Whitepaper

MAKING BETTER OSCILLOSCOPE MEASUREMENTS

Products:

- R&S®Scope Rider
- R&S®RTC1000
- R&S®RTB2000
- R&S®RTM3000
- R&S®RTA4000
- R&S®RTE1000
- R&S®RTO2000
- R&S®RTP

James Lewis | Rohde & Schwarz | Version 1.00 | 08.2020

ROHDE&SCHWARZ

Make ideas real

Contents

1 Overview

This white paper covers the most common mistakes when making scope measurements. After reading this paper you will understand how different settings affect your results, what specifications to consider, and what the right probe to use is. Whether you are working with a 100 MHz handheld or a 16 GHz lab scope, these tips will help you setup your scope to be ready to trigger and acquire your signals.

2 Introduction

With any oscilloscope, the journey to better measurements begins at the intersection of three key questions:

- What are you trying to measure?
- What is your oscilloscope capable of measuring?
- Which settings will ensure useful results?

Within the overlap of the answers, five key items determine what you can actually measure: analog bandwidth, sample rate, system rise time, vertical resolution, and triggering functions. Many of these interact and, collectively, all will help you make better measurements.

To provide context, this white paper starts with a brief look at a general block diagram for an oscilloscope. From there, we explore the relationship between analog bandwidth and sample rate before offering rules of thumb that relate to your signal under test (SUT). Next, the narrative drills down on the underlying interactions that provide a foundation for better measurements.

Along the way, we present practical tips that will help you optimize scope settings and ensure meaningful results. We have also included a brief overview the Rohde & Schwarz lineup of oscilloscopes.

2.1 Context: General Block Diagram

As a foundation, let's walk through a generalized block diagram of an oscilloscope. Not every scope will have this exact structure; however, the model includes the major elements that matter most (Figure 1).

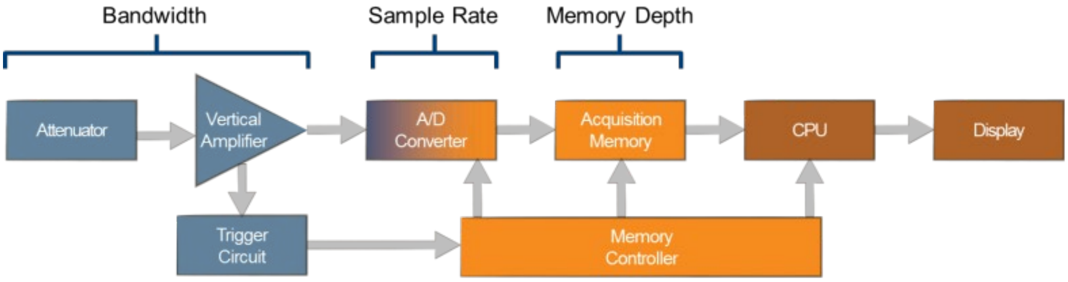


Figure 1: In this example block diagram, the major elements of a digital oscilloscope define what it can measure accurately and repeatably.

Working from left to right, the signal flow is as follows. The SUT passes through the attenuator stage, which, if needed, reduces the input level to be within the allowed maximum voltage range. Next, the vertical amplifier boosts or buffers the signal for optimum scaling into the analog-to-digital converter (ADC). Through sampling and conversion, the ADC creates a digital representation of the incoming signal, and the digital samples are stored in the acquisition memory.

The central processing unit (CPU) crunches the incoming data and formats it for display, presenting waveforms and results for the user to examine and analyze. In the background, the memory controller provides overall coordination and management of the ADC, the acquisition memory and the CPU.

As indicated with brackets, three sections determine oscilloscope performance. Within the *analog bandwidth* section, the vertical amplifier acts like a low-pass filter, potentially affecting the shape and amplitude of the measured waveform. In the *sample rate* section, the ADC is expected to capture a complete and accurate representation of the incoming signal, no matter how simple or complex it may be. Finally, the *memory depth* section provides built-in capacity to store the acquired samples. It may go without saying, but deeper memory is better when dealing with dynamic, transient, long or complex signals.

We'll take a closer look at each major element in the next few sections.

2.2 Bandwidth and Sample Rate

Rather than working through an extended academic derivation, let’s start by clarifying the relationship between *analog bandwidth* and *sample rate*. Alone, neither determines what you can actually measure.

Rather, the answer is found within the interrelationship between the signal under test (SUT), the analog bandwidth, the ADC sampling rate, and the actual range of frequencies that must be measured (Figure 2).

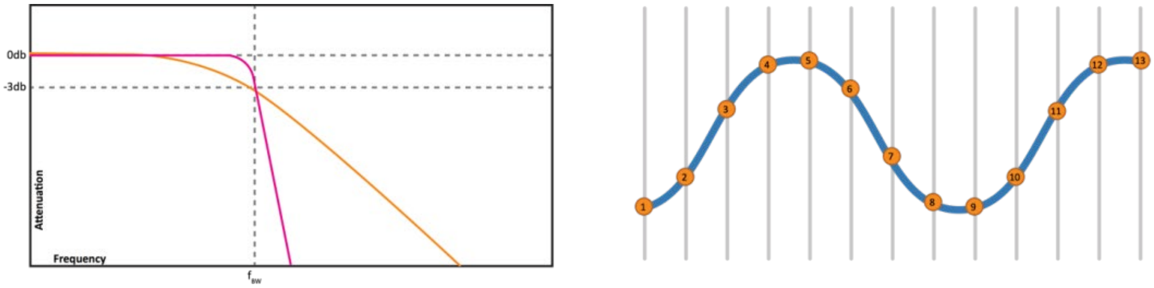


Figure 2: Analog bandwidth (left) has implications for amplitude accuracy versus the fundamental frequency and its harmonics. In turn, this affects the ADC’s ability to accurately represent and reproduce the incoming waveform (right).

The filtering effect of the analog bandwidth determines the extent of the signal content the scope can see and measure. Rule of thumb #1: the analog bandwidth needs to be 3x to 5x the fundamental frequency or clock rate of the measured signal.

