Educational Note

WAVEFORM ACQUISITION RATE AND WHY IT MATTERS

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Contents

1 Overview

Modern digital oscilloscopes have many specifications regarding their capabilities and performance. Some of these specifications, such as bandwidth, sample rate, and memory depth are well-understood, as are the benefits that can be obtained from improved performance in these areas. Equally important but often less well-understood are acquisition rate and blind time, and this educational note provides a practical introduction to these specifications and explains why acquisition rate and blind time are important in many oscilloscope applications.

2 From analog input to waveform display

A high-level overview of oscilloscope signal processing is shown in Figure 1

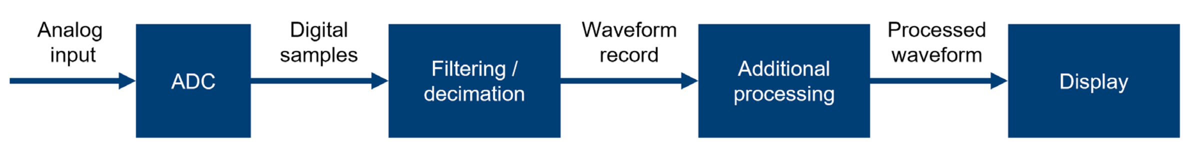

Figure 1 - Oscilloscope signal processing overview

An analog signal present at the oscilloscope's input is sampled by an analog to digital converter (ADC). These digital sample values are then often "decimated," that is, they are reduced in number using one of several different algorithms or methods. These samples may also sometimes be filtered in order to improve vertical resolution and/or to reduce noise. This process produces waveform samples, which are then stored in memory as a waveform record. A waveform record is essentially a sampled version of the input signal after those samples have been decimated and/or filtered.

Once a waveform record has been created, additional processing may also be performed on it, such as averaging or mathematical functions. Finally, the waveform record is passed to the display system, which then displays or "draws" the waveform on the oscilloscope screen.

Ideally, this acquisition cycle would repeat every time a trigger event is detected, but most modern digital oscilloscopes cannot perform an entire acquisition cycle every time the trigger condition is met by the input analog waveform.

3 About acquisition processing

The above-mentioned acquisition cycle can be broken down into two distinct phases, as shown in Figure 2.

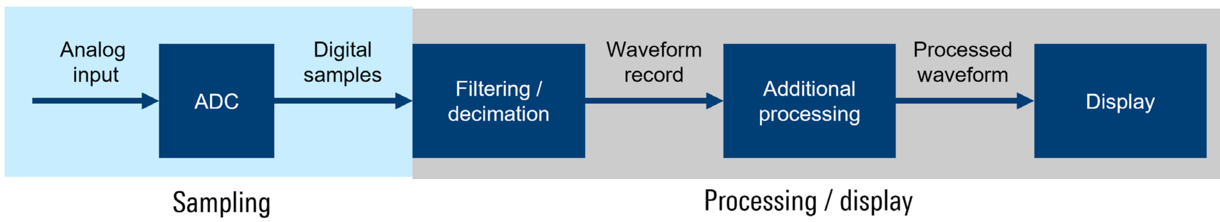

Figure 2 - Sampling and processing / display phases

The first phase involves sampling analog the analog input waveform and creating digital sample values. The second, and in many ways the more important, phase is processing the acquired samples or waveforms and then displaying them on the oscilloscope screen.

Both of these different types of processing – the sampling phase and the processing / display phase – can be performed either in hardware (ASIC or FPGA) and/or in software. Hardware-based processing is almost always superior to software-based processing in terms of performance. However, regardless of whether processing is performed in hardware or in software, an oscilloscope does **not** acquire new samples during this processing. The analog input signal is effectively “ignored” while the oscilloscope processes the previous acquisition and a new acquisition only occurs after processing and display of the previously acquired waveform is complete. This period of time during which the oscilloscope is not acquiring new samples is commonly referred to as **blind time**, although in some cases, the term “dead time" is also used to describe this period during which the input signal is not being sampled or processed.

All digital oscilloscopes have some amount of blind time. As discussed in the previous paragraph, after samples are acquired, the oscilloscope requires a non-zero amount of time to process and display those samples and during this blind time important information may be missed or lost. For example, in Figure 3, the runt pulse indicated by a red arrow was not detected because this runt occurred while the oscilloscope was “blind.”

