

# **Siglent SDS1104X-E Review**

# Introduction

The new Siglent SDS1x04X-E series SPO have entered the world market and appear to have the potential of setting a new price/performance standard in the entry level class.

The most striking features are:

- 4 channels
- Sample rate **2 x 1GSa/s** or 4 x 500MSa/s
- Bandwidth 100MHz or **200MHz**
- Memory depth **2 x 14Mpts** or 4 x 7Mpts
- Up to >100k Wfm/s (up to **>400k** in sequence mode)
- Vertical true full resolution sensitivity down to **500µV/div**
- Segmented memory up to **80000 segments** for **history** and **sequence** mode
- **Full speed mask test**
- **1Mpts FFT** with SA-oriented user interface
- Automatic **measurements** use full record length with **no decimation**
- **Bode plotter** for network analysis
- Full connectivity over USB and **LAN**, optional WiFi
- Built-in web server
- Optional external AWG SAG1021 up to 25MHz
- Optional **16 channel MSO** with 1GSa/s up to 14Mpts

Siglent were kind enough to offer me an early SDS1104X-E for evaluation and I couldn't resist finding out whether this scope has the potential to meet the high expectations. The SDS1x04X-E series scopes aren't expensive, yet they are certainly not the cheapest DSOs around. But then again, I figure many of us would be looking for the best value for money rather than just the cheapest price. As can be seen from the listing above, these models have a whole lot to offer – certainly more than the average DSO in this class.

In any case this appears to be a very interesting product and I felt it deserves an in-depth review. Because of my very limited spare time this has actually started long before the scope was finally released. Consequently, most of the review is based on a pre-production hardware and early firmware, which raises the question how to deal with issues encountered during evaluation. Of course it would not be fair to point out bugs of an unfinished firmware that was never meant to be released to the public.

Thankfully it turned out to be not a big problem, as most of the functionality was of surprising high quality already, with only minor issues that did not prevent me from doing my tests the way I had them planned and getting the results I'm going to present now. Of course there were (and sure as hell still are) a number of flaws, particularly in the areas that are either completely new or have undergone a major re-design:

- Serial decoding had been redesigned and looks promising, but needs further refinement.
- MSO Option was not yet available.
- Bode Plotter first shot, good concept, but certainly far from finished yet.
- XY-mode currently some emergency solution that will see some major re-design.
- Sequence mode is currently broken, but Siglent promised a fix within a short time.

A full and final review of these functions listed above will be published later, after a firmware with the necessary fixes has been released.

# Differences to SDS1202X-E

Even though the Siglent SDS 1x04X-E has a lot in common with the SDS1202X-E, it is still a newer design and one step further in some areas. It particularly has got some exclusive features and this is also reflected by the new front panel layout. The obvious differences are listed below:

**Connectivity.** The SDS1104X-E now offers a 2nd USB host port at the rear, which is handy for connecting one of the new options: the WiFi dongle or the SAG1021 AWG (or any other Siglent SDG device). This way, the front panel USB connector remains free for an USB memory stick.

**Sbus Connector.** This is where the new SLA1016 logic probes are connected. This will add 16 digital channels with a max. sample speed of 1GSa/s and up to 14Mpts memory.

**Shared vertical gain and position controls.** Some people might not like this, but there is no alternative in a compact 4-channel DSO like this. I don't see a big problem either; for real work, separate controls don't offer a big advantage in my experience. In R&D I set up the channels within a minute or so in order to monitor the critical signals. Then I tweak the hardware and/or firmware until I get the desired result, which might take hours or even days without touching the vertical settings. If anything, I'm more likely to alter timebase, trigger, math or measurements rather than channel gain and position. Other input channel related settings like input coupling and bandwidth limit are not directly accessible anyway. A service technician on the other hand might often change gain and/or position when probing many different test points in sequence, but this is usually done with just one single channel where separate controls would not make a difference.

**Search.** Now this scope finally got the first implementation of a search function, which allows finding certain trigger conditions within a long record. It does not search across the history though (where we would need it the most) and I really hope we'll get that eventually with a later firmware.

**Navigate button group.** This is finally the solution for the old problem of dialing in a huge amount of delay with the horizontal position control. The new navigate function is essentially an automatic knob twiddler that works in three speeds and it can also browse through search events and history frames. I've learned to appreciate this feature pretty quickly.

**No Ext. Trigger input.** Other than the SDS2x04X, which still offers an external trigger input even for the four channel models (albeit on the rear side of the instrument), the SDS1x04X-E doesn't have that anymore. But then again, with up to 20 possible channels (4 analog + 16 digital), this is only a very minor loss.

To sum it all up, the obvious differences between the SDS1x04X-E and the older SDS1202X-E are:

- 4 channels
- No ext. Trigger input
- Sample rate **2 x 1GSa/s**
- Memory depth **2 x 14Mpts**
- **Search** function
- Dedicated **Navigate** buttons
- **Bode plotter** for network analysis
- Built-in web server
- Optional WiFi
- Optional external AWG SAG1021 up to 25MHz
- Optional **16 channel MSO** with 1GSa/s up to 14Mpts

# Base Functionality

Before looking at all the bells and whistles, I always want to make sure that the base functionality is sound and the scope will do a proper job, also as a substitute for analog scopes. After all we want a reliable tool.

## Display

### SPO (Super Phosphor Oscilloscope)

Obviously a major task of any oscilloscope is to display waveforms. Early DSOs did just that in a very restricted way – this was one of the many reasons why particularly analog engineers disliked them and rather stuck with their trusted analog scopes, because these were not only free of limitations and artifacts, but also provided a lot more information than just timing and waveform: it was the trace intensity, which depends on the trace speed and frequency and simply comes down to the fact that a certain spot on a CRT screen will be brighter when it is hit by the electron beam longer and/or more often than others.

DSOs eventually got more memory and became fast enough (i.e. could capture many thousand waveforms per second) so that a similar behavior as the analog scope could be emulated. This is universally known as intensity grading and for digital scopes yet another variant could be added, known as color grading. The quality of the implementations differs a lot between various DSO models and every vendor has its own name for this technology. Siglent calls it SPO (Super Phosphor Oscilloscope).

The Siglent SPO technology is nothing new and has proved to give excellent results. We already know it from the existing Siglent SDS 1kX(-E) and 2k(X) scopes. Yet I shall review it once again just for completeness and because it's the basis for all the future demonstrations in this article.

Most modern DSOs provide some sort of intensity grading (though some implementations barely deserve that name), even in the entry level class. Not all do color grading though, which can be very beneficial especially for displaying narrow pulses or steep edges in general. This Siglent SPO offers both. It also offers the choice of dots and vectors display as well as persistence.

Dots mode just shows the individual sample points as they have been acquired by the ADC. Vectors mode interconnects these points in order to create a contiguous trace without gaps, which in turn slows acquisition down a bit. On the other hand, this scope is fast enough, so that we can make do without vector mode most of the time, because the sheer amount of dots from many acquisitions mapped to the screen at the same time will give the impression of a contiguous trace as well. Furthermore, we can always do an acquisition in dots mode and then turn on vectors in stop mode later.

Now let's examine a popular example with an amplitude modulated signal.

A 10MHz sine carrier is 50% amplitude modulated with a 1kHz sine and we look at the carrier first.

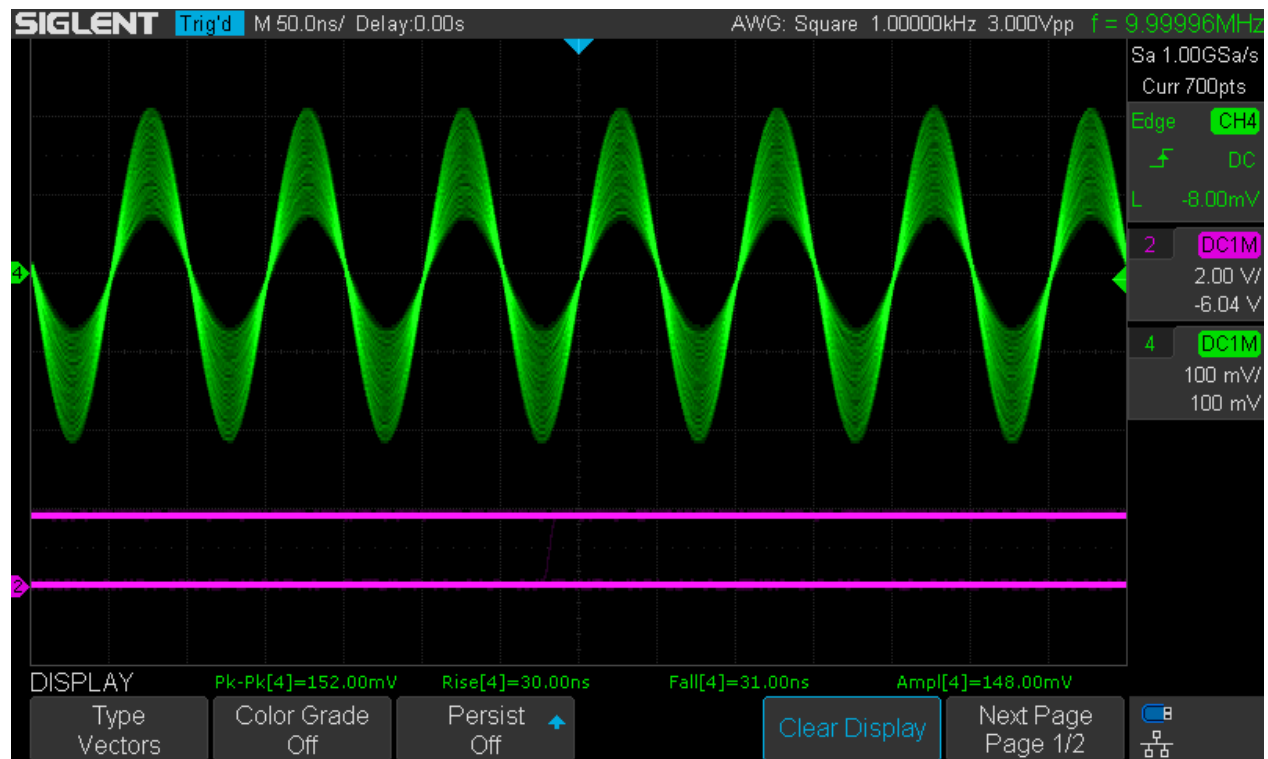
Channel 4 shows 7 periods of the modulated carrier and because of the fast waveform update rate, we see all possible states of the carrier at once. The intensity of the trace is higher at the regions that are more frequently hit, which is of course at the edges, but also at the extremes of the envelope because of the sine as a modulation waveform.

Channel 2 displays a sync signal for the modulation waveform, but this is only 1kHz and of course not synchronous when triggering on the 10MHz carrier.



