



Leveraging mainstream computer interfaces for test and measurement

By Lee Atchison

IEEE 488, the workhorse of test and measurement (T&M), is nearly 25 years old. Although it has been part of the scene for decades, it continues to be a popular choice today. However, while it is still useful for a large number of applications, it simply can't handle all of the test needs that modern applications require.

IEEE-488 is being challenged by newer and faster technologies

New applications are demanding such advances as:

- higher performance
- higher reliability
- multiprocessing capability

These and other attributes either don't exist on IEEE 488, or they would be difficult to implement.

At the same time, the mainstream computer industry – driven by a need to resolve similar problems – has come up with newer and better interface technologies that are finally beginning to satisfy the needs of test and measurement engineers.

The development of high-technology interfaces to handle data transfers has been fueled by computer applications such as...

- multimedia video presentations

- video compression and transmission
- the internet

...along with advanced peripherals such as:

- color printers
- scanners
- high-speed modems

With video, in particular, the dreaded phrase real-time has finally crept into the vocabulary of mainstream computer industry professionals. In addition, price pressures have forced the computer industry to focus on low-cost solutions to these extravagant needs.

As a result, huge efforts have been invested into alternative interface technologies such as USB and FireWire, in the hope of addressing these problems. Those in the test and measurement community can finally look toward the computer industry for solutions to their increasingly demanding interfacing needs.

The new standards of FireWire and USB, in particular, have the potential to go a long way toward replacing IEEE 488 and satisfying T&M applications needs in such critical areas as:

- cost
- performance
- features

Without a doubt, the day is coming when one or both of these two interfaces will be included as standard on your controller of choice – without the cost and headache of adding hardware to your PC.

This article discusses the new technologies of USB and FireWire. It details the advantages and disadvantages of each, and how they compare to IEEE 488 in the key areas of price, performance, and features.

History of IEEE 488

IEEE 488, also known as HP-IB or GPIB, entered the marketplace as one of the first ways to connect a computer to external instrumentation.

Originally developed by Hewlett-Packard, it was designed to provide easy and standard connection between:

- computers
- controllers
- instrumentation

With its widespread acceptance and use, IEEE 488 quickly found its place as a computer interface standard as well. It was a popular choice as a connection to early printers and hard disks. In fact, the CS80 protocol was a hard disk protocol based on IEEE 488, and remained in regular usage as late as the early 1990s in HP-UX and RMB workstations for hard disk connectivity.



IEEE-488 has been the industry standard interface for connecting instruments to computers for automating measurements.

However, for the rapidly evolving computer industry, the shortcomings of IEEE 488 became apparent quickly. The advent and regular usage of other computer industry standards, such as SCSI, soon replaced IEEE 488 as a computer peripheral connection method.

Although the computer industry moved on, the test and measurement industry still found value in IEEE 488. IEEE 488 not only continued to grow in popularity for T&M applications, it still enjoys regular usage today. Improvements to the IEEE 488 standard, specifically geared for T&M applications, have assisted in the continuation of its life within this specialized niche. Industry-wide standards such as IEEE 488.2 and SCPI made it substantially easier to implement and also expanded its overall usefulness.

Computer industry leads the way

The computer industry made the shift away from IEEE 488 very quickly in the game. SCSI soon dominated the high-speed I/O interconnect market, with RS-232 and parallel ports taking control of the lower speed I/O needs. Computer peripherals of all types are available using these I/O mechanisms.

With the new-found popularity of Windows-based PCs, the computer industry discovered the need to build on these standards. Developers wanted to create I/O standards that were better, faster, and easier to use. And they wanted these standards to be useful, not only for the mainstream computer market, but for the even larger general-purpose consumer

electronics market. Fueled by the sales volume and potential of these lucrative markets, general-purpose computer and electronics industry representatives took on the task of developing new and better solutions.

Considering the viable possibilities that came from this development work, by far, the most support for emerging interface technologies today falls behind two emerging standards:

- USB
- FireWire

These two standards are positioned to take over most, if not all, of the I/O interconnect market. This is not only true for personal computers, but for professional computers, and consumer electronics as well. Soon, everything will be utilizing these two standards, including:

- televisions
- stereos
- VCRs
- home computers
- business computers

USB, positioned for the low-end cost/performance tradeoff, will be used for low-cost peripherals such as mouse and keyboards. FireWire, which is higher on the cost/performance spectrum, will be the choice for such advanced applications as:

- multimedia
- high-speed computer peripherals (scanners and printers)

- consumer audio-video electronics (VCRs, TVs, DVDs, and DSS satellite systems)

Test & measurement

While all of this evolution and innovation has taken place within the computer/electronics industry, the test and measurement industry has been much slower at adopting new standards. The old workhorse, IEEE 488, is still the most widely used instrumentation connection interface.