The sample rate determines the scope’s ability to completely represent and reconstruct the SUT. Rule of thumb #2: the ADC sample rate needs to be 2.5x to 5x the analog bandwidth.

Applying the rules together, an accurate measurement of a 100 MHz signal would require 300 to 500 MHz of analog bandwidth and a sampling rate in the range of 750 MSa/s to 2.5 GSa/s (megasamples per second or gigasamples per second, respectively).

From this, it should be clear that the most challenging signals will be very fast, highly complex, or both. On the analog side, an especially daunting signal would be a gigahertz carrier with complex modulation and burst behavior. In the digital domain, high-speed signals with rapid rise times, multiple signal levels and variable pulse widths will be among the most difficult to characterize accurately.

2.3 Bandwidth versus Analog Content

Bandwidth defines the analog content an oscilloscope can measure. Here, we have to answer a pair of questions: “How much bandwidth do you need?” and “How much bandwidth can your scope provide?”

The required bandwidth depends on the SUT. For a pure sine wave—distortion-free, no harmonics—the necessary bandwidth is the same as the maximum frequency to be measured.

With a square wave, the necessary bandwidth is a multiple of the maximum fundamental frequency. This follows from Fourier theory: a square wave is a sum of odd-harmonic sine waves of decreasing amplitude (Figure 3, left). As a result, the fewer the number of odd harmonics that are in-band, the less accurate the representation, reproduction and measurement of the incoming square wave signal (Figure 3, right).

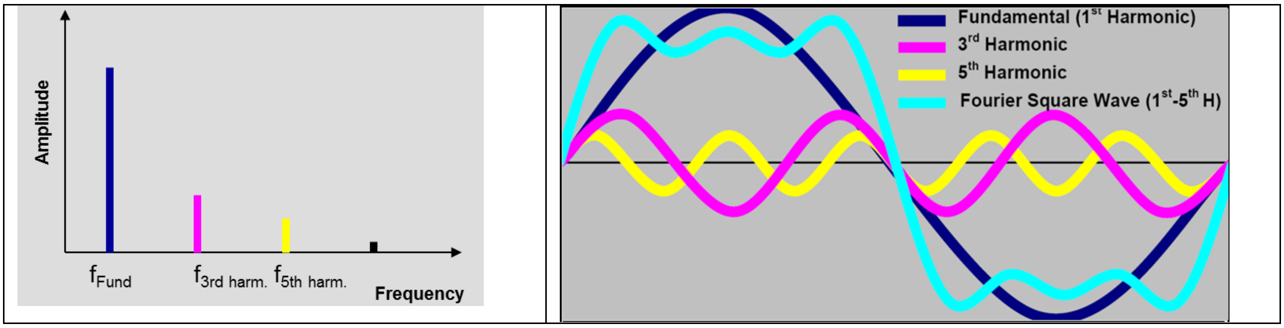


Figure 3: Summing only a subset of the odd harmonics (e.g., first, third and fifth) that comprise a square-wave signal produces an incomplete representation of the incoming waveform (above right).

The complement to this is the analog bandwidth of the oscilloscope. As noted earlier, this section of the signal path acts like a low-pass filter. This is due to the response of the vertical amplifier, which has a known –3 dB point. It is important to note the difference between the bandwidth (or input) sections of analog and digital oscilloscopes. As shown in Figure 4, analog scopes (orange trace) generally have a gentler roll-off than do typical digital scopes (red trace).

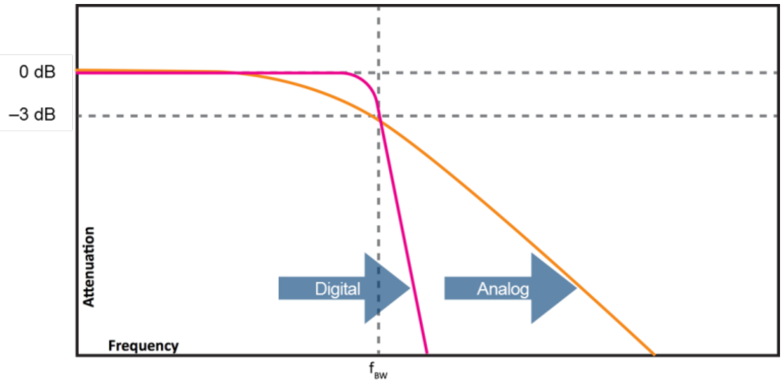
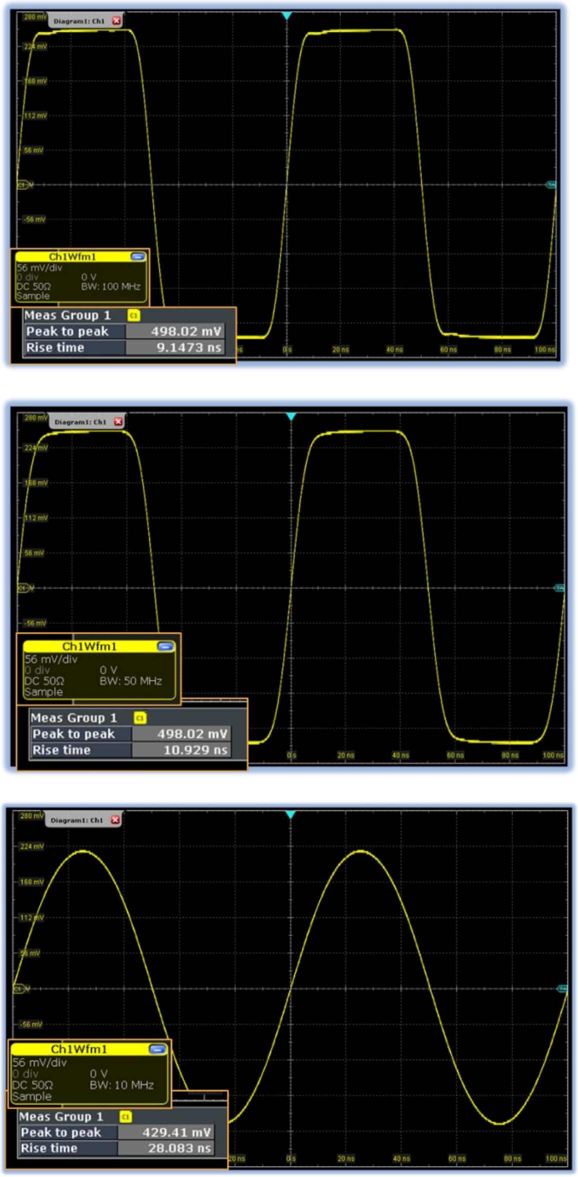


Figure 4: With a digital scope (red trace), the “brick wall” roll-off means the unaffected amplitude accuracy extends closer to the specified bandwidth.