MOD\_10MHz\_1kHz\_50%\_50ns\_Vect\_IG

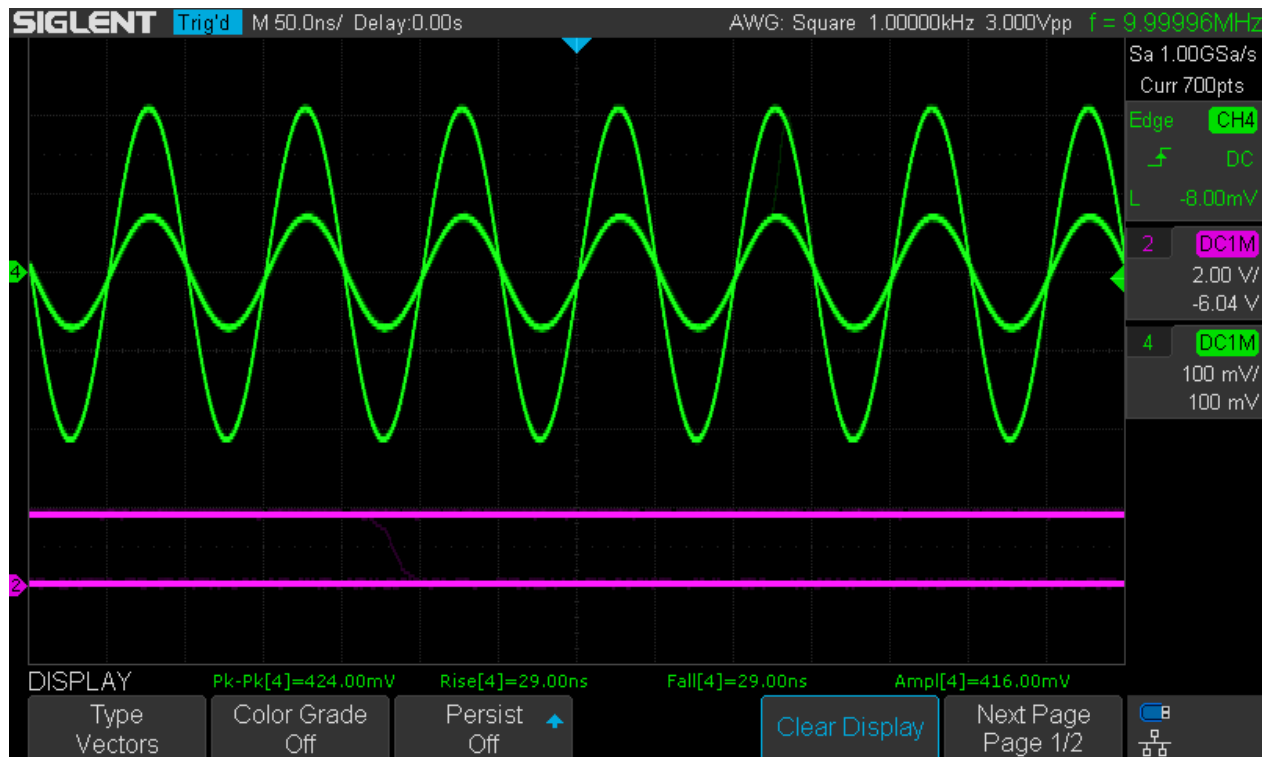
Of course it looks different with other modulation waveforms, like a triangle (ramp with 50% symmetry) for example.



MOD\_10MHz\_1kHz\_50%\_50ns\_Vect\_IG\_ramp

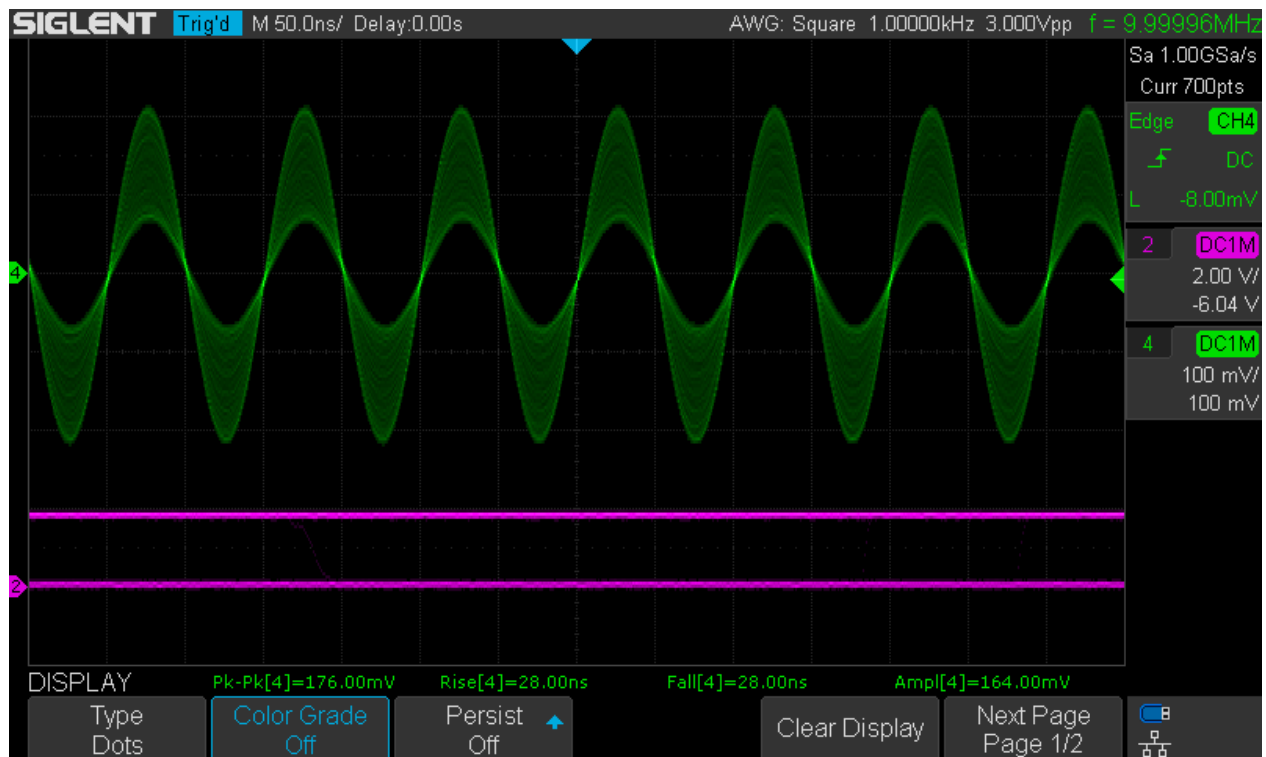
As expected, the trace intensity is now pretty much uniform in the vertical direction.

Another extreme can be seen by selecting a squarewave as the modulation source.



MOD\_10MHz\_1kHz\_50%\_50ns\_Vect\_IG\_square

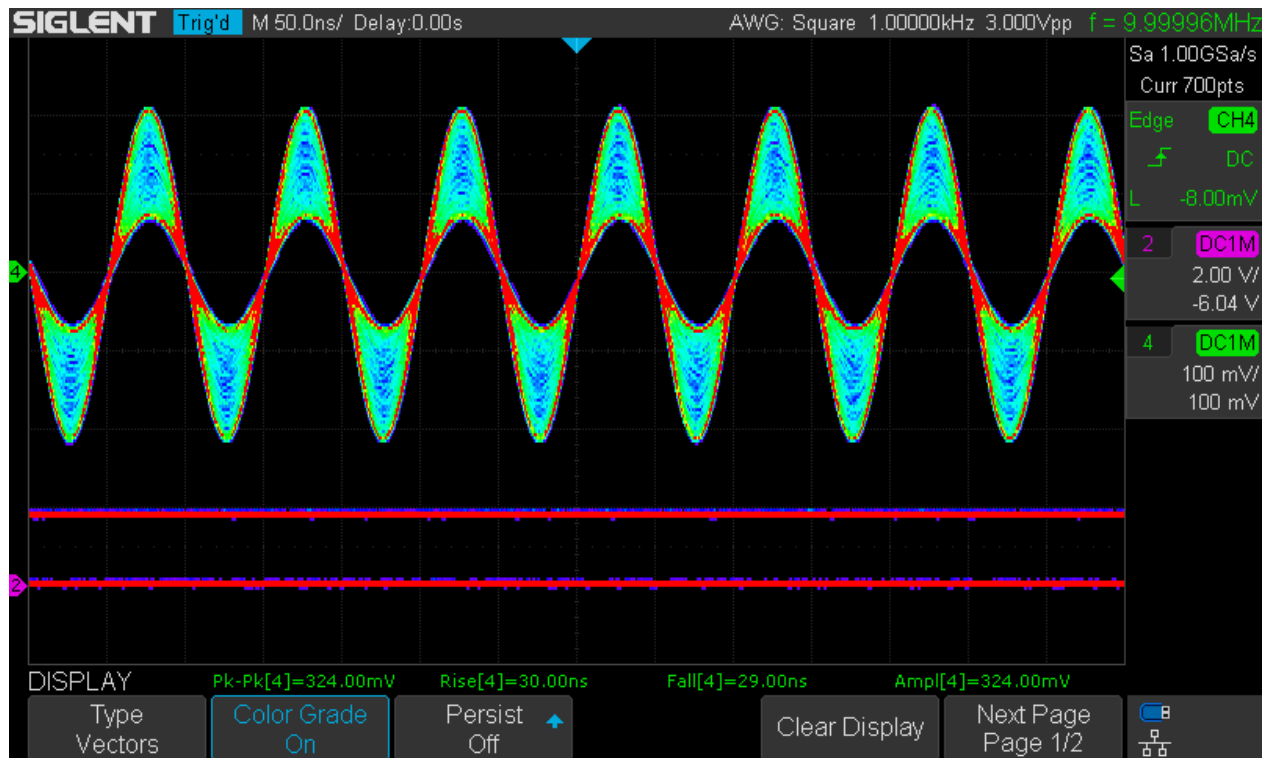
Now only the extremes are displayed, because a squarewave modulated carrier just switches between two discrete amplitude levels. Let's go back to the sine modulation with dots instead of vectors:



MOD\_10MHz\_1kHz\_50%\_50ns\_Dots\_IG

Without any interpolation, the trace image gets a bit dimmer, but it still works, hinting on the high speed acquisition in this DSO.

Now let's see what it looks like with color grading:



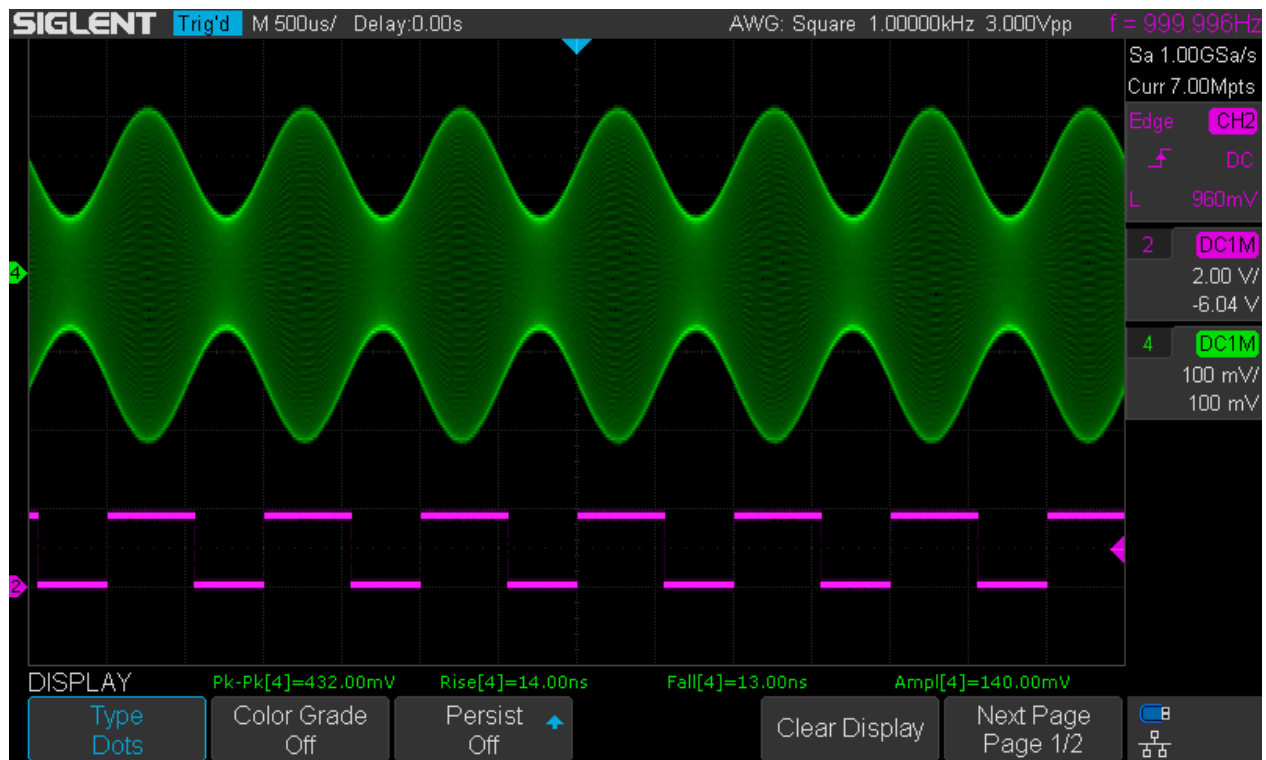
MOD\_10MHz\_1kHz\_50%\_50ns\_Vect\_CG

For unknown signals, this might give an even better insight what's really going on.

