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: Standard is Better Than Better

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ABSTRACT

For decades, test equipment makers have built instruments with GPIB as the main standard of I/O communication. In recent years, this has meant that T&M users were forced to utilize various time-consuming methods to connect GPIB-speaking instruments to the engineer's non-GPIB PC or network. With the recent shifts to laptops and more closed computers with fewer slots, and with the focus on time to market, T&M users cannot afford to waste time making instruments connect. Fortunately, a plethora of options is emerging to help this situation, and this article will survey the various ways in which test equipment, new or legacy, will become a better citizen in the user's environment.

BACKGROUND

End users of T&M instruments have been increasingly using computers to control their instruments and to acquire data from them. The exponential growth in the performance of PC-based computer systems has fueled this trend. Inexpensive, yet powerful, industry-standard PCs have enabled the T&M engineer to utilize his instrument with greater effectiveness and efficiency. Yet, the fundamental technology used to connect the computer with the instrument has not evolved at the same pace as the computer technology itself. Indeed, instrument connectivity is one of the most important issues for both equipment users and equipment vendors. End users have precious little time to invest in connecting their instrument with their computer and establishing fundamental communication between the two. For their part, equipment vendors are inundated with support calls from customers whose only real problem is that they cannot communicate with their instrument. Standard PC-based I/O technologies offer relief from many of these frustrations. Connectivity standards such as USB and Ethernet are now emerging as an extremely attractive technology for connecting PCs to T&M hardware. Their use is simple and familiar. In many cases, the overall I/O performance realized with technologies such as USB can be dramatically better than existing T&M I/O technologies such as GPIB. The improvement of PC standard I/O over T&M-specific I/O in both performance and ease-of-use is certain to continue, as the enormous momentum carried by the PC computer industry and the consumer electronics industry is brought to bear on their continued development. The following sections in this article will examine how industry standard I/O technologies, such as USB and Ethernet, offer an increasingly attractive alternative to existing T&M-specific I/O technologies, such as GPIB.

RS-232

One of the oldest I/O technologies used to communicate with T&M hardware is RS-232. Countless instruments have shipped, and continue to ship, with RS-232 communication ports. With such an extensive history, one might think that T&M users have mastered this technology and its use would be as familiar and natural as that of a telephone or automobile. Yet, RS-232 remains a perennial support and ease-of-use headache for T&M customers and vendors alike. Most of the difficulties posed by RS-232 communication can be understood by simply examining the name of the standard itself – "RS-232" stands for "*Recommended* Standard 232". The operative word here is *recommended*. A major source of headaches with RS-232 is that there are several different variations on the standard with multiple implementations. Today, there are multiple different types of cables with different types of connectors. Thus, for the end user, the confusion begins before either the computer or the instrument it needs to connect to have been powered on. An RS-232 port on an instrument expects a specific type of connector and cable, and if the user fails to select the right type of cable, then they may waste a good deal of time diagnosing a problem that has nothing to do with their application. Once the proper physical connection has been made, there are still some annoying protocol options that the user must properly configure to communicate with their instrument. Every instrument will communicate using a specific configuration, which includes such low-level details as the type of error correction, the number of start bits, and the number of data bits. Forcing the user to interact at such a low level with their instrument is an all-too-common and time-consuming source of frustration and error.

Further plaguing the use of RS-232 for instrument connectivity in T&M applications is its poor performance. The technology and the standard have fundamental limitations in the level of performance that can be obtained. It has aged with little industry attention paid to its evolution and consequently little invested in further development in the technology. As a result, other I/O technologies have come into favor with orders-of-magnitude improvement in performance.

GPIB

At present, the predominant technology used to connect computers with T&M instruments is GPIB. Vendors ship instruments with GPIB ports more than any other I/O technology. The performance benefits GPIB offers over RS-232 are considerable. GPIB-based solutions can transfer data at rates as high as several megabytes per second. GPIB's relatively low overhead results in good performance when moving small amounts of data, known as small block transfers. These factors have contributed to the widespread acceptance of GPIB as a viable T&M connectivity solution. However, GPIB suffers from some of the same fundamental problems as RS-232 as well as from some unique problems of its own.