Because most real-world signals are complex, a simplistic approach doesn't provide a useful answer to "How much bandwidth do you need?" The foregoing assessment of analog roll-off is the foundation of the earlier rule of thumb: the bandwidth of your oscilloscope needs to be three to five times (3x to 5x) the fundamental frequency or clock rate of the SUT.

Actual measurements will demonstrate this point. Figure 5 shows a series of measurements on a 10 MHz square wave as bandwidth is reduced from 100 MHz to 50 MHz to 10 MHz. In the top figure, the 100 MHz bandwidth means the representation of the SUT includes the third, fifth, seventh and ninth harmonics (30, 50, 70 and 90 MHz, respectively). As bandwidth is narrowed and more harmonics are filtered out, the wave shape and its peak amplitude become less and less accurate.



Ch1Wfm1
56 mV/div
0 div 0 V
DC 50Ω BW: 100 MHz
Sample

Meas Group 1	
Peak to peak	498.02 mV
Rise time	9.1473 ns

Ch1Wfm1
56 mV/div
0 div 0 V
DC 50Ω BW: 50 MHz
Sample

Meas Group 1	
Peak to peak	498.02 mV
Rise time	10.929 ns

Ch1Wfm1
56 mV/div
0 div 0 V
DC 50Ω BW: 10 MHz
Sample

Meas Group 1	
Peak to peak	429.41 mV
Rise time	28.083 ns

Figure 5: From top to bottom, measuring the same 10 MHz square wave with narrower bandwidths produces increasingly inaccurate results in terms of wave shape and amplitude (see numerical values in each lower-left inset).

2.4 Rise Time versus Bandwidth

Once again, it is useful to reframe the foregoing rule of “3x to 5x bandwidth” as *necessary but insufficient*, by itself. Circling back to Fourier theory and the measurement of square waves, the inclusion of more odd harmonics improves the representation of the actual waveform. With square waves, obtaining the sharpest possible edge in the measured waveform is equally essential to accurate representation and reconstruction.

Rise time is a key characteristic of any square wave. As a refresher, rise time measures the steepness of that edge. Figure 6 illustrates the definition of rise time: it is the time required to transition from 10 percent to 90 percent of the steady-state level of the measured signal.

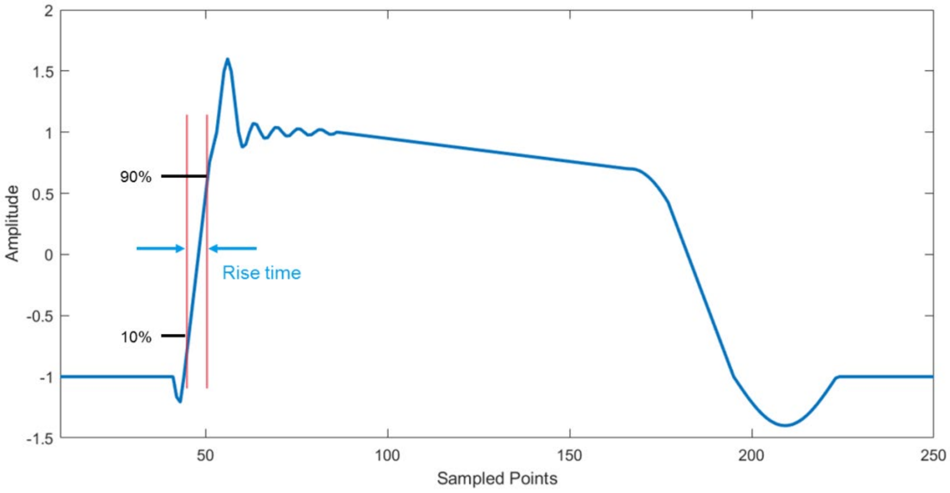


Figure 6: Transition-time measurements are affected by the scope’s analog bandwidth and internal rise time.

For any oscilloscope, two attributes affect its ability to measure rise time accurately: analog bandwidth and internal rise time. These are united in a practical approximation for analog scopes: the system bandwidth, in hertz, equals 0.35 divided by the rise time. In equation form:

$$f_{BW} = 0.35/t_r$$

Defining each element:

- f_{BW} is the calculated system bandwidth of the oscilloscope; also, the necessary SUT bandwidth
- t_r is the transition time from 10 percent to 90 percent of the steady-state level
- 0.35 is the constant for a first-order passive filter; value varies by oscilloscope