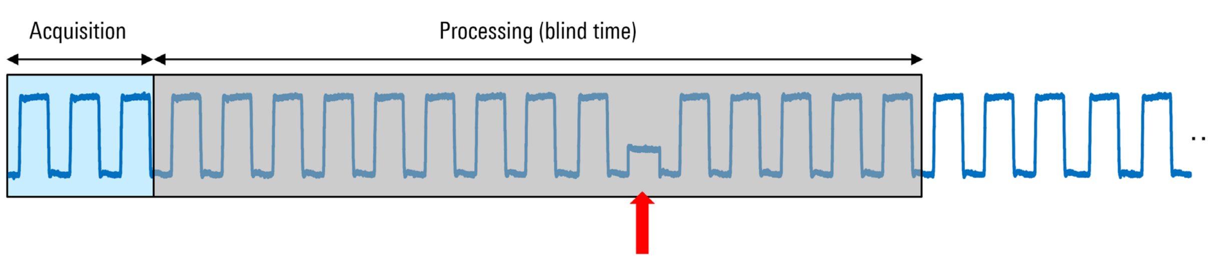

Figure 3 - Runt pulse missed during blind time

An oscilloscope will only start a new acquisition after both acquisition and processing are complete, and therefore, the total acquisition time, or the time required to capture and display one waveform on the screen, consists of both the time required to acquire the samples as well as the time required to process those samples (Figure 4).

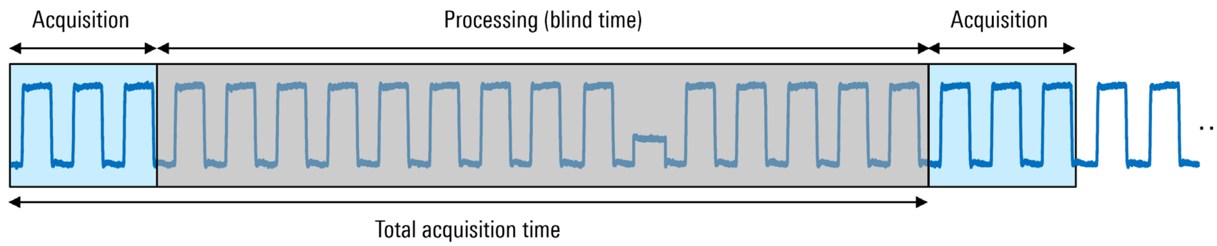

Figure 4 - Acquisition time consists of sampling time and processing time

Acquisition time is a user setting, but blind time is a primarily a function of two different factors. One of these is the number of samples that need to be stored and processed: the greater the number of samples, the more time is required to store and process those samples. The other factor is the amount and the type of processing performed on these samples or waveforms. This will be covered in much more detail in section 4. It is very important to keep in mind that for many oscilloscopes, the percentage of time the oscilloscope is "blind" can be quite high. Blind times of up to 99% are not uncommon, even for many modern, high-performance oscilloscopes.

4 About waveform acquisition rate

A new acquisition can only occur at the end of waveform processing, that is, at the end of the oscilloscope's blind time, and therefore waveform acquisition rate is used to quantify how quickly an oscilloscope can trigger, process, and display waveforms. Acquisition rate is specified in units of waveforms per second (wfms/sec), and in almost all cases, a higher waveform acquisition rate is always desirable. Note that different oscilloscope manufacturers refer to this metric in different ways, such as "update rate," "capture rate," etc. As can be seen in Figure 5, reducing blind time reduces the total acquisition time, and therefore smaller blind times improve the overall acquisition rate or increases the number of waveforms acquired per second.

