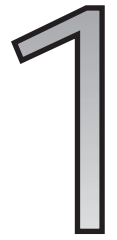
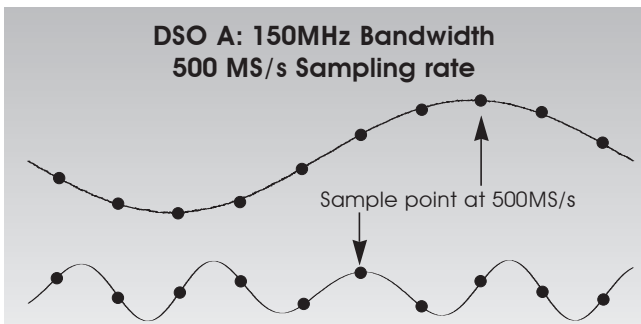
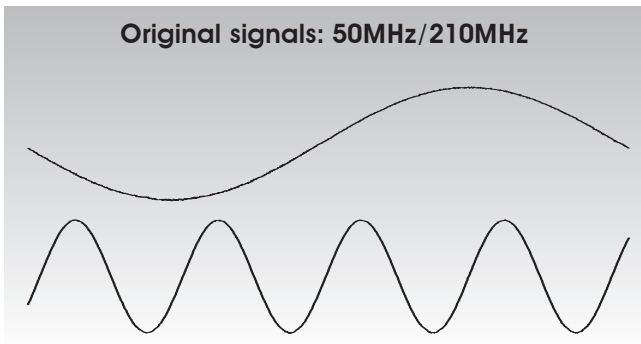


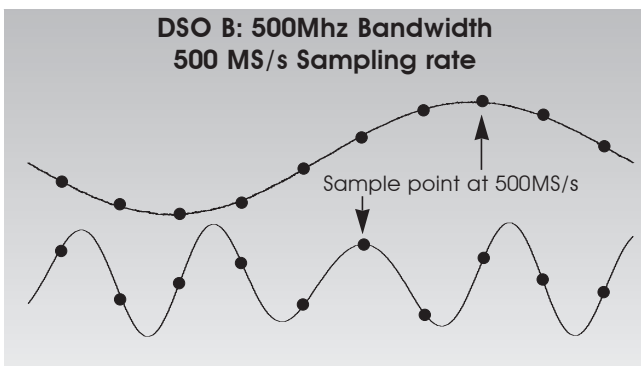
How does the sample rate of a Digital Oscilloscope affect the bandwidth?



In a traditional analogue oscilloscope, the term “bandwidth” defines the frequency response of the input and hence the maximum frequency component which can be accurately displayed. In a DSO, the analogue bandwidth, although relevant, is less important than the effective bandwidth, which is determined by the sample rate.



The 50MHz signal is displayed correctly. The 210MHz signal is attenuated slightly by the analogue bandwidth of 150MHz but the waveshape itself is correct.

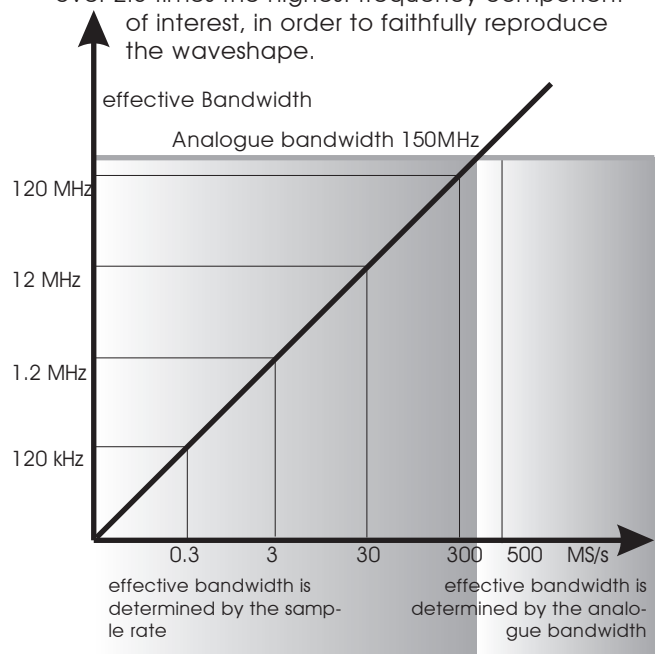


Thanks to the higher analogue bandwidth, both signals are displayed without attenuation but