Up to now, we have used a 50ns/div timebase and triggered on the 10MHz carrier. We can trigger on the modulation signal and use a much slower timebase accordingly.

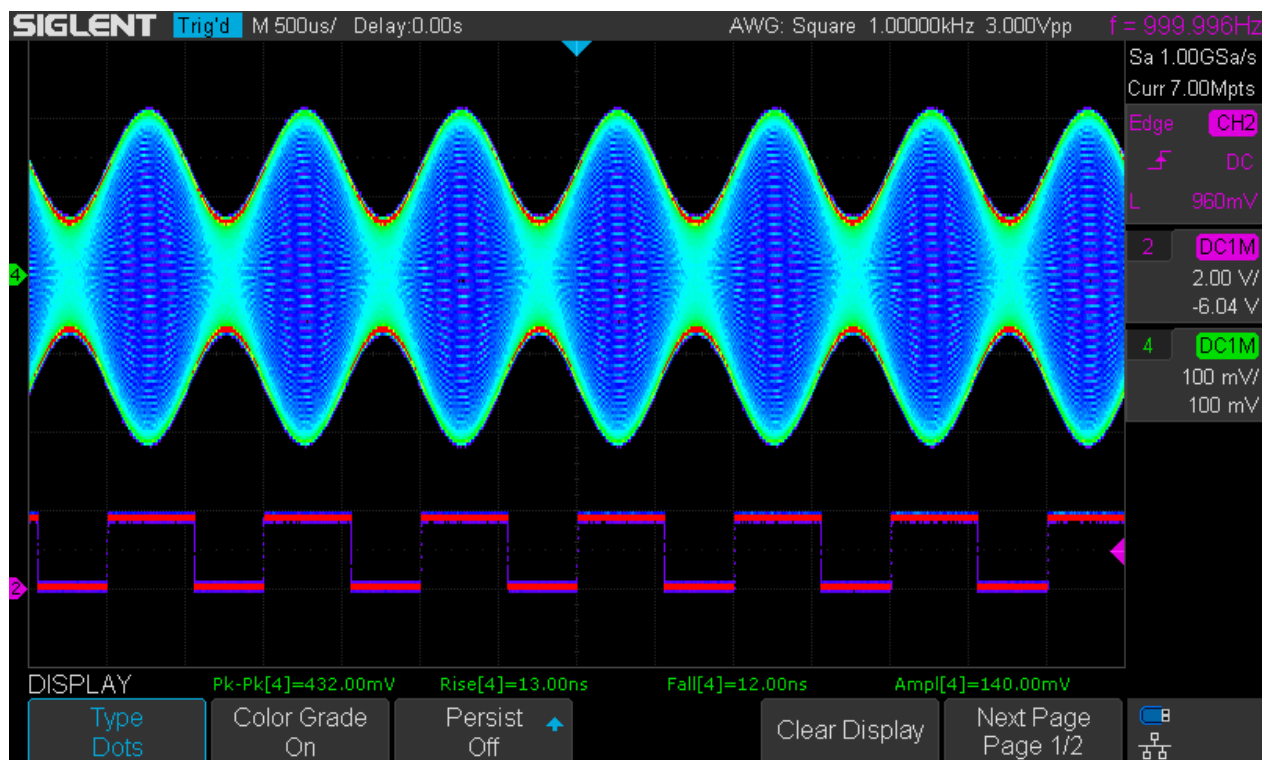
In this case we are triggering on the sync signal on channel 2 and the timebase is set to 500µs/div. At this relatively slow speed, the room inside the envelope is naturally always filled by the carrier trace, but we still need a high acquisition rate in order to accomplish the intensity grading.

Only Dots mode is shown here, because at slow timebase settings like this, it absolutely makes no difference – vectors mode looks exactly the same.



MOD\_10MHz\_1kHz\_50%\_500us\_Dots\_IG

The same situation as above, but this time with color grading:



MOD\_10MHz\_1kHz\_50%\_500us\_Dots\_CG



## Display Modes

The Siglent X-series scopes have a number of settings that affect signal representation on the screen that might be a bit confusing at first. So right at the start, we shall have a closer look at them in order to learn how to setup the scope for optimum results.

Some of these settings will be discussed again in the *Acquisition* chapter, but a brief overview will be given here together with some basic rules that should be easy to remember. It is highly recommended to stick with these rules and only go a different route for very good reasons.

- **Acquire – Interpolation:** always use Sin(x)/x for analog waveforms, x for (digital) pulses.
- **Acquire – Acq. Mode:** Fast is standard, use Slow only if for some reason you do not want to see multiple traces after a signal drop-out in normal trigger mode. Be aware that this will significantly decrease waveform update rate.
- **Display – Type:** For normal Run mode, use Dots whenever feasible to get highest fidelity for signal reproduction as well as highest speed. Use Vectors when you need to aid visibility for fast edges, narrow pulses, in stop mode and some special functions like Acquisition Mode Slow, in History and for FFT.
- **Display – Color Grade:** Use this whenever you like, especially for aiding visibility on fast edges and narrow pulses – particularly useful for screenshots. Be aware that is not the best setting for multi-channel acquisition because channels look indistinguishable on the screen.

Some examples shall demonstrate the effect of various combinations of the settings mentioned above. A 30MHz square wave with extremely fast edges (<100ps) and Sin(x)/x reconstruction is used for all the following tests.

Let's start with a pair of screenshots for Acquisition Mode Fast, Display Type Dots versus Vectors and Color Grade Off.



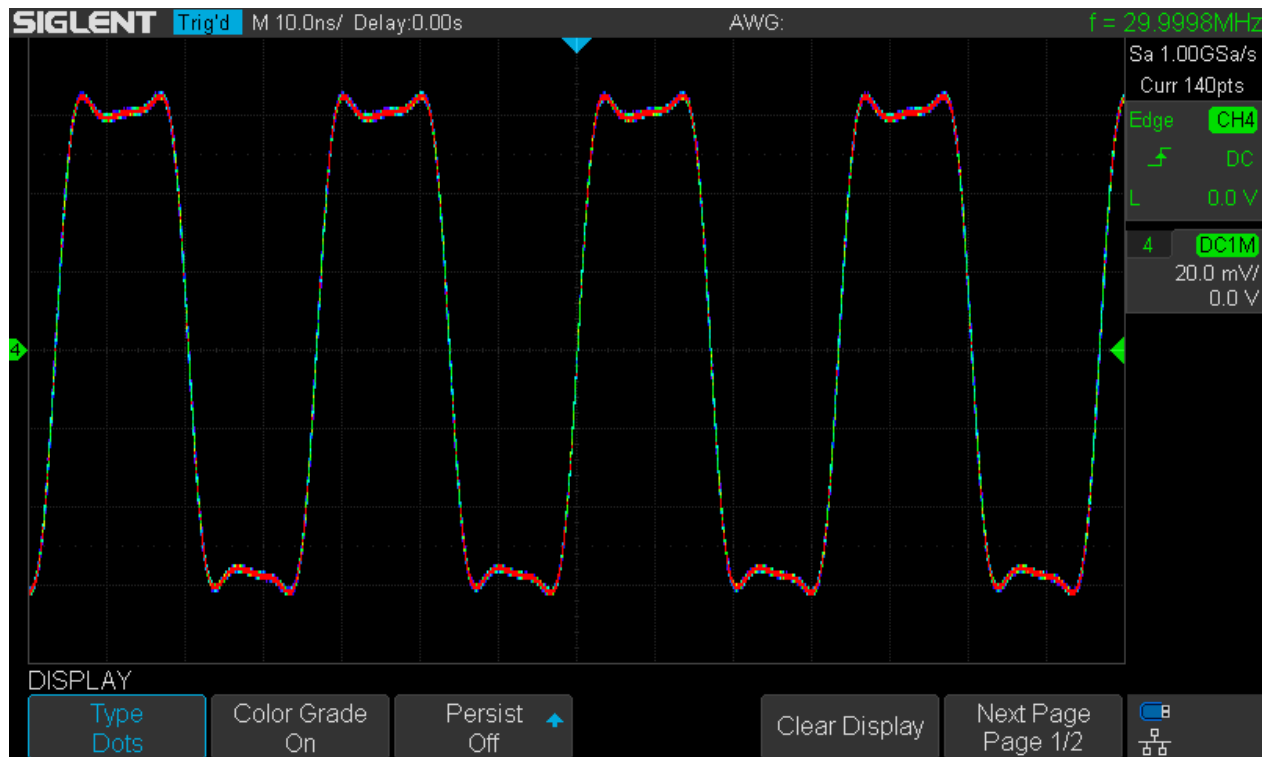
SDS1104X-E\_Square\_30MHz\_10ns\_fast\_dots



SDS1104X-E\_Square\_30MHz\_10ns\_fast\_vectors

The signal representation is very similar, just the fast edges are a little brighter. Generally, intensity grading works better with dots in many cases.

Here is a similar pair of screenshots for Acquisition Mode Fast, Display Type Dots versus Vectors and Color Grade On.



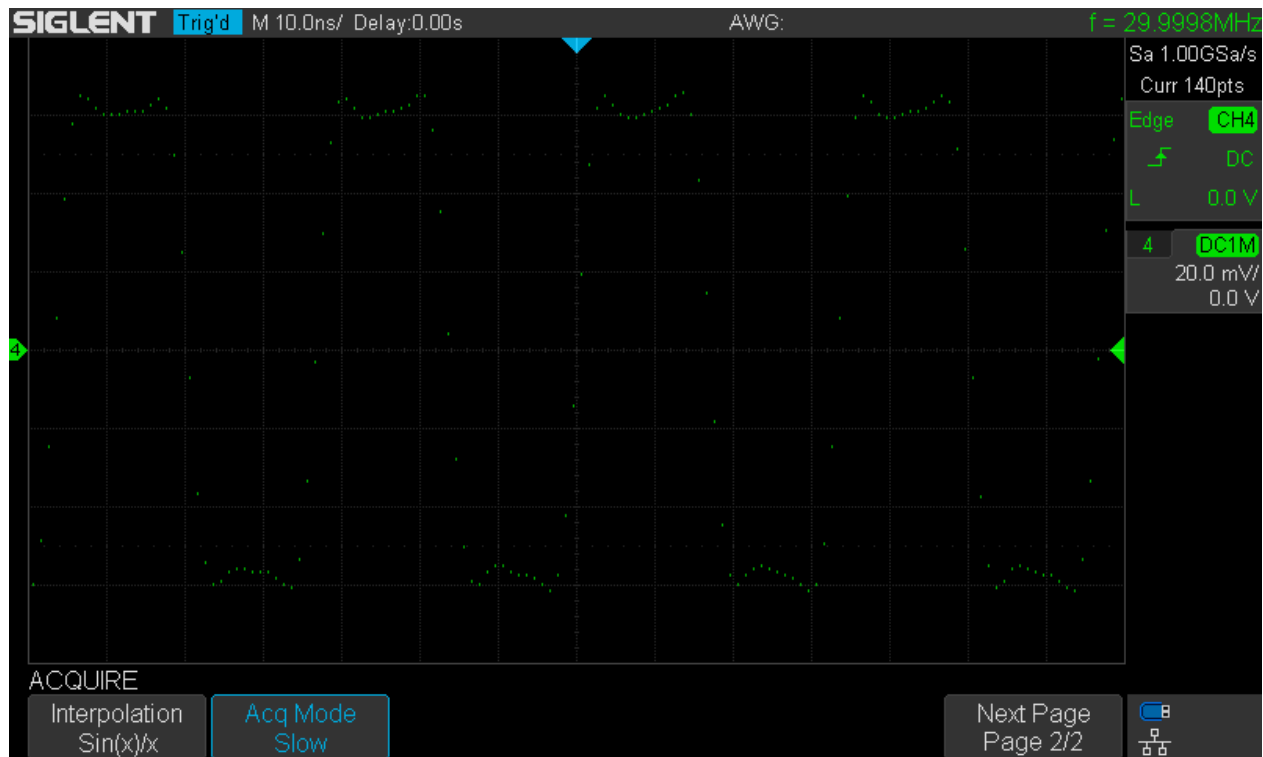
SDS1104X-E\_Square\_30MHz\_10ns\_fast\_dots\_color