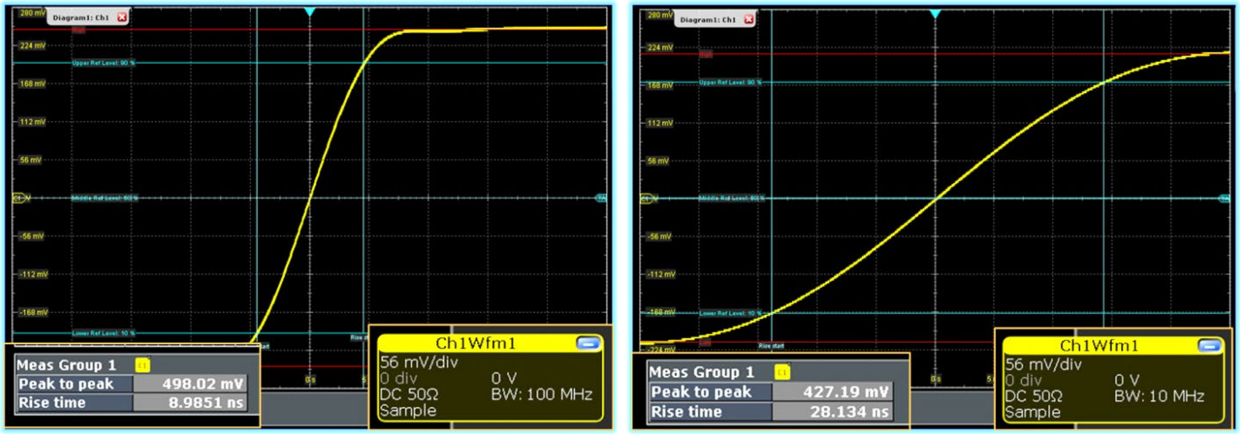
The constant depends on the actual low-pass filtering effect of the preamplifier. While a factor of 0.35 is appropriate for the gentle roll-off of an analog oscilloscope, a constant in the range of 0.40 to 0.45 is a more accurate representation of the brick-wall behavior of a digital oscilloscope (refer back to Figure 4).

A simple manipulation of the equation produces corollaries for system rise time as a function of bandwidth:

- Analog scope: $t_r = 0.35/f_{BW}$
- Digital scope: $t_r = 0.40/f_{BW}$

In many cases, this factor can be found in an oscilloscope's published specifications. As an example, the R&S®RTP digital scope uses a factor of 0.43.

The relationship between bandwidth and rise time is clearly visible in the real world. Figure 7 shows two measurements of a 10 MHz square-wave signal: on the left, a bandwidth of 100 MHz produced rise time of 8.9851 ns and peak-to-peak amplitude of 498.02 mV; and on the right, a 10 MHz bandwidth produced 28.134 ns rise time and 427.19 mV peak-to-peak (see lower-left inset in each trace).



Meas Group 1
Peak to peak 498.02 mV
Rise time 8.9851 ns

Ch1Wfm1
56 mV/div
0 div 0 V
DC 50Ω BW: 100 MHz
Sample

Meas Group 1
Peak to peak 427.19 mV
Rise time 28.134 ns

Ch1Wfm1
56 mV/div
0 div 0 V
DC 50Ω BW: 10 MHz
Sample

Figure 7: Insufficient bandwidth leads to errors in measurements of rise time and peak-to-peak amplitude.

To fully account for potential rise-time error, we must extend this concept to include the entire test setup: oscilloscope, cables, probes, fixtures, and so on. From this, the overall *measurement system rise-time performance* is a "square root of the sum of squares" calculation:

$$t_{MEAS} = [(t_{SUT})^2 + (t_{SCOPE})^2]^{½}$$

The percent error between the measured and actual rise times is based on the measured rise time calculated from the root sum of squares:

$$t_{ERROR} = [(t_{MEAS} – t_{SUT})/t_{SUT}] \text{ x } 100$$

As an example, consider an SUT with 300 ps rise time and a digital scope with a 100 ps rise time:

$$t_{MEAS} = [(300 \text{ ps})^2 + (100 \text{ ps})^2]^{½} = 316.23 \text{ ps}$$

$$t_{ERROR} = [(316 – 300)/300] \text{ x } 100 = 5.41\%$$

Table 1 provides a summary of measurement error in terms of the ratio of system rise-time error versus actual SUT rise time. In short, the better the system rise time, the lower the measurement error.

Rise-time ratio (scope vs. SUT)	Percent error
1:1	41%
2:1	12%
3:1	5%
5:1	2%
10:1	0.5%

Table 1: To ensure measurement error of less than 10%, the oscilloscope rise time should be at least 2.2x faster than the SUT rise time.

3 Sample Rate versus Signal Representation

In the ADC, sampling acquires amplitude values at a precise clock rate, and therefore sample resolution is the inverse of the sample clock rate. For most current-generation oscilloscopes, sample rates are in the range of megasamples or gigasamples per second (MSa/s or GSa/s). Figure 8 illustrates the 1 GSa/s acquisition of a pure sine wave and, taking the reciprocal, the resulting resolution is 1 nanosecond per sample.

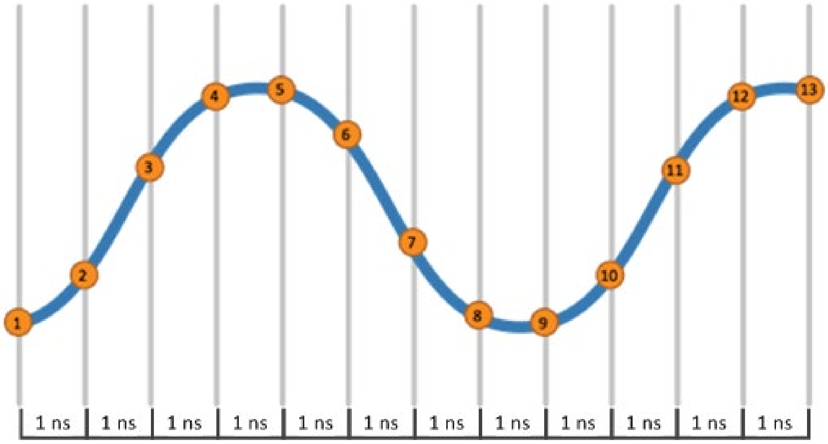


Figure 8: Sampling at a precise interval is fundamental to an accurate representation of the incoming signal.

Back to an earlier question: What sample rate do you need? The answer depends on the frequency content of the SUT and the Nyquist/Shannon sampling theorem, perhaps better known as the Nyquist theorem.[1] One

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[1] Harry Nyquist and Claude Shannon worked at Bell Labs, and both made significant contributions to the foundational work often taken for granted in modern digital signal processing. For more, see the "Nyquist-Shannon sampling theorem" entry in Wikipedia.

of the foundational ideas is the transformation of a continuous-time signal into a discrete-time signal (i.e., a sampled waveform).

