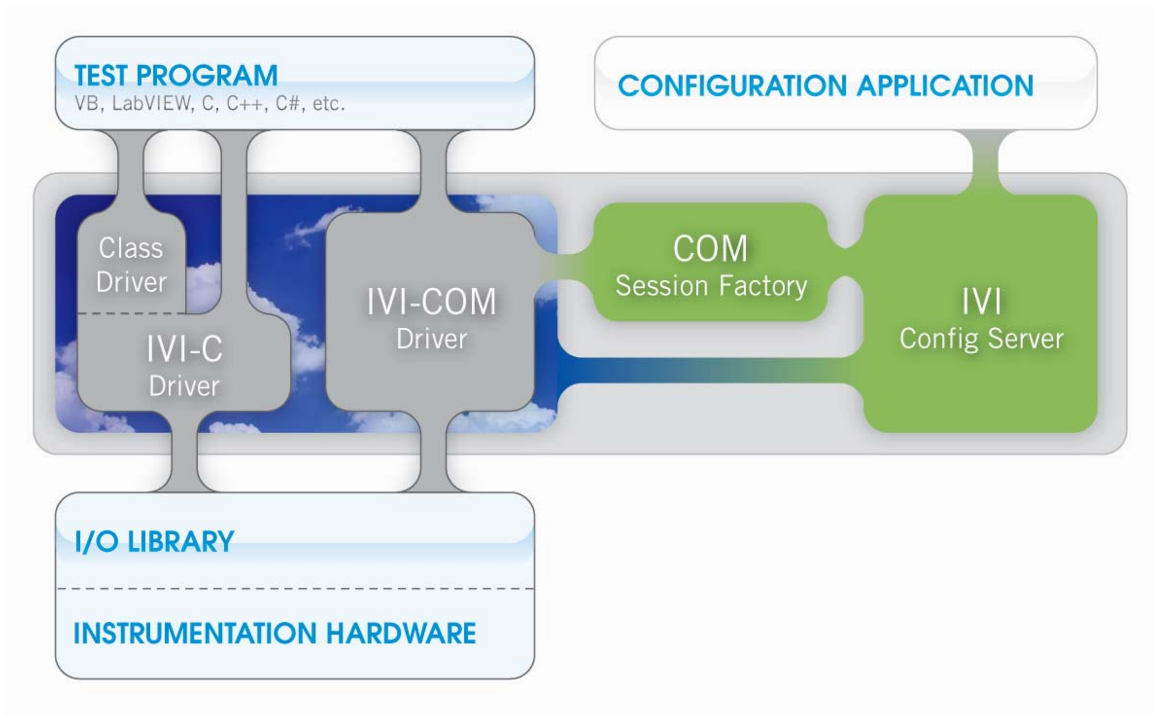
[1] IVI also includes two other technologies – Measurement Stimulus Subsystems (MSS) and signal-based drivers. MSS describes an architecture for achieving even higher degrees of interchangeability than traditional IVI drivers can achieve. Signal-based IVI drivers bring an ATLAS-style signal-based programming model to IVI. For purposes of this paper, neither of these technologies will be discussed further.

the detailed application programming interface (API) that class-compliant IVI drivers must expose.

The **IVI architecture specifications** cover a broad range of generic functionality that IVI drivers must support – even if they do not comply with any IVI-defined instrument class. These specifications prescribe everything from driver installer and help file requirements to standardized error reporting and API style. Indeed, the IVI architecture specifications are arguably the most valuable aspect of IVI.

The **IVI shared components** are a series of freely available and redistributable software modules developed and maintained by the IVI Foundation. These components are designed to ensure consistent implementations of important IVI driver features, such as configuration, error reporting, and multithreading. The IVI shared components must be installed on any system that will use IVI drivers – be it a driver developer workstation or an operator test station.

The following illustration shows how the various components of an IVI-enabled test system fit together.



