Research on High precision Yime Measurement and Analysis method Based on Oscilloscope

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Abstract. High precision time measurement technology is of great significance. It is necessary to test and analyze high precision time, whether it is engineering practice such as telecommunication, chip design, or theoretical research such as atomic physics experiment, as well as space technology such as satellite positioning, radar pulse, etc. With the help of oscilloscope, the time and delay information can be obtained with high accuracy on the premise of high accuracy on the premise of high fidelity acquisition of measured signal. In this paper, aiming at how to use oscilloscope for high-precision time test and analysis, several key factors affecting the accuracy of oscilloscope time test are analyzed, and reference methods and test examples are provided for high-precision time test.

Keywords: Sampling rate, Bandwidth, Time deviation, Real-time interpolator.

1. Introduction
With the rapid development of electronic technology, the speed of signals is getting higher and higher. Any small time changes in high-speed signals will have a huge impact on the entire system. High-precision time testing has become the key to the success of electronic systems. In high-speed data transmission systems, the time interval of signals, the delay between signals, and the jitter of signals must be strictly controlled. Only accurate and effective testing and analysis of these time parameters can make the system operate normally and improve system performance and stability. This article focuses on how to use the oscilloscope to perform high-precision time testing. It first discusses several key factors that affect the accuracy of the oscilloscope test, analyzes and studies how to evaluate the time test accuracy, and finally gives examples of high-precision time testing.

2. Analysis of factors affecting high-precision time testing
To use the oscilloscope for high-precision time testing, you need to first evaluate whether the oscilloscope's technical specifications meet the time test requirements. High-precision time testing is affected by many factors, including the oscilloscope's bandwidth in multi-channel sampling mode, multi-channel time deviation elimination, multi-channel sampling rate, interpolation error, multi-channel high-speed acquisition memory, and trigger system.
2.1. Analysis of Factors Influencing Multi-channel Time Deviation on Measurement Error

When the oscilloscope is performing multi-channel delay test, due to different channel delays or cable and probe delays, etc., there will be a channel time deviation of the test system. During testing, attention should be paid to using the multi-channel time deviation elimination (Deskew) function, and the time deviation should be corrected in units of less than 1 picosecond according to the test requirements.

2.2. Analysis of Factors Influencing Sampling Rate on Measurement Error

The high sampling rate can not only avoid signal aliasing and obtain high-fidelity signal waveforms, but also the key to obtain high-precision time information. As the sampling decreases and the sampling interval becomes larger, the accuracy of the time test decreases, as shown in the following figure. To carry out multi-channel delay test, the oscilloscope should meet the condition that each channel independently supports high-speed ADC sampling, so as to avoid the impact of the reduced sampling rate on the test error in multiple channel mode.

![Figure 1. Analysis of Factors Influencing Sampling Rate on Measurement Error](image)

2.3. Analysis of Factors Affecting Measurement Errors by Real-time Interpolation Acquisition Mode

The interpolation error is an error caused by linear interpolation between actual voltage samples. This error can be improved using the \( \sin(x) / x \) sinusoidal interpolation algorithm in the oscilloscope and the vertical dynamic range of the oscilloscope. Real-time interpolation can improve the accuracy of time testing. Real-time interpolation is to insert mathematical operation points between two actual data sampling points. The inserted data points can improve the accuracy of time measurement under a faster time base and make the waveform closer real. Among them, real-time interpolation techniques include linear interpolation and sinusoidal interpolation \( \sin(x) / x \), the figure on the left in the figure below is an example of sine wave using \( \sin(x) / x \) interpolation, and the figure on the right is using linear interpolation Examples of poor sine waves. It can be seen from the figure that the sinusoidal \( \sin(x) / x \) interpolation technology is closer to the real waveform, and the time test accuracy is higher. Therefore, when using the oscilloscope for high-precision time test, the interpolation mode is used with high-speed acquisition memory There are multiple samples within the difference of 20ps between ADC samples, resulting in higher time resolution. The minimum time interval is 0.2ps.
2.4. **Analysis of the factors affecting the measurement error of high-speed acquisition memory**

For an oscilloscope, the sampling rate \( \times \) acquisition time = acquisition memory. To test high-precision, long-time interval signals, high-speed acquisition memory is required in conjunction with high-speed sampling. For the communication signal that collects 1.2G carrier in 1ms time, such as BPSK, the memory length required at the maximum sampling rate = 50GS / s \( \times \) 1ms = 50M. Analyzing the storage design of modern oscilloscopes, the silicon germanium (SiGe) semiconductor integrated acquisition front end is used, and each channel has an independent high-speed memory, which ensures that the maximum sampling rate and storage length are supported at the same time, making it possible to meet high-precision time testing.

2.5. **Analysis of Factors Influencing Trigger Capability on Measurement Error**

When multiple acquisitions are required to obtain time information, the oscilloscope's own trigger jitter will accumulate on the signal under test and affect the time test results. The trigger jitter of high-performance oscilloscopes is generally about 1ps, which is enough to meet the test requirements for high-precision testing. For high-speed RF communication signals, another important indicator is the trigger bandwidth. If the trigger bandwidth is insufficient, the signal under test cannot be synchronized. Therefore, the trigger bandwidth of all trigger functions (including edges and various advanced triggers) of the oscilloscope needs to be high enough to ensure stable acquisition of the signal under test makes time testing more accurate.