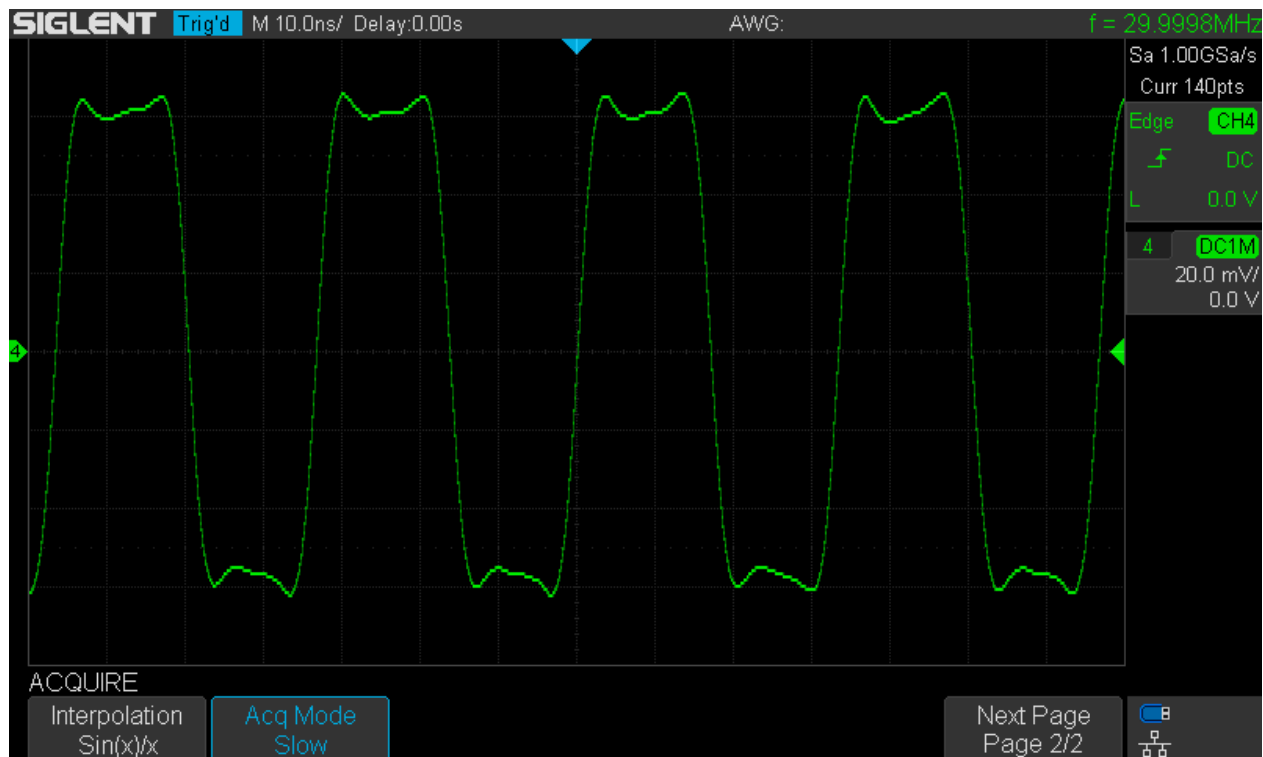
SDS1104X-E\_Square\_30MHz\_10ns\_fast\_vectors\_color

Again the signal representation is similar, just with vectors the fast edges appear in the same color as the rest of the signal. In general, color grading works better with dots in many cases.

Here comes a pair of screenshots for Acquisition Mode Slow, Display Type Dots versus Vectors and Color Grade Off.



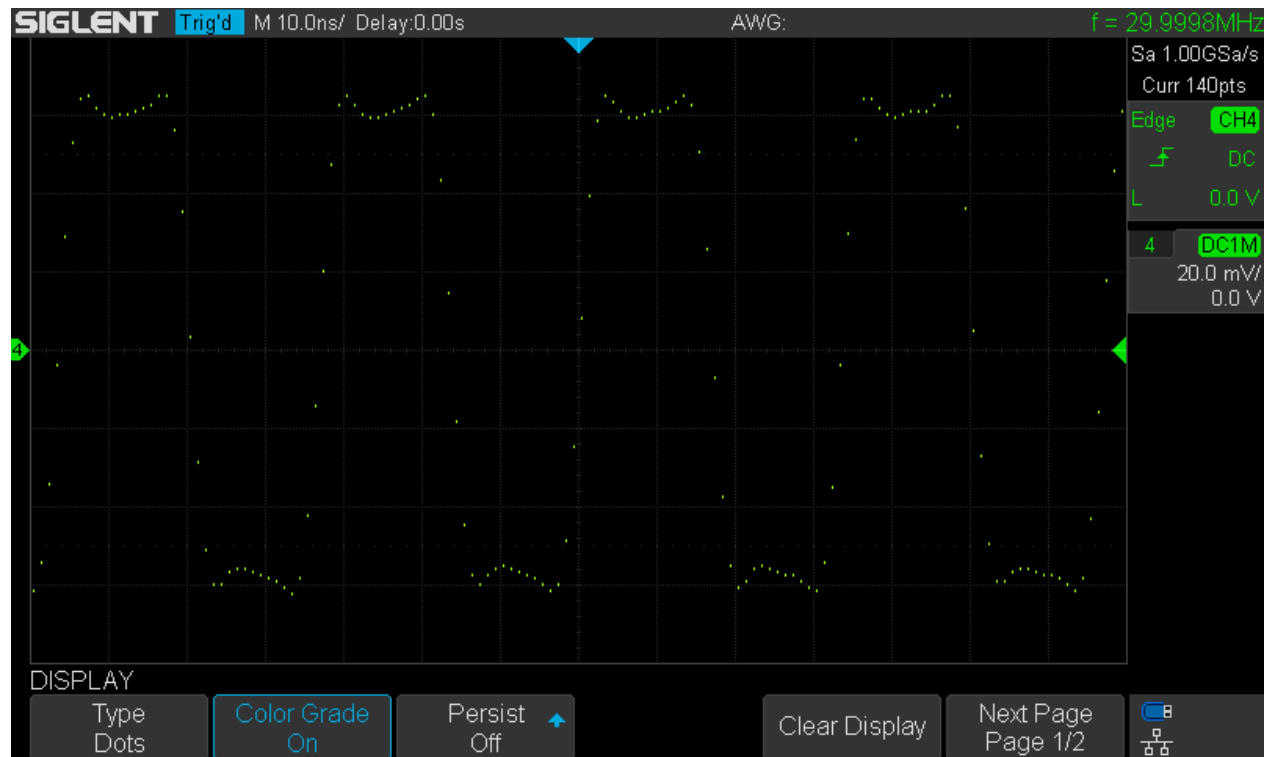
SDS1104X-E\_Square\_30MHz\_10ns\_slow\_dots



SDS1104X-E\_Square\_30MHz\_10ns\_slow\_vectors

In Slow Mode, the difference is striking and we would use Dots only in special situations when we need to see the true samples of the input signal. We still get some intensity grading though.

Here is a similar pair of screenshots for Acquisition Mode Slow, Display Type Dots versus Vectors and Color Grade On.



SDS1104X-E\_Square\_30MHz\_10ns\_slow\_dots\_color

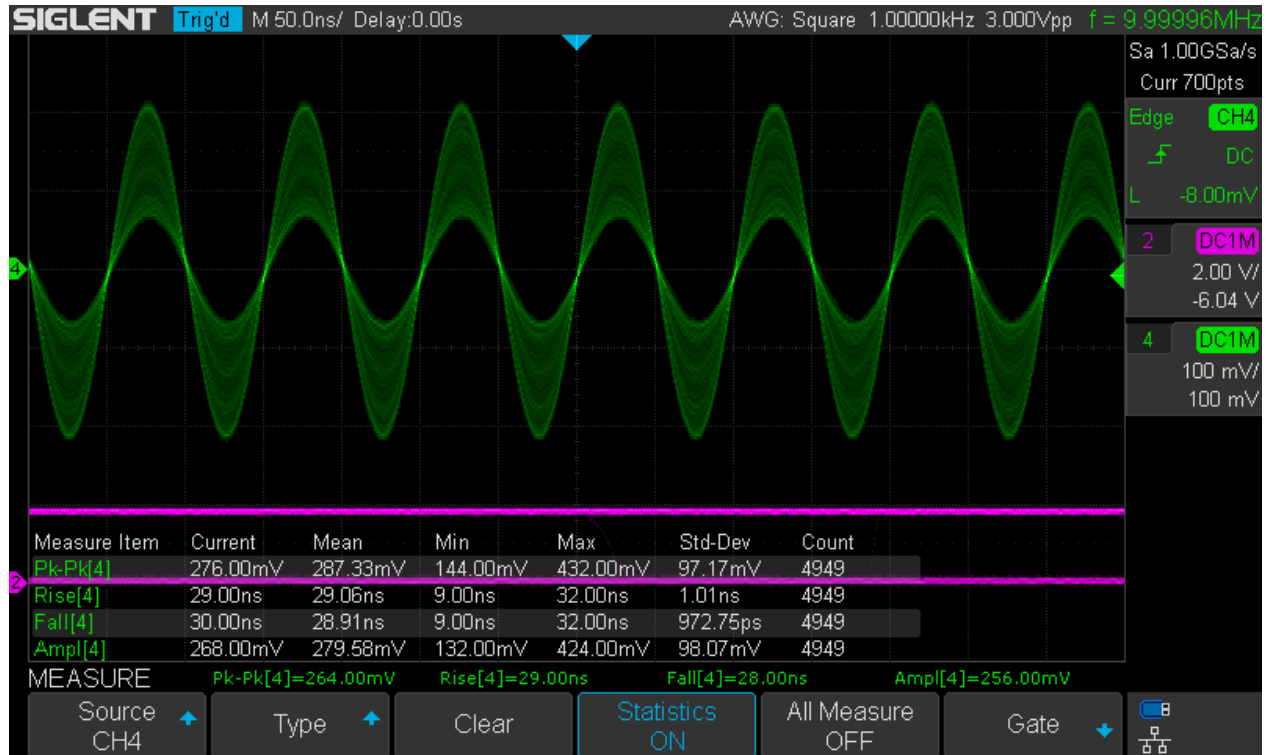


SDS1104X-E\_Square\_30MHz\_10ns\_slow\_vectors\_color

Once again, the difference is striking and we would use Dots only in special situations.

## A first glance at measurements

Have you noticed the measurements for peak-peak and amplitude for the examples in the SPO section? They are different in every screenshot. That's only natural, as the measurements can only be valid for one single acquisition, whereas the amplitude of the carrier changes all the time because of the modulation. To get meaningful measurements in this situation, we need to enable statistics.



MOD\_10MHz\_1kHz\_50%\_500us\_Dots\_IG\_stat

Now we can see the minimum, maximum and mean value of the amplitude measurements. From these figures, it becomes obvious that it's indeed a 50% modulation, as min is roughly 50% of mean and max is 150% respectively.