## IT'S NOT ALL ABOUT INTERCHANGEABILITY

By far, the biggest misconception about IVI is instrument interchangeability – the ability to substitute instruments in a test system without modifying the test program. However, "true" interchangeability is only achieved when a measurement system produces the same-answer result with different test equipment. This can prove to be considerably more difficult than simply outfitting the system with IVI-compliant instrument drivers. While many test programmers can indeed realize the benefits of interchangeability. Test systems that use instruments for which an IVI instrument class exists and that use a fairly modest set of functionality can benefit enormously from interchangeability.

Some of the instruments used in a particular test system may not have an associated IVI instrument class, making interchangeability impossible. For those instruments that do fall within an IVI instrument class, it also may be the case that the IVI-defined functionality covers only a small portion of the instrument's capability. In fact, as the instrument complexity goes up, the ability to interchange actually goes down. Modern spectrum analyzers, for example, typically have much more functionality than is defined in the IVI spectrum analyzer instrument class. Test programs that use functionality outside of the class specification are obviously not interchangeable.

Confronted with the preceding interchangeability challenges, some manufacturers and test programmers choose to not consider IVI any further. Some even go so far as to completely dismiss IVI if their instrument does not comply with an existing IVI-defined instrument class. These manufacturers and test programmers often make these decisions without a full understanding of everything IVI offers.

## WHAT COMPLIANCE REALLY MEANS

For the manufacturer and the programmer alike, it's important to understand the meaning of IVI compliance. There are essentially two "degrees" or "levels" of IVI compliance – **basic compliance** and **instrument class compliance**. What many fail to recognize is that they can author a fully compliant IVI driver for an instrument that does not support any IVI-defined instrument class. IVI defines a number of standard functions and features that compliant drivers must support, as well as numerous other architectural requirements that drivers must meet. These capabilities and requirements are completely independent of whether the driver supports an IVI-defined instrument class. Drivers with this basic level of compliance can be advertised as being fully IVI compliant and can be used in development environments that support IVI drivers. Such a driver even meets the IVI driver requirements of the LXI Consortium for instruments that want to advertise LXI compliance. Moreover, drivers that support this basic level of compliance offer all of the same features and benefits as class-compliant IVI drivers, with the sole exception of interchangeability.

The second level of IVI compliance is IVI class-compliance. If an instrument falls into one of the IVI-defined instrument classes, such as DMM, oscilloscope, or function generator, then it is possible to create an IVI driver that supports the IVI-defined interfaces for the corresponding instrument class. Class-compliant drivers have the same features, benefits, and architectural requirements as non-class-compliant drivers – with the added benefits of interchangeability.

## TYPES OF IVI DRIVERS

IVI drivers currently come in two versions – **IVI-COM** and **IVI-C**. IVI-COM drivers use Microsoft COM technology to expose driver functionality, while IVI-C drivers use conventional Windows DLLs to export simple C-based functions. Both of these interface technologies can be used to implement any degree of IVI compliance – basic compliance or full instrument class compliance. However, it is crucial to understand the important differences between IVI-COM and IVI-C drivers before making a decision on which technology to adopt. Though the prime purpose of this paper is to communicate the benefits of IVI in general, some of the benefits are unique to IVI-COM.

At the time of this writing, the IVI Foundation also is well on its way to completing new standards for building IVI.NET drivers. Developers will be able to produce these drivers using any .NET language – such as C#, Visual Basic.NET, and Visual C++.NET. IVI.NET drivers will expose native .NET interfaces to simplify integration with .NET applications. The arguments presented in this paper apply equally well to the upcoming IVI.NET driver standards.

## ONE DRIVER TO RULE THEM ALL

One of the principal challenges instrument manufacturers and software integrators face in the Test and Measurement industry is adapting their software to a profusion of application development environments (ADEs). Some users may choose Visual Basic, C#, MATLAB, or Agilent VEE, while other users need to work in National Instruments LabWindows or LabVIEW. Before IVI, the driver strategy that many instrument manufacturers pursued was to develop, distribute, and maintain separate drivers for each environment they wanted to target. LabVIEW customers required LabVIEW drivers, while Visual Basic customers required a Visual Basic driver. This led to duplicate work and increased overall cost. As a matter of practicality, manufacturers also would have to choose a subset of ADEs to support, and this would invariably alienate or frustrate that segment of customers working in one of the unsupported ADEs.

