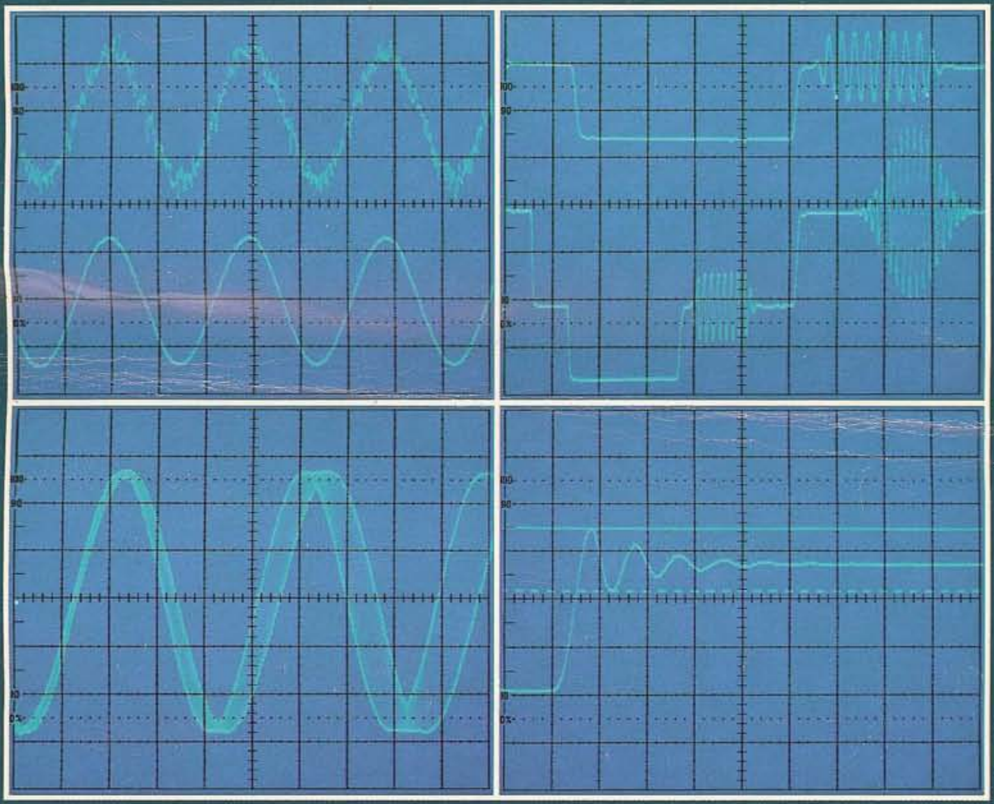
The Digital Storage Oscilloscope



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Introduction

This primer is about digital storage oscilloscopes: how they work; how you can make one work for you; and how to choose one that fits your needs.

The concepts governing the operations of digital storage scopes are described in the first chapter. The subjects include analog-to-digital conversion, digital time bases, sampling, aliasing, and the features some digital storage scopes use to counter aliasing.

The features of digital storage scopes are covered in the next chapter. General descriptions of how you might want to apply these features are also included there.

CHOOSING A DIGITAL STORAGE SCOPE is the last chapter. It describes how you can determine whether a digital scope will perform well enough for your needs. The subjects include measurement parameters you can use to make this judgement: Useful Storage Bandwidth — which tells you the maximum frequency sine wave a digital scope can store; and Useful Rise Time — which describes how fast a pulse the instruments will store accurately. There is also a discussion of timing measurements in which you'll find that a digital storage oscilloscope can make timing measurements much finer than its sample interval. After reading this chapter you will have the performance indicators you need to choose an instrument and to make comparisons between digital and analog storage scopes. The chapter, and this booklet, ends with a summary of the features you'll want to consider when you finally pick your digital storage scope.

Throughout the primer, digital storage scopes are compared to and contrasted with their closest cousins, the analog storage scopes, but some other storage instruments are neglected here. Chart recorders, scope cameras, waveform digitizers (or "transient recorders" as they are sometimes called), and oscillographs are all perfectly suited for their intended applications, but reviewing them here would have resulted in greater length than is practical in this primer.

Digital Storage Scope Concepts

The fundamental difference between the digital storage scope and its analog relatives is the form of storage. Digital scopes store data representing waveforms in a digital memory; analog storage scopes store waveforms within the crt (cathode ray tube). Digital storage requires digitizing and reconstruction processes as illustrated by Figure 1. "Digitizing" consists of "sampling" and "quantizing". Sampling is the process of obtaining the value of an input signal at discrete points in time; quantizing is the transformation of that value into a binary number by the analog-to-digital converter (ADC) in the digital scope. You determine how often digitizing occurs by using the switch on the time base. The time base uses a very precise digital clock to time the analog-to-digital (A/D) conversion and to store the data in memory. The rate at which this happens is the digitizing rate (or sampling rate). Once the data is in the digital memory, it can be read out at a fixed rate and reconstructed for displaying.

The ADC takes a voltage somewhere in the continuous range of possible voltages and outputs a number to represent it. The input voltage may have any value within the converter's range (3, 4, 3.5, 3.5163 volts, etc.), but the ADC can only discriminate between values to the limit of its resolution. So every quantized voltage output by the ADC is an approximation for a subrange of possible analog values. It is the size of the subrange that is important to you when you make voltage measurements. This size is the resolution of the ADC and it is determined by the number of bits in the binary number used to represent the analog input.

An ADC that outputs a 2-bit binary number ("bit" is from binary digit) can only represent four subranges; for a full scale of 0-10 volts, the subranges are 0-2½, 2½-5, 5-7½, and 7½-10 volts. With more bits the full scale is further subdivided and the minimum subrange expressed is smaller. So the more bits used to express the input voltage, the better the resolution of your measurements.

Two of the bits in the binary output of an ADC have names. The first digit is the most significant bit — the MSB — and the last digit is the least significant bit — the LSB. The LSB expresses the smallest subrange the ADC is capable of resolving. This is the "weight" of the LSB and it tells you how accurate your voltage measurements *can* be with that particular ADC. For example, in the 4-bit converter diagrammed in Figure 2, the weight of the LSB is 0.625 V (10 V times $^{1}/_{16}$). The weight of the LSB tells you how accurate your measurements can be ideally, but that's not a guarantee. The accuracy is dependent on more than just the resolution of the ADC as you'll see when you read further.

Analog-to-Digital Conversion

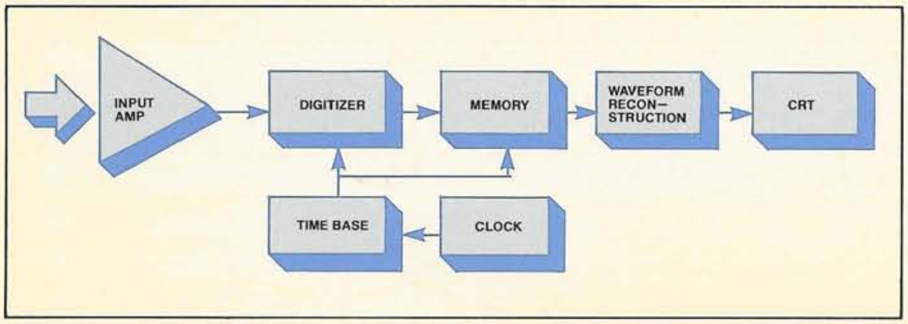


Figure 1. The analog input signal is conditioned by the input amplifier, sampled and quantized by the digitizer, and then the resulting word data is stored in the digital memory. The rate at which the signal is sampled and stored is selected with the time base and timed by the scope's digital clock. The digitized data in memory is then reconstructed and displayed by the cathode ray tube.

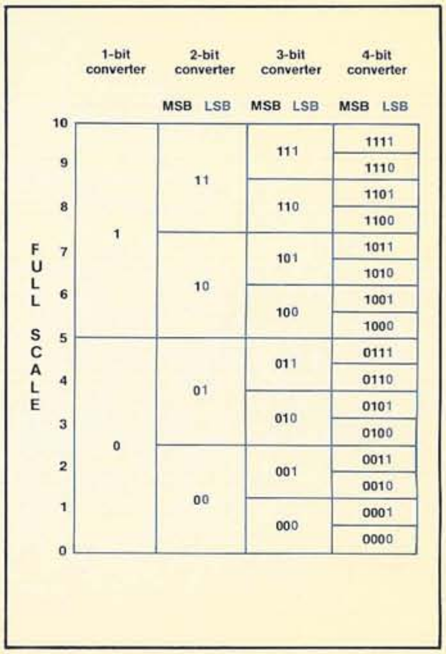


Figure 2. Four A/D converters are shown subdividing a full scale range of 0 to 10 volts. Each bit the ADC's use represent an equal-sized subrange of analog values, so these are called "quantizing units". The "weight" of the LSB for each of the converters can easily be seen in the drawing as the size of the quantizing units decreases with the addition of bits.

Table 1. Expressions of Resolution

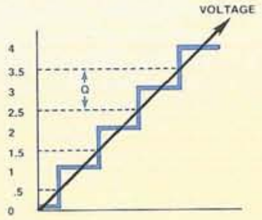
BITS	PERCENTAGE	PPM	LEVELS
1	50%	500,000	2
2	25%	250,000	4
3	12.5%	125,000	8
4	6.25%	62,500	16
5	3.125%	31,250	32
6	1.563%	15,625	64
7	0.781%	7,812	128
8	0.391%	3,906	256
9	0.195%	1,953	512
10	0.098%	977	1024
11	0.049%	488	2048
12	0.024%	244	4096
13	0.012%	122	8192
14	0.006%	61	16,384
15	0.003%	31	32,768
16	0.0015%	15	65,536
17	0.0008%	7.6	131,072
18	0.0004%	3.8	262,144
19	0.0002%	1.9	524,288
20	0.0001%	.95	1,048,576

The resolution of a measuring system is an important specification. Because resolution depends on the number of bits used by the converter, "bits of resolution" is common terminology: converters are said to have "a resolution of 1 part in 2^n" or "*n*-bit resolution" where n is the number of bits. Sometimes ADC's are described as having "2^n levels of resolution"; this is the number of elements or items that can be distinguished with that converter. You can translate levels back to bits of resolution with Table 1. The table also lists expressions of resolution in the equivalent percentage and in parts per million. From the table you can see that it doesn't take many bits to get good resolution.

Accuracy and Resolution

The terms "accuracy" and "resolution" are not synonymous. Resolution is the distinguishing of individual items while accuracy is "the conformity of an indicated value with a true or accepted standard value". To picture the difference, imagine a scale with a 3-digit readout. When you step on it, the display reads 150 pounds. The registered weight could have been anything from about 149½ pounds to about 150½ pounds. So the resolution of this scale is 1 pound, the smallest unit that can be distinguished.