The effective bandwidth can be expressed as:

$$BW_{DSO} = \frac{\text{Sampling rate}}{2.5}$$

This formula only applies to sinusoidal (single frequency) signals, which allows the instrument’s sinusoidal interpolation feature to be used. For more complex signals, the sampling rate should be well over 2.5 times the highest frequency component of interest, in order to faithfully reproduce the waveshape.

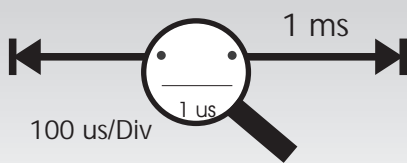


The effective bandwidth of a DSO is mainly determined by the sample rate!

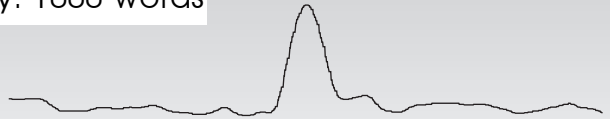
2 Is a long Memory really important?

A potential DSO user may feel that a long memory is unimportant as the display resolution of the horizontal axis (commonly limited to 500 pixels) is the determining factor for signal resolution. The length of the memory does, however, have a direct impact on the sample rate that is set and hence the effective bandwidth and reproduction quality.

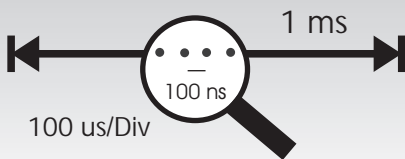
The Memory length determines the sampling rate!



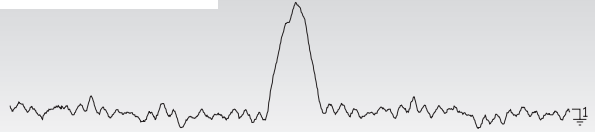
Memory: 1000 words



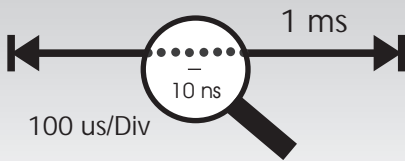
With a timebase setting of 100us/Div on a DSO, a memory length of 1000 words gives a sample rate of 1 MS/s. This equates to an effective bandwidth of 400kHz even if the DSO has a 500MHz analogue bandwidth and the potential to sample at 500 MS/s.



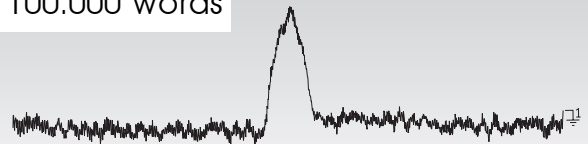
Memory: 10.000 words



With the same timebase setting and the memory increased to 10 kwords, the sample rate increases to 10 MS/s and the effective bandwidth to 4 MHz.