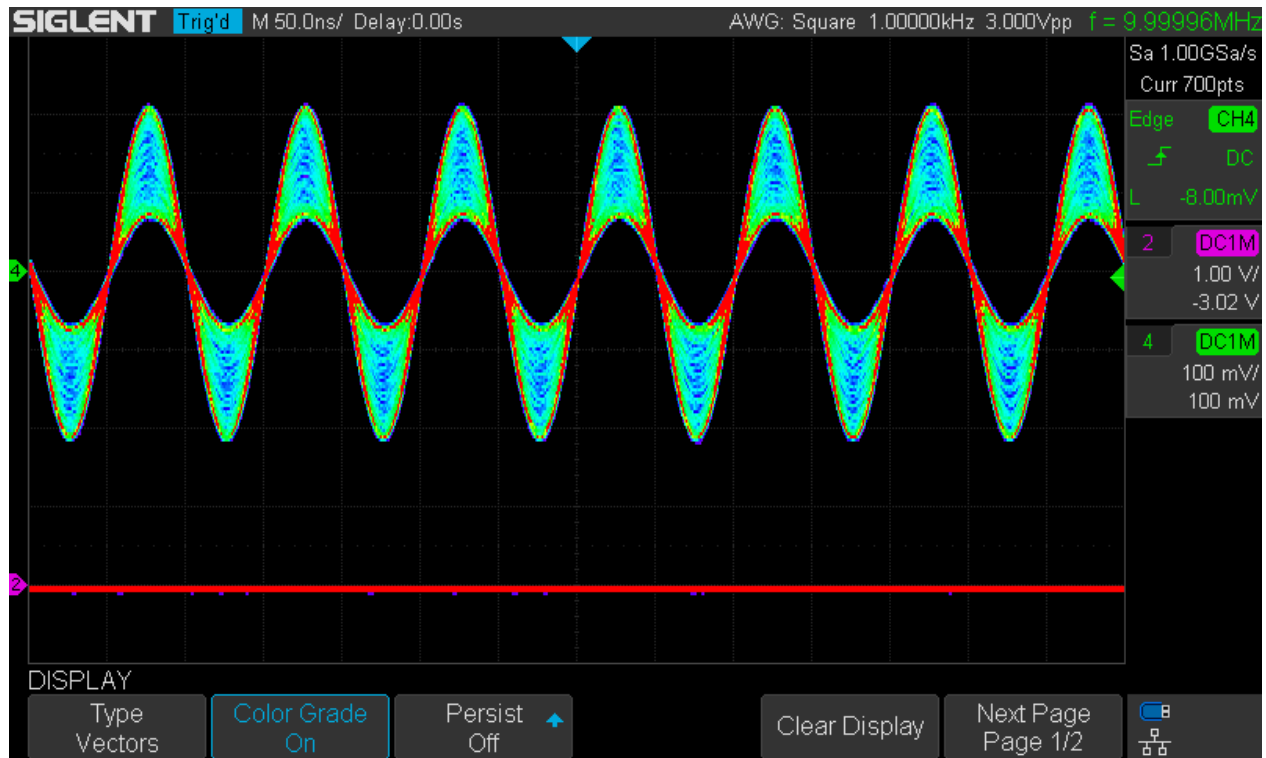
## Persistence Mode

Persistence is another feature for emulating analog scopes, because CRT screens always had some persistence by nature and then there have been special analog storage scopes with very long persistence times and the ability to explicitly clear the screen. This is just a means to make rare events better visible. Instead of being displayed on the screen for just the fraction of a second, we can keep them displayed for a certain time, 1s, 5s, 10s, 30s and infinite in case of the SDS1104X-E. Of course there is also a menu button to clear the display, which is useful whenever a persistent image is no longer needed.

Here's an example how persistence can be used to detect rare events.

Channel 4 still displays the already familiar amplitude modulated waveform, and it is worth noticing it is not affected by the persistence mode. This is an important feature, as persistence doesn't kill intensity or color grading while still displaying unusual events.

An unsynchronized pulse, 10ns wide, is fed into channel 2 at a rate of 10Hz and it rarely can be seen for the blink of an eye at the given timebase of 50ns/div. We see just a flat line almost all the time, just as in the screenshot below.



Pulse\_10Hz\_10ns\_P0

Now let's turn on 30s persistence and wait a minute, just to see what happens.



Pulse\_10Hz\_10ns\_P30

Now at a certain point we can even see 3 pulses at the same time, If channel 2 was expected to actually be just DC, then the persistence mode gives us all the information to trigger on the undesired signal and

subsequently look for correlated actions that might cause this. So it's a nice tool for troubleshooting, but certainly not the only one in this DSO.

## Horizontal Zoom

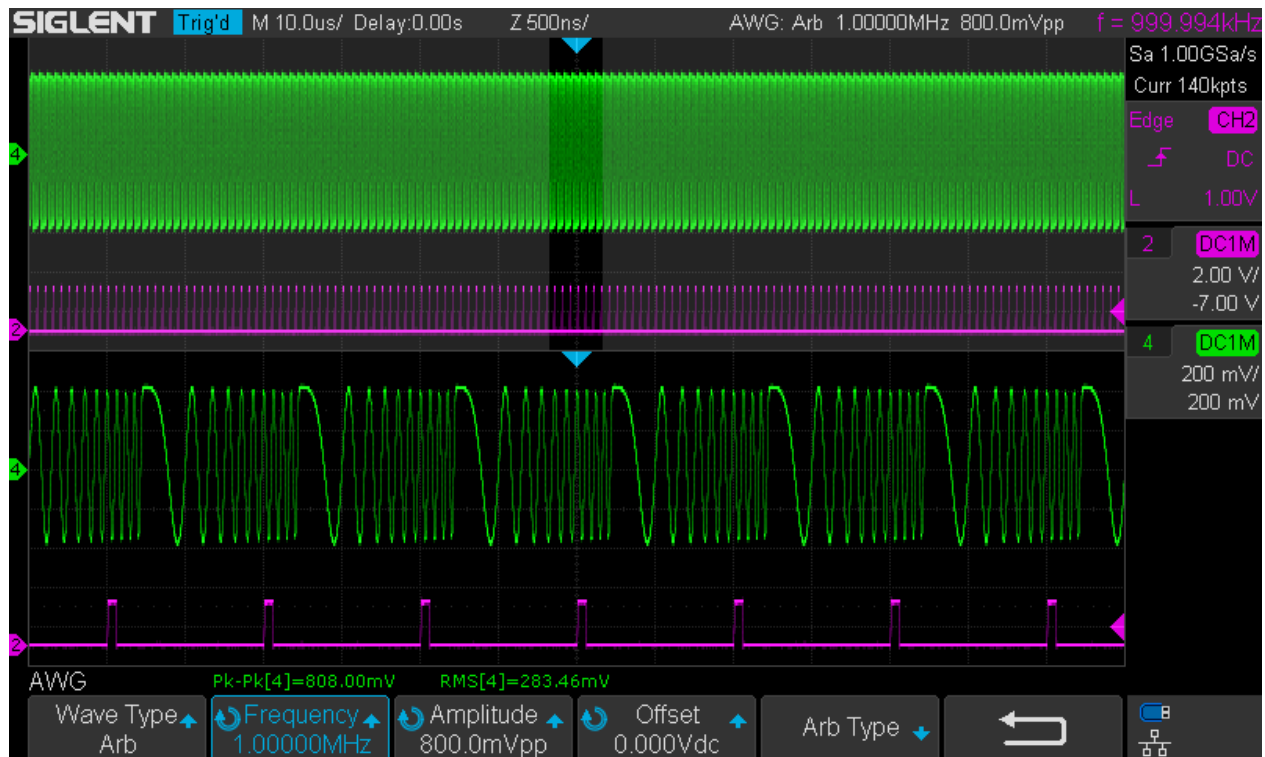
Horizontal zoom is an important feature, particularly for deep memory scopes. There are two different methods to accomplish this: Zoom Mode as well as changing timebase in stop mode after acquisition has been completed.

### Zoom Mode

Zoom Mode allows the observation of signal details at high time resolution while still keeping an eye on the entire acquisition period at the same time. This works real time in run mode.

As an example, we can take a look at the Chirp signal at 1MHz from the optional SAG1021 AWG fed into channel 4. This is a complex signal that cannot be properly displayed using a simple edge trigger, so for this demonstration the sync signal from the SAG1021 is fed into channel 2 and the scope triggers on that. Of course there are certain means as well as advanced triggers that would allow us to trigger from the main signal, but that will be dealt with later in a separate chapter.

The following screenshot shows the full 140kpts record at 10 $\mu$ s/div in the (upper) main window and the 500ns/div zoom window below. Now we can see the entire record, spotting any interesting events or anomalies, while inspecting signal details at the same time. Of course we can move the zoom window to any position we like within the record.



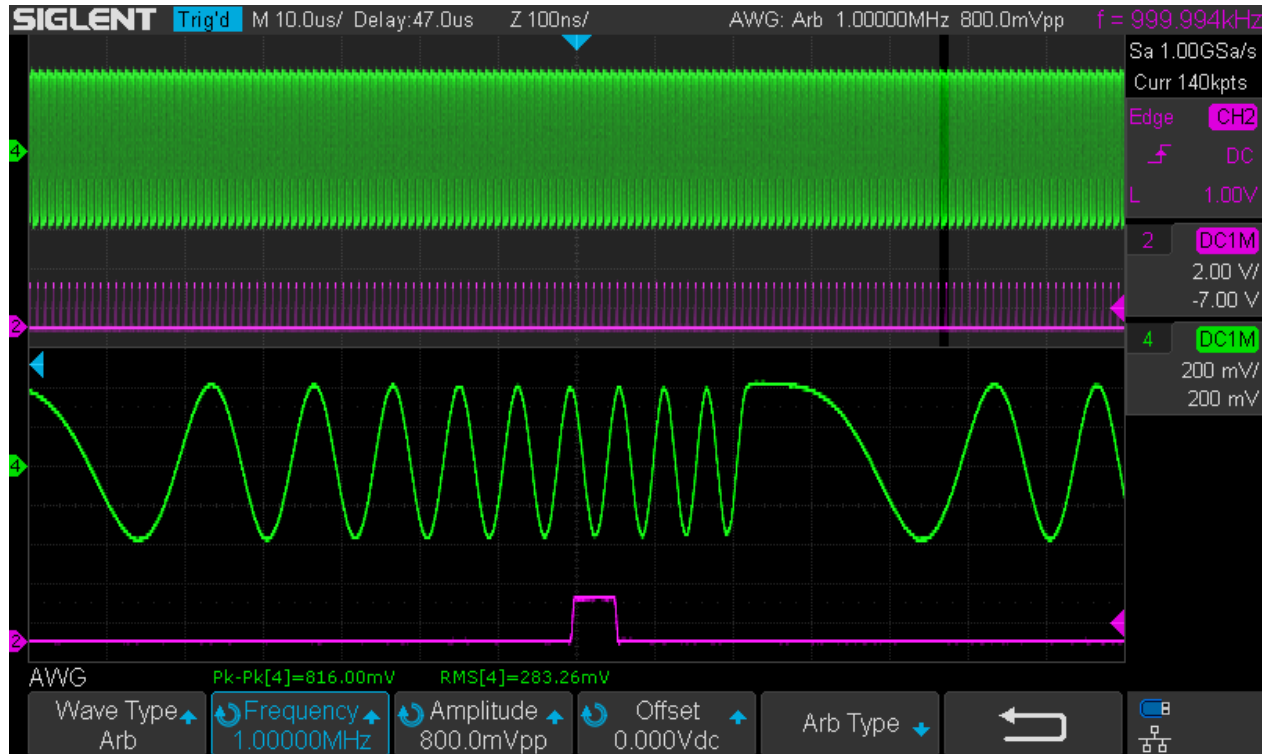
Zoom\_M10us\_D0\_Z500ns

Positioning the zoom window is normally done by adjusting the horizontal position control, which can become tedious very quickly, especially with high zoom factors. The solution is to start with a lower zoom factor, center the zoom window upon the event of interest and then zoom in further as needed.