One of the most evident disadvantages of GPIB is price. When compared with other connectivity options, such as USB and Ethernet, GPIB is positively exorbitant. Currently, a GPIB board will cost the customer around $500, which is not only an order-of-magnitude more than other I/O standards, it is possibly more

than the customer has paid for the entire computer they are trying to connect! GPIB cabling is also very expensive and extremely bulky. The limited range of GPIB requires even more expensive and even more bulky cables if longer communication distances are required in an application. The cost pressure of GPIB connectivity can largely be attributed to the simple fact that, unlike standard PC I/O like USB, GPIB is highly specialized to the T&M market. It simply does not enjoy the same economy-of-scale as the PC or consumer electronics market. In fact, GPIB is really a dual-source technology, available only from National Instruments and Agilent Technologies. An end-user cannot simply go to the nearest Comp-USA and purchase a GPIB interface board. This adds cost pressure to the technology and reduces familiarity with the technology. This also means that no investment in the development of GPIB exists outside the T&M community. It does not have the mind share of multiple industries, as do technologies like USB and Ethernet.

Ease-of-use is also an issue with GPIB. The most fundamental ease-of-use observation with GPIB boards is that the end user must open up their computer and put something in it to communicate with their instrument. Ten years ago this might have been a palatable experience for a large proportion of users, but today the age of Plug-n-Play devices has raised the ease-of-use bar for what users expect when connecting new devices with their computer. Older GPIB devices even require the user to manipulate switch settings for such things as DMA. This complicates the process for the end user and introduces ample opportunity for error. Unlike industry-standard USB, GPIB connectivity is sometimes difficult to achieve with notebook computers. While it is nearly impossible to purchase a notebook computer today *without* a standard USB port, none ship with GPIB ports built-in. Instead, notebook computers are typically equipped with PCMCIA slots to which a GPIB interface may be attached. However, these PCMCIA slots are very often already in use by other critical PCMCIA devices, such as network cards. As a result, GPIB is expected to give way to more convenient and more performant connectivity options for the T&M engineer.

USB

The most apparent advantage that USB enjoys over GPIB is that USB is truly ubiquitous. Virtually every new computer that ships today has at least one USB port built into it. Moreover, the reach and popularity of USB extends far beyond the PC industry itself. People are using USB to connect to all manner of consumer electronic devices, such as digital cameras and camcorders. This has a number of important implications for the T&M user. First, end-user familiarity with USB is large and growing rapidly. T&M engineers are very likely to already have experience working with USB devices both at work and at home. Thus, they will likely encounter little difficulty when using USB to connect to their T&M hardware. Also, the proliferation of USB devices in the market place creates an economy-of-scale that is unmatched by any other I/O technology, including GPIB. This makes cost a complete non-issue for USB, as it is virtually “free”.

While both RS-232 and GPIB suffer from ease-of-use concerns, USB's widespread popularity can largely be attributed to the fact that it is extraordinarily easy to use. Unlike RS-232, USB implementations are quite standard and consistent. Unlike GPIB, cabling is simple, small, and very inexpensive. USB devices also almost always support standard Plug-n-Play functionality. Users simply plug their USB device into an available port on the computer and the system immediately detects and identifies the device. Little more interaction with the user is required. This has become very much a customer expectation in the general consumer electronics space and there is no reason that T&M customers shouldn't expect the same. Indeed, a full Plug-n-Play standardization effort is already underway in the T&M community which will make traditional T&M instruments equipped with USB ports as easily accessible as consumer electronic devices. This will be critical for the modern T&M engineer whose job is increasingly unable to accommodate time devoted to establishing basic instrument communication.

Even at this relatively early stage of development, USB offers exceptional performance when compared with GPIB. The current USB 2.0 standard operating speed is 480 MBits/sec. More important, however, is the potential that these performance figures have to grow over time. Perhaps USB's greatest asset is its tremendous momentum. Unlike GPIB and RS-232, USB occupies the mind space of multiple industries and is propelled by a market that dwarfs the T&M marketplace. The effect that this can have on factors such as cost has, to a large degree, already been realized. However, the technological advances that emerge from the combined efforts of various markets have yet to be fully appreciated. To be sure, the benefits will be far greater in number and impact than those that the T&M industry alone could achieve with a niche technology like GPIB.