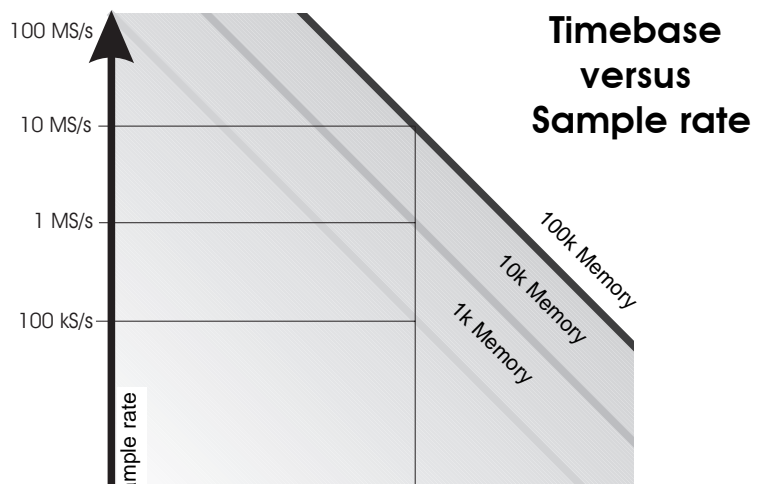
Memory: 100.000 words



With a further memory increase to 100 kwords, the sample rate is 100MS/s and the bandwidth is 40MHz.

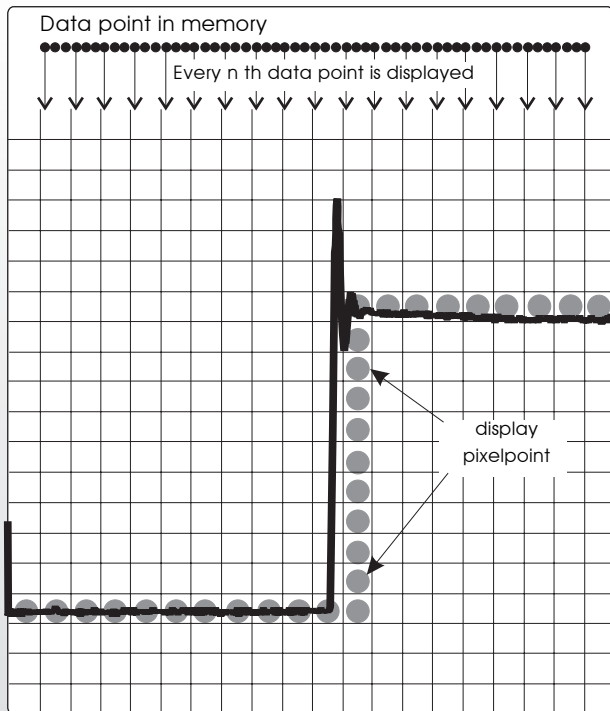
The sampling rate can be expressed as

$$\text{Sample rate} = \frac{\text{Memory length}}{\text{Time/Div} \times 10}$$



What is the display really showing? 3

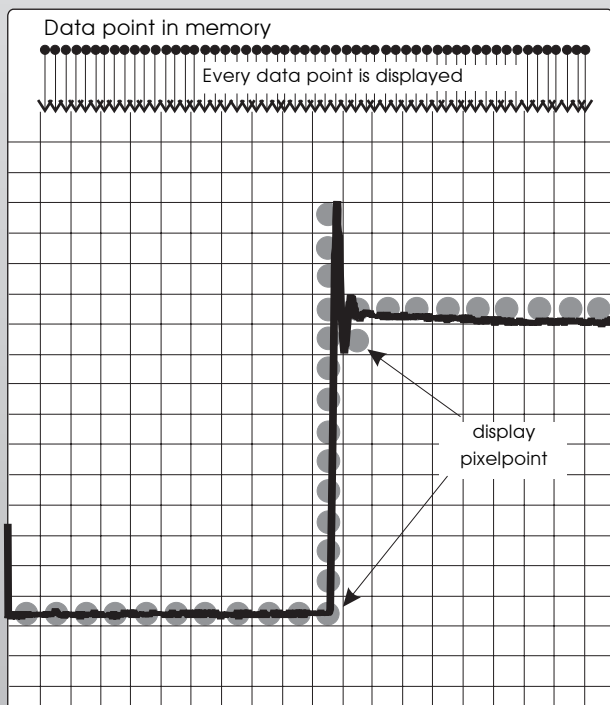
Traditional Signal representation



Only every nth data point is displayed.