This scope also provides a group of dedicated buttons for navigation, which make life a lot easier whenever a certain portion of a long list or long record is to be inspected. This is particularly the case with

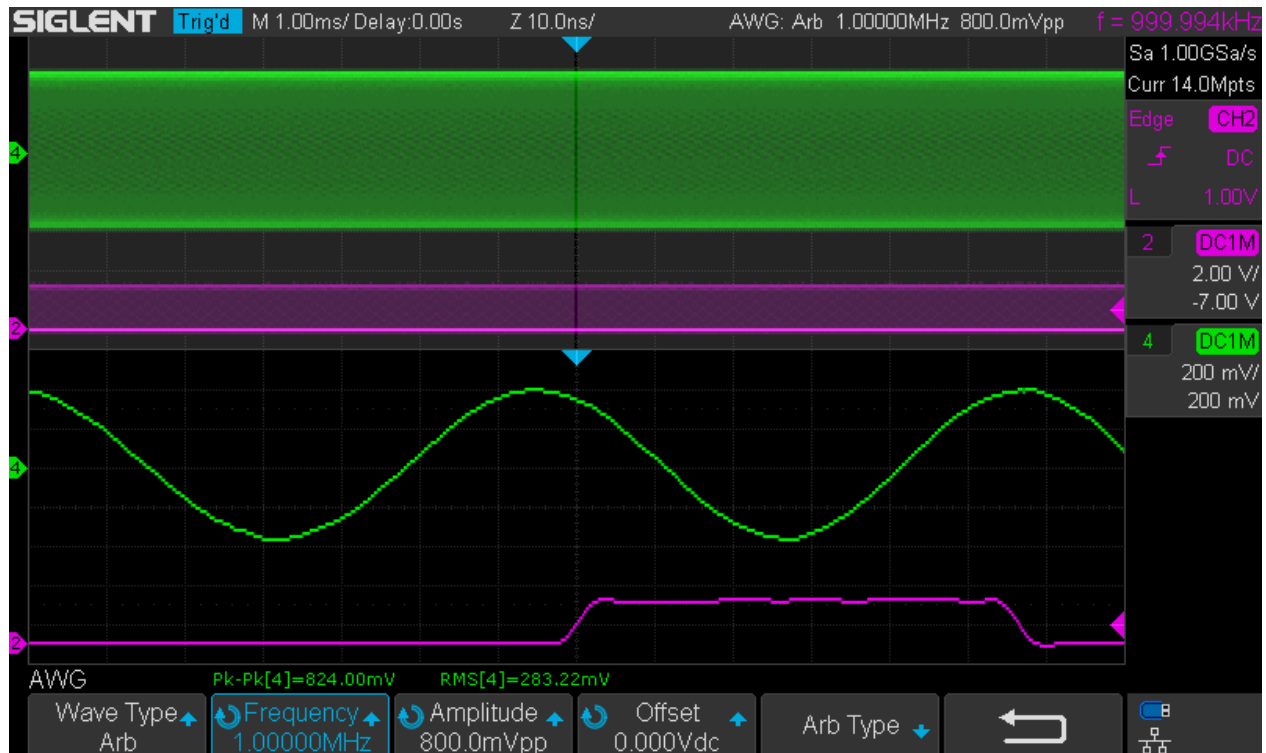


the time axis, where we can zoom in up to 1:1000000, i.e. would have to scroll through 1 million screen widths to get from one end of the record to the other.



Zoom\_M10us\_D0\_Z100ns\_D47us

Finally there is a screenshot showing a 1:100000 zoom ratio, i.e. a 10ns/div zoom window in a 1ms/div record. This is rather extreme already.



Zoom\_M1ms\_D0\_Z10ns

## Changing Timebase in Stop Mode

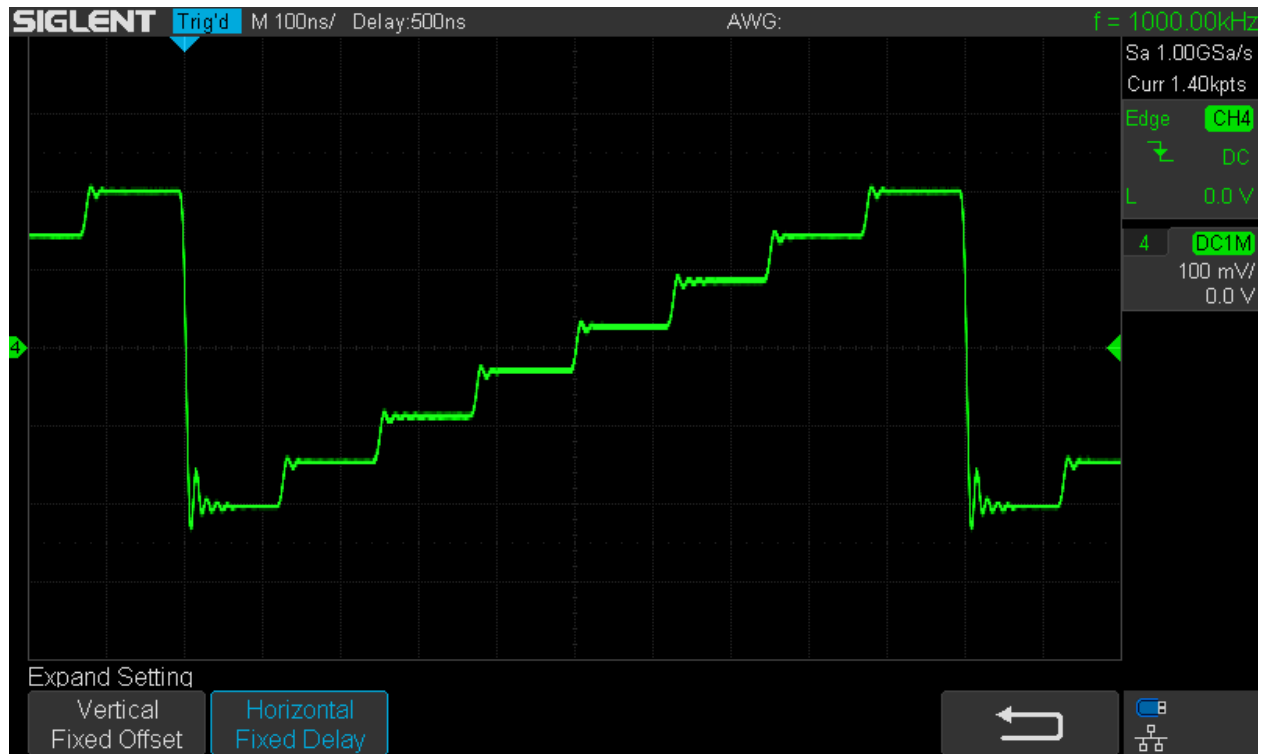
We can stop acquisition anytime by putting the scope into stop mode and then inspect signal details at higher time resolution by simply selecting a faster timebase. This is easy as long as we are interested in the signal details at the trigger point and the trigger position is at the center of the screen. In that case, we can zoom in and out by just changing the timebase.

Sometimes we need to look at a signal detail at a point of the trace that has a certain delay with regard to the trigger point. By zooming in (lowering the timebase) the point of interest will eventually move out of the visible screen area. This is easy to handle though, as we just need to adjust the horizontal position control in order to bring the signal detail to the center of the screen.

In the following example we are interested in the rising edge of the stair step in the middle of the waveform, but are triggering on the falling edge. Of course we could easily trigger on the desired rising edge directly, so this is just to demonstrate a situation as described above, where we set a certain delay (500ns in this example) to bring the interesting part to the center of the screen width.



Now we can once again zoom in and out by just altering the timebase and the signal detail of interest will stay at the center of the screen. This is called Constant Delay mode and is the default behavior.



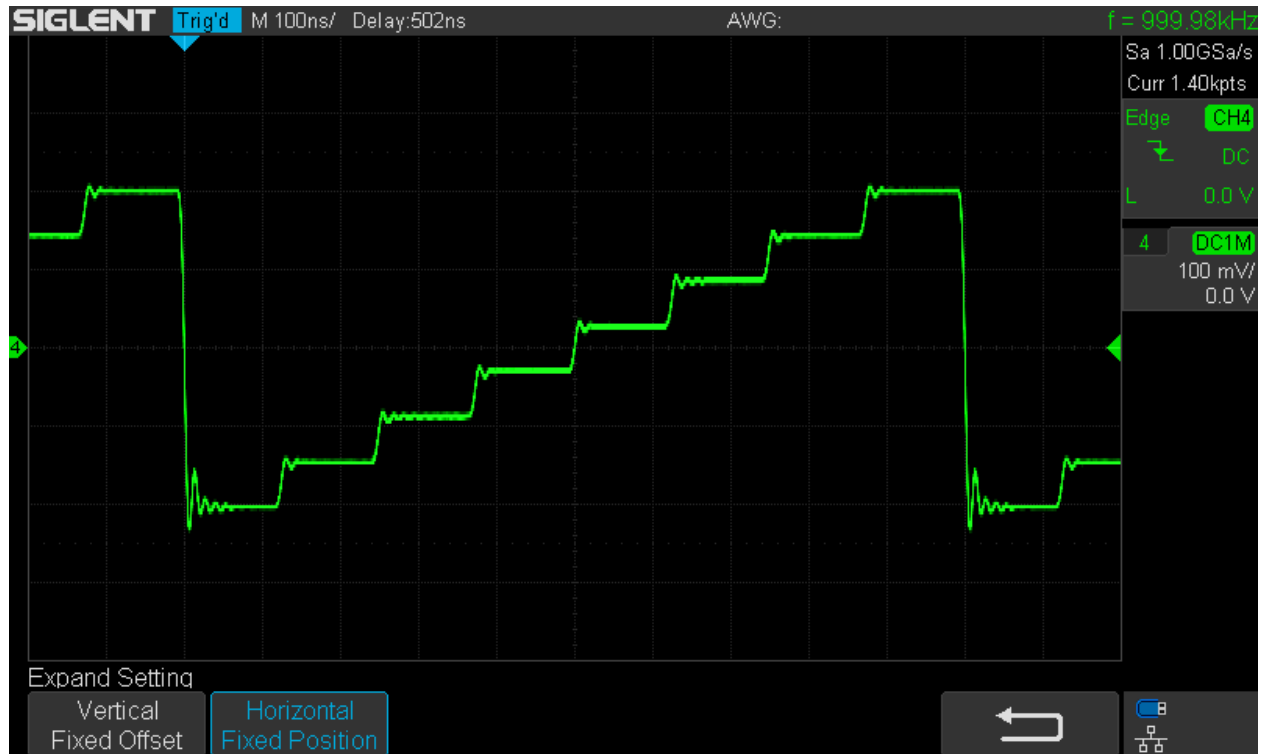
HPos\_0\_Delay+500ns\_M100ns\_FD

What if for some reason we want the trigger reference position not to be at the center, but at e.g. 10% of the screen width, because it's mainly the portion after the trigger that we are interested in? In default mode, the trigger position changes together with the timebase to maintain a constant delay. To deal with that scenario, we have to define a fixed reference position instead.



HPos\_-5div\_Delay+5div\_M200ns\_FP

Again we can zoom in/out by altering the timebase and the trigger position will stay put.

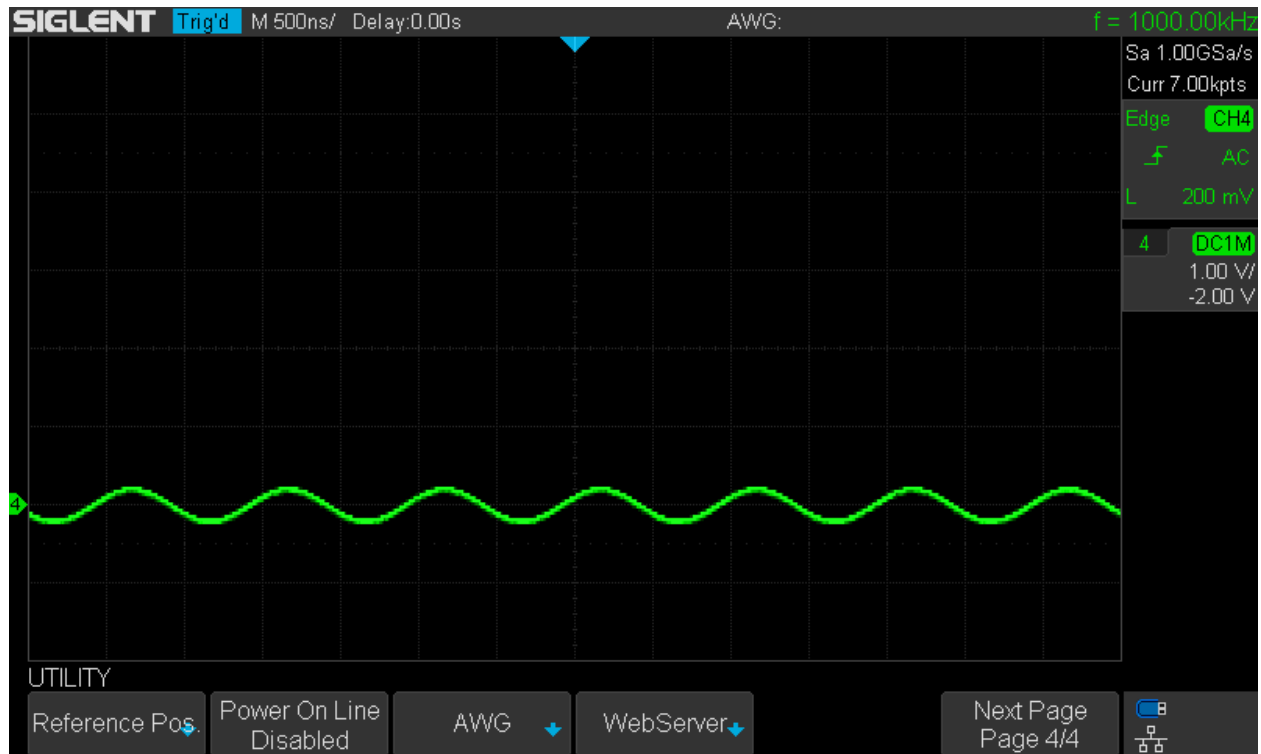


We still have no means to deal with scenarios where we want to look at a signal detail at a certain delay with regard to the trigger position *and* the trigger position not being at the center of the screen. I've already submitted a change request and got the confirmation that this will be implemented in a future update.