The VXIbus standard, which offers a higher speed (at higher cost), has made a few inroads. VXI is not only standards-based, modular, and scalable, it has a small foot print and is easy to reconfigure. But even VXI technology remains somewhat dwarfed by the dominance of the HP-IB market and its inherent limitations. A few mainstream I/O interfaces have been used for instrumentation, such as RS-232 and LAN, but only in very limited cases.

More about USB and FireWire

USB stands for Universal Serial Bus, a serial communications bus that provides up to 12 Mbits per second communications.

Unlike its predecessor RS-232, this new standard:

- supports multiple devices
- offers a standard connector
- provides power to peripherals with low-power needs such as the mouse or keyboard

USB is intended for low to medium-speed computer peripheral communications. As such, this interface is ideal for:

- low-speed printer
- audio peripheral
- modems
- mouse
- keyboard

USB is easy to connect and easy to configure, supporting standard plug-and-play configuration mechanisms. This new standard offers economic advantages and is readily available on host computers at this time. In fact, virtually every computer shipped today provides at least one USB connector. Compatible peripherals are beginning to proliferate, and more will be introduced, no doubt, as time goes on.

FireWire, also known as IEEE 1394, is a higher-speed communications standard. FireWire currently has several 200 Mbit implementations, although 400 Mbit implementations are starting to appear. Talk of providing 800 Mbit and even faster connections is already underway.

FireWire provides higher performance than USB, but as you might expect, these efficiencies come with a higher pricetag. FireWire is intended for use with high-speed peripherals such as:

- hard disks
- scanners
- CD-ROMs
- printers
- multimedia connections

At the same time, it is designed for consumer electronics, such as:

- TVs
- VCRs
- DVDs
- stereos

The intention behind the FireWire technology is to take its place as the interconnect for the sum total of stereo components, as well as all video/TV components. In this respect, FireWire would replace RCA or other analog connectors, providing both:

- digital audio/video signal transfer
- control and synchronization signals

The consumer implications for such a "master control" system are exciting. Imagine being able to press a button on your remote control that tells your VCR that you want to record a show. Your VCR goes out and sets up your satellite dish to the proper channel, instructing it to send the digital audio/video signal to record. The VCR then tells your TV to turn on and display what the VCR is recording. Finally, the VCR sets up your stereo to

output the hi-fi sound, initializing the Dolby signal processor. This entire chain of events is automatically carried out by standard communications signals.

The next step would be to connect your computer to the picture, allowing it to control your audio/visual system. Your computer could also send or receive multimedia information to or from your:

- hard disk
- CD-ROM
- DVD-ROM
- other peripherals

All this and more is the promise of FireWire technology.

Moving forward

Now is the time for the test and measurement industry to step up to the plate. Newer, higher-speed, higher-reliability, and higher-functionality I/O connects are needed in our world as well. But where are we going to find these advanced functions?

At this point, the two main choices are:

- expand existing T&M standards
- adopt computer/electronic industry standards

Expanding IEEE 488

Using existing T&M standards (such as IEEE 488) and expanding the "tried and true" does have some appeal, primarily based on the tremendous support that already exists within the T&M marketplace for this standard. HS-488 is one proposed expansion of the HP-IB specification. While this approach is tempting at first

glance, it also poses some significant disadvantages.

The most notable drawbacks include:

- minimal performance improvements
- difficulty in supporting multiple connections
- lack of support for a high volume of instruments
- limited economies of scale
- lower reliability

Granted, we might be able to tweak double or even triple performance improvements out of the existing IEEE 488 standard, but not much more than that. Although HS-488 quotes a five times boost in performance, real systems in the real world will probably realize much less.

The prime disadvantages of IEEE 488 still remain. Most notably, the extreme difficulty in carrying on multiple communications sessions from computer applications to different instruments. IEEE 488 was designed in a time of single-process computers, not to mention a very small number of instruments.

Today, parallel test execution is growing increasingly important as time-to-market and cost-of-test pressures continue to escalate. IEEE 488 has virtually no support for multiple processes and large number of instruments.

Furthermore, the fact that IEEE 488 is being used almost exclusively in the test and measurement market translates into a very limited customer set. And this specialized niche makes it extremely difficult to leverage economies of scale when driving the price down or the feature set up.