QUANTIZING THEORY



As the analog voltage (black line) increases, it crosses transitions or "decision levels" (dotted blue lines), which causes the ADC to change states as represented by the solid blue line. This is the process of quantizing. In an ideal ADC represented by the drawing, the transitions are at half-unit levels and Q represents the distance between decision levels which is also called the "bit size" or "quantization size". Even in the theoretical ADC there is always a "quantization uncertainty" because though Q may be very small, it is still a finite range and any analog value within that range can be present. The quantization uncertainty is expressed as ±½ LSB. Another way of looking at this uncertainty is in this drawing.

As the plot of the quantizing error shows, the output of an ADC may be thought of as the analog signal plus some quantizing noise. Of course, the more bits in the ADC, the less significant the noise is.

In the real world, the decision levels are not firm lines, but are bands and an analog value within one of those bands could be translated to either of two discrete outputs. Real ADC's might also have different Q distances between the decision levels because of errors of nonlinearity and gain. In a good ADC none of these errors will add up to more than ±½ LSB.

DATA RESOLUTION AND SCREEN RESOLUTION

Resolution is an important concept because the ability of a measurement instrument to resolve small units of information (either voltage or time in the case of scopes) sets the ultimate limit of the instrument's accuracy. Digital storage scopes have great potential resolving power in both dimensions: voltage resolution as determined by the ADC; time resolution as determined by the memory size. But often this resolution remains a potential because the data is presented as a waveform on the crt and that forms the limit.

The resolution possible on the crt of an analog scope is a function of the screen size and the electron beam spot size and shape. Along the horizontal axis the resolution can be measured with a shrinking raster and it varies from 100 to 300 lines, or items, of resolution. The vertical axis has a higher resolving power; you can distinguish changes of 1 part in 500 to 1 part in 1000. The higher resolution here results from the way scopes are used: vertically, you want to detect a small change; horizontally, you want to make a measurement that requires distinguishing between two cycles or two pulses.

The screen resolution of an analog scope is the measurement resolution. That isn't true of digital instruments, though they may have similar crt's. The digital scope has its memory, and there the resolution of the measurement can be greater. This greater resolution is available: you can digitally expand the trace; you can use cursors; and you can use the data output facilities to get the digital data itself.

You can make a numerical comparison with the products of the vertical and horizontal resolutions of the two kinds of instruments. Analog scopes vary from 50,000 to 300,000 elements of resolution; digital scopes vary from 32,768 to 16,777,216. That last number is from a digital storage scope using a 12-bit ADC and storing the waveform in 4096 data words.

But what's the accuracy of the scale? Imagine getting an official 150-pound weight from the Bureau of Standards. When you put the weight on the scale, the readout said 147 pounds. Now you know that the accuracy of the scale is 2% (3 divided by 150) — at 150 pounds. Accuracy however, is always specified for the full range of possible measurements and maybe this scale is accurate within 15% over its entire range of 1 to 999 pounds.

Note that your measurements cannot be more accurate than the scale's resolution; that's why resolution is an important specification for a measuring instrument, either scale or scope. Another, equally important, reason is that resolution determines your ability to see fine detail or small changes in your measurement. If you were dieting, for example, you would be interested whenever the scale showed that you'd lost a pound. In this case, you are less interested in the scale's accuracy than you are its resolution.

Vertical Accuracy in a Digital Scope

With the difference between resolution and accuracy in mind you can see that the vertical resolution of a digital storage scope is simply the ADC's resolution, but the accuracy is a different matter. Accuracy depends on more than the resolution; it also depends on the linearity of the input amplifier which is just like those used in analog scopes. As a consequence, the possible accuracy implied by the ADC resolution (0.391% for an 8-bit converter; 0.098% for 10 bits) will not be the accuracy of your measurements. Instead you will usually find the same accuracy specifications for all scopes; 1-3%.

But with digital storage you'll gain from using cursors; they will improve the repeatability of your measurements by reducing human errors and reducing the effects of crt nonlinearities.

Digital Time Bases

The clock used by a digital scope is usually a crystal oscillator of an established frequency. An analog scope uses a ramp to generate the time base and will usually be spec'ed at 1-2% accuracy. The digital clock is so precise, however, that 0.01% is possible. More importantly, the stability of digital clocks is great over either the long or the short term, and because the digital time base is derived by counting cycles — not from an analog ramp — the linearity is better by orders of magnitude.

Resolution in the horizontal dimension is also excellent. Here the figure is derived from the record length used to store the waveform. For a waveform stored in 512 data words (think of that as 512 discrete elements), the resolution is 9 bits.

If you use a digital scope to just write the data on the screen once (as opposed to using the averaging feature described in the next chapter) and you choose not to use cursors and expansion, then the accuracy of your timing measurements will be limited by the screen resolution of the scope. The screen resolution is a function of the electron beam's spot size and shape and it limits your measurements to about 2% of the full scale — the same accuracy you can get with an analog scope. (Accuracy of 1% is possible with analog scopes capable of delayed sweep.) But you can use expansion and cursors to take advantage of the digital time base accuracy. With the cursors, the accuracy is limited by the clock accuracy, or the data or cursor resolution — whichever is worse.

Horizontal Jitter

One of the characteristics of all digital storage scopes until the introduction of the Tektronix 468 was horizontal jitter that occurred with multiple acquisitions of a signal. The jitter would be ±½ a sample interval (a sample interval is the amount of time between samples) and was a result of the way digital scopes store the waveform. A digital scope is always acquiring the input signal; it doesn't wait for the trigger event like an analog scope. Consequently, there is no consistent timing relationship between the digitizing clock and the trigger event. So on successive triggers and repaintings of the signal, the relationship between the clock and the waveform on the screen can vary ±½ a sample interval. The trace then appears to jiggle back and forth on the screen and this severely limits the usefulness of the instrument in magnified viewing.

Horizontal jitter does not appear with single acquisitions, and with the Tektronix 468, jitter is unobservable even during horizontal expansion of repetitive signals.

Digitizing the Data

At intervals controlled by the clock, the A/D converter transforms an analog value into a discrete binary number to be stored in memory. The input signal is said to be "strobed" by the clock, a reference to the effect of a strobe light when it freezes motion. The rate at which the A/D conversion takes place is the digitizing or sampling rate. Digitizing rates are stated in samples/second or frequency, in bits/second, and sometimes with a sample interval or time/point number. For simplicity's sake, frequency is used in this book.

DIGITIZING RATES

Sampling rate or digitizing rate specifications are expressed in a number of ways. Most common is frequency, the number of samples/second. Sometimes the information rate is given; this is the number of bits of data stored in a second. To translate an information rate into frequency, just divide by the number of bits the ADC uses. Sample interval or a time/point is also used; these are the reciprocal of the frequency.

To determine the digitizing rate for a particular TIME/DIV switch setting:

$$\text{DIGITIZING RATE} = \frac{\text{NUMBER OF DATA WORDS/DIV}}{\text{TIME/DIV}}$$

The number of data words per division is:

$$\text{NUMBER OF DATA WORDS/DIV} = \frac{\text{RECORD LENGTH OF WAVEFORM}}{\text{SWEEP LENGTH IN DIVISIONS}}$$

For example, if a waveform is stored in 512 data words and the scope shows all 512 points within 10 divisions (some scopes use a screen size of 10.24 divisions), then the number of data words per division is 51.2. Dividing that by the TIME/DIV setting gives you the digitizing frequency. For 1 second it would be 51.2 Hz; for 10 μs, it's 5.12 MHz.

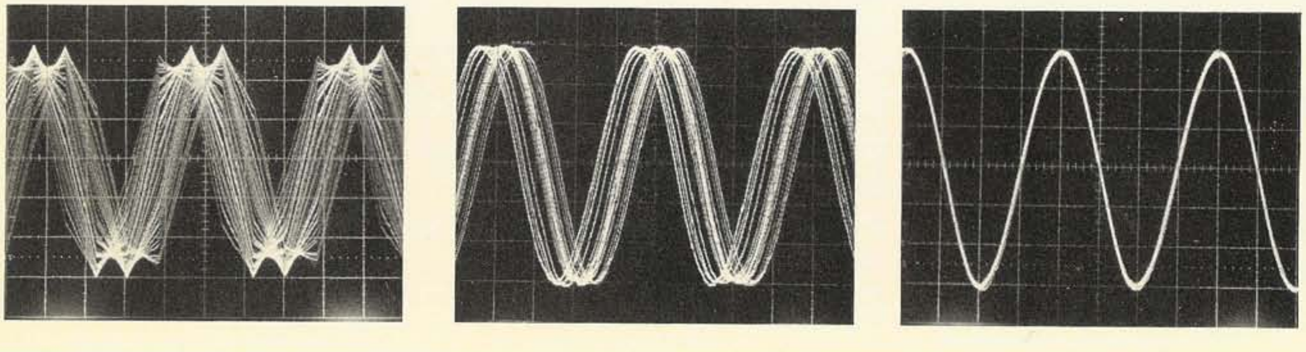


Figure 3. The waveforms acquired by a digital scope are digitized under the control of a free-running clock. When multiple acquisitions of a signal are stored, the timing relationship between the clock and the trigger can vary ±½ a sample interval. Horizontal jitter is the result. Jitter is minimized by using large memories to store the waveform (which makes each horizontal element smaller), but the jitter will still limit horizontal magnification. Jitter correction is a feature of some digital storage scopes and with these instruments, there is little jitter in either normal or magnified viewing. The photos above are the result of many acquisitions of a 5 MHz sine wave. The first display should be familiar to users of digital scopes. The second shows the effects of a sine interpolator on the same signal (interpolators are described later in this chapter). The greatest improvement in the usefulness of the display results when both sine interpolation and jitter correction are used.

SAMPLING TECHNIQUES

There are two digitizing techniques that you shouldn't confuse: real time sampling and equivalent time sampling. Digital storage scopes use real time sampling so that they can capture both repetitive and single-shot signals. Sampling scopes use equivalent time sampling and are limited to capturing repetitive signals. Some digital storage scopes use equivalent time digitizing to extend their useful frequency range.

The two equivalent time techniques — random sampling and sequential sampling — build up a picture of the input waveform by capturing a little bit of information about each signal repetition. Eventually they have enough information to reconstruct the entire waveform.

Not all signals you want to store are repetitive. Some happen only once; some happen so infrequently that they might as well only happen once. That last category includes pulses that occur less than once in a second. It would take a sampling scope 15 minutes to build a picture at that rep rate. If you're working with repetitive signals, however, a sampling plug-in like the 7S12 for the Tektronix 7000 Series scopes can extend your ability to store signals out to 14 GHz at a very modest price.