IVI drivers truly provide the ability to develop a single driver and provide a first-class user experience in virtually every popular ADE. *Beyond anything else, this is far and away the single most important benefit of IVI.* **IVI-COM drivers work seamlessly in nearly all ADEs**, including:

- Visual Basic 6.0
- Visual C++ 6.0
- Visual C#
- Visual Basic.NET
- VBA environments (Excel, Word, PowerPoint, etc.)
- MATLAB
- Agilent VEE
- LabVIEW

IVI-COM drivers inherit this seamless integration benefit largely, but not entirely, from the COM technology on which they are based. COM is ubiquitous on the Microsoft platform, and most development environments provide a first-class user experience with any COM component – including IVI-COM drivers. Even with the arrival of Microsoft's latest client operating system, Windows Vista, COM remains pervasive. Most core operating system features in Windows Vista continue to be implemented using COM – not .NET, as many would be led to believe. Suffice it to say, COM will remain an important component technology on Windows for the foreseeable future.

IVI-C drivers round out the ADE coverage of IVI by catering to National Instruments LabWindows/CVI. The IVI specifications even prescribe how to author a driver that exposes both IVI-COM and IVI-C interfaces from a single driver DLL. This gives complete coverage of all important ADEs with a single driver. Some driver development tools, such as Pacific MindWorks' Nimbus Driver Studio, provide automatic support for building these kinds of "dual-mode" drivers.

## USER FAMILIARITY

One of the most effective ways to frustrate test programmers is to provide them with a dozen different ways to accomplish the same common programming tasks. Without a standard driver technology such as IVI, this is precisely what test programmers are confronted with. By following the IVI standard, manufacturers provide the test programmer with a driver that is at least familiar, if not completely interchangeable. If the user has worked with any other IVI driver from any other vendor at any point in their career (and the chances of this are increasing every day), then they will instantly know how to at least perform some basic tasks with any new IVI driver they encounter. They also will know how to access instrument-specific and other advanced features of the driver. The net result is a tremendous advantage in the "out-of-the-box" experience with an instrument manufacturer's product.

Many simple tasks, often taken for granted, cause a great deal of test programmer confusion if not performed in a standard fashion. Driver instantiation, initialization, and shutdown are some of the most basic tasks every test programmer must perform. Every IVI driver provides the same functions for performing these basic operations. The specific behavior of these functions, with respect to resource management and instrument I/O, also is prescribed by IVI. If a test programmer can quickly create a simple program that communicates with a newly received instrument, then that will positively influence their initial overall satisfaction.

Configuration and installation also are common tasks that test programmers need to be able to perform without having to learn something new. The IVI Configuration Store provides a single location where the user can, at a minimum, discover what drivers are installed on their system. They can further discover a number of important details about their driver, such as the type of driver (IVI-COM or IVI-C), specific instrument models it supports, and the IVI interfaces it exposes. Without a standardized driver, programmers might have to dig through any number of header files, registry settings, help documents, and readme files. Simply having a single, well-known place to set the instrument's I/O resource address provides a very real test programmer benefit.

Instruments often contain multiple instances of the same type of functionality. An oscilloscope, for instance, might have several channels with the same measurement capabilities, or a spectrum analyzer might support multiple traces from a series of acquisitions. IVI refers to these as *repeated capabilities* and provides a uniform mechanism for accessing them. Test programmers work with the same well-known methods and properties for discovering repeated capabilities, iterating through a list, accessing a specific repeated capability, and even applying a user-specified virtual name to selected repeated capabilities. Since all but one of the existing IVI instrument classes define repeated capabilities, it's important to provide a consistent, familiar and easy-to-use interface.