Because of performance limitations, many DSOs are incapable of displaying the entire contents of their memory. Instead, they select and display every nth point of the acquired data. This technique enables a fast display update to be achieved as there is no need to show more data points than there are pixels available on the display. However, as the display data is decimated, important signal details may be lost as the sample rate is effectively reduced.

Modern Signal Representation



The entire contents of the memory are displayed.

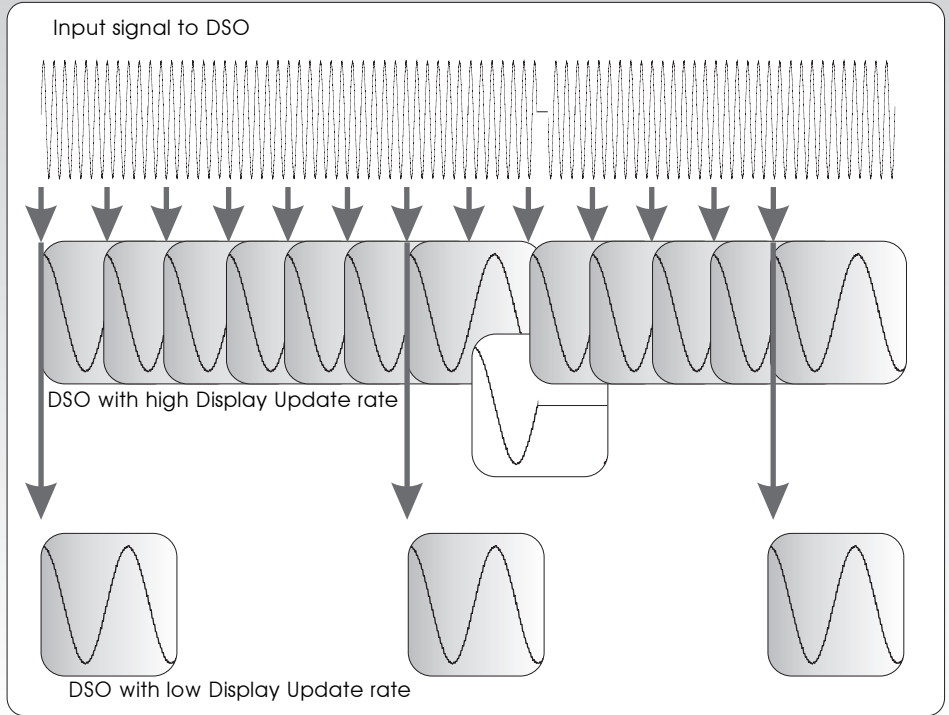
Every sample point is represented. If a number of samples occur within one pixel of the display, then a peak to peak assessment is made and the extreme values are displayed vertically and joined together. In this way, the entire contents of the memory are made visible. This method requires the DSO to be able to process the display data at a very fast rate. The DSOs from Yokogawa will show the entire contents of the memory and thanks to the state-of-the-art modern microprocessor architecture, the signals are displayed and updated at very high speed in spite of the complex processing required.

4

How important is a fast display?

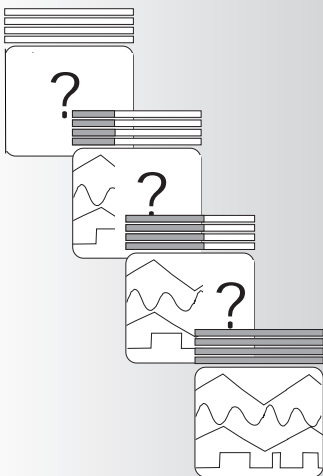
You can only display a signal if you acquire it!

The biggest disadvantage of DSOs compared to analogue oscilloscopes is the relatively long dead time between measurements. The DSO needs to process the data in its memory after every acquisition before it can be displayed. Whilst the data is being processed and displayed, the instrument is incapable of acquiring new data. Therefore, the faster the data is processed, the shorter is the dead time between acquisitions. Indeed, it is only possible to achieve high display update rates with state of the art multi-processor architectures.