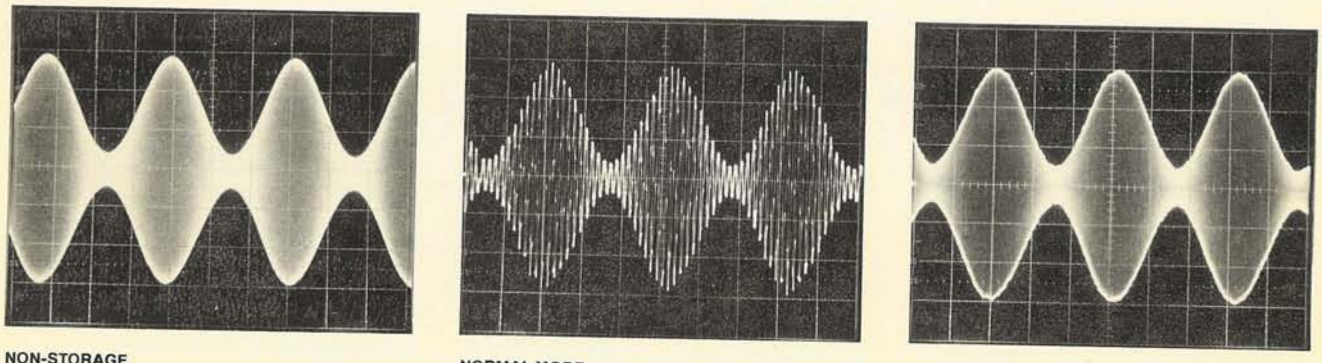
Once you know the maximum digitizing rate of a digital storage scope, you can determine if the instrument will meet your needs by applying sampling theory. Application of the theory shows that any signal of *f* frequency must be digitized more than 2*f* times to be fully recovered. Note the wording; exactly two times won't do. Sampling and digitizing has to be 2+ times the signal frequency.

Another way of stating the same rule uses the Nyquist frequency; it is half the digitizing frequency and no frequency at or above it can be recovered without error. In real life you will rarely be looking at a pure sine wave, so it will be the signal components above the Nyquist limit that will be reconstructed somewhere below the Nyquist frequency in the waveform you capture with a digital storage scope.

Sampling theory and the speed with which ADC's can work limit the frequencies you can capture faithfully with a digital storage scope. Violating the rule results in what is called an "aliasing error". (The limitations described do not apply to sampling scopes which operate on a different principle as described in "Sampling Techniques".)

Aliasing and Anti-Aliasing

Pushing a digital storage scope past its limits results in errors different from those you encounter with an analog scope used past its limits. The error is aliasing, and there is only one way to avoid it: always digitize more than twice as fast as the highest frequency in the signal. The simplest way to do that is to make sure you pick a TIME/DIV setting that results in a high enough digitizing rate. If you can't do that, you can use an anti-aliasing filter to eliminate frequencies above the Nyquist limit. That avoids aliasing, but it also removes any indication that higher frequencies are present in your signal. (Note that a bandwidth-limiting switch is not an anti-aliasing filter. The rolloff of a bandwidth-limiting device is usually 6 dB/octave and an anti-aliasing filter should have at least 12 dB/octave or some high frequency components will still appear as aliasing.)



NON-STORAGE

NORMAL MODE

ENVELOPE MODE

Figure 4. These photos are of an amplitude-modulated signal as it was displayed by a non-storage scope, by a digital storage scope, and by a digital scope using the envelope mode. The modulating frequency is reproduced easily in both digital acquisitions. The carrier, however, is being digitized at a rate much less than two samples per period and is shown as a lower frequency in the middle photograph. The evelope mode used as an anti-aliasing feature results in a display very much like the non-storage signal. If the carrier had been at a lower frequency and digitized appropriately, the envelope and normal mode displays would have been similar.

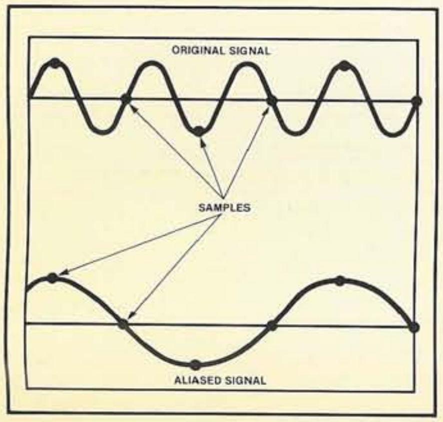


Figure 5. If a signal is digitized less often than necessary, aliasing results. The drawing represents a 120 Hz signal digitized at 160 Hz; the aliased waveform is 40 Hz.

Another useful anti-aliasing feature included in many digital scopes is a real time analog mode. When you suspect aliasing, you can switch to this mode (which usually offers greater bandwidth, like the non-storage mode of an analog scope) and check the signal.

A more useful method of anti-aliasing is to design the scope so that you are warned when aliasing occurs. The evelope mode of the Tektronix 468 is an example of this type of feature. In this mode vectors are drawn between the highest and lowest values recorded for the digitized data words. The result is a display that prevents you from assuming an aliased signal is accurate. See "The Envelope Mode" for more details.

Digital Storage Scope Displays

How a digital storage scope reconstructs the data in its memory for display on the crt is equally as important as how it captures and digitizes the input signal. Three display reconstruction techniques are currently used in digital scopes: dot displays, linear or pulse interpolators, and sine interpolators.

Dot Displays

As illustrated by the block diagram in Figure 6, the dot display is reconstructed by using a DAC to transform the data words in memory into analog position information to be written on the crt.

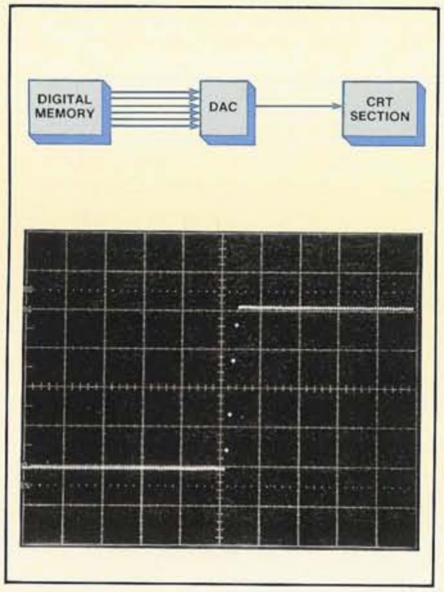
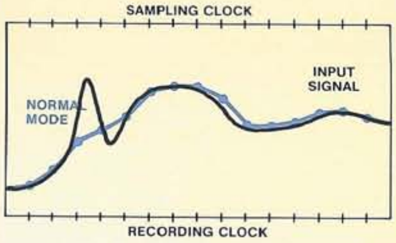
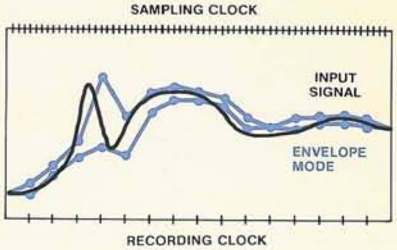


Figure 6. The binary data words in the memory of a digital storage scope are translated into analog values by a DAC before being used by the crt section to construct a display such as the one in the photograph.

THE ENVELOPE MODE

In the normal operating mode of a digital storage scope, the input signal is digitized at the frequency related to your TIME/DIV switch setting. One data word is stored in memory for every sample taken. In the evelope mode of the 468, samples are taken at a much faster rate but recorded at the frequency specified by the TIME/DIV switch. Instead of recording just one data word for each sample, however, two are recorded: the minimum and the maximum. The results of this kind of digitizing are shown in the drawings.





As the illustrations show, a signal excursion that occurred between the normal sampling points is captured and displayed by the envelope mode. The envelope mode has an obvious use in detecting aliasing, but it also has other uses. With the dual sampling rates of the envelope mode you can see as much of the waveform as you need to (as captured by the TIME/DIV settings) and still catch glitches (with the faster rate). The envelope mode also lets you use the 468 to automatically catch minimum and maximum signal values over long periods of time. These uses of the envelope mode are described in the next chapter, APPLYING DIGITAL STORAGE SCOPE FEATURES.

But as the frequency of your input signal increases with respect to the digitizing rate, there will be less dots available to form the trace. The result, especially with periodic waveforms like sine waves, is perceptual aliasing errors. Perceptual aliasing is a kind of optical illusion (see Figure 7) that occurs because when you look at a dot display, your mind tends to form continuous waveforms by connecting each dot with its nearest neighbors. The next closest dot in space, however, may not be the next closest sample of the waveform. The result is that you can easily misinterpret the data on the screen and that it takes a large number of dots (about 25 for every cycle of the sine wave) to present a recognizable display.

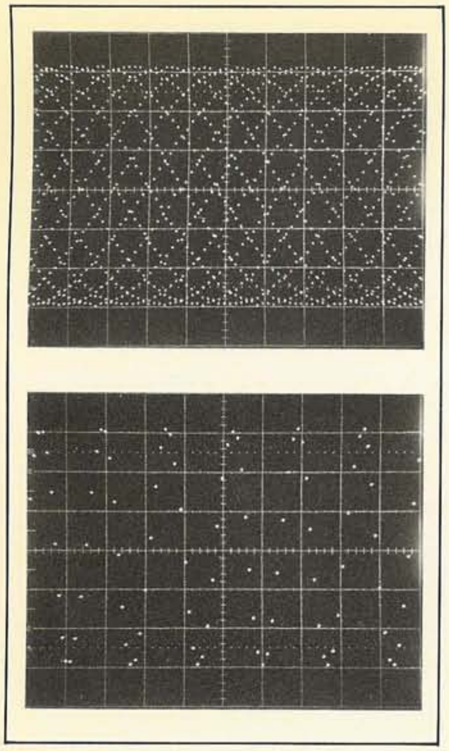


Figure 7. Perceptual aliasing errors are so named because sometimes the dot display can be interpreted as showing a signal of lower frequency than the input signal. But this is not true aliasing. The actual waveform is there; your mind — not the scope — makes the mistake. Note that in the top photo what seems to be many untriggered sine waves is really one waveform. In the second photo the trace has been expanded ten times and the original input is easier to see. The signal in the photos has been digitized well above the frequency demanded by sampling theory.

Pulse Interpolation

Some digital storage scopes use interpolators to generate new data words between those acquired by the scope. Then all the data words are passed to a vector generator which draws lines between the data points on the screen. ("Data words" in memory become "data points" when displayed.)

An interpolator may be optimized for displaying either pulses or sine waves; those that work best for pulses are linear or pulse interpolators. When this interpolator is used to display a sine wave, perceptual aliasing is eliminated and only 10 vectors per cycle of the sine wave is necessary to reconstruct a recognizable display. Pulse interpolators also make glitches more visible by connecting every data point and preventing a single dot far from the rest of the waveform from being overlooked.

As long as the vectors on the screen are short, an accurate representation of the input sine wave is possible, but with long vectors, the displayed waveform and the input signal may not coincide. A linear interpolator can indicate a different shape for the waveform anytime the samples taken by the scope do not fall exactly on the peaks of the signal. This envelope error — illustrated by Figure 8 — is not the result of aliasing.