Another excellent example of a seemingly benign task that causes a surprising amount of programmer frustration is basic error reporting. Windows provides a dizzying array of options for reporting errors to application programs. One can use simple return codes or perhaps COM HRESULTs (both of which can easily be ignored by the test programmer's application). Alternatively, components can use the GetLastError/SetLastError idiom, which the test programmer only knows about from reading the documentation. These functions are thread-based and can easily produce erroneous results (errors within errors) if used improperly. Windows also offers a couple of exception types -- structured exceptions and C++ exceptions, which the user must be careful not to mix within an application. COM adds to this its own error-reporting mechanism via the IErrorInfo interface.

With drivers, the error reporting situation is further complicated by the need to support at least three sources of errors – those coming from the driver, those coming from the I/O layer (such as VISA) and those coming from the instrument itself. IVI standardizes error reporting, so the programmer has a well-known set of functions for enabling error reporting, discovering if an error has occurred, and retrieving detailed error information. Without such standardization, the test programmer is left to contend with any number of unfamiliar error reporting schemes. IVI goes one step further by providing shared software components that assist driver developers in implementing features such as error reporting, thereby improving consistency across manufacturers.

## TOOLS, TOOLS, TOOLS

What often makes a software standard compelling is the quality and availability of tools. With IVI, there is no shortage of developer and test programmer tools on the market. Even though IVI drivers are internally more complex and offer a broader array of features than other types of drivers, the robust tooling makes IVI drivers easier to develop than non-standard drivers. Consider, for example, the inherent complexity in building a COM component. Most instrument manufacturers have limited, or no experience with COM. Constructing a COM-based driver without a tool is simply impractical for most companies in the industry. Because IVI standardizes on how COM components should be constructed, documented, and deployed, software tools are available to automatically handle the required code generation. As a result, the test programmer is insulated from the intricacies of COM. For example, Pacific MindWorks' Nimbus Driver Studio is a software tool that greatly reduces the amount of time it takes to write an IVI-COM driver.

Tooling is what makes standards thrive, and it is encouraging to survey some of the currently available tools with built-in IVI support.

- Agilent VEE
- Agilent T&M Toolkit
- The MathWorks MATLAB
- National Instruments LabWindows/CVI
- National Instruments LabVIEW
- National Instruments Measurement Automation Explorer
- National Instruments TestStand
- National Instruments Signal Express
- Pacific MindWorks Nimbus
- Teradyne TestStudio
- TYX PAWS

By furnishing an IVI driver with its instruments, the instrument manufacturers' products will instantly integrate into any of these environments, as well as a number of others. The usability and accessibility of their instrument will automatically improve – with no additional effort required on their part.

## TRACKING THE STANDARDS

IVI drivers are coupled to a variety of disparate standards and Windows technologies. Without exception, these standards are moving targets – continually evolving and growing. Drivers must track all of these changes, irrespective of whether the drivers are IVI drivers or not. Most fundamentally, drivers must keep pace with changes in the Windows platform itself. Some of the Windows technologies on which a driver must rely include Windows Installer, Windows help, the .NET platform, the Windows API, and security. Important ADEs, such as Microsoft Visual Studio also are moving targets, and the IVI Foundation goes to great lengths to ensure IVI drivers operate well in such environments. All of these technologies require considerable expertise to master and a great deal of resources to track.

Windows Vista introduces a host of new challenges, as does 64-bit application development. Each standard and operating system must be carefully studied and followed if drivers are to remain robust, performant, and easy to use. Most instrument manufacturers and test programmers find this a daunting challenge and have neither the resources nor the desire to commit to tracking a large number of software technologies. This is where the IVI Foundation provides enormous value.

Many members of the IVI Foundation provide a wide array of software products to the Test and Measurement industry. Consequently, they must, for their own interests, carefully track the same set of software and hardware standards on which drivers rely. In order to guarantee their products continue to support IVI, members must ensure that IVI drivers evolve with these standards correctly and in a timely fashion. To that end, member companies bring considerable software talent to the IVI Foundation meetings to address how IVI should evolve to meet the changing software landscape. Much of the real detailed work required to incorporate new technology into IVI also is done outside of the IVI meetings, typically at the member company facilities using the company's own R&D resources. When the collective knowledge of all of these resources is harnessed at the IVI Foundation meetings, the group is very well empowered to keep IVI moving in the right direction. In a very real sense, all IVI users are directly leveraging the valuable software talent of numerous test and measurement industry leaders.