If a continuous-time signal *x(t)* has no signal content above B hertz, Nyquist and Shannon proved that it can be *completely described* with a stream of samples spaced 1/(*2B*) seconds apart. Consequently, the ADC must sample at a rate *greater than* twice the maximum frequency of interest *or* $f > 2B$. Any sample rate greater than twice B satisfies this condition.

An example from digital audio helps illustrate the combined effects of sampling rate and analog bandwidth. Digital audio recorders have traditionally used a sampling rate of 44.1 kHz or 48 kHz to achieve “perfect reconstruction” of audio signals in the band of 20 Hz to 20 kHz (i.e., the accepted range of human hearing). Thus, the sampling rate is 2.205 to 2.4 times the maximum frequency of 20 kHz.[2]

3.1 Aliasing

When the combination of incoming signal and sampling rate violates the Nyquist/Shannon rule, the signal is “under sampled” and the system does not capture all of the information about the continuous-time signal. Figure 9 provides a visual explanation: the incoming signal is a 1 GHz sine wave (green dashes) but the sampling rate is 750 MHz (orange dots).[3] The solid blue line is an “image” or “alias” signal at a frequency of 250 MHz, which is the difference between the sampling rate and the fundamental frequency of the SUT.

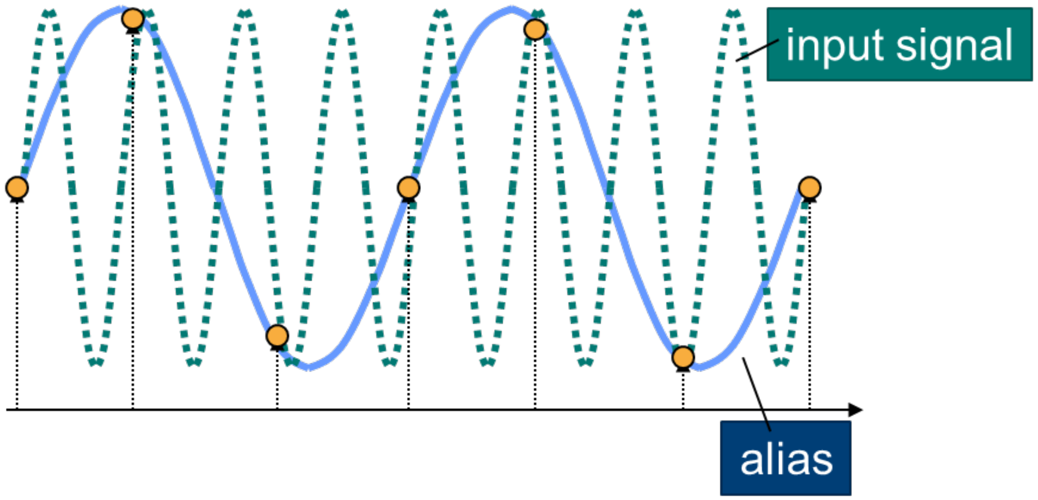

Figure 9: In this scenario, “actual aliasing” occurs in the representation of the measured data (orange dots), and “perceptual aliasing” occurs in the displayed reconstruction of the under-sampled waveform (blue trace).

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[2] The merits of the higher rates used in current-generation digital recorders and music players (e.g., 192 kHz) will be left to the interested audiophile.

[3] Assume the analog bandwidth is at least 3 GHz so therefore is not a factor.

Reiterating Nyquist/Shannon, sample rate determines the ability to completely represent and reconstruct the incoming signal. In this case, a sampling rate of 2.5 to 5.0 GSa/s is necessary to faithfully represent and reconstruct the 1 GHz sine wave.

3.2 Vertical Resolution versus Accuracy

Manufacturers often talk about the “vertical system” within an oscilloscope. This really means “voltage measurement” and includes the vertical amplifier and ADC.

For the best representation of the incoming signal, we want to span all of the ADC bits. In a scope, we use the volts-per-division (V/div) control to spread the waveform from the bottom to the top of the graticule. The goal is to make the waveform as big as possible without clipping: in a scope, what you see is what the ADC measures. Covering the full graticule makes it easier to see the details, and it also improves trigger performance.

When discussing oscilloscope performance, the number of bits in the ADC is often treated as a banner specification. At root, the number of bits determines the number of amplitude levels the ADC can resolve. The basic equation is 2^(number of bits) equals the number of voltage levels the ADC can measure. Table 2 provides values for 8, 10, 12 and 16 bits as well as the per-level voltage resolution if the graticule has 10 vertical divisions and the display is set for 100 mV/div.

ADC resolution	Levels	Volts per level
8-bit	256	3.9 mV
10-bit	1,024	979 µV
12-bit	4,096	244 µV
16-bit	65,536	15.26 µV

Table 2: As a mathematical exercise, the raw number of ADC bits provides a best-case scenario for vertical resolution (10 vertical divisions, 100 mV/div).

This narrative must include a caveat: bits don’t tell the whole story. Noise from the vertical amplifier might exceed the voltage resolution near the bottom of the graticule. Thus, a low-noise 8-bit scope may be superior to a 12-bit oscilloscope with a noisy front end when working with extremely small signals (e.g., those with low amplitudes close to the noise floor).