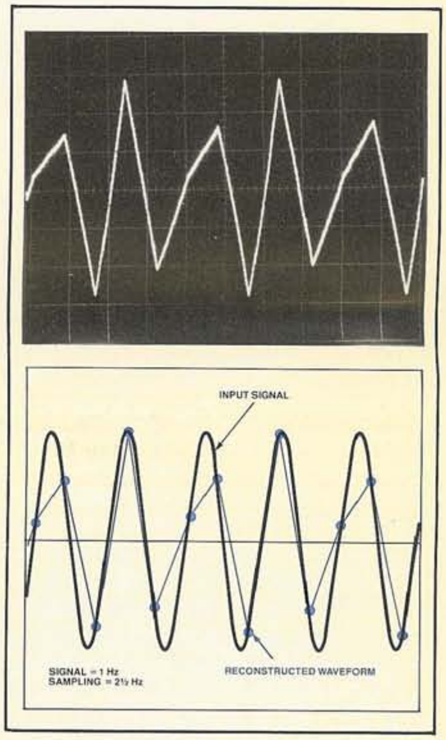


Figure 8. Envelope errors occur when the digitized data points do not fall on the peaks of the input signal. This type of error can occur with either dot displays or interpolated displays, and it can appear on both step function and periodic waveforms. In the photo the signal peaks fall outside some of the samples and the sine wave becomes jagged when constructed from the data points. In the drawing the true nature of the sine wave is shown.

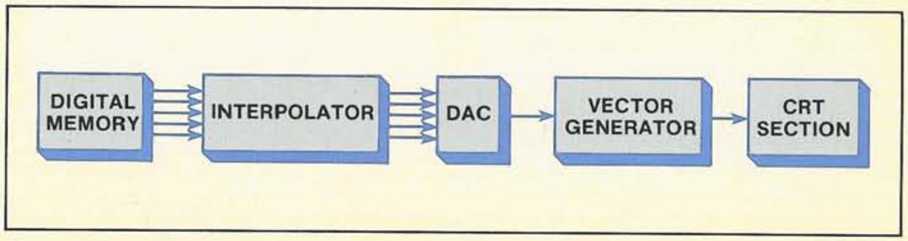


Figure 9. The interpolated display construction can be diagramed as above. A program within the digital storage scope interpolates between the data points as they are stored in memory and adds the interpolated points to the data before it is passed to the DAC for translating to analog values to be used by the crt section of the scope.

Sine Interpolation

Another display reconstruction technique uses an interpolator designed for reproducing sine waves. As long as no aliasing took place when the original data words were gathered, this interpolator will not introduce errors when displaying sine waves. The sine interpolator in the Tektronix 468 illustrates the advantages of this display type for reconstructing sine waves; only 2.5 data words per cycle are necessary to display the signal.

Interpolators can be optimized for displaying either sine waves or for pulses, but not for both. The compromise can only be made at the expense of the interpolator's performance. The same interpolator that makes sine waves more accurate introduces what looks like pre-shooting and over-shooting on pulses (see Figure 10). Conversely, an interpolator with good pulse response will cause amplitude rolloff or sharp edges on sine waves. The best approach is to offer a choice: sine interpolation for sine wave viewing, pulse interpolation for pulse viewing.

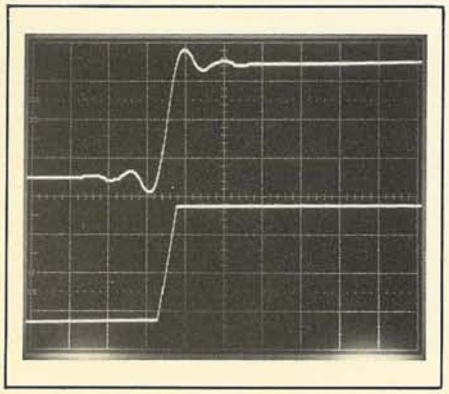


Figure 10. Displays constructed with sine interpolation avoid perceptual aliasing and envelope errors when used to display sine waves. But an interpolator designed for good sine wave response can add what looks like pre- and over-shooting to the display of a step function when there are less than three samples taken on the step. The error is minimized if more than three samples are taken and with narrow spectrum waveforms like sine waves. The photo above is a double exposure of a signal with no samples on the step; the first trace is drawn with a sine interpolator and the second with a pulse interpolator.

Comparing Digital and Analog Storage Instruments

Digital storage scopes store data in binary form which entails sampling and quantizing. As a consequence, digital storage scopes must behave differently than analog scopes. The differences show up in the storage abilities of the two kinds of instruments, in what happens when you use them past their limits, and in the nature of the measurement errors you can encounter. Table 2 summarizes these differences briefly, and in the last chapter, we will return to these subjects and compare digital and analog instruments in greater detail.

Table 2. CRT and Digital Storage Comparisons

	CRT STORAGE	DIGITAL STORAGE
STORAGE ABILITY	**Trade off between signal amplitude and maximum stored frequency**	**Maximum stored frequency is independent of amplitude**
	Difficulty in writing fast/slow transitions without blooming	**No blooming**
		Additionally, the envelope mode allows fast glitch catching at any sweep speed
BANDWIDTH	**Fixed, as determined by the amplifier response and/or writing speed**	**Variable, as determined by the digitizing rate selected with the TIME/DIV switch; or fixed, with the envelope mode**
PERFORMANCE BEYOND BANDWIDTH	**Bandlimiting rolls off amplitude; high slew rate transitions will not be written**	**Aliasing creates false signals; narrow pulses will not be stored**
RESOLUTION	**Resolution is uniform: vertically, it is limited by spot profile; horizontally, by trace width**	**Quantized vertical resolution; horizontal resolution limited by memory size and display reconstruction type**
MEASUREMENT ERRORS	**Error characteristics are independent of the input signal; rolloff due to bandlimiting, linearity, etc. can be measured and used to improve measurement accuracy**	**Error characteristics are dependent on the timing relationship between the input signal and sample clock; maximum errors are on the same order as analog systems, but the error characteristics do not allow their use to improve accuracy**

Applying Digital Storage Scope Features

Digital technology in a storage scope results in advantages to you. Compared to analog storage instruments, digital scopes are easier to use and have more capabilities. They are easier to use because you don't need interactive controls to store a waveform and because the storage takes place in a digital memory, not in the crt. Digital storage scopes also offer a list of features you can't find elsewhere. These can include pre-trigger viewing, automatic babysitting operations, digital data output, and signal processing.

This chapter contains a description of how you use a digital scope and several examples of how you can apply their features to your measurement needs.

Digital Storage Scopes Are Easy To Use

As with any storage scope when you are using a digital storage scope, you are either "storing" and viewing waveforms as they occur, or you are "saving" them for further examination. In both cases, the digital storage scope substitutes push button controls for the several interactive potentiometers of other storage scopes.

Digital storage oscilloscopes may have two or more channels of data acquisition and a time base that behaves just like the non-storage scopes you are used to. Some will have delayed sweep capabilities or plug-ins you can use to adapt the instrument to all your measurement needs. Generally, if you know how to use a non-storage oscilloscope, you'll be able to operate a Tektronix digital storage scope with little, if any, additional effort.

Another contribution to the ease of use you'll find with digital storage scopes is their display flexibility. With a direct view storage tube once you've stored a waveform, you can't change it. There is no way to reposition or expand a stored trace with those scopes. You can do both with digital storage scopes. The number of traces you can store and recall depends on the scope's memory size and how many data words are used to represent the signal.

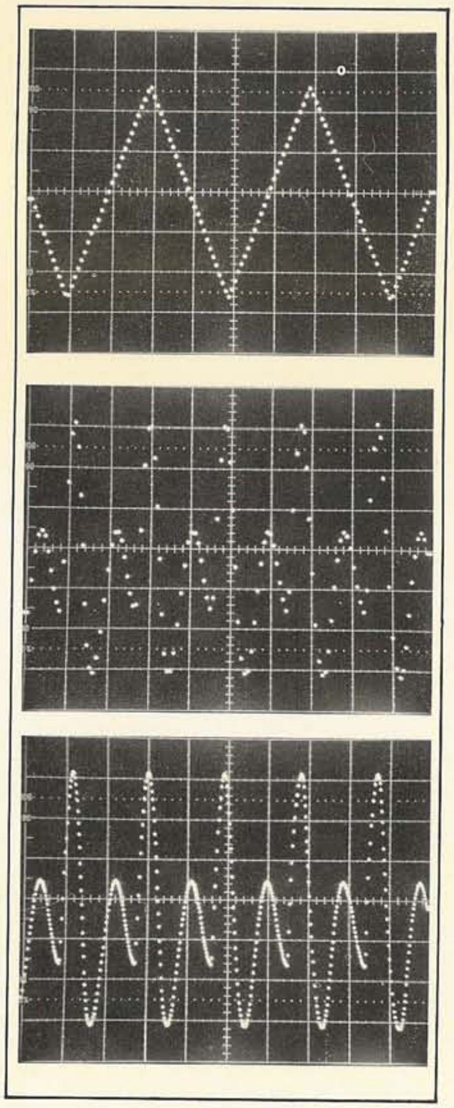


Figure 11. The number of data words necessary to display a waveform depends on its shape and how much you need to know about it. For example, at 128 points the triangle waveform (top) is accurately represented, but a complex waveform will require many more points. At 128 points, a more complex waveform (center) is not easily perceived, however, at 512 points the waveform (bottom) is more accurately represented.

Another display feature made possible by digital storage is shown in Figure 12. The two bright spots on the waveform are cursors that may be set by the user. The LED readout above the screen displays either time or voltage or both between the two cursors. The digital readout reduces misinterpretations by an operator. Coupled with expansion, the cursors improve repeatability of your measurements.

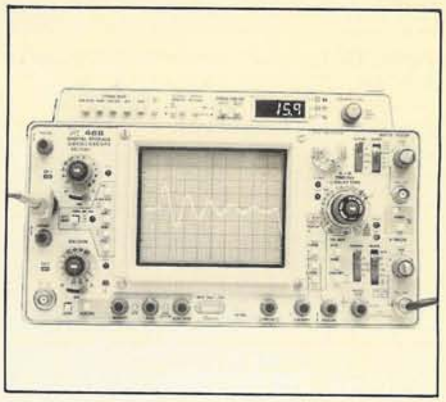


Figure 12. Digital storage scope advantages include the ability to make cursor measurements like the one shown above. In the example, the LED readout shows the time between two cursors on the screen. The time shown is adjusted automatically for the TIME/DIV setting of the instrument. With this particular instrument, the cursors may also be used for voltage measurements.

In some digital scopes, characters are displayed on the screen along with the waveform. They tell you the waveform parameters: minimum or maximum voltage; peak-to-peak voltage; RMS voltage; energy; area; frequency; period; rise or fall time; delay; and pulse width.

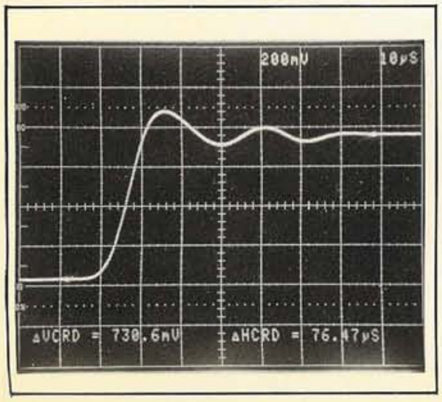


Figure 13. Character generation is another advantage of using some digital storage oscilloscopes. In the photo above, the Tektronix 7854 Oscilloscope settings are shown on-screen. The information printed at the bottom of the screen is the voltage difference and intervening time between two dot cursors on the waveform.