## WHAT COM BRINGS TO THE TABLE

A large part of what IVI-COM drivers have to offer derives from the core technology on which they are based – the Microsoft COM technology. While a detailed discussion of COM is beyond the scope of this paper, it is nonetheless instructive to briefly examine how COM dramatically improves driver technology. The most obvious benefit of COM is that it is supported across a very large number of ADEs. Environments such as Microsoft Visual Studio provide numerous features for seamlessly integrating COM components in any kind of application – from Visual Basic 6 applications to Visual C#.NET applications. Usability features, such as object browsers and IntelliSense, all operate based upon COM and IVI-COM drivers inherit all of these benefits.

COM is a binary standard, and as such, allows any combination of programming language or compiler to be employed. This also means that components from different software manufacturers can interoperate safely and reliably. By contrast, Windows DLLs – considered by some to be a component technology – are really just a distribution standard and do not address some of the basic interoperability issues with software. Without a binary standard such as COM, compiler manufacturers often elect to implement language features in a proprietary manner, rendering components that are "untouchable" by code generated from other manufacturers' compilers. C++ exception handling is an excellent example of such a feature. A C++ exception output from a function compiled with Compiler A cannot reliably be caught by the test programmer's code from Compiler B. On the other hand, COM error handling works seamlessly across processes and computers and between components built with different compilers.

COM also offers a very powerful feature known as location transparency. Simply stated, COM allows test programs to communicate with components without regard to whether those components are running in the same process, in a different process, or even on another computer on a network. In the cross-process case, remote communication is completely implemented by the COM runtime, with no extra work required of the driver developer or the test programmer. In the absence of this feature, IVI-COM test programmers would have to contend with low-level, inter-process communication facilities, such as sockets, named pipes, or memory mapped files.

Finally, COM provides the ability to mix and match components with very different degrees of thread safety – all within the same application. Some components are authored by developers with multi-threaded applications in mind. These developers want to maximize the performance of their components, but they must take great care to ensure internal data is protected from concurrent access. Other components, perhaps legacy components, have not at all been authored with multi-threaded access in mind. For these thread-unaware components, the COM runtime automatically injects itself between multi-threaded callers and the component in order to serialize access to the component.[2] In this way, COM layers multi-thread safety on top of components that otherwise could not be used in multi-threaded scenarios.

## INDUSTRY MOMENTUM

Good standards are often built upon other good standards. Important associations within the test and measurement industry have decided upon IVI as their driver technology of choice. The LXI Consortium requires an IVI driver to be provided with any device claiming LXI compliance. The LXI Consortium recommends IVI-COM, although IVI-C is considered acceptable. As one of the most promising, active and dynamic standards bodies in the industry today, LXI lends a considerable amount of credence to IVI by relying on IVI for LXI's standard software interface.

The Synthetic Instrument Working Group (SIWG) is an industry body, sponsored by the Department of Defense, that is tasked with defining an architecture for building test systems composed of generic hardware and software modules. Instead of using

[2] COM accomplishes this by creating a hidden Window that continually pumps messages from other components, serializes them, and then dispatches them one at a time to the target component. This ensures no more than one method call lands on the component at a time. The process is similar to how Windows messages from multiple input devices (keyboard, mouse, etc.) are serialized and dispatched to listening applications.

complex, multi-function instruments (such as a spectrum analyzer or "one-box" tester), synthetic instrument (SI) systems use more fundamental components, such as a high-speed digitizer coupled with standardized software. Rather than being tied to a particular vendor, test programmers can develop systems with best-in-breed components that fill multiple roles. As with the LXI Consortium, the SIWG is developing IVI instrument classes for SIWG's standard software interface to SI devices.

The SCPI standard and the VXI Plug-n-Play standard are two mature and pervasive standards that are now part of the IVI Foundation. In order to facilitate long-term maintenance and to ensure consistency with future software standards, both of these organizations felt it was best to be acquired by the IVI Foundation.

