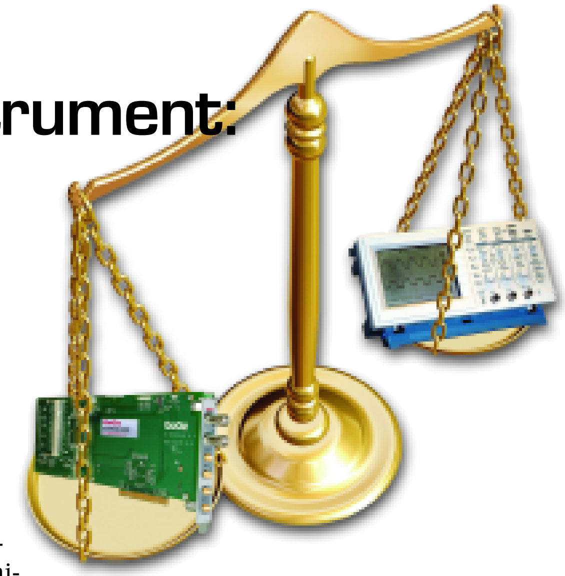
Choosing a waveform instrument: DSO or digitizer?



Understanding the capabilities of both types of measurement systems clarifies your options

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When confronted with the need for an instrument with which to examine the attributes of waveforms, engineers today have a fundamental choice: a standalone digital storage oscilloscope or a digitizer designed to work within a PC? Examining the attributes of both types of measurement devices is the best way to successfully answer the question.

Both standalone digital storage oscilloscopes and PC-based digitizers have as their functional heart an A/D converter chip. The essential difference between the two instruments is their packaging.

Historically, standalone DSOs package the A/D converter within an autonomous box with built-in controlling knobs, a display, and analysis functions. Transfer of data from a DSO to a remote PC has been a secondary, relatively slow, function.

By contrast, PC-based digitizers are usually installed within a standard PC in intimate contact with the PC's operating system, usually at the kernel level. In recent years, high-end DSOs have come with the Windows OS installed so that the DSO is becoming more like a digitizer within a PC. Nonetheless, the DSO is still a closed box in which the installation of additional hardware is not possible.

DSO advantages

Since the early days of analog oscilloscopes, one of the instrument's principal uses has always been rapid waveform visualization during benchtop signal measurements. Due to their minimal dead-time and to their exploitation of the natural persistence of display screen phosphors, traditional analog scopes allowed virtually 100% viewing of fast signals.

Accordingly, modern DSOs are optimized for signal visualization. For instance, even Windows-controlled DSOs use special hardware and software to write waveform data directly to graphics hardware for the fastest possible display refresh. PC-based digitizers generally cannot provide DSO refresh speeds, since they use standard Windows graphical interfaces. So-called digital-phosphor DSOs now simulate the persistence action of the analog scope's phosphor displays.

A second advantage of DSOs is their extensive signal-conditioning capability. Most DSOs may accept a much wider range of signal amplitudes than PC-based digitizers. Furthermore, most DSOs have a wide portfolio of probe technologies available. With such probes, users can measure signals with hundreds of volts of amplitude or bandwidths of over 10 GHz.

The highest available sampling speeds and input bandwidths (40 Gsamples/s and over 10 GHz, respectively) are still available only on standalone DSOs. The main reason for this is that the high-speed sampling A/D converter chipsets needed for such performance are proprietary technology of the leading oscilloscope manufacturers. Furthermore, highly specialized probe technologies are required in order to correctly connect to high-bandwidth signals.

Digitizer advantages

The advantages of PC-based digitizers arise from their defining ability to operate within an open PC environment. A host PC may be equipped with almost any imaginable array of other PC-based digitizers, other instrument cards, and controlling software. In this way, the PC may be transformed into a measurement system that is fully customized for the user's requirement.

For instance, a scanning ultrasonic inspection system may be equipped with a PC-based pulse-generator/receiver card to excite ultrasonic transducers, a PC-based digitizer to acquire received ultrasonic signals, a positioning motor to control the sample position, and a high-end graphics card for advanced data display. Operation of all PC-based cards may be integrated under one controlling software application designed for a specific ultrasonic measurement. The instrument may then be defined as the software application itself, a concept which is often referred to as synthetic or virtual instrumentation.