Some digital scopes offer a display feature called "roll mode"; in this mode, new information is acquired by the scope and used to constantly update the screen. The effect is like looking at a strip chart recorder.

If you need to make measurements with a B-H magnetization curve or draw pressure-volume diagrams for an engine, the X-Y display mode of a digital storage scope can help you. Unlike most analog scopes, you'll have two full-bandwidth channels with a good phase relationship because there are no delay lines in a digital storage scope.

So there are many reasons why a digital storage scope is easy to use, including:

- push button storage controls
- expansion and repositioning of stored waveforms
- cursor measurements
- character generation
- roll mode, and
- good phase relationship between channels.

Of course not every digital scope will have all the features listed, but all should have a bright, crisp trace that won't fade. The trace on the crt of a digital storage scope will always be as bright as that on a non-storage scope — even if the signal you captured was a single-shot event. You'll be able to use most digital storage scopes in almost any ambient light conditions, and the writing speed performance of a digital scope doesn't deteriorate with usage.

Finding Out What Happened Before the Trigger

You set a trigger on a digital storage scope just like you do with any scope: you pick a slope and a level. But the time relationship between that trigger point and the information stored and displayed by the scope is more flexible than with analog scopes. With digital scopes, the point at which the trigger occurred doesn't have to be the first thing you see on the screen; data can be stored in any proportion before and after the trigger point. If you're operating the scope so that the display begins before the trigger point, you've selected pre-trigger viewing and you can see what happened to the signal before the trigger occurred.

Pre-trigger viewing is possible because a digital storage scope is constantly translating the voltage at the probe tip at the digitizing rate you selected. The trigger needn't start the recording; it is only a reference point.

Pre-trigger viewing can be the only way to solve some problems. Suppose, for example, you had to solve a power-supply problem in a computer. Triggering on the console warning light without pre-trigger viewing only lets you see what happened after the crisis, not what caused it. See Figure 14.

Pre-trigger viewing is a help anytime you want to find out what caused something and the something is the only thing you have to trigger on.

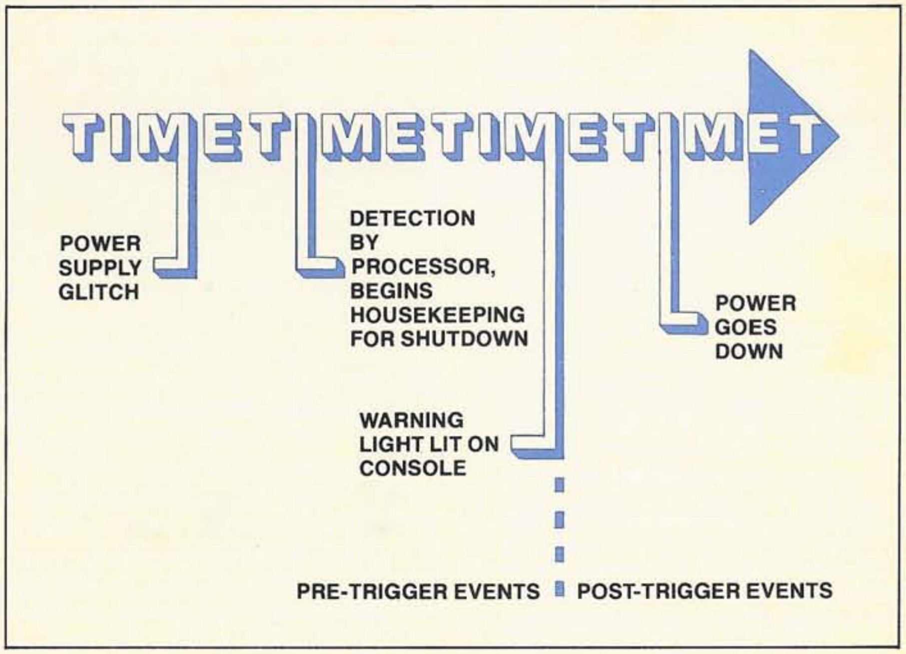


Figure 14. Computers and other "intelligent" machinery contain logic that monitors the power. If one of these circuits detects a problem, the central processing unit interrupts everything else and begins a power-down sequence that saves important data and prevents permanent damage. If you can only look at events after the power-down routine, the task of finding the cause of the failure is much more difficult. With pre-trigger viewing features, the digital storage scope allows you to find out what happened before the crisis, not just afterward.

Babysitting Your Problems

Suppose that while you were looking for the power-supply problem you got a call that another of your machines was down. Of course you can't be two places at once, but you could leave your digital scope in the single-sweep mode and go on your second call. When you got back, if a trigger had occurred, your scope will have automatically captured the data you needed. The information would be stored in the digital memory; it wouldn't have faded from the screen or been lost to an erase cycle.

This babysitting mode is based on the scope triggering at an event you want to capture, not on a timer or a counter. Either post- or pre-trigger viewing is possible with babysitting by trigger event. Once you've set up the scope, you don't have to touch the controls again; so you can go elsewhere and let the automatic feature take over.

Almost any digital storage scope can babysit for you that way, but some have another automatic mode. Remember the envelope mode described as an anti-aliasing feature in the last chapter? With it, the scope captures many examples of a repeating signal and saves all the minimum and maximum values of the waveform. To make the envelope mode a babysitter, you decide how long you want the scope to run this way and then you can see how much noise there is on a data line. Or you can monitor a line printer that occasionally drops bits and comes up with the wrong character or a garbled message. For these situations you would hook up your digital storage scope and leave it running — unattended of course — for as long as necessary. When you get back, you can see if, and by how much, the signals exceeded the specifications. The display might look like that pictured in Figure 15.

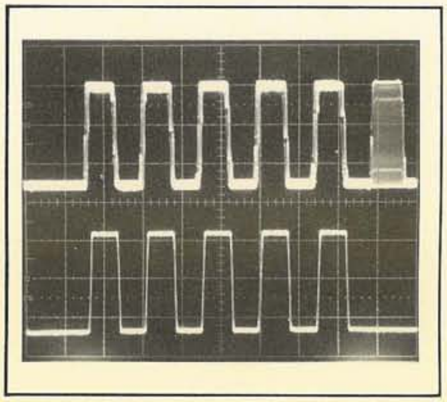


Figure 15. The envelope mode display of a digital storage scope is shown above. The variations about each pulse are a result of noise in the signal. The filled-in pulse is either a pulse that was missing in one of the sweeps, or it represents the opposite: one that appeared and should never have been there. The envelope mode is one form of babysitting; it captures the minimum and maximum voltage excursions of a signal over a specified time frame.

You can use the envelope mode to hunt for fast spikes on slow signals, or to watch any amplitude or frequency variations of a signal — all automatically.

Catching Glitches

Dale

Glitches are exasperating creatures. Sometimes they're there; sometimes they're not. The disappearing act makes them hard to catch, particularly if you're hunting for a glitch in some digital product. Glitches by nature are fast, and the waveform you want to see might require a TIME/DIV setting that wouldn't show the glitch even when it was there. The envelope mode is useful here — as well as for babysitting and for detecting aliasing — because it offers you dual digitizing rates. One, selected by the TIME/DIV switch, lets you get the complete picture on the screen; the faster envelope mode rate will catch the shorter duration signal variations you would miss otherwise as long as they last longer than the envelope mode's minimum sample interval.

Glitch-catching isn't the only time two digitizing rates will help you. High-voltage arcing in an x-ray tube is another example. Compared to the x-ray exposure times (from milliseconds to several seconds), the arcing is much faster and won't be captured without the faster envelope mode digitizing.

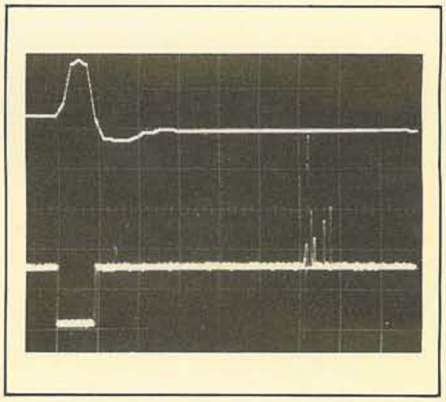


Figure 16. One of the uses of the envelope mode is as a glitch-catcher. The mode allows you to select the TIME/DIV switch setting that gives you all of the signal you want to see while the envelope mode display is built from data captured at a much faster digitizing rate. For example, the photo above shows the effect of arcing on the grid drive waveform of a crt. The envelope mode acquisition (bottom trace on the photo) was triggered on a blanking pulse while the digital scope's settings were 20 v/div and 50 ms/div. The single sweep acquisition captured the normal operation of the blanking pulse and the abnormal arcing that occurred .25 seconds after the crt was intensified. That trace was saved as a reference waveform and another acquisition (top trace) was taken to show the spike captured at 50 v/div and 200 ns/div.

Keeping Records

Because the data captured by a digital storage scope is available as binary data words in the scope's memory, it is easily transmitted and recorded. If the reasons you use a storage instrument include making permanent records, you can take advantage of the data output features of some digital scopes. The data can be transmitted to a central computer system for futher processing, sent to an X-Y recorder for hard copies, or simply and permanently stored on

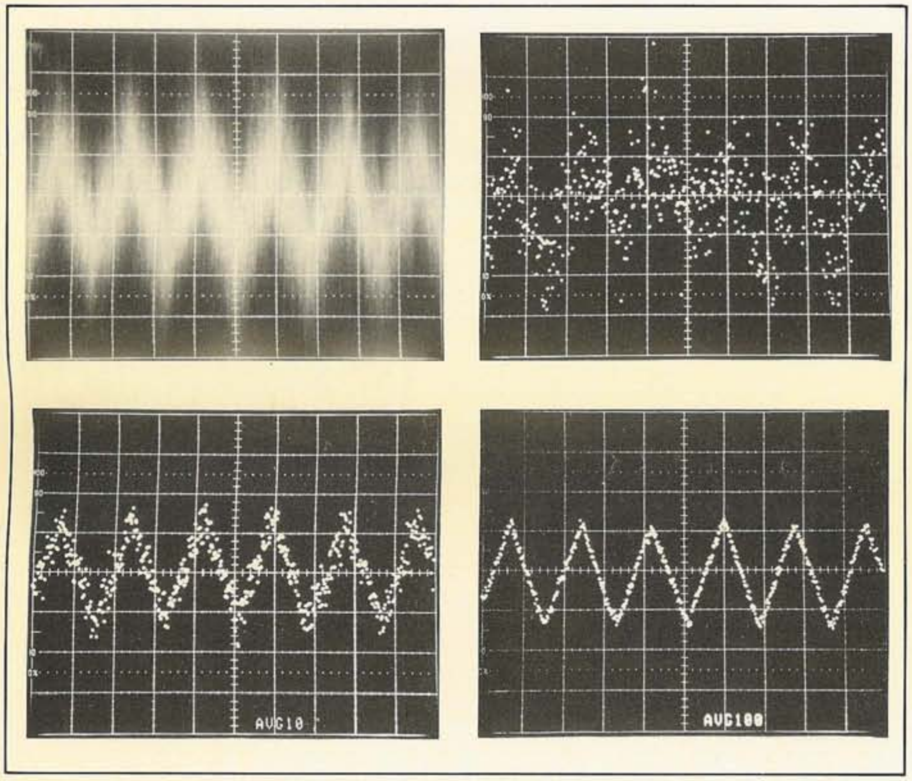


Figure 17. When a signal is digitized, the data that represents it can be manipulated in any number of ways. Some digital storage scopes use this opportunity for signal processing to increase measurement accuracy by averaging to reduce the noise component in the signal. In the photos above, a noisy signal is shown by a conventional display (upper left) and then digitized but before averaging (upper right), then after taking 10 averages (lower left), and after taking 100 averages (lower right).

tape or disc units. Data logging can be the core of an automated testing system or it can just be an automatic documentation process for you work.