## Vertical Zoom

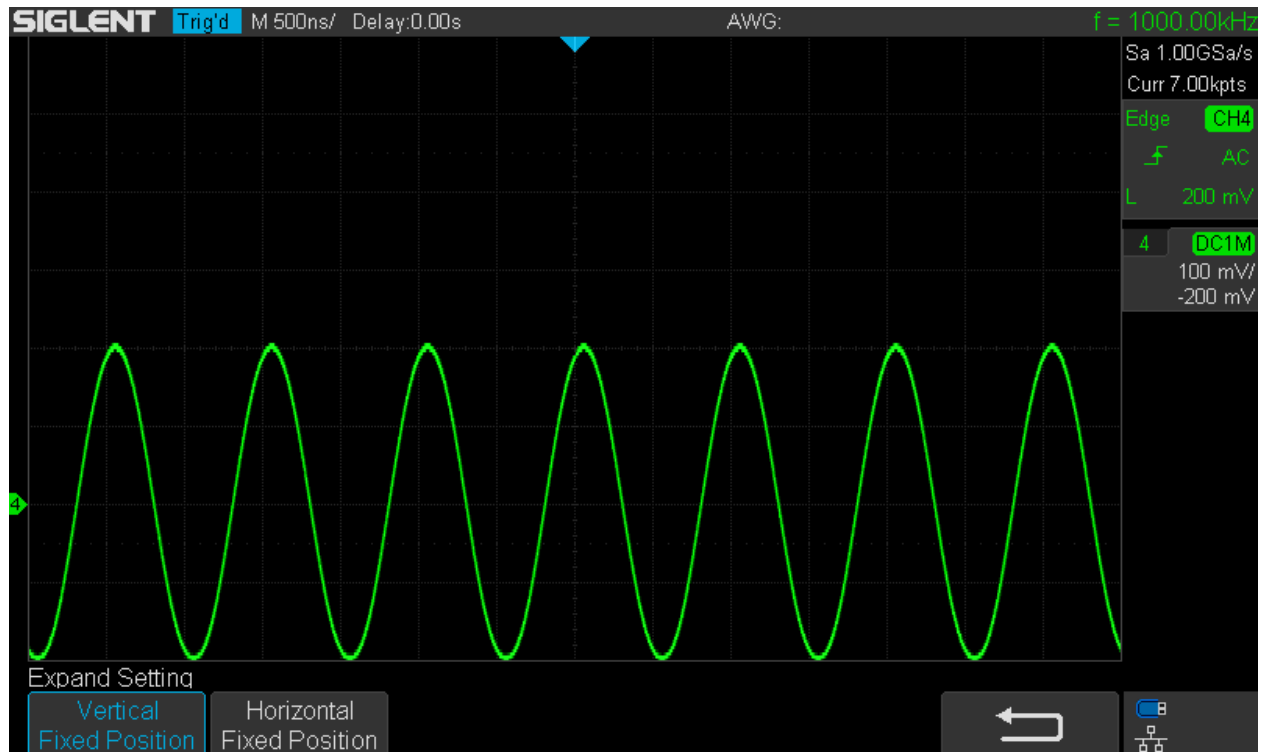
Vertical zoom may be required for closer inspection of signal amplitude details. It can be done by altering vertical gain/sensitivity in run as well as stop mode. This is easy as long as we are interested in the signal details at the vertical trace position, which can be set at any height within the screen. In that case, we can zoom in and out by just changing the vertical sensitivity. This is called Constant Position mode and is the default behavior.

The example below shows a 400mVpp sine at the gain of 1V/div and at a position of -2 divisions, set by the position control in constant position mode.



VPos\_Off0\_Pos-2div\_Gain1V\_FP

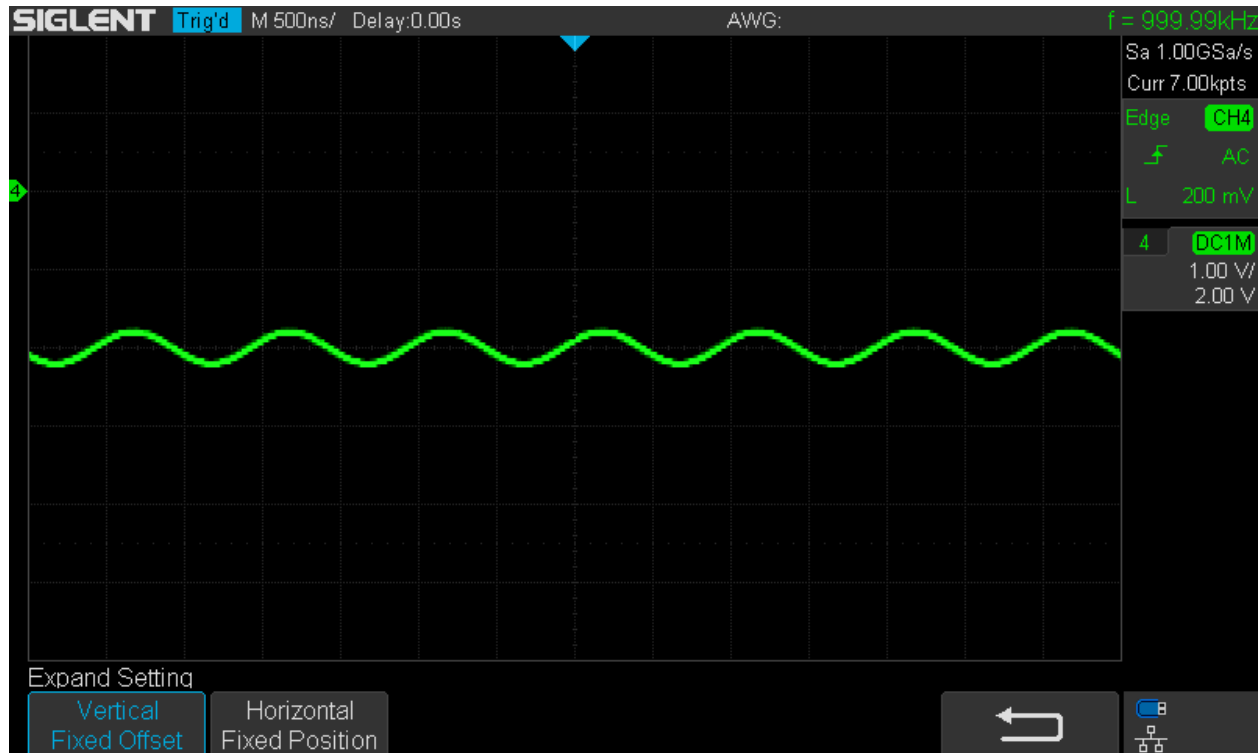
If we want to magnify the waveform, we can increase the vertical sensitivity to 100mV/div and everything works as expected: the trace position remains constant.



VPos\_Off0\_Pos-2div\_Gain100mV\_FP

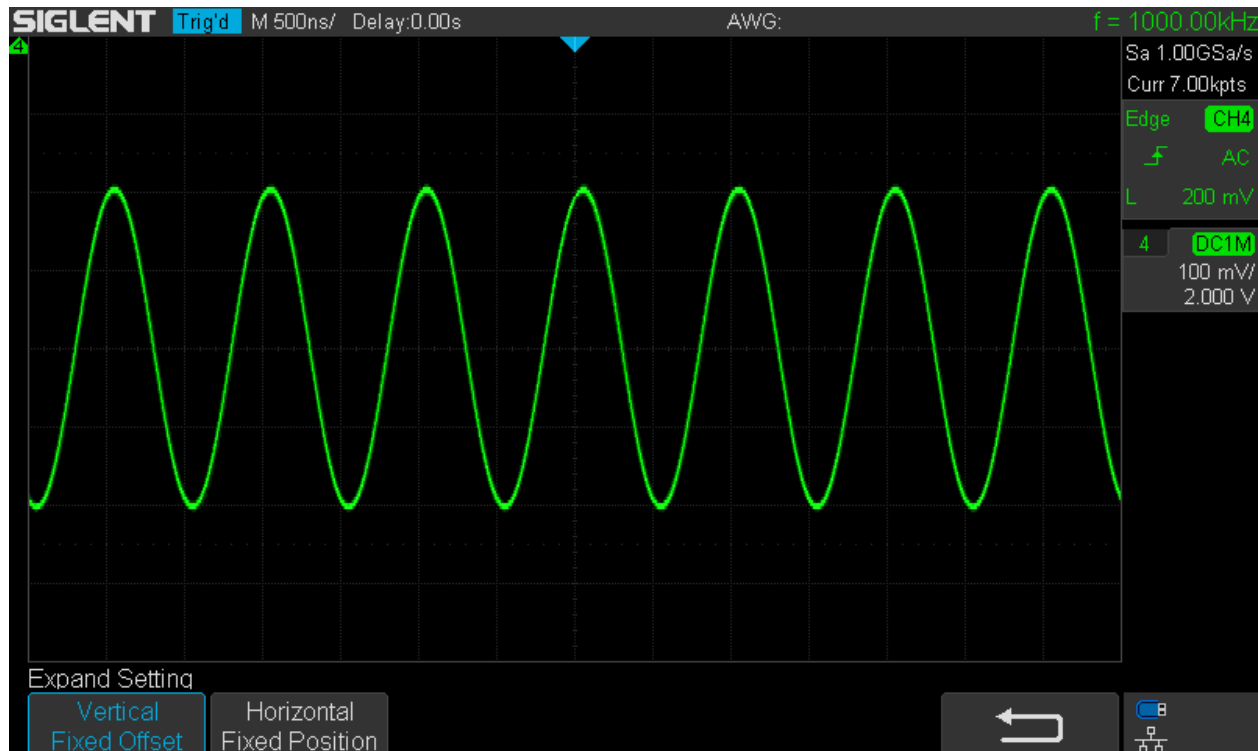
Sometimes we need to look at a signal detail at a point of the trace that has a certain offset with regard to the trace position. By zooming in (increasing the gain) the point of interest will eventually move out of the visible screen area. To avoid this, we need to change the “Expand Setting” strategy to Constant Offset

and then use the vertical position control to bring the signal detail to the center of the screen. In the example below, the signal has a -2V DC offset that is compensated with the channel position control by setting a +2V offset at 1V/div.



VPos\_Off-2V\_Pos+2V\_Gain1V\_FO

Once again we can zoom by changing the vertical gain and the trace position remains centered.