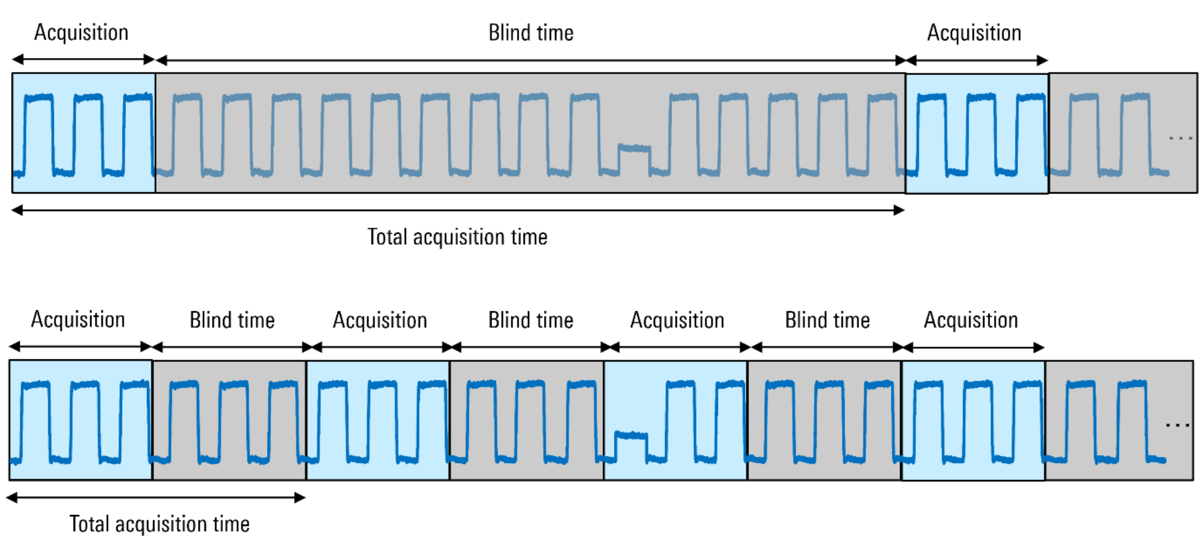

Figure 5 - Smaller blind times reduce total acquisition time and thus improve waveform acquisition rate

5 Factors influencing waveform acquisition rate

Blind time has both a fixed (non-variable) component and a variable component. The variable component is typically much larger than the fixed component.

Figure 6 - Blind time consists of a fixed and a variable component

Variable blind time is primarily a function of three factors. The first of these is the record length, or memory depth, used for each acquisition. It should be intuitively clear that as the number of samples increases, the amount of time needed to perform operations on those samples will also increase. The number and the type of any post-processing functions is also an extremely important contributor to blind time – this topic is covered in more detail in the following section. And finally, digital oscilloscopes require a certain amount of time to prepare a waveform record for display on the screen, that is, to create the pixel representation of the signal. The extent to which each of these three factors affect variable blind time is a function of both the acquired data and the oscilloscope architecture.

It should however be noted that in some cases, acquisition rate is limited by the user settings rather than the oscilloscope's hardware and/or software. For example, if an oscilloscope with 10 horizontal divisions is configured with a timebase of 100 ms per division, the maximum achievable waveform acquisition rate is only one waveform per second. This is because these settings mean that the oscilloscope must capture and display one full second of time before it can display a waveform on the screen and begin a new acquisition.

6 Processing and acquisition rate

The impact of processing on acquisition rate is particularly important with regard to blind time. The maximum acquisition rate of an oscilloscope is typically achieved when an oscilloscope is not performing any type of analysis functions, since all analysis functions require some amount of additional processing time. Examples of common analysis functions, in rough order of impact, include cursors and automated measurements, histograms, mask testing, math functions (including the fast Fourier transform or spectral analysis), etc. Parameters of these functions will also affect processing requirements. For example, using a narrower resolution bandwidth with an FFT typically increases processing load. Regardless of the type or function, in almost all cases performing these functions in hardware instead of in software can greatly reduce blind time and increase waveform acquisition rate.

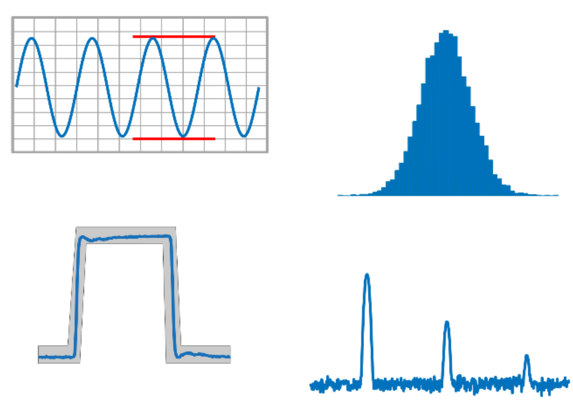

Figure 7 - Common types of processing which affect blind time

7 Advantages of blind time reduction

Reducing blind time, or increasing acquisition rate, reduces overall test time in four main ways, namely: better signal visibility, a higher probability of capturing infrequent or rare events, better usability and instrument responsiveness, and higher statistical confidence.