It is important to know if the data output from a scope is compatible with your other equipment. GPIB (IEEE 488-1975 General Purpose Interface Bus) or RS-232-C standards may be specified, but these standards specify little more than pin locations and voltage levels. You should also determine if the data itself is formatted to a standard as it is for all Tektronix digital storage instruments. Some digital scopes vary in data format even within products from the same company source.

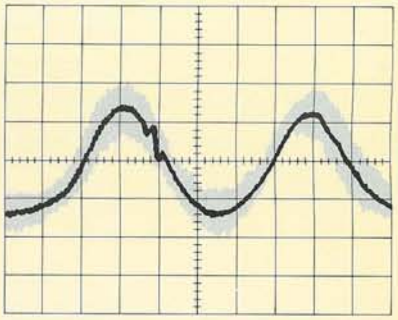
Signal Processing

Signal processing is another possible feature with digital storage scopes. Signal processing can include translating raw data into finished information. Examples include computing the parameters of a captured waveform (RMS voltage, energy, rise time, etc.) for output to the screen as shown in Figure 13 or for output through the data logging facilities.

Signal processing can also let you capture more accurate data. An example of this is signal averaging, a useful feature because although sometimes it's the noise on a signal that you want to measure, most of the time, it's not. Signal processing can eliminate noise by averaging many different frames of the signal as shown in Figure 17. Processing a signal with averaging can increase both the resolution and the accuracy of your measurements.

INCREASING RESOLUTION AND EXTENDING ACCURACY WITH AVERAGING

Resolution—meaning the smallest unit you can distinguish—can be increased by the signal processing capabilities of a digital storage scope. Suppose for example, that you needed to make a vertical measurement on a noisy signal like the one represented by the drawing below.



The resolution of your measurement could be as bad as 1½ divisions and only as good as ½ division, depending on what part of the signal you were measuring. After averaging — represented by the line inside the noisy signal — your resolution would be closer to $^{1}/_{5}$ or $^{1}/_{10}$ of a division. (Divisions are the units here because the voltage they represent depends on your VOLTS/DIV setting.)

With the resolution increased, the accuracy of your measurements can also increase. The reason digital averaging has this effect is that the signal you want to measure is related to time in a very specific manner: it has the same trigger each time the scope reads it. The noise surrounding the signal, however, is not related to time and does not depend on a trigger. Because the noise is random, its arithmetic mean (average) is zero. As you average the waveforms, you increase the signal-to-noise ratio of the information you obtain. For uncorrelated noise, the S/N ratio is improved by a factor of $\sqrt{n}$, where n is the number of waveforms averaged. For example, if your measurements can vary by 10% because of noise, the signal-to-noise ratio is 10:1. Taking an average of 4 signals brings that up to 20:1 (10 x $\sqrt{4}$) or 5%.

Summary

Table 3 lists the features of digital storage scopes that you might find useful in your applications.

Table 3. Digital Storage Scope Features

FEATURE	OPERATIONS	APPLICATIONS
✓ Pre-Trigger Viewing	Data is stored constantly; trigger is only a reference point; it doesn't start the data acquisition	Look at events occurring before the trigger; useful when the trigger event occurs after the event(s) of interest
✓ Babysitting (with trigger)	Trigger can stop or start single sweep acquisition	Unattended recording of signal occurrence of interest
✓ Babysitting (with envelope mode)	Envelope mode saves minima and maxima of signals	Unattended recording of signal excursions over selected time frame
✓ Glitch-Catching	Envelope mode detects variations wider than minimum digitizing interval	Capturing fast variations of slower signals
Record Keeping	Digital data in scope's memory can be output to other equipment	Any permanent record keeping, hard copies, further data processing
Signal Processing	Digital data in memory is available for computations	Output of waveform data after processing to the screen, or through the data output facilities; also allows more accurate measurements with averaging

Choosing a Digital Storage Scope

Useful Storage Bandwidth and Useful Rise Time are two measurement parameters you can use to compare the performance of digital storage oscilloscopes. These measurement parameters are described in the following paragraphs, and a discussion of timing measurement accuracy follows. The chapter concludes with a list of features and specifications you can use when you choose a digital scope for your needs.

Useful Storage Bandwidth

Bandwidth is the specification that describes the ability of a scope to display sine waves. When you add a camera to a non-storage scope to make it a storage instrument, however, you use another specification as a criterion: photographic writing speed. With direct view crt storage scopes, the stored writing speed specification is usually your criterion for choosing an instrument. The reason writing speeds are used and not bandwidth is that it is usually the amount of charge (or light) that can be deposited on the target (or film) that forms the upper limit of the instrument's storage capabilities; it is not usually the frequency response of the instrument's amplifiers. Of course both writing speeds are directly related to the frequency of the signal that these instruments can store; see Figure 18.

When digital storage scopes are discussed, most users would like a single figure of merit — like bandwidth or writing speed — that describes the maximum signal frequency these instruments can store. Useful Storage Bandwidth is a way to specify that maximum "useful" frequency.

The DIGITAL STORAGE SCOPE CONCEPTS chapter described how the digitizing rate of a digital scope changes with the sweep speed you select. The same chapter described the influence of display reconstruction on how easily you can identify and measure sine waves on a digital scope. Both factors enter into the Useful Storage Bandwidth; it is dependent on digitizing rate and on display type as Figure 19 illustrates.

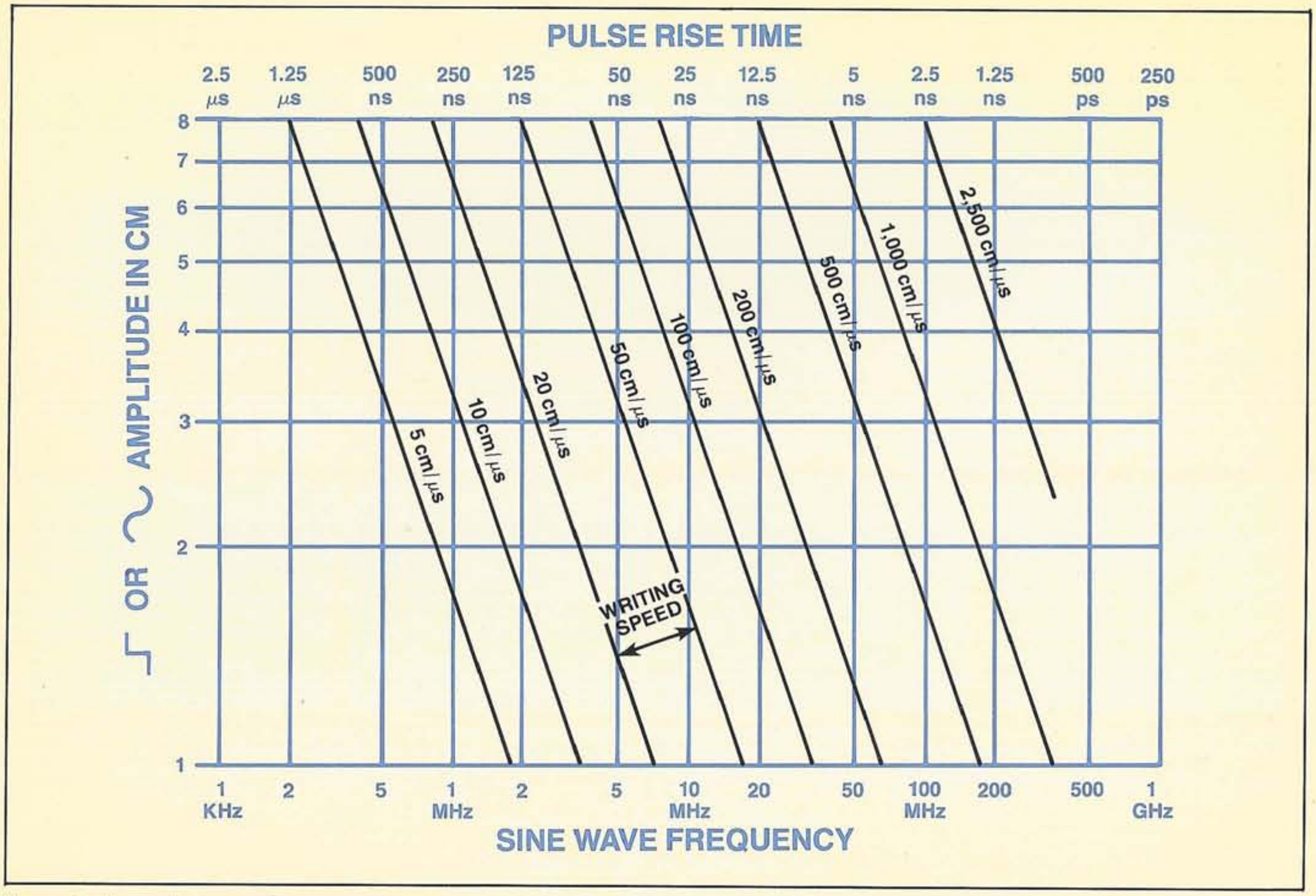


Figure 18. How quickly a crt storage scope must write on the screen is dependent on the speed of the input signal and on the size of the trace it must draw. The chart above shows trace size in centimeters vertically and the speed of the input signal along the horizontal axis. For sine waves, use frequency and for pulses, use rise time to determine the writing speed necessary to store the signal.