All of the industry bodies that are turning to IVI for software standardization give testimony to the argument that IVI will continue to grow and that future industry organizations will look to IVI for driver technology.

## USABILITY IN .NET

As mentioned previously, the IVI Foundation is currently developing standards for constructing native IVI.NET drivers. While these drivers will offer a number of compelling benefits, existing IVI-COM driver technology provides an excellent experience for test programmers working in .NET languages, such as C# and Visual Basic.NET. IVI-COM drivers can be supplied with special .NET wrappers known as *interop assemblies*. These interop assemblies make the IVI-COM driver appear to .NET clients as if it were a native .NET component. Thus, these drivers can be seamlessly integrated into .NET applications.

IVI currently supports .NET in two ways: 1) providing, as part of the shared software components, pre-built interop assemblies for all of the IVI-defined instrument classes; and 2) providing an IVI specification that explains how to create interop assemblies for instrument-specific functionality. As with many other aspects of driver development, the Microsoft-provided tools and processes for constructing interop assemblies leave too much ambiguity to ensure consistency between IVI drivers. Thus, the IVI interop assembly specification was developed to augment the standard Microsoft process with more precise rules for IVI drivers. For example, the interop assembly produced by using Visual Studio and its default settings is often incompatible with the one produced using the command line – even though the underlying interop utility (tlbimp.exe) is the same and the underlying IVI-COM driver is the same.[3] The IVI interop assembly specification instructs the driver developer on how to avoid these subtle pitfalls.

## DESIGN FLEXIBILITY

A common misperception about IVI drivers is that the design of the driver interface is too restrictive. Developers look at the IVI-defined interfaces for a particular instrument class and immediately conclude that IVI is not suitable for them because their device supports a broader array of functionality than IVI specifies or because their device models instrument behavior very differently than IVI does. In fact, IVI drivers are composed of two sets of functionality – class-compliant functionality defined by IVI and instrument-specific functionality defined by the instrument manufacturer. The class-compliant functionality is actually optional, so manufacturers who do not feel their instrument matches an IVI definition at all can simply choose to ignore the class specifications. The resulting driver can still be IVI compliant, as discussed earlier in the section entitled *What Compliance Really Means*.

The instrument-specific functionality in an IVI driver need not follow any prescribed set of functionality. Rather, driver developers have tremendous freedom in designing a driver interface that is intuitive for their particular customer base. Many IVI experts argue that the instrument-specific interfaces are the most important part of an IVI driver because they expose the unique features of the instrument – features which may have been the primary reason the customer selected the instrument in the first place. It is important to understand that a fully compliant IVI interface can easily be designed to accommodate virtually any way of abstracting the instrument's functionality.

In addition to giving the driver developer design flexibility, IVI provides a series of design guidelines to follow that ensure the driver works well in most ADEs. A great deal of effort has been invested by IVI Foundation members to explore and document subtle design requirements that, if ignored, would render many drivers unusable in certain environments. For example, one rule of IVI-COM interface design is that methods cannot have more than one output-only parameter. If multiple output parameters are needed, then they must be specified as input-output (two-way) parameters. The reason is that Visual Basic 6 will leak memory if a method has more than one output-only parameter.

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[3] A specific incompatibility that can occur is when the driver uses array parameter types. This is, of course, quite common in IVI driver designs. Visual Studio will, by default, expose arrays as the .NET `System.Array` data type, while the command line utility tlbimp will expose arrays as strongly typed arrays, such as `double[]`.

Memory leaks in applications are notoriously difficult to find and they often are even more difficult to fix once they have been located. Without the IVI specifications to guide them in their designs, many driver developers would fall into this trap and most would have great difficulty understanding what was going on.

IVI drivers also are constructed in hierarchies of methods and properties. This makes it easy for test programmers to navigate the available functionality of the instrument. These hierarchies are particularly important for instruments with large functional surface areas, such spectrum analyzers and RF signal generators. The IVI specifications provide guidance on how to properly construct these hierarchies so that they are usable in a wide variety of ADEs.

## EXTENDED DRIVER FEATURES

The IVI specifications describe four features of IVI drivers which provide unique capabilities beyond other driver technologies. These features are range checking, coercion recording, state caching, and simulation.