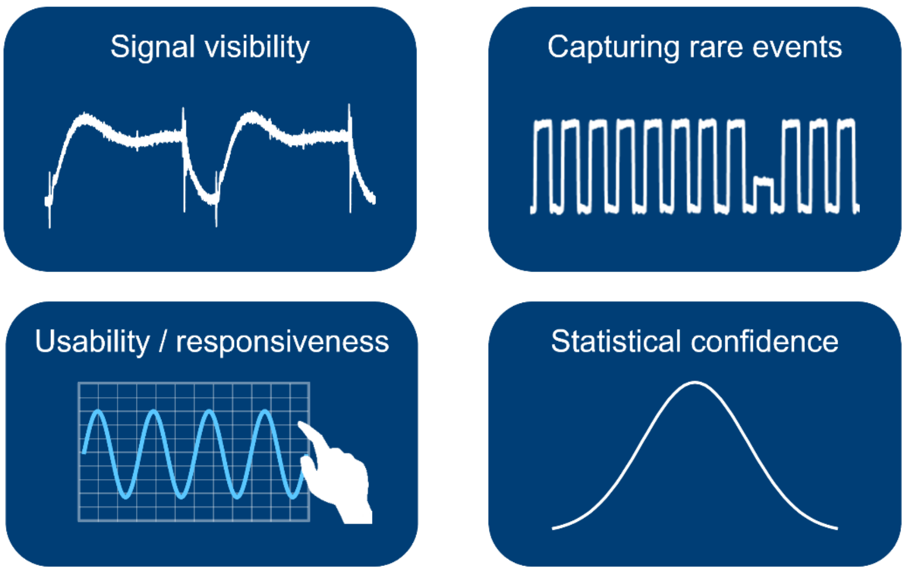

Figure 8 - Advantages of blind time reduction

7.1 Signal Visibility

Most oscilloscopes have a natural persistence in that the display is only updated once every 50 milliseconds. This “observation window,” consisting of all the waveforms acquired during that time, is used to create the image that is displayed on the oscilloscope screen. A higher waveform update rate, or shorter blind times, means that more waveforms will be captured within a single observation window, resulting in a more accurate depiction of the analog input signal.

Figure 9 shows the difference between how a signal is displayed when using a slow update rate (top) and a fast update rate (bottom). As can easily be seen, a faster update rate shows a more accurate and more detailed waveform, particularly with regards to noise and small or infrequent events. In addition to being able to more easily visualize these details, a higher acquisition rate also allows the user to trigger on these less frequent events or waveform details.