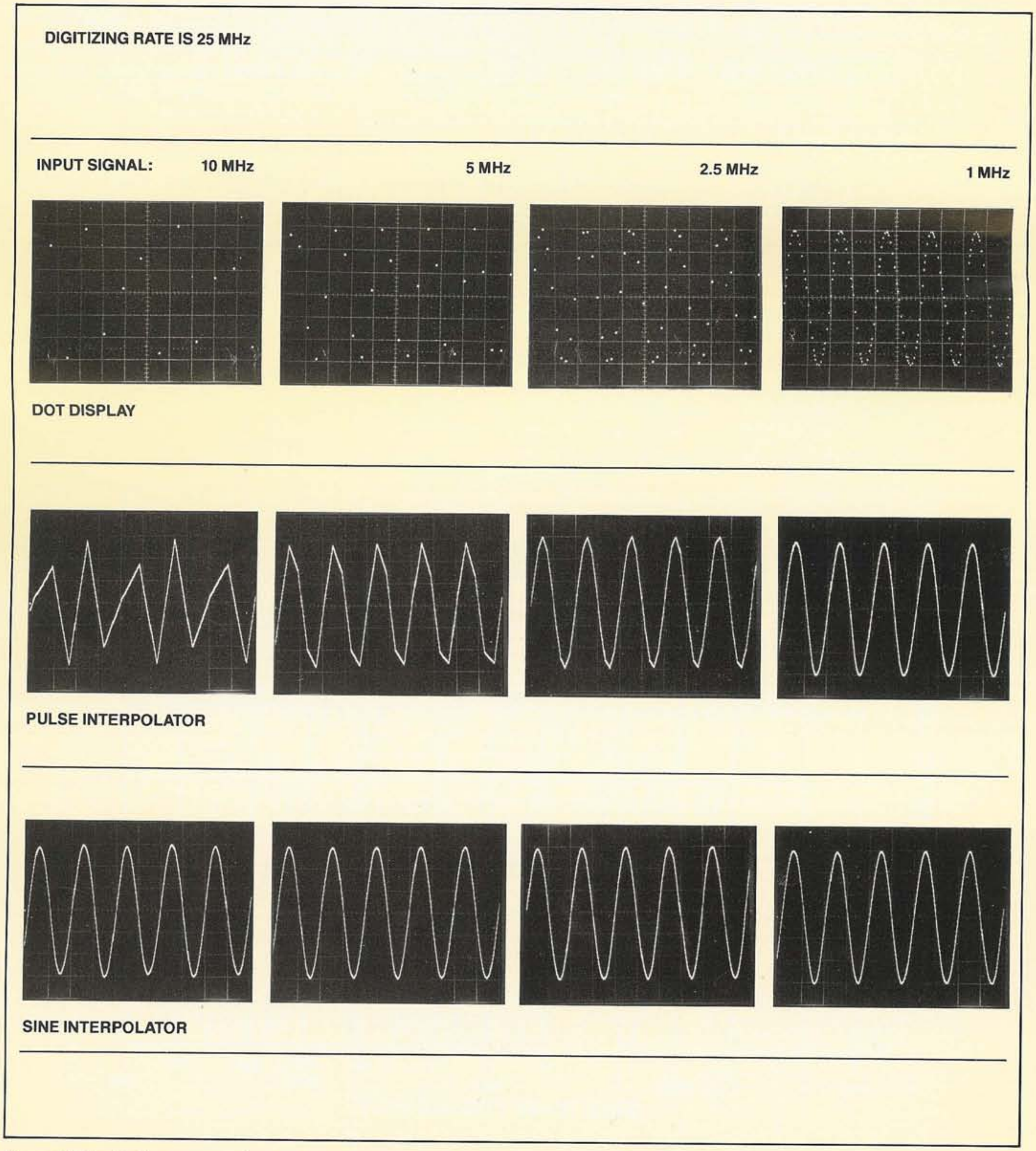


Figure 19. The display reconstruction type influences the Useful Storage Bandwidth of a digital scope. To trace a recognizable sine wave takes about 25 samples per cycle with dot displays. Pulse interpolator displays produce a useful trace with about 10 vectors per cycle; envelope errors make your measurements more difficult when less are used. The sine interpolator in the Tektronix 468 display shown in the last series of photographs reproduces sine waves with only 2.5 samples/cycle, finally approaching the limits that sampling theory suggests.

Dot displays suffer from perceptual aliasing and from envelope errors. To reduce or eliminate these, about 25 samples of each cycle in a sine wave must be displayed. So for a full scale, sinusoidal signal, the Useful Storage Bandwidth is defined as:

$$USB_{(MHz)} = \frac{\text{MAXIMUM DIGITIZING RATE}_{(MHz)}}{25}$$

Note that the number of samples/cycle necessary to recognize the input signal on a dot display changes with the amplitude of the trace. If the trace is smaller, then the data points on the screen are closer together and perceptual aliasing is reduced. In this respect, the Useful Storage Bandwidth for dot displays is similar to a writing speed specification; this is not true for either of the interpolated displays.

Interpolation is another subject introduced in the CONCEPTS chapter; it is the addition of data words between the original sampled points. When a linear interpolator is used and vectors are then drawn between all the data points, recognizing a sine wave is much easier though envelope errors still remain. For a linear interpolator, then, the Useful Storage Bandwidth is defined as:

$$USB_{(MHz)} = \frac{\text{MAXIMUM DIGITIZING RATE}_{(MHz)}}{10}$$

A sine interpolator results in a further improvement in your ability to perceive and measure sine waves. For the sine interpolator used in the Tektronix 468, the Useful Storage Bandwidth is:

$$USB_{(MHz)} = \frac{\text{MAXIMUM DIGITIZING RATE}_{(MHz)}}{2.5}$$

Please note that the Useful Storage Bandwidth divisor above is dependent on the particular interpolator used in the instrument; not every sine interpolator is the same.

Useful Storage Bandwidth can be used for more than comparing digital storage scopes to digital storage scopes; it can also be used to compare the performances of analog and digital scopes. Compare the Useful Storage Bandwidth to bandwidth directly, or derive a Useful Storage Bandwidth from a writing speed specification with:

$$USB_{(MHz)} = \frac{\text{WRITING SPEED}_{(DIV/\mu s)}}{10}$$

That corresponds to a fully-written sine wave 3.2 divisions in amplitude; writing speed units are in screen divisions per microsecond and not centimeters since screen sizes vary and because your measurements are made in terms of divisions. The formula is somewhat arbitrary, but it will give you a figure you can use for comparison purposes.

Useful Rise Time

Not every measurement involves sine waves. The parameter that reflects a storage instrument's ability to accurately record pulses is rise time. For analog instruments, the rise time may be approximated from the bandwidth:

$$T_{r(ns)} \approx \frac{.35}{BW_{(MHz)}}$$

When you try to measure an input signal rise time that is much faster than the rise time of an analog scope, what you actually get is the rise time of the system: scope and input combined. The measured rise time in this case is approximated by:

$$T_{r(measurement)} \approx \sqrt{T_{r(signal)}^2 + T_{r(instrument)}^2}$$

For digital scopes, however, simple geometry shows that if a very fast signal is measured and displayed with a pulse interpolator, the displayed rise time can vary from 0.8 to 1.6 sample intervals. As Figure 20 shows, the displayed rise time depends entirely on where the samples fell on the input signal.

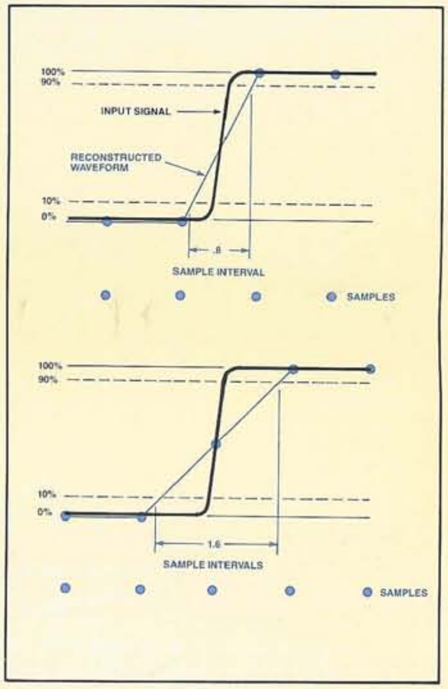


Figure 20. To demonstrate how the errors in a rise time measurement made by a digital system can change with the sample placements, the same input step is shown in both drawings. In the first, the step occurs exactly half-way between samples. The rise time of the resulting vector display (in blue) is 0.8 sample intervals in this situation. On a different acquisition of the same signal, however, the samples may fall as shown in the second drawing. In this worst case, the rise time indicated by the display is 1.6 sample intervals — the maximum possible.

It turns out that the *maximum* positive rise time errors produced by a pulse interpolated display closely follow the form of an analog scope's errors (Figure 21) when the analog system has a rise time of 1.6 sample intervals; maximum negative rise time errors are much smaller. Thus, because the most limiting measurement errors that occur when you use 1.6 sample intervals as the nominal rise time are similar to the errors of an analog scope, the Useful Rise Time can be defined as:

UT_r = MINIMUM SAMPLE INTERVAL x 1.6

If, for example, you wanted the Useful Rise Time of a digital scope with a maximum digitizing rate of 10 MHz, you would multiply the minimum sample interval (0.1 μs) by 1.6; the Useful Rise Time is then 0.16 μs or 160 nanoseconds.

Note that the Useful Rise Time is based on a pulse interpolator. Dot displays have additional error possibilities because of the truncation of resolution; with the same number of samples on the input step, the dots simply don't trace the shape of the signal. Interpolators designed for displaying sine waves show rise times that are faster than the input signal because of the pre-shooting and over-shooting introduced when there are only a few samples on the input step.

It is important to remember that — unlike the rise time of analog instruments — you cannot use Useful Rise Time and the measured rise time to work back to the signal's rise time. The Useful Rise Time is based on the worst possible error; the actual error in any given measurement can vary between the maximum negative and maximum postive values, depending on the placement of the samples on the input signal. The error range is graphed in Figure 21.

The Useful Rise Time and Useful Bandwidth parameters illustrate a significant difference between analog and digital scopes. While the analog instruments show a bandwidth and rise time that do not change with sweep speed, digital storage oscilloscope bandwidths and rise times change with the TIME/DIV switch setting because of the changing digitizing rate. The Useful Bandwidth and Useful Rise Time parameters, however, give you an indication of the fastest signals that can be captured with digital scopes, much as bandwidth and rise time specifications do for analog instruments.