VPos\_Off-2V\_Pos+2V\_Gain100mV\_FO

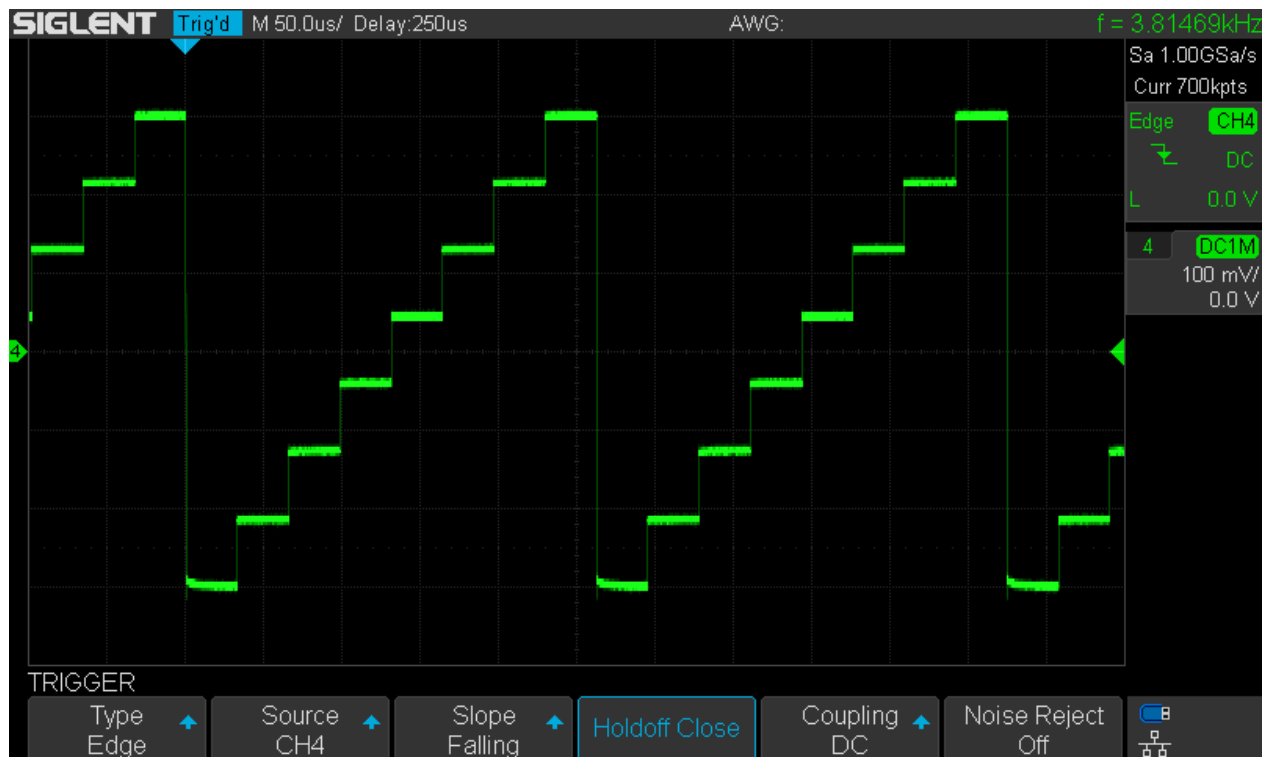
Of course this is again just a demonstration, as we could easily get rid of the DC offset by just changing the input coupling to AC, but it would be different with a unipolar pulse train for example.

We still have no means to deal with scenarios where we want to look at a signal detail at a certain offset with regard to the trace position *and* the trace position not being at the center of the screen. I've already submitted a change request and got the confirmation that this will be implemented in a future update.

## Reference Waveforms

Sometimes we want to compare a certain waveform in a circuit before and after a tweak or under various conditions in general. This would be the main application for reference waveforms.

Here is a staircase waveform generated by an AWG in “Play Mode”, which means that all sample points are output at max. sample speed. This causes a rather odd fixed output frequency, but at the same time it avoids the errors and artifacts introduced by the normal DDS process.

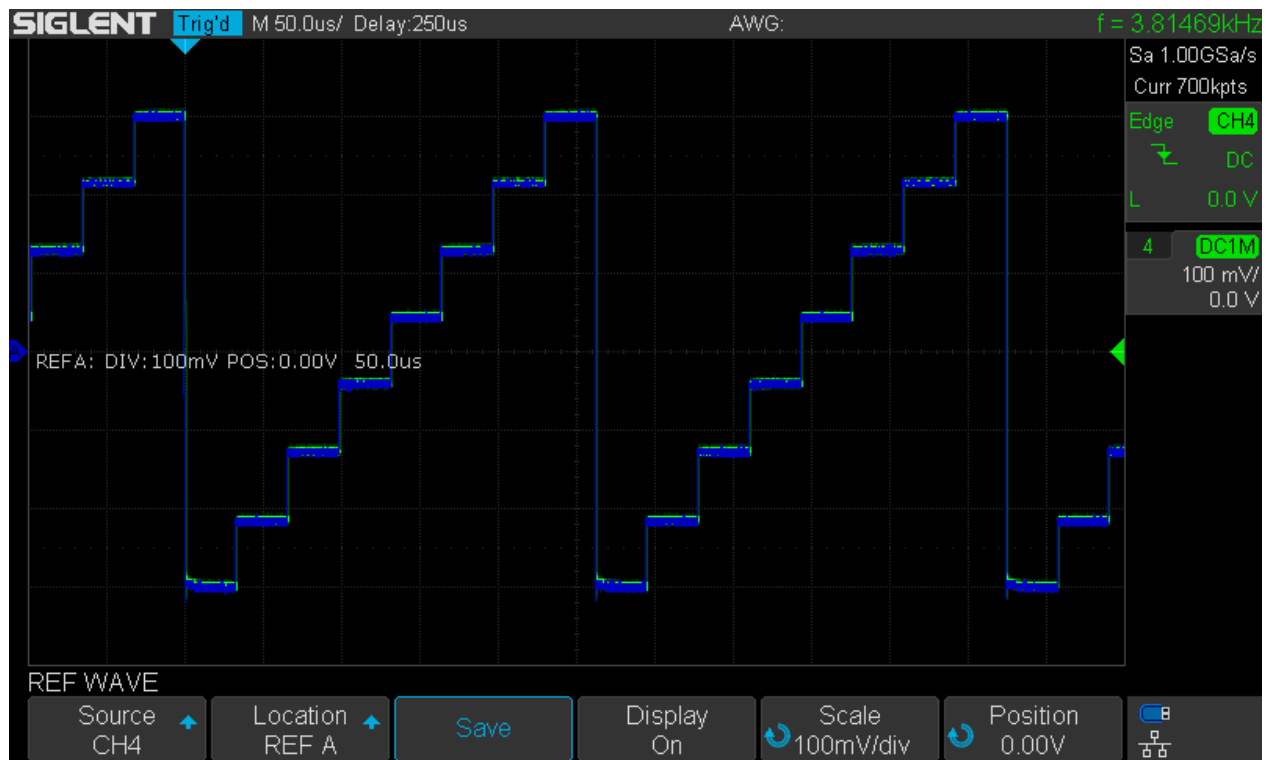


SDS1104X-E\_REF\_Stair\_Orig

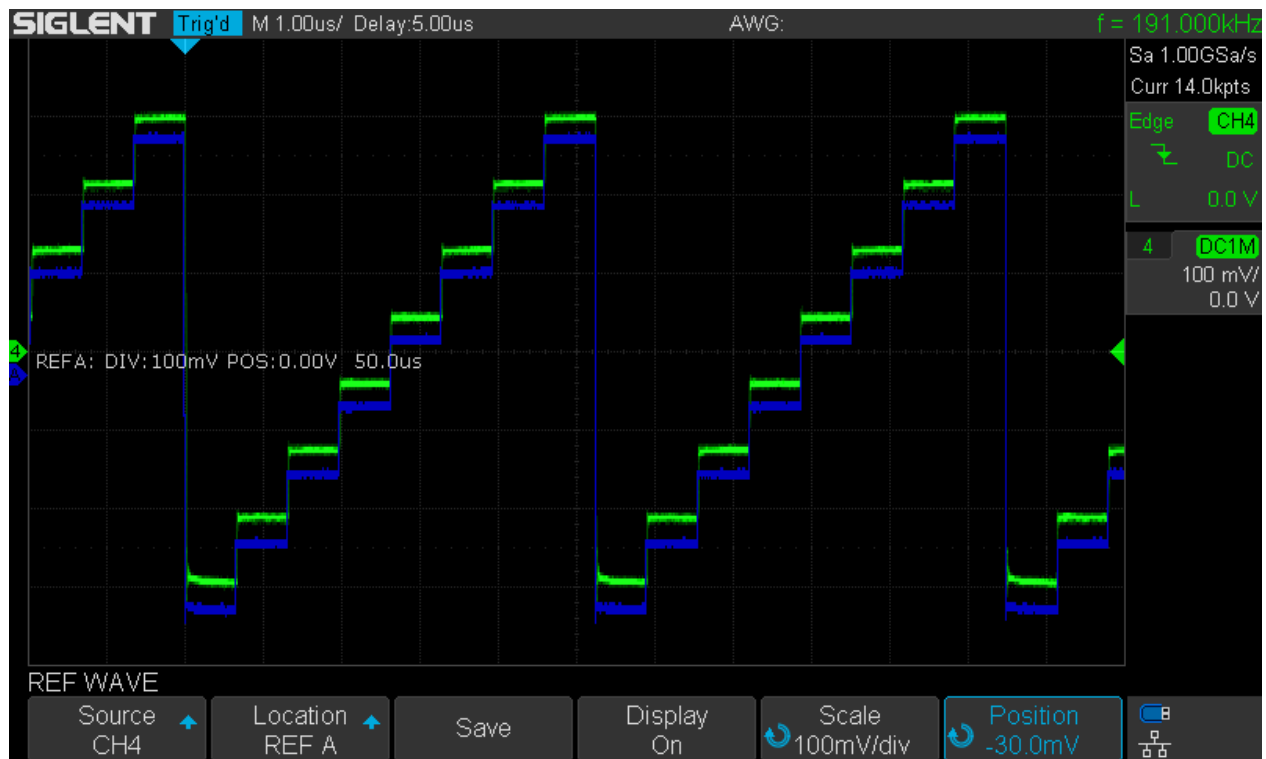
So this is the clean waveform that is ideally suited to act as a reference that could be compared to the same waveform output in DDS mode at a vastly different frequency.

Reference mode is enabled by pressing the [Ref] button on the front panel and then after selecting the appropriate channel and the reference location, the Save soft menu button can be pressed. This saves the current waveform on the selected channel to the selected internal location (REF A in this example). This internal reference memory is permanent, so the stored reference waveforms will be retained over a power cycle of the instrument.

The screenshot below shows the original waveform together with the reference on top.



SDS1104X-E\_REF\_Stair\_Save



SDS1104X-E\_REF\_Stair\_Compare

The screenshot above shows the reference waveform recalled from REF A together with the same waveform created in DDS mode at a much higher frequency than before. As expected, the differences are pretty much invisible.



The reference waveform has been shifted down a bit in order to make both waveforms clearly distinguishable. This also demonstrates the possibilities to adapt the position and scale of the reference waveform, so that offset and gain of a circuit can be compensated.

We can change the timebase as has been done in this example, but the reference waveform will always remain the same. In some rare cases it might be useful to change the timebase for the reference waveform, but this would require a re-sampling of the waveform, which is not going to give good results for a small dataset like this. The reference files are just a few kilobytes in size and high quality re-sampling would require to save the entire acquisition data, which might be up to 14Mpts (up to 140Mpts on a SDS2kX), which is too high a prize for satisfying a rare use case.

Finally, a practical example shows the difference between a 200MHz SDS1202X-E and the 100MHz 1104X-E when rendering a 30MHz squarewave with ultra fast edges (<100ps). The reference waveform has been saved to an USB stick on the SDS1202X-E and imported into REF D on the SDS1104X-E. There is a minor bug as the imported reference waveform shows an original timebase of 50 $\mu$ s, whereas 5ns would be correct of course. Other than that, the difference in bandwidth clearly shows; the reference waveform contains much more high frequency details. But then, for a fast signal like that, even 237MHz (the actual -3dB bandwidth of the SDS1202X-E) is not nearly enough to show the true waveform – but at least it's a lot closer to the truth. For most applications the exact waveform does not matter as long as the zero crossings and the amplitude are reasonably correct.



SDS1104X-E\_REF\_Square\_30MHz\_SDS1202X-E