Display update rate for DSOs (example: 4 channels, 10 kwords per channel)

High speed display update on Yokogawa DSOs



16.6 ms

Display update on conventional DSO



ca 140 ms

Due to their parallel architecture, Yokogawa DSOs are designed to display measurement data for each channel simultaneously. This results in

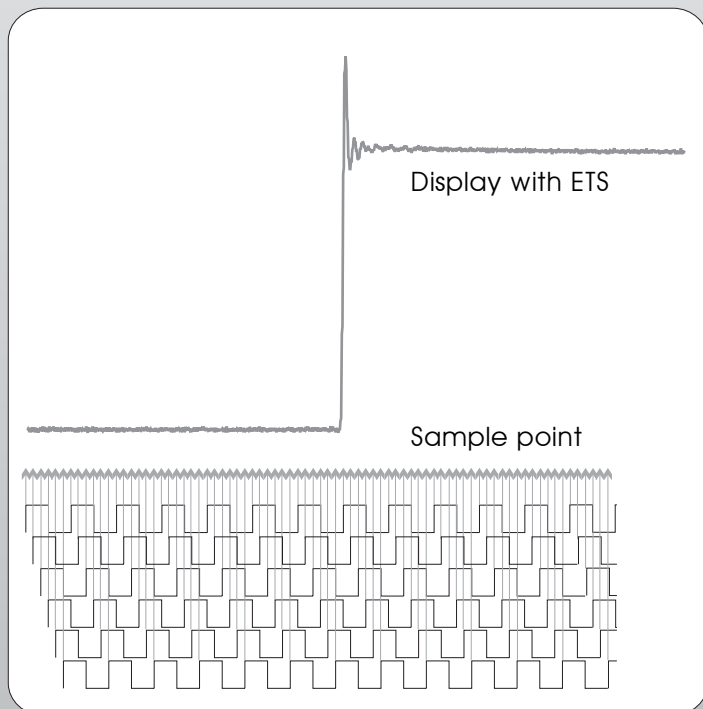
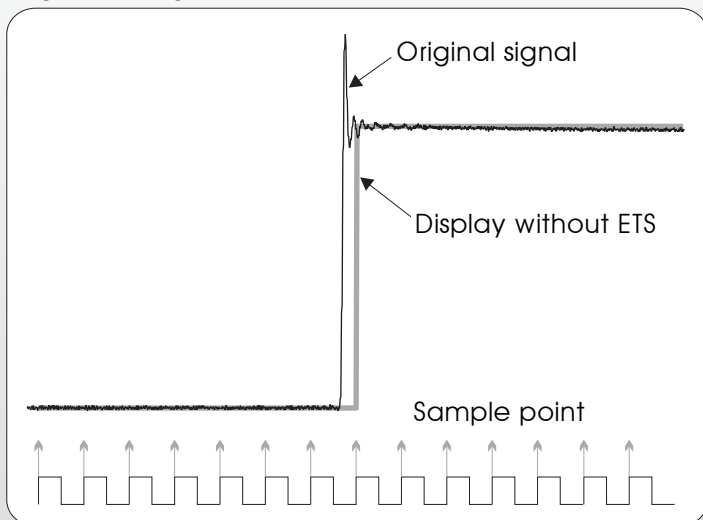
In conventional DSOs the transfer of data into the four display memories is performed consecutively since there is only one main processor available to perform all functions. This type of design offers a much lower display update rate. In order to achieve a high number of triggered measurements per second, it is as important to have a high display update

What is ETS and why don't all DSOs feature it

5

Signal acquisition at higher sampling rates.

