The basics of choosing a digitizer

You don't have to be an expert to choose the digitizer that's best for you, but you do need to understand how the digitizer design affects your measurements to make a wise choice. And the first and most important requirement is: Know your waveform, because choosing the right digitizer depends first and foremost on the types of waveforms you digitize. This will steer you to one type of digitizing method or another, depending on the following general rules:

1. **For transients or non-repetitive waveforms, real-time digitizing is required.**
2. **For repetitive waveforms, either real-time or equivalent-time digitizing can be used.**
3. **For repetitive waveforms above about 50 MHz, equivalent-time digitizing is usually most economical.**

Of the above rules, the first is hard and fast: With transient or non-repetitive events, there's no chance for a second look. Digitizing has to be done as the event occurs. This makes real-time digitizing the only choice for transients. The following information will help you choose the right digitizer for your application.

Meeting Nyquist

Bandwidth is a familiar specification for analog instruments and it applies to waveform digitizers as well. A digitizer's analog input circuitry has a bandwidth which has the same implications as bandwidth in any other instrument.

Digitizers have a kind of digital bandwidth too, determined by the relationship of sample rate to waveform frequency content. The critical frequency is called the Nyquist frequency, and is equal to half the sampling rate. Basically, the Nyquist frequency is the highest frequency component definable by sampling.

If you acquire a waveform having frequency components above the Nyquist frequency, those higher components will be aliased to appear below the Nyquist frequency as low-frequency components. This has minimal impact as long as the major frequency components of the waveform already exist below the Nyquist frequency. In extreme cases, however, loss of significant high-frequency content through aliasing can cause stretching of transitions and rounding of waveform corners. The result is similar to exceeding the bandwidth specification of an analog instrument, except high frequencies reappear as low frequencies, instead of merely being attenuated.

Now, think about what happens if you acquire a sinusoid at or near the Nyquist frequency — you'll only get two samples per cycle of the sinusoid. While that may be sufficient to define it in the frequency-domain, two samples per cycle is woefully short of providing usable time-domain resolution. What is needed for correct digitizing is substantial oversampling. The Nyquist frequency needs to exceed the bandwidth of the instrument to produce multiple samples per cycle. For most digitizers (and in the accompanying chart), Nyquist frequency is specified in terms of maximum sample rate or time between points. These relationships can be expressed by: FN = Sample Rate/2 or ½ * Sample Interval.

Kinds of digitizers

Now that we've looked at the relationship between bandwidth and maximum sample rate, you can pick the kind of digitizing you need. There are really only two kinds to choose from — real-time and equivalent-time. Figures 1 and 2 illustrate the difference.

Real-time digitizing for everything would be ideal, but there are limits. Real-time digitizing of a high-frequency waveform requires very fast sampling and conversion rates along with very fast memory for storing the data. For example, to capture just two samples per cycle on a 100-MHz sine wave requires a sample rate of 5 nanoseconds/point. That means leading-edge, state-of-the-art digitizing and memory technology. This need for speed usually results in a speed/resolution trade-off, the major disadvantage of continuous real-time digitizing.

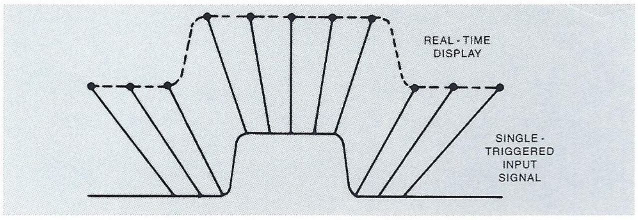

Figure 1. *In real-time sampling, samples are taken one after the other, in order, from the beginning of signal acquisition to its end.*

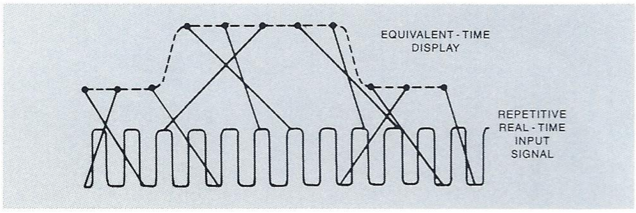

Figure 2. *Equivalent-time digitizing can use either random or sequential sampling (random is shown in the illustration). In both cases, a few samples are taken from each of numerous acquisitions of a waveform and then assembled into a representation of one waveform (the dotted line).*

The exception in real-time digitizing is the scan conversion technique. But scan conversion is not really continuous. A scan converter takes a snapshot of the waveform and then spends a block of time doing the conversion of all samples as a batch, rather than continuously digitizing on a sample-by-sample basis like other real-time digitizers.