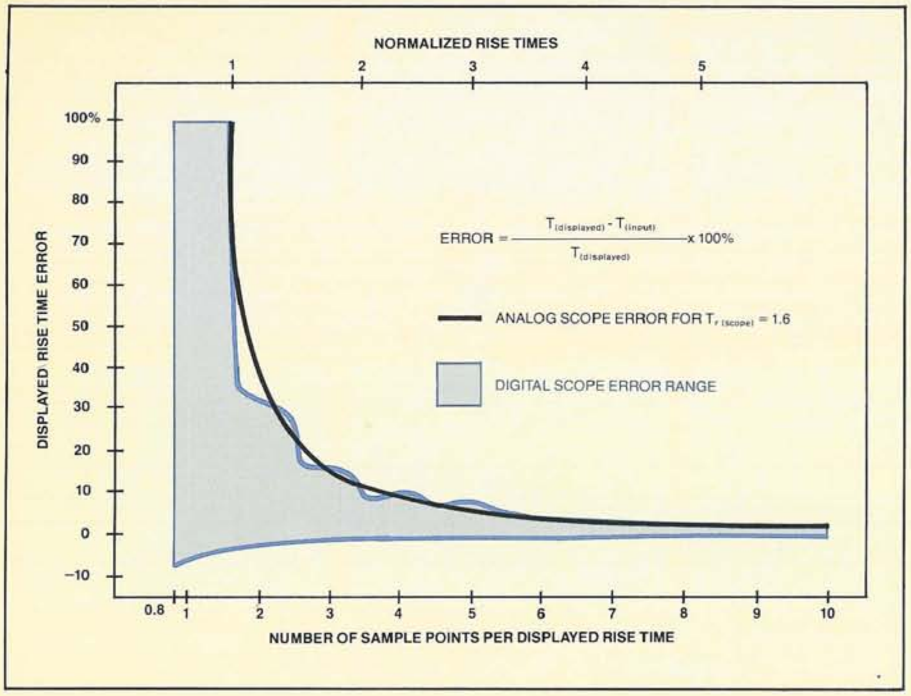


Figure 21. A computer model of a digital storage scope display was used to generate the rise time error ranges shown above. To make the results independent of any particular digitizing rate, the horizontal axis is the number of sample points per displayed rise time of the input step function, while the errors plotted vertically are shown in percentages of displayed rise time. The input step was a worse case — an exponential step. For comparison, the error curve of an analog system with an equivalent rise time is also plotted.

Timing Measurements

The accuracy of the timing measurements you make with any scope is influenced by errors within the measuring system and limited by the system's resolution. For analog scopes, the sources of errors are the instrument's bandwidth and inaccuracies within the time base, and the limit to resolution is the trace width. For digital scopes without interpolation of any kind, the error sources are the same and the limit to resolution is the minimum sample interval.

With digital expansion (in addition to the expansion achieved by increasing amplifier gain — which is a feature of both analog and digital scopes) and with the use of interpolators to fill in information between sample points, the limits of your timing measurements are extended. In practice, then, the errors in your timing measurements will be dependent on the number of samples taken of the input signal.

Timing measurement errors will also depend on the type of input signal and on the kind of interpolator used. Pulse-to-pulse timing and pulse width are examples of measurements for which a pulse interpolator works best. In these cases, the errors due to interpolation can be very small; for example, with three samples on the rise time of the input signals, an error of less than ± 5% of the *sample interval* is present. For a waveform displayed with 500 data points on the screen, this is ±0.01% of full scale.

For measurements like sine wave period and phase, a sine interpolator is best. In this case, at only 2.7 samples per cycle of the input signal, the timing error introduced by the interpolator is less than ±0.5% of the sample interval — ±0.001% of full scale with 500 data points.

These errors are shown plotted against the number of sampled points in Figures 22 and 23. The error curves demonstrate that errors due to interpolation will probably not be the limiting factors in your measurements; they are usually smaller than the errors caused by noise.

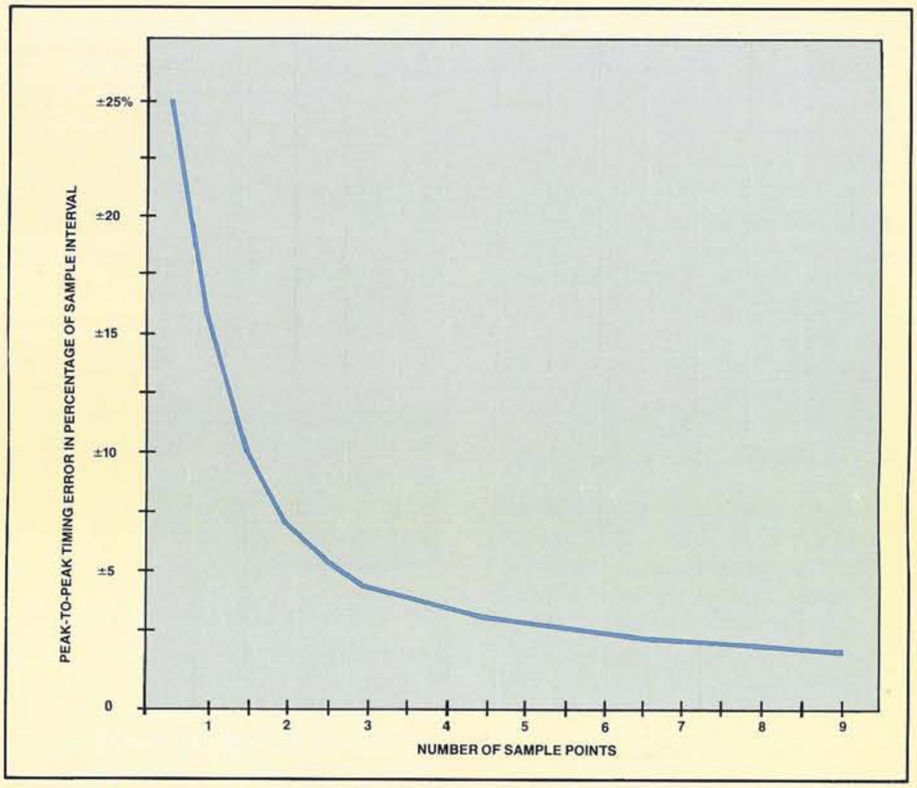


Figure 22. The errors introduced when measuring pulses with a pulse interpolator are shown above. The errors are plotted as measured from the 50% point of one waveform to the same point of another. To keep the results independent of the scope's digitizing rate, the error is reported as a percentage of the sample interval.

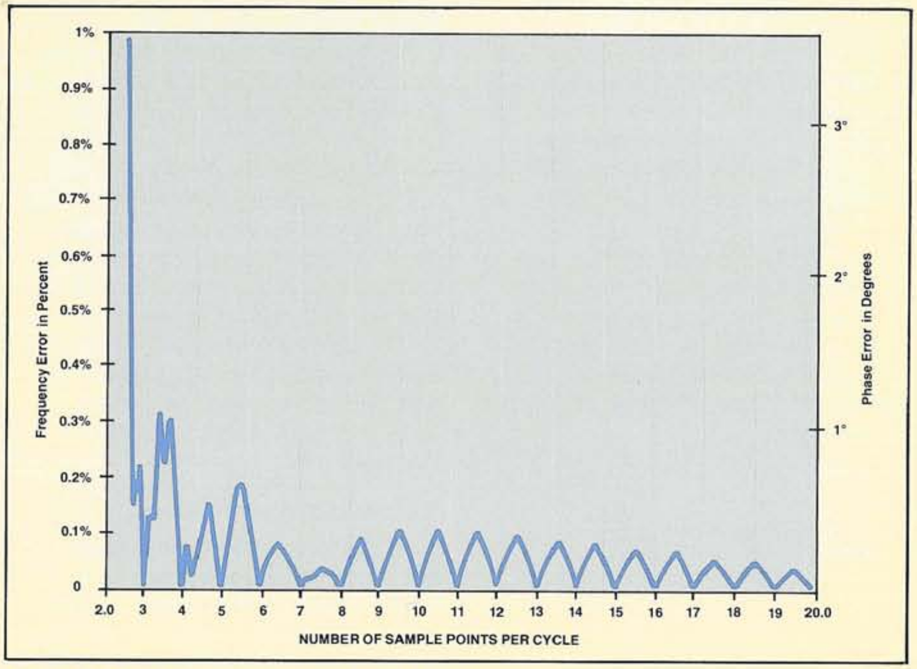


Figure 23. The maximum error introduced in frequency and phase measurements by the sine wave interpolator in the Tektronix 468 is plotted above. The error curve shown is for a single sine wave cycle.

Conclusion: Checklist for Choosing a Scope

You can determine which digital storage scopes will make the measurements you need by comparing Useful Storage Bandwidth and Useful Rise Time figures. You'll then know if the instrument has the speed you need. But remember that the usefulness of an instrument depends on more than just its performance; it also depends on its features and on some other variables described below.

■ Accuracy and Resolution

Accuracy, resolution, and the difference between the two are important concepts when you are selecting a measurement instrument. Consult the accuracy specs, but don't neglect the resolution because with signal processing and data output features, you *can* take advantage of the resolution in a digital storage scope. Remember that the vertical resolution is based on the number of bits used by the ADC. Generally less than 7 bits is not advisable, while more than 10 is probably overkill if the instrument's accuracy is 1%.

Horizontal resolution is a function of the record length and the interpolation method. For a given measurement, interpolators offer several times the measurement resolution per sample point when compared to dots alone.

Also be sure not to confuse the entire memory size with the record length used to store one waveform. Though the advertised memory size might be 1024 data words, a waveform might be stored in only half that number.

■ Measurement Parameters

Besides accuracy and resolution, you should consider the measurement parameters that apply to your needs. If you are interested in sine wave measurements, then Useful Storage Bandwidth is important. If pulse measurements are to be made, then the Useful Rise Time is important.

Since the display reconstruction type also affects your measurements, make sure the display technique is compatible with your needs: pulse interpolation for pulse measurements and sine interpolation for sine waves. A choice is best if you have to make both kinds of measurements.

■ Non-Storage Bandwidth

Should you want to use a digital storage scope in a non-storage mode, don't forget to consult the instrument's non-storage bandwidth specification. This is the analog spec, not the Useful Storage Bandwidth.

■ Signal Processing Features

Most digital storage scopes include some signal processing; averaging, peak-to-peak voltage, and some time measurements are frequently offered. You will have to decide how much signal processing you need and if more capabilities will be worth the extra price. Maybe you already have the processing power; then it becomes the data output facilities that are important. Do you want RS-232 or GPIB standard interfaces? Is the data output format compatible with your computing equipment, or will you have to write software for translating it?

■ Pre-Trigger Viewing

Most digital scopes offer you pre-trigger viewing, but the amount of time included in that view could be important to you. Take the time base switch settings and record lengths used by the instrument into account when you decide.

■ Anti-Aliasing Features

Aliasing can happen with any digital storage oscilloscope. Decide what anti-aliasing features — if any — you will need. Anti-aliasing filters, an envelope mode, and non-storage operating modes are examples of features to consider.

■ Ease of Use

There's one good way to find out if a scope is easy to use: use it. If you can't arrange a trial, make a judgement based on other instruments from the manufacturer. If you expect to be carrying the instrument around, check its portability. And take a look at the manuals for the scope; good manuals make learning to use a new instrument easy.

■ Product Support

Besides documentation, there are other areas of product support to investigate. Is there a training program, good applications notes, and a dependable service organization behind the instrument you want?

New digital storage oscilloscopes are introduced regularly. Making a list of what's available as this booklet goes to press would only result in an out-of-date list. You'll have to do that research on your own, but with the information here, you should have a head start in evaluating what digital scopes can do for you — and what they can't do. You should have a good idea of where and when the capabilities of these new storage instruments will help you. And you should be able to make the best decision about which scope you need.

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