**Range checking** in IVI drivers validates input parameters against valid values accepted by the instrument. Often, range checking is performed within the instrument itself.

**Coercion recording** allows test programmer applications to query the driver for cases where parameters passed into a driver method or property had to be changed by the driver to values suitable for the instrument. For instance, a particular DMM may accept voltage range settings of 3, 30, and 300 Volts. When a test programmer's application attempts to set the voltage range to a value of 50, the driver may change the value to 300 to ensure the instrument is properly configured to perform the desired measurement. IVI drivers internally take note of these changes and store them for retrieval by test programmer's applications.

**State caching** is an optional feature of IVI drivers and can improve overall test application performance by eliminating redundant instrument I/O calls. When an application sets a property on an IVI driver to a new value, the driver stores this value in local memory. Subsequent queries for that property are serviced by directly accessing local memory, rather than by performing a time-consuming instrument I/O call. Similarly, subsequent calls to set the value of the property will not trigger an I/O operation unless the value supplied is different than the one stored in the driver's local memory cache.

**Simulation** is by far the most important IVI driver feature. Consequently, the IVI specifications require that all IVI drivers implement simulation. When simulation is enabled, the IVI driver performs no instrument I/O. Rather, it synthesizes values for output parameters so that test programmers can begin developing and testing their applications without requiring an actual instrument. With long procurement cycles for many types of instruments, having physical access to an instrument is a luxury many test system developers do not always enjoy. The simulation support provided by IVI drivers is indispensable in such situations.

Not only do the IVI specifications explain how these features should work, they also specify the functions that must be exposed so that the test programmer can control these driver behaviors. Standard functions mean that test programmers have a common, well-defined mechanism for enabling state caching, range checking, and simulation and for reading coercion information from the driver. This improves the test programmer's overall comfort level and confidence in building their application.

## BACKWARDS COMPATIBILITY WITH VXI PLUG-N-PLAY

IVI-C drivers are built on many of the same fundamental technologies as previous-generation VXI Plug-n-Play drivers. Users familiar with VXI Plug-n-Play (PnP) drivers will find using IVI-C drivers very familiar and natural. IVI-C drivers use the same data types as PnP drivers, such as `ViStatus`, `ViSession`, `ViInt32`, and `ViBoolean`. The details and hierarchy of IVI-C functions and attributes are represented in the same function panel (.fp) files and attribute information (.sub) files as PnP drivers. IVI-C drivers also use the exact same attribute programming model as PnP. Specifically, IVI-C drivers use functions such as SetAttributeViInt32 along with a #define'd constant to set the values of driver attributes. This is a familiar idiom for programmers experienced with PnP drivers. Error handling also builds upon the existing PnP specifications.

The IVI Foundation even went so far as to break its own naming conventions in certain places in order to facilitate backwards compatibility with PnP. IVI requires that driver functions start with an uppercase character. Yet, some IVI-C functions, such as `init`, `close`, and `reset`, all start with a lowercase character because that is how these functions were defined by the VXI Plug-n-Play standards.

## CONCLUSION

The IVI standard is widely misunderstood and often mis-marketed – even by some of its staunchest proponents. While interchangeability does work in a number of scenarios, IVI offers test programmers many more benefits than interchangeability. Above all, instrument manufacturers can focus their energies on developing and maintaining a single driver that will provide a first-class user experience in a wide variety of development environments. The collective expertise of IVI Foundation member companies is continually applied to ensure IVI drivers stay in lock step with the ever-changing software and hardware landscape and that test programmers will enjoy a consistent and familiar experience with IVI drivers. An impressive array of IVI-enabled tools is available from an assortment of suppliers, and more IVI tools are on the way. As LXI instruments continue to emerge, IVI drivers will become more pervasive, establishing not only a core industry competency and comfort level in their use, but in fact creating a fundamental end-user expectation. Taken as a whole, IVI offers more to test programmers, driver developers, and instrument manufacturers than any other driver option. There are truly few, if any, reasons to consider anything else.