There's a way out of the dilemma. If the waveform is repetitive, you don't have to capture it in real time. A typically lower-cost approach for repetitive waveforms is using equivalent-time methods to achieve higher effective sampling rates, as high as 100 gigahertz or more in some cases.

The equivalent-time sampling technique limitation is that it can only be used to its full range on repetitive waveforms. For single-shot acquisitions, the bandwidth is much lower since the digitizer must take data in real time. That means the sample rate is the actual — not the effective — real-time sample rate of the equivalent-time digitizer. As a result, the single-shot digital bandwidth will be one-half the actual sample rate. Newer digitizers provide a different solution to this dilemma

— combining real-time and equivalent-time digitizing in one instrument. This extends the effective bandwidth of the digitizers.

Vertical resolution

How fine and how deep do you need to look at the waveform you captured? Vertical or amplitude resolution for digitally-stored waveforms is determined by the number of bits used in digitizing. An 8-bit digitizer, for example, resolves amplitude to 1 in 256 distinct levels. So if the vertical (or voltage) range of the digitizer is one volt, 3.9 millivolts can be resolved (1 volt/2^8). For more resolution, more bits are required, and a 10-bit (1 out of 1024) or 12-bit (1 out of 4096) digitizer might be specified. The accompanying table will help you relate bits of resolution to other methods of expressing resolving power.

BITS	PERCENTAGE	PPM
1	50.0%	500,000
2	25.0%	250,000
3	12.5%	125,000
4	6.25%	62,500
5	3.125%	31,250
6	1.563%	15,625
7	0.781%	7,812
8	0.391%	3,906
9	0.195%	1,953
10	0.098%	977
11	0.049%	488
12	0.024%	244

As always there are trade-offs; vertical resolution is no exception. Generally the higher the digitizing rate, the fewer bits that can be used.

Horizontal or time resolution

Horizontal or time resolution is the time interval between samples on the acquired waveform. This is given by the inverse of the sample rate and can also be computed by dividing record duration by the number of samples in the record.

It's important to specify a resolution adequate for definition of waveform detail. To make rise-time measurements, for example, the sample rate has to be fast enough to place more than just a few samples on the pulse's transition. The more samples on the rise, the better its definition and the greater the measurement resolution. But this depends on adequate vertical resolution too. Defining rise time depends as much on being able to find the 10% and 90% amplitudes of the pulse with the desired resolution.

For time resolution, there are two things to consider — record length and sampling rate. Record length is the number of waveform points or samples acquired and is usually a power-of-two number: 128, 256, 512, 1024, etc., points. Some digitizers have a fixed record length and the sample rate is varied by the horizontal time-base setting. For example, for a digitizer with a 512-point record length and a time-base setting of 50 microseconds/division for 10 horizontal divisions, the sample interval or time resolution is (10 * 50E-6)/511, or 0.978 microseconds. In other digitizers, both record length and sample rate are directly selectable, giving you more acquisition flexibility.

It is important to match record length, sample rate, and record duration capabilities to your acquisition needs. A transient having a fast rise and slow exponential decay requires more record length than short duration pulses or most types of repetitive waveforms. You need fast sample rate for resolution on the fast rise and long record length in order to contain the slower portion of the record as well.

Built-in waveform processing

Whatever the method of sampling and digitizing, the point is the same: Express the waveform as a set of discrete values that can be stored in digital memory. Then, signal processing techniques can be used to extract the required information from the digitized data. The ability to obtain waveform measurements at a push of a button is a significant step toward greater measurement productivity. No more counting screen divisions and multiplying by scale factors. And, no matter who pushes a button to initiate a measurement, the measurement is done the same way every time by the instrument.

Productivity through programmability

With programmable controls, digitizer set ups for various measurement configurations can be stored, then recalled as needed. Productivity and repeatability are increased since the system can execute standard setups faster and more accurately than a human operator.