3. **Design of high precision time test method**

Through the above analysis, to carry out high-precision time testing, you first need to determine the basic indicators of the selected oscilloscope to meet the test requirements, paying special attention to the time base stability index of the oscilloscope. Time base is a main indicator of oscilloscope. In the oscilloscope sampling system, the stability of timing components directly affects the accuracy of timing measurement. If there is an error in the time base, then measurements based on that time base will have an equal or greater error. After the selection of the oscilloscope, the following test methods are designed to achieve the best test accuracy.

3.1. **Oscilloscope bandwidth selection**

Choose a high-performance oscilloscope that can achieve sufficient bandwidth while using multiple channels, so that the signal under test can be collected without distortion. Sometimes it is necessary to use a high-bandwidth oscilloscope to test some low-frequency signals. The background noise of the oscilloscope will also affect the high-precision time test to a certain extent. At the same time, because the oscilloscope is a broadband receiver, the larger the bandwidth, the greater the noise. In the high-performance oscilloscope settings, you can select the appropriate oscilloscope application bandwidth range according to the signal bandwidth, so that you can achieve the best time test accuracy.
3.2. **Time deviation and interpolation error correction**

Before performing multi-channel delay test, adjust the Deskew of the oscilloscope to eliminate the time deviation between the channels of the test system. Make full use of the vertical dynamic range of the oscilloscope, make the input signal amplitude reach the full scale of the oscilloscope, and set the sampling rate of the oscilloscope to the highest supported rate. When the time accuracy of the test needs to be higher, the premise of the highest sampling rate of the multi-channel ADC hardware Next, by setting the Sin (x) / x sinusoidal real-time internal difference in the oscilloscope, the time test accuracy can be further improved.

3.3. **Trigger settings**

Set the trigger of the oscilloscope so that the waveform under test is displayed stably on the oscilloscope. If the test exceeds the time interval of milliseconds, you can use the "Trigger Delay" function of the oscilloscope, that is, delay a fixed time after triggering. For long time interval measurement, the long-term stability accuracy affects the main factors of high-precision time testing. In order to improve the test accuracy, the standard 10M external reference clock input on the oscilloscope is connected to an external high-stability time base to improve time measurement accuracy, such as cesium Bell, Rubidium Bell, etc. For short-time delay testing, the long-stability feature will not greatly affect the time accuracy of the test. Use a long memory at a high sampling rate to collect waveforms for direct testing.

4. **Test case**

Taking satellite communication test as an example, in satellite communication, it is required to test the synchronization signal and the jitter change of the radio frequency communication signal at a fixed phase reversal point after a delay of 100ms. The synchronization signal is a rise time sub-nanosecond pulse signal, the RF communication signal is a QPSK modulated signal, and the carrier frequency is 5 GHz. The following figure shows the two waveforms of the measured signal. The yellow waveform is the synchronization signal and the purple waveform is the RF signal.

Figure 3. Schematic diagram of measured signal waveform

The signal is tested with a high-precision oscilloscope and a high-stability time reference. The bandwidth of the oscilloscope is 20GHz. When four channels are used at the same time, it supports 50GS / s real-time sampling rate. In the four-channel working mode, the maximum high-speed acquisition memory of each channel is 200M, and Rich analysis and display functions for broadband signals.

Connect the synchronization signal and the RF signal to channel 1 and channel 2 of the oscilloscope respectively. Channel 1 is used as the trigger channel of the oscilloscope, that is, to
trigger on the synchronization signal; channel 2 tests the RF communication signal, and performs the most on The best settings make the time test accuracy the highest. Due to the need to test the synchronization signal and the time jitter change of the RF communication signal after a delay of 100ms, the Trigger Delay function of the oscilloscope is used, that is, trigger on channel 1, and after a delay of a fixed time of 100ms after the trigger, the channel 2 RF signal waveform is collected to find the phase inversion Point, through the cursor, statistically test the jitter information relative to channel 1 to obtain the test result, as shown in Figure 4.

![Enlarged view of RF communication signals](image)

**Figure 4.** Schematic diagram of the test result of the signal under test

The nominal time base accuracy of the oscilloscope for testing is $1.2 \times 10^{-6}$. Without the influence of other error components, the accuracy of testing a 100ms time signal is about 100ns, which is difficult to meet the requirements of high precision time testing.

$$DTA = 0.06\times 20\text{ps} + 1\text{ppm} \times 100\text{ms} = 101.2\text{ns}$$

It can be seen from the above calculations that for long-term accurate delay testing, the long-time stability accuracy of the time-based system is very important. For the above applications, the external high-stability time base (rubidium clock) is connected to the oscilloscope's standard 10M external reference clock input to improve the time measurement accuracy. The accuracy of the test oscilloscope time base system reaches no more than $1 \times 10^{-10}$ index. The time accuracy obtained by testing 100ms time information can reach the level of 11.2ps, thus meeting the requirements of high-precision time testing.

$$DTA = 0.06\times 20\text{ps} + 1\times 10^{-10} \times 100\text{ms} = 11.2\text{ps}$$

5. Conclusion

Faced with various high-precision time testing needs, first of all, we should choose the appropriate testing tools and methods according to the actual application and index requirements. High-performance oscilloscope is a key tool for high-precision time test. Before performing high-precision time test, you need to understand the key indicators and test methods of the oscilloscope's impact on the accuracy of high-precision time test, and the impact of different test parameters on the test results. High-precision time testing requires evaluation of the overall performance of the oscilloscope, such as multi-channel oscilloscope bandwidth, multi-channel time deviation elimination, multi-channel sampling rate, real-time interpolation acquisition mode, trigger system, and high sampling rate that needs to be matched with it. Under the length of the acquisition memory, to complete high-precision time testing and analysis.
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