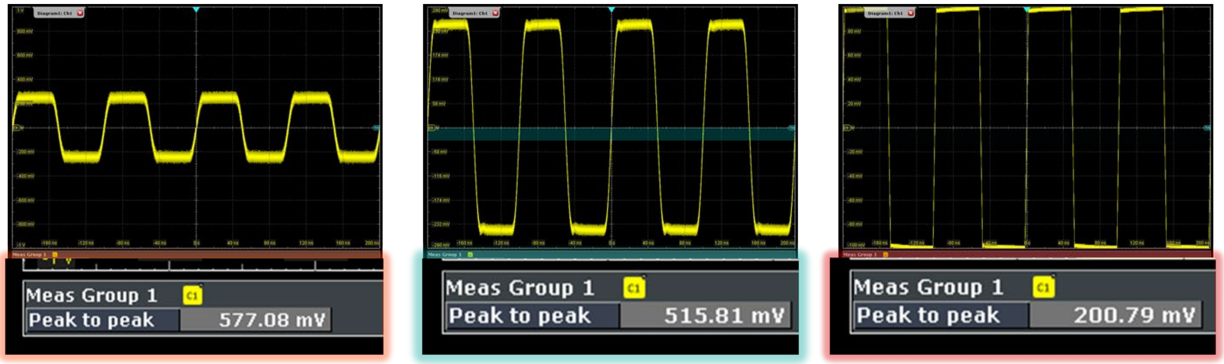
3.2.1 Three tips for better vertical results

Building on the preceding, three tips will help you make better amplitude measurements.

Tip #1: Fill the screen without clipping

As noted above, what you see is what the scope measures. From this, you want to scale the waveform vertically across as much of the display as possible without clipping.

The sequence in Figure 10 drives home the point. Measurements were made using an 8-bit scope, meaning 256 levels are spread across 10 vertical divisions. In the left trace, a setting of 250 mV/div reduces the SUT to just two divisions, using roughly 52 levels for the measurement and yielding a peak-to-peak reading of 577.08 mV. In the middle, changing to 125 mV/div spreads the SUT across most of the graticule, maximizing vertical resolution and providing a peak-to-peak value of 515.81 mV. On the right, a setting of 20 mV/div overdrives the preamp and causes clipping: detail from the top of the waveform is missing, and the peak-to-peak voltage reading is off by a factor of 2½ (just 200.79 mV).



Meas Group 1 C1
Peak to peak 577.08 mV

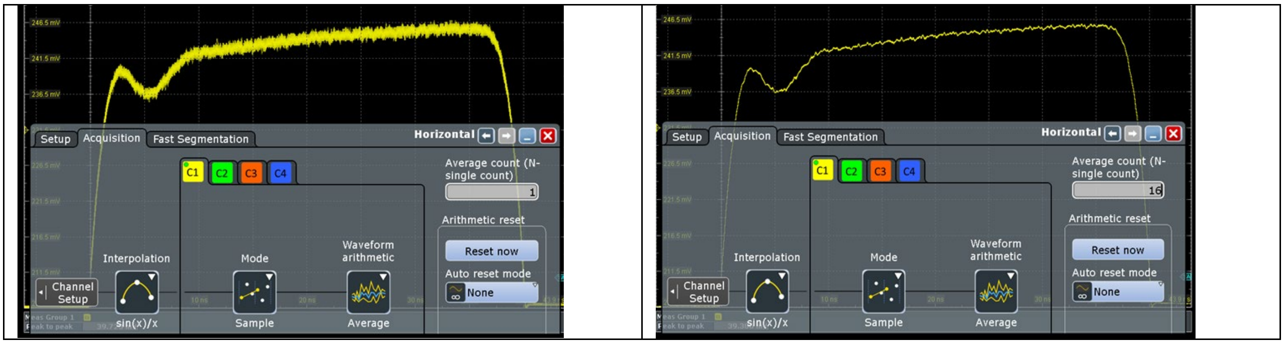
Meas Group 1 C1
Peak to peak 515.81 mV

Meas Group 1 C1
Peak to peak 200.79 mV

Figure 10: When it comes to the per-division setting, under-scaling (left) and over-scaling (right) will cause erroneous results.

Tip #2: Use averaging

When using triggering to measure a repetitive waveform, averaging in the time domain reduces noise and improves measurement accuracy. Roughly speaking, every doubling in the number of averages provides a half-bit improvement in the effective number of bits (ENOB) from the ADC. In addition, every added bit provides a 6 dB improvement in signal-to-noise ratio (SNR). Thus, by averaging multiple triggered waveforms together, the scope produces a single result that has less variation and an improved SNR (Figure 11).



Interpolation: sin(x)/x
Mode: Sample
Waveform arithmetic: Average
Average count (N-single count): 1
Auto reset mode: None

Interpolation: sin(x)/x
Mode: Sample
Waveform arithmetic: Average
Average count (N-single count): 16
Auto reset mode: None

Figure 11: Comparing no averages on the left to 16 averages on the right, the result is a more accurate representation of the measured waveform.

On the plus side, averaging maintains the full bandwidth and sample rate of each measurement. However, there are also tradeoffs. First, averaging improves SNR only when working with repetitive waveforms. Transients are averaged out, either disappearing or taking on a distorted form (depending on where and how often they occur). A related tradeoff: the scope cannot trigger on interesting details within the signal because averaging is a post-processing function, meaning the trigger section sees only the original incoming waveform.

Understanding ENOB

Effective number of bits (ENOB) is an IEEE metric used to measure the vertical performance of a device such as an ADC or a system such as an oscilloscope. ENOB is measured by capturing a perfect sine wave and then computing the measured deviation. Even though an ENOB measurement takes into account signal integrity issues such as noise and distortion, it omits factors such as offset error and phase distortion that can affect the results.

Oscilloscope ENOB is not a single number but rather a series of curves. An ENOB curve exists for each oscilloscope bandwidth and every vertical setting, and this means a complete ENOB characterization for an oscilloscope is a series of plots. Even so, oscilloscope manufacturers often publish a typical ENOB value based on one bandwidth and one vertical setting.

Tip #3: Use high definition mode

To further enhance waveform measurement and analysis, some oscilloscopes provide a “high resolution” or “high definition” mode. This is a form of real-time averaging that takes in multiple samples, averages them, and creates additional points in the waveform (Figure 12).