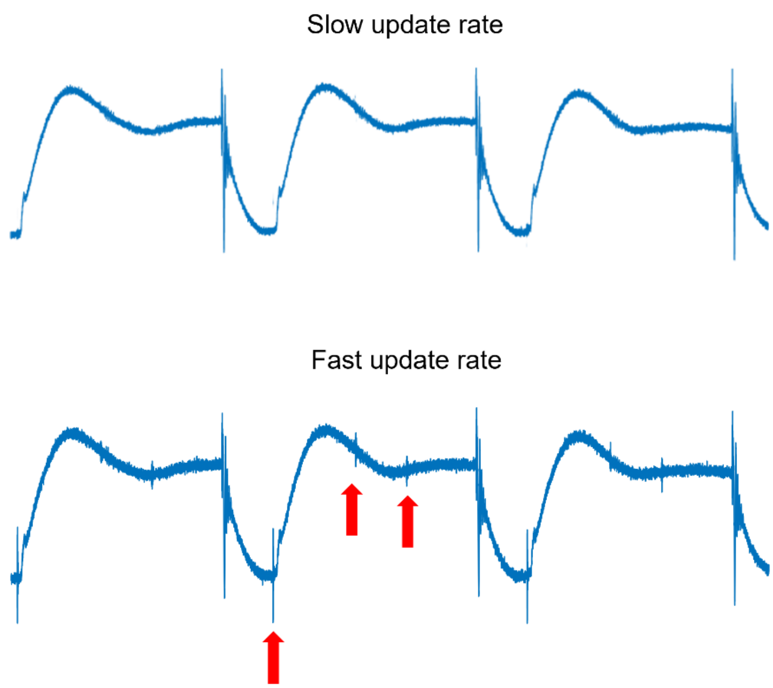

Figure 9 - Increased waveform details when update rate is increased

7.2 Capturing Rare Events

A related advantage is capturing rare events. As previously mentioned, events which occur during an oscilloscope's blind time are not acquired, and therefore potentially important or significant events can be missed if the acquisition rate is not sufficiently high. In general, the higher the acquisition rate of an oscilloscope, the greater the probability of capturing infrequent or rare events such as a glitch.

Figure 10 illustrates this numerically. With a waveform update rate of only 100 waveforms per second, there is a very low probability of detecting even a relatively frequent fault, regardless of measurement time. As the waveform update rate is increased, the probability of detection also increases, and at very high waveform update rates, the probability of detecting or capturing the fault rises significantly. As can be seen in this graph, higher acquisition rates can decrease overall test time because there is a higher probability of detecting an infrequent event.

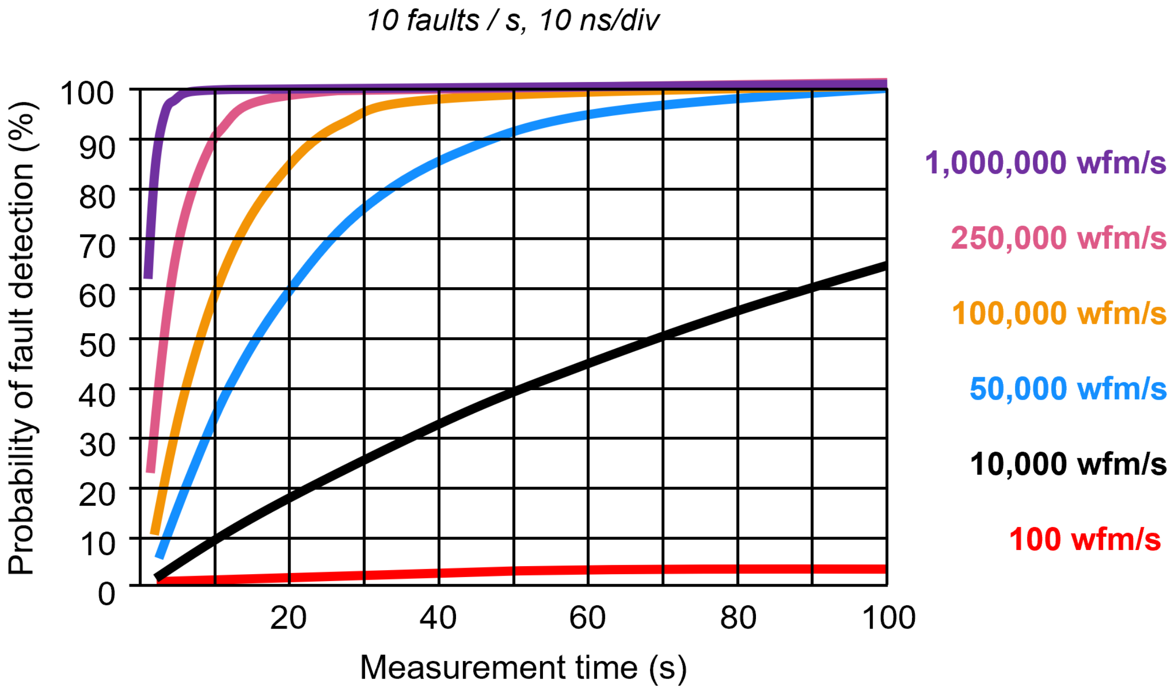

Figure 10 - Probability of capturing a rare event as a function of waveform acquisition rate

7.3 Usability / Responsiveness

Waveform acquisition rate also affects the usability or responsiveness of an oscilloscope. In most modern oscilloscopes, waveform processing takes priority over user interface functions. This means that the oscilloscope will only update the display or respond to user input at the end of each acquisition cycle or at the end of the oscilloscope's blind time. Consequently, a faster acquisition rate – or a shorter blind time – will make an oscilloscope more responsive in terms of both display and controls. A more responsive oscilloscope improves the overall user experience: greater responsiveness decreases user frustration and the probability of user error, and as a result overall test time is also reduced.