In order to display the ringing on leading edges or determining their rise time, very high sample rates are necessary. In single shot mode, the maximum available sample rate is often not high enough to obtain the desired display resolution. A clever trick can, however, increase the effective sampling rate. If the point at which the A/D converter actually samples is shifted by a few picoseconds relative to the trigger point for each acquisition, then Equivalent Time Sampling (ETS) rates in the Gigahertz region can be achieved. The ETS method can only be applied to repetitive signals.



The ETS mode is available on all Yokogawa DSOs. Thanks to their low jitter A/D converters, they can achieve ETS sampling rates as high as 50GS/s with a display update rate that is only slightly slower than that achieved in normal mode. This very high performance is only possible by using parallel processor architecture.

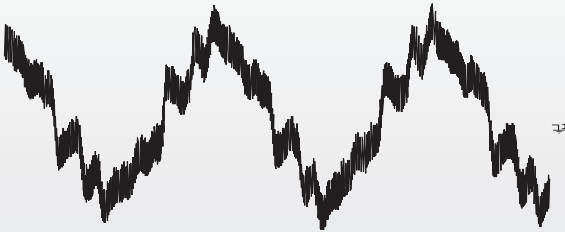
6

A resolution of 12 bits with an 8 bit A/D converter. How is it possible?

An increase in vertical resolution can commonly be achieved by averaging successive triggered measurements. As the number of averaged measurements increases so will the signal to noise ratio. However, this type of averaging is only applicable to repetitive waveforms and many types of DSO cannot perform averaging on single shot signals.

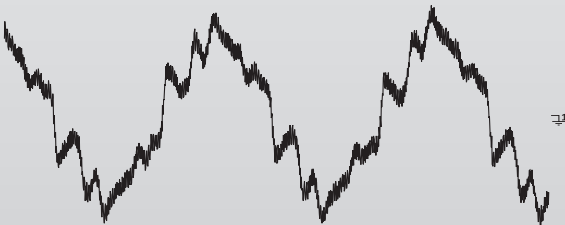
Improved resolution and reduced noise content due to averaging and smoothing.

Original signal



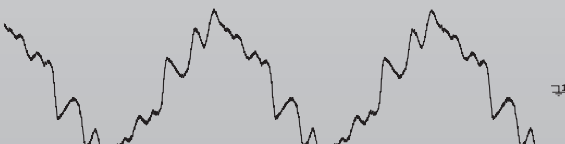
Smoothing

Smoothing is performed by software and can thus be carried out after the measurement has been completed. For example, 5 successive measurement points can be averaged.

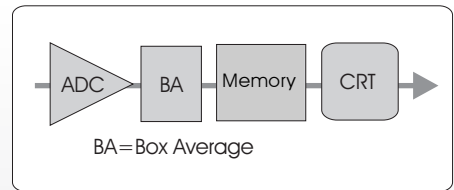


Averaging

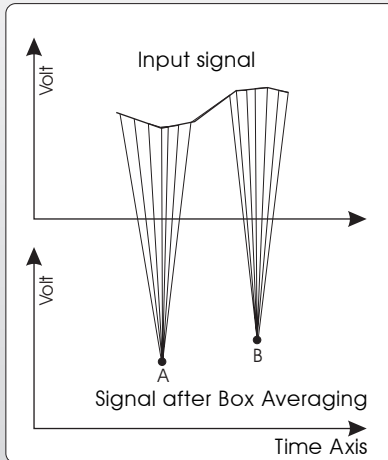
The conventional averaging technique is to calculate and display the mean waveform obtained from several triggered measurements (not possible for single shot waveforms). This results in the reduction of random signal components and an increase in resolution.



Improved resolution for single shot signals using BOX AVERAGING



Yokogawa has applied this complex technique to obtain an improvement in the vertical resolution for single shot waveforms. A number of successive measurement points, defined by the timebase setting, are averaged. For example, if a 10 MS/s sample rate is set and the maximum sampling rate of the instrument is 200 MS/s, measurement data is sampled at this higher rate and then averaged.