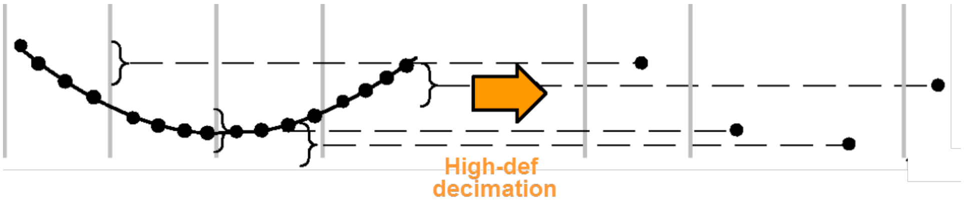
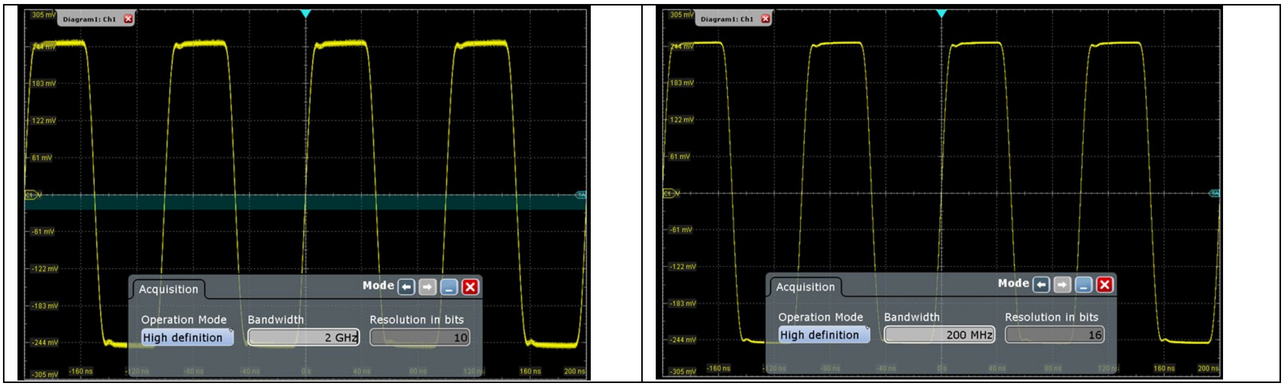


Figure 12: High-definition mode provides additional vertical resolution by creating new points from sampled points.

Similar to waveform averaging, high-definition mode reduces noise; however, it provides somewhat less improvement in SNR (Figure 13). This mode also has the added advantage of working with non-repetitive waveforms, including single-shot phenomena.



Operation Mode: High definition
Bandwidth: 2 GHz
Resolution in bits: 10

Operation Mode: High definition
Bandwidth: 200 MHz
Resolution in bits: 16

Figure 13: With the same signal and scope, the result with high-definition mode (right) has less noise and more detail than the measurement with wider bandwidth and fewer bits.

There are two negatives to consider: the averaging process reduces the effective scope bandwidth due to data decimation; and because most scopes implement this as a post-processing function, real-time dynamics will not be visible.

As an aside, the R&S®RTO, R&S®RTP and R&S®RTE oscilloscopes implement the high-definition mode in hardware as samples are being acquired. Consequently, the user can set up triggering to initiate measurements based on the high-definition waveform.

4 Triggering for Stable Measurements

Triggering enhances the measurement of single-shot events, periodic signals (especially when averaging), and more. Setting up a dependable trigger will ensure stable displays and meaningful measurements.

4.1 Understanding digital triggering

In a conventional oscilloscope, triggering is an analog event that initiates data acquisition. The process works a bit differently inside a digital scope. Even when using basic rising-edge triggering, the algorithm identifies an analog event (e.g., user-entered trigger type and level) and tags the appropriate digital sample (Figure 14). Because the front end is running continuously, the trigger controls when the acquisition finishes and presents the triggered waveform on the display.

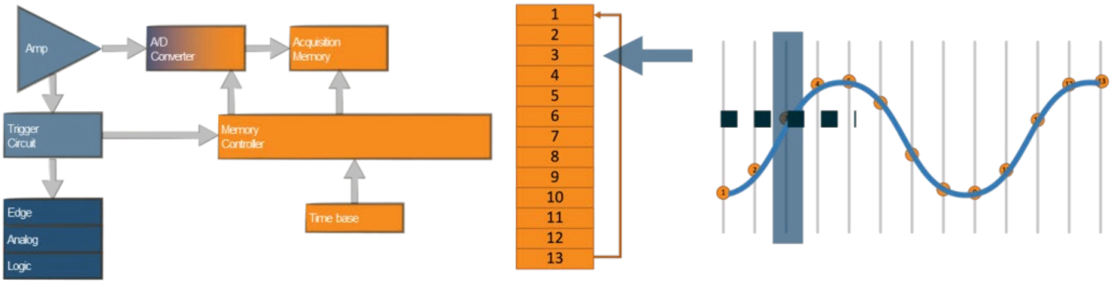


Figure 14: When a trigger occurs, the scope flags a specific digital sample in the cyclic memory buffer.

4.2 Setting the trigger conditions

A brief look at the available settings will help clarify digital triggering. Figure 15 shows the screen of an R&S®RTM oscilloscope with highlights added for this explanation. The orange rectangle highlights the active channel (C1), the user-entered trigger level (20 mV) and the selected trigger type (rising edge). The orange circle shows the trigger level relative to the 500 mV/div scaling of the display. Finally, the blue oval indicates the actual trigger point on the waveform.

Figure 15: Indicators on the oscilloscope screen provide essential information about trigger conditions and the actual trigger point.

To the right of the rectangle, the screen also shows “Auto” (“automatic”) as the active sweep mode. Three modes are commonly available: auto, normal and single. Auto mode works well with repetitive waveforms or when probing and debugging. Normal mode updates only when the specified trigger event is met, making it useful when measuring relatively slow signals. Single is like normal but will trigger just once when the specified conditions are met.