Other intrinsic attributes of PC-based digitizers are modularity, customizability, and scalability. The user need only select the number of PC-based digitizers that is sufficient for the required channel count.

Digitizers with different performance specifications may be mixed within the same PC. If more channels or memory are required in the future, the system may easily be scaled up for higher capacity.

The single greatest advantage of the PC-based digitizer is its ability to transfer data at ultrahigh speeds of over 200 Mbytes/s through the PCI bus to user-accessible PC RAM, from where it may be rapidly analyzed, displayed, or sent to long-term storage. While DSOs may be able to internally process and display waveforms at a high rate, they are typically connected through a relatively slow external bus, like GPIB, to a PC. As a result, while DSOs can continuously acquire waveforms at rates of only 10s to 100s of waveforms/s, PC-based digitizers are able to continuously acquire up to 10,000 waveforms/s.

For high channel counts, an additional advantage of PC-based digitizers is their compactness. More than 32 simultaneous input channels may routinely be assembled within one chassis. Furthermore, additional hardware and software features can usually be added more easily to a PC-based digitizer than to a DSO.

Different approaches

While DSOs and PC-based digitizers each have their own strengths, certain waveform measurement requirements are approached by the two instruments using strikingly different methods. One requirement is to manage high-dynamic-range signals containing both high- and low-amplitude components; the classic example is a square wave with small ringing oscillations superimposed upon it.

PC-based digitizers are available in a range of vertical resolutions—typically 8, 12, 14 or 16 bits. The higher the resolution, the more levels (256, 4,096, 16,384, and 65,536 levels, respectively) into which the A/D converter can divide the input range. The higher resolution allows the digitizer to be sensitive to smaller embedded signal features.

While in theory nothing inhibits the manufacture of DSOs with resolutions greater than 8 bits, they are extremely rare, if not nonexistent. The reasons for this are the implied sampling-speed limitations of higher-resolution A/D converters and the fact that 8 bits are usually sufficient for human visualization. DSOs typically approach the problem by providing a flexible dc-offset adjustment so that high-amplitude signal components may be cancelled out and small-amplitude components may be electrically amplified.

A different approach is also typically used for acquisition of highly nonrepetitive signals, or repetitive signals with rarely occurring features. DSOs have approached this problem by providing highly complex triggering capability that allows triggering on rare events. Persistent digital-phosphor displays allow retention of rare events on the DSO display.

PC-based digitizers usually offer less complex triggering and approach the problem by providing ex-

Comparison of standalone DSO and PC-based digitizer attributes

Attribute	Standalone DSO	PC-based digitizer
Waveform visualization	Rapid refresh	Slower refresh
Signal conditioning	Very flexible	Less flexible
Max bandwidth	10 GHz	~1 GHz
Sampling rate	40 Gsamples/s	<10 Gsamples/s
Scalability	Limited	Highly scalable channel counts and memory depths
System integration	Limited	Flexible
Continuous waveform capture rate	10 to 100 Hz	1,000 to 10,000 Hz
Compactness/portability	High for 2 to 4 channels	High for 8+ channels
Customizability	Low	High

tremely deep acquisition memory; Gage's CompuScope digitizers, for example, are available with up to 4 Gbytes of on-board acquisition memory. The acquired waveform may then be analyzed to find the rare event. The deep memory also lets the user analyze a nonrepetitive signal in its entirety.

Finally, measurements of waveform parameters, such as rise time and pulse width, are usually done rapidly by the on-board processor within a DSO. This often increases data throughput to a PC dramatically, since raw waveform data transfer is no longer required.

Since its raw-data throughput is so much faster, the PC-based digitizer generally performs waveform parameter measurements on the host PC. This provides complete analysis flexibility, since the user is not limited to the functions or methods provided by the DSO manufacturer. Recently, digitizer manufacturers have offered in-line on-board data processing through the use of increasingly powerful FPGA and DSP chips.

Knowing the attributes of both instruments (see *table*) makes choosing the correct instrument for your applications fairly straightforward. As a rule of thumb, we can say that for benchtop applications where signal visualization of unknown and widely variant signals is required, the standalone DSO is clearly the instrument of choice. On the other hand, when the nature of the signal is broadly known and the user wants to create a measurement system that rapidly and automatically monitors signals, the PC-based digitizer has an overwhelming edge. ■