The advantage of electronics industry standards

Being able to use computer/electronic industry standards such as USB and FireWire has many advantages that avoid the primary pitfalls of IEEE 488. Most notably:

- outstanding performance gains, with more on the way
- excellent support for multiprocessing environments
- standard operating systems; standard programming languages
- ease of use; easy connections
- drastic price reductions due to mass integration

The mainstream computer/electronics industries will demand more and more performance out of their I/O connections. The T&M market can simply follow on their heels and realize drastic performance



The VXIbus standard is being utilized to a greater extent in functional test applications.

benefits with very little investment. FireWire solutions are already available that utilize a 400 Mbit interface, which is 50 times the base maximum performance of 1 Mbyte (8 Mbit) for HP-IB. Also in the works are discussions of an 800 Mbit FireWire solution, as well as a 1 Gbit+ solution.

These mainstream standards are designed for use with modern operating systems and programming languages. As such, they are very easy to use in multiprocess, multithreaded environments – even multiple-CPU environments. Also, they are typically easy to use from such mainstream computer languages as:

- C++
- Visual BASIC
- Java
- ActiveX

By leveraging the existing work of the computer/electronics industries, the economies of scale will allow the developer to lower the price and drive feature sets up. It is already nearly impossible to buy a computer from any major computer house without finding USB built into the system.

This situation forms a favorable contrast to the days when buying a computer meant purchasing a separate \$500 HP-IB card. But these new technologies offer even more intrinsic savings. USB cables are usually priced from \$10 to \$20 each, as opposed to HP-IB cables that sell for \$100 to \$200 each. The attractive prices for USB and FireWire will continue to drop as these new technologies become more deeply integrated into the mainstream.

Ease of use and ease of connection are imperative to the home electronics market. The ability to easily connect a TV to a VCR, and use them both conveniently with little or no effort, is incredibly important when dealing with consumers. The T&M industry can leverage this ease-of-use push to make its own products easier to use and integrate, thus lowering the cost of test. Imagine being able to connect test instrumentation to standard off-the-shelf computers without needing a screwdriver, or having to open up the computer to install an interface card.

With so much of the ground already covered, the T&M community can stop investing in improvements for the I/O connection, and start spending dollars on improving T&M value-added components, such as better measurements and systems. Rather than investing in HS-488, why not invest in test systems that lower the cost of test?

Bridging the gap

Now that the benefits of these new technologies have been firmly established, the question remains: How do we bridge the gap between these new interfaces and existing HP-IB systems? The answer is gateways. Gateways are boxes that perform protocol conversions from one interface technology to another, and they are already available on today's market.

These gateways take the form of RS-232 to HP-IB converters, as well as LAN to HP-IB converters. Very soon, you will see USB to HP-IB and FireWire to HP-IB converters. Hewlett Packard already offers a FireWire to VXI converter product. This converter features a lower cost and greater ease-of-use than previous VXI connect mechanisms such as:

- MXI or MXI II
- VXLink
- embedded controllers

With its many efficiencies, this converter offers an example of the economies of scale that can be generated by using an industry standard interconnect. USB products useful to T&M are also starting to appear.

Making use of USB/HP-IB and FireWire/HP-IB gateways enables the design engineer to accomplish several goals at once:

- Allows the connection of existing HP-IB instrumentation to standard computers without the use of a plug-in card, utilizing built-in USB/FireWire connectors
- Allows the addition of USB/FireWire instrumentation to existing systems of HP-IB and VXI instruments, enabling them to all operate together in a complete system

In the short term, USB and FireWire can augment the use of HP-IB using these gateway boxes. In the long term, however, it is likely that USB and FireWire, along with future computer/electronics industry standards, will completely replace the need for HP-IB. Until this total conversion occurs, mixed systems will dominate the scene for quite some time to come. The need for USB and FireWire to work seamlessly with HP-IB and VXI will be a necessity in order to make this transition easy and painless. Ω



Lee Atchison graduated from the University of Minnesota with a BSCS and BSEE in 1987 and immediately started to work for Hewlett Packard. Lee has been a staff engineer, project leader, and is presently an R&D project manager. Since coming to HP, he has been involved in several standards committee activities, including the VXI Consortium, IEEE 488.2, IEEE P-1174, and the VXIplug&play Systems Alliance. In addition to holding a patent in I/O interfacing technology, Lee wrote the SICL I/O interface standard and led the development of HP's SICL and VISA library implementation. Lee also authored the book, Object Oriented Test & Measurement Development in C++, published by Prentice-Hall.

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