7.4 Statistical Confidence

Another benefit of a higher acquisition rate is higher statistical confidence. Oscilloscopes are often used to generate statistical data, such as determining the average rise time of series of pulses. Each acquisition of a pulsed input signal can be considered a sample in the statistical sense of the word. Confidence intervals decrease as sample count increases, and therefore a greater number of acquisitions yields "better" results in terms of a narrower confidence interval: this is shown in Figure 11. Thus the more acquisitions that are used to make a rise time measurement, the greater the confidence in the calculated average rise time. A higher waveform acquisition rate produces more samples per unit time, and therefore a higher waveform acquisition rate can greatly reduce the test time needed to obtain the desired statistical confidence.

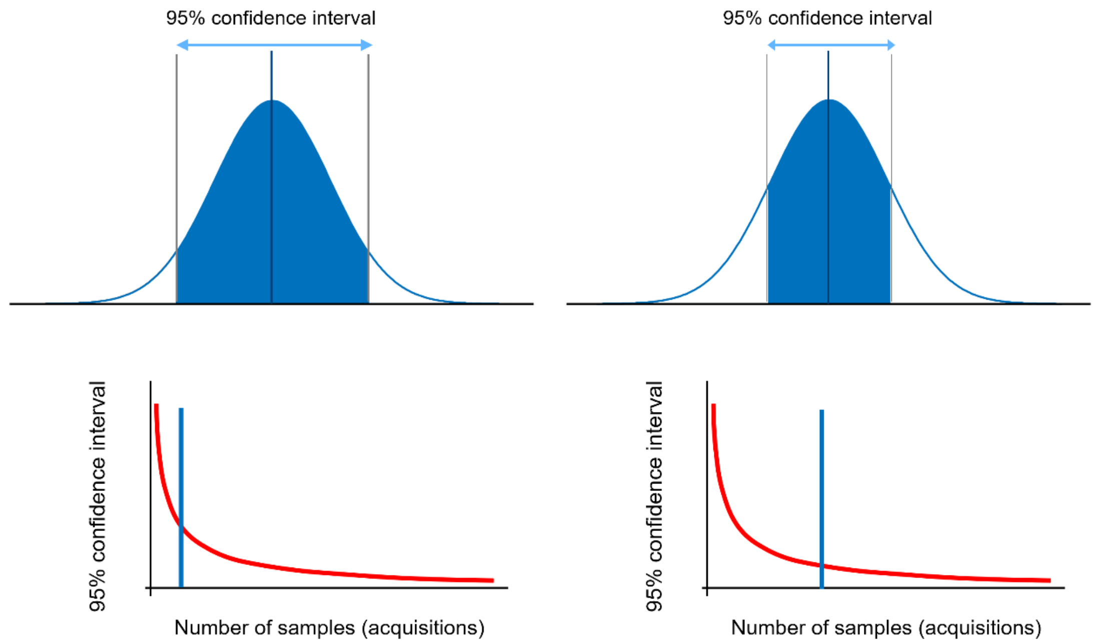

Figure 11 - Confidence interval decreases as number of acquisitions increases

8 Summary

All digital oscilloscopes must process and display acquired samples before starting a new acquisition. During this processing and display time, the oscilloscope is “blind“ in that it cannot process additional waveform information. In many oscilloscopes, the percentage of blind time can be very high: sometimes up to 99%. Blind time has both fixed and variable components, with variable blind time being largely a function of the number and types of processing performed on the acquired samples. Examples of these types of processing include different types of cursors and measurements, zoom, mask testing, math functions, and FFT or spectrum analysis. The impact of all of these different types of processing can usually be reduced by implementing them hardware. In addition to providing a more accurate representation of the input analog waveform, higher acquisition rates are always desirable, since smaller blind times can reduce overall test time thanks to an increased probability of capturing rare events, greater instrument responsiveness, and higher statistical confidence.

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Educational Note | Waveform Acquisition Rate and Why It Matters
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