ETHERNET

Ethernet has been a workhorse of the computer industry for many years. Home networks, office intranets, and the Internet itself are often bound together with Ethernet. Within the T&M industry, more and more instruments are coming available with built-in Ethernet ports. With its well-established heritage in general computer connectivity, Ethernet is poised to become a popular alternative for T&M instrument connectivity. As an industry standard technology, Ethernet enjoys many of the same benefits as USB. Like USB, Ethernet is a very pervasive technology. Its widespread use in many computer-related industries makes it easily available and very inexpensive. Like USB, the prevalence of Ethernet-based devices means that T&M customers are likely to be familiar with the technology when they use it to communicate with their instrument. Cabling is simple and inexpensive and the distances it can cover are vast indeed. Even some of the ease-of-use considerations with setup and cabling are being addressed by industry innovations. For instance, users typically need to decide between a cross-over type cable versus a straight-thru (or patch) cable based on the two devices they wish to connect. Today, some Ethernet ports have the ability to auto-detect the type of cable to which they are connected and adjust their operation accordingly. Thus, even the user that connects the "wrong" type of cable will easily be able to connect to their instrument. This is an excellent example of the type of advancement that is enabled by having the focus of an entire industry, rather than that of the T&M industry alone.

One of the most compelling advantages of standard I/O in general, and Ethernet I/O in particular, is the broad range of I/O services available to the user. Ethernet communications underlies a wide variety of value-added communications applications. At the low-level, TCP/IP stacks are most often implemented on Ethernet. High-level services such as browsers, email, instant messaging, and NetMeeting all are run on top of Ethernet-based communications. Though these particular examples apply more to non-T&M applications, they are based on layered services that T&M engineers and vendors can exploit. The infrastructure than enables these advanced applications is a product of the broad mind share Ethernet possesses. Such enabling infrastructure is highly unlikely to be developed for GPIB or RS-232. Remote communications is becoming increasingly important in T&M applications, and Ethernet provides a very natural fit for practically any manner of remote I/O. Security is another increasingly desirable feature in communications and connectivity, and, indeed, Ethernet-based systems provide much more potential for secure connectivity than do GPIB or RS-232. Services such as *telnet* and *ftp* are already in use on T&M instruments equipped with Ethernet ports. Today, T&M engineers can use these services to upgrade instrument firmware or to install new measurement algorithms to their instrument with the same ease-of-use they have when installing a new game on their home PC.

Advanced software communication protocols such as COM, DCOM, CORBA, and SOAP are also already readily available on Ethernet, which enables a host of new instrument communication services. IVI-COM instrument drivers are already poised to become the industry standard for instrument control. Additionally, some of these newer communication protocols offer the possibility of dramatically better communications performance. One aspect of instrument I/O performance that is widely overlooked is the fact that most instrument I/O is text based. Controlling the instrument by sending text commands back and forth is not ideal from a performance standpoint. The time it takes the instrument to parse the text and interpret it cannot only be a considerable performance hit, it can actually be the dominant factor in I/O communication speed. With text-based communications like those used in GPIB instruments, it is indeed often the case that parsing and interpreting SCPI text ultimately limits the performance of system communications. With protocols like DCOM available on Ethernet, the T&M application has the ability to directly invoke operations on the instrument without using text-based SCPI commands. This would remove the biggest I/O performance bottleneck within the system. This is yet another example of how “riding on the coattails” of standard I/O enables T&M users to reap benefits that would not be available to T&M-specific technologies, like GPIB. It is unlikely that DCOM or CORBA, for example, will be ported to operate over GPIB or RS-232 anytime in the near future. The tremendous momentum carried by Ethernet, however, will continue to push it to new performance levels. Gigabit Ethernet is already a reality and in commercial use. In the face of such broad-based advancement in Ethernet and USB, wringing an extra ounce or two of performance out of GPIB will become increasingly difficult to achieve, and the industry’s investment in it will become increasingly difficult to justify.

CONCLUSION

T&M users have been relying on T&M-specific communication protocols such as GPIB to communicate with their instruments. While some improvements in performance and usability have been achieved over the years, standard I/O technology such as USB and Ethernet offer compelling advantages in terms of cost, ease-of-use, and performance. Fueled by an enormous and growing PC computer market and consumer electronics market, USB and Ethernet offer features and price-performance that are difficult, if not impossible, to achieve with T&M-specific technology, like GPIB. T&M users can expect to see an increasing number of instruments emerge that use USB and Ethernet as their primary I/O mechanism. If the success and popularity of these standard I/O technologies in the general technology marketplace is any indication, then T&M users indeed have a good deal to look forward to.