Instrument control and waveform data transfer over the GPIB or RS-232C interfaces opens another realm of measurement possibilities. Highly complex measurement sequences can be reduced to programs that automatically set up the instruments, gather the data, process the data, and output the results. Now, the amount of data storage and processing that can be done is essentially limited only by the computer and peripheral power you have available.

The features

Besides built-in measurement functions and programmability, there are many other features to choose from — and more are being added with each new instrument that is introduced. The following list should suggest some that might determine which digitizer best fits your needs: Multiple waveform storage, oscilloscope-type display, cursor measurements, averaging, peak detection, settings storage, programmable setups, built-in signal processing, envelope mode, pre- and post-triggering, save-on-delta, sample rate switching, analog real-time capability, and roll mode.

Finding out more about digitizers

Your two best sources of information about digitizers in general, and Tektronix digitizers in particular, are **HANDSHAKE** and the Tektronix products catalog. Please contact your local Tektronix Field Office or sales representative for a catalog or a demonstration of Tektronix digitizers. For a subscription to **HANDSHAKE,** write to HANDSHAKE, Tektronix, Inc., Group 157 (94-958), Box 500, Beaverton, Oregon 97005.

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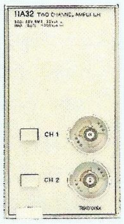
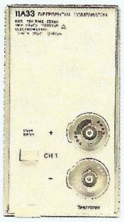
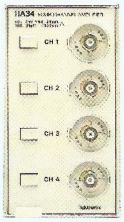
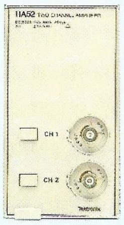
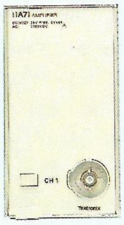
Select your performance...

New 11000-Series plug-ins

Plug-In	Description	Bandwidth/Risetime			
		11301	11302	11401	11402
11A32 Two Channel Amplifier 	Dual-trace plug-in with switchable 50 ohm or 1 megohm input impedance. Two four-pole (24 dB/octave) bandwidth filters (100 MHz and 20 MHz) are available per channel to reduce unwanted high-frequency noise. High-resolution DC offset provides a resolution of 25 microvolts and range of ±1.0 volt (equivalent to 16 bits).	300 MHz 1.2 ns	350 MHz 1 ns	350 MHz 1 ns	400 MHz 875 ps
11A33 Differential Comparator 	Single-channel differential comparator plug-in with high common-mode rejection ratio and fast overdrive recovery. Input impedance is switchable between 50 ohms, 1 megohm, and 1 gigohm. Calibrated DC offset of ±8 volts at maximum sensitivity of 1 mV/div provides an effective screen height of 16,000 divisions for very high resolution and high accuracy measurement of DC signal components. Built-in comparison voltage (V_C) allows precise measurement of the fine details on very large signals with unprecedented accuracy and resolution.	150 MHz 2.4 ns	150 MHz 2.4 ns	150 MHz 2.4 ns	150 MHz 2.4 ns
11A34 Four Channel Amplifier 	Four-trace plug-in with switchable 50 ohm or 1 megohm input impedance. Two four-pole (24 dB/octave) bandwidth filters (100 MHz and 20 MHz) are available per channel to reduce unwanted high-frequency noise. High resolution DC offset provides a resolution of 25 microvolts and range of ±1.0 volt (equivalent to 16 bits).	250 MHz 1.4 ns	250 MHz 1.4 ns	300 MHz 1.2 ns	300 MHz 1.2 ns
11A52 Two Channel Amplifier 	Dual-trace high-speed plug-in with 50-ohm input impedance and good VSWR and overdrive recovery. Two four-pole (24 dB/octave) bandwidth filters (100 MHz and 20 MHz) are available per channel to reduce unwanted high-frequency noise. High-resolution DC offset provides a resolution of 25 microvolts and range of ±1.0 volts (equivalent to 16 bits).	350 MHz 1 ns	400 MHz 875 ps	500 MHz 700 ps	600 MHz 540 ps
11A71 Amplifier 	Provides highest bandwidth currently available for the 11000-Series. Input impedance is 50 ohms only. DC offset is used to position the trace in units of 0.25 division (coarse) and 0.025 division (fine). Total offset range is 10 divisions at all sensitivities.	400 MHz 875 ps	500 MHz 700 ps	500 MHz 700 ps	1 GHz 350 ps