Depending on the types of signals you might be measuring, the typical choices of rising edge, falling edge or both may not be sufficient. When working with dynamic signals, specialized formats, or other interesting events (e.g., burst activity or variable pulse widths), we encourage you to look for other types of trigger modes: glitch, width, runt, window, timeout, interval, slew rate, state, pattern, TV, and data-to-clock.

5 Rohde & Schwarz Oscilloscopes

At Rohde & Schwarz, we focus on delivering oscilloscope innovation that inspires measurement confidence. Our range of scopes is engineered to fit your requirements and your budget, from top value to top performance (Figure 16). Hallmarks include excellent signal fidelity, uniquely low noise, high acquisition rate, an innovative trigger system, a clever user interface, and real-time de-embedding.

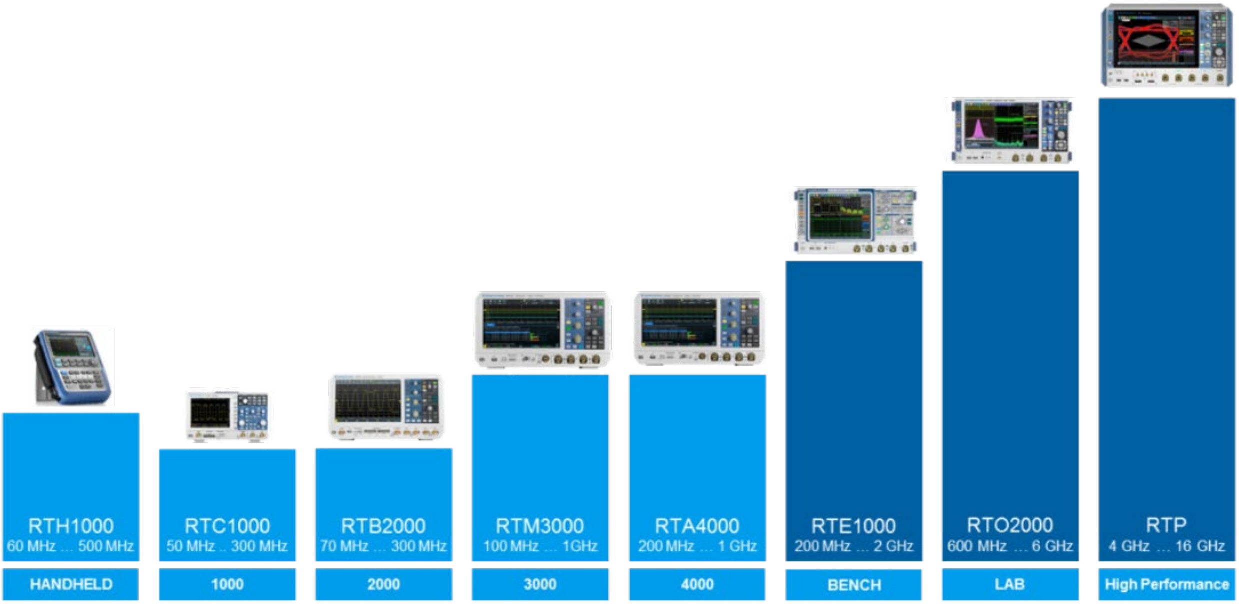


Figure 16: The Rohde & Schwarz range of oscilloscopes spans a wide array of price/performance points.

Proceeding from left to right in Figure 16:

- **R&S®Scope Rider**: Whether debugging embedded devices in the lab or analyzing complex problems in the field, the rugged handheld R&S®Scope Rider offers exceptional performance and capability.
- **R&S®RTC1000:** High sensitivity, multi-functionality and a great price are what make the R&S®RTC1000 oscilloscope so special. State-of-the-art, high-performance technology in a fanless design meets the requirements of embedded developers, service technicians, educators, and more.
- **R&S®RTB2000:** “Power of ten” (10-bit ADC, 10 MSa memory and 10.1-inch touchscreen) combined with smart operating concepts make the R&S®RTB2000 oscilloscopes the perfect tool for university labs, design troubleshooting, production test, and service groups.
- **R&S®RTM3000:** Designed as a daily problem-solving tool, the R&S®RTM3000 combines the “power of ten” with a unique interface for all R&S probes.
- **R&S®RTA4000:** Designed with class-leading signal integrity and responsive ultra-deep memory, the R&S®RTA4000 brings “power of ten” to a new level. Offering sharp waveforms and greater accuracy, it delivers measurement confidence when facing unexpected challenges.
- **R&S®RTE1000:** These scopes offer a fully integrated multi-domain test solution with time, frequency, protocol and logic analysis. From embedded design development to power electronics analysis to general debugging, the R&S®RTE1000 handles everyday challenges quickly, accurately and easily.

- **R&S®RTO2000:** Offering bandwidths from 600 MHz to 6 GHz, this series excels at time- and frequency-domain testing. With excellent signal fidelity, 1M waveforms/sec, up to 16-bit vertical resolution, and intuitive SmartGrid operation, you can measure quickly and with confidence.
- **R&S®RTP:** The R&S®RTP high-performance oscilloscope combines high-class signal integrity with a fast acquisition rate. Customized frontend ASICs and realtime processing hardware enable highly accurate measurements with unprecedented speed in a compact form factor.

6 Conclusion

Our journey started with three questions: *What are you trying to measure? What is your oscilloscope capable of measuring? Which settings will ensure useful measurements?* In the intersection of the answers, scope attributes and signal characteristics are linked in multiple dimensions:

- Analog bandwidth versus ADC sample rate
- Bandwidth versus analog content
- Rise time versus system bandwidth
- Preamp filtering effects (e.g., gentle or brick-wall roll-off)
- ADC sample rate versus signal representation (e.g., aliasing)
- Vertical resolution versus accuracy
- Trigger modes, settings, and capabilities

As described here, careful consideration of these attributes and their interactions will help you make better measurements in a wide variety of situations.

Within the Rohde & Schwarz lineup, our scopes are engineered to fit your requirements and your budget, from top value to top performance. Across the portfolio, our focus is on delivering oscilloscope innovation that inspires measurement confidence.

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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