The Yokogawa DL2700 series of DSOs uses sophisticated hardware circuitry to carry out the averaging immediately after each sample has been A to D converted. Some DSOs (without hardware) compute the average values after the total acquisition has been completed.

The Box-Average process thus offers the following advantages:

- 1) The contents of the entire acquisition memory can be used
- 2) The averaging process occurs in realtime.

The improvement in the s/n ratio is \sqrt{n} where n= number of samples averaged.

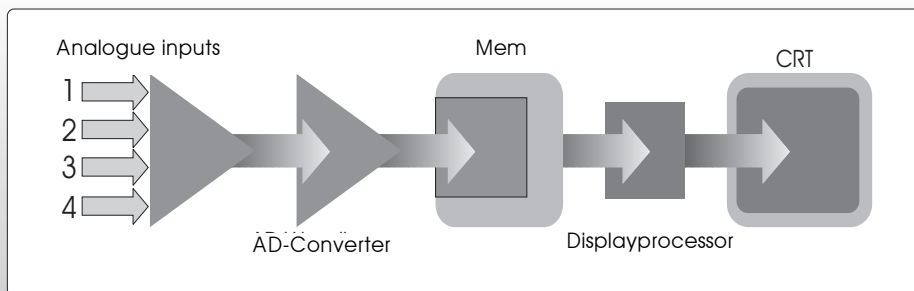
By averaging over 256 samples, the signal to noise ratio is improved by a factor of 16. This results in an increase in vertical resolution of 4 bits. Therefore if the A/D converter has a resolution of 8 bits, the box average method can increase the verti

How important is the internal architecture of your DSO?

7

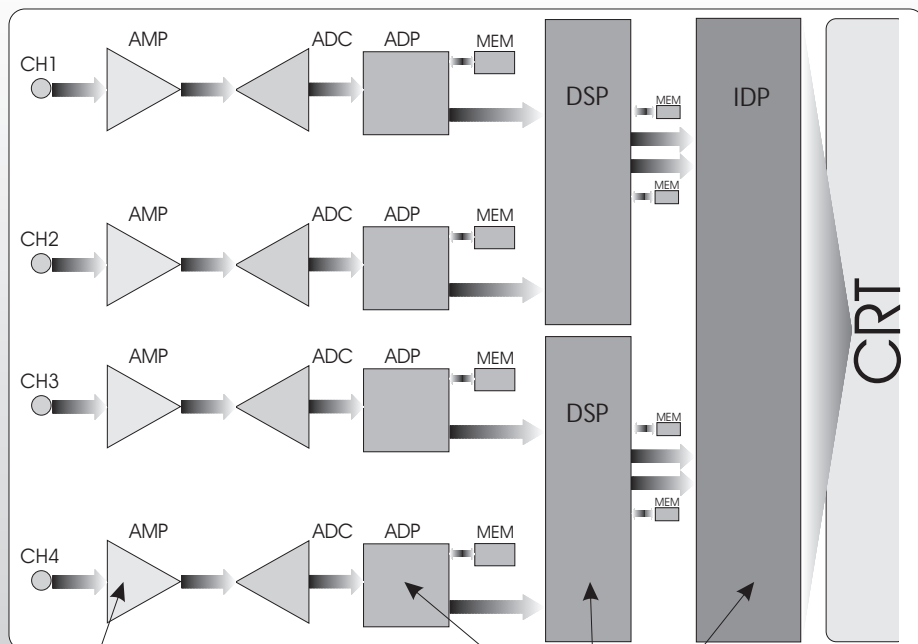
DSOs with traditional serial architecture.

A DSO based on this serial concept, consists of one or a few microprocessors placed in series. These microprocessors are responsible for signal handling from beginning to end. More data will result in a slower signal throughput caused by the limited handling speed of the microprocessor. This type of DSO can be easily recognised by the fact that an increase in memory length results in a slower screen update rate, typically down to a few updates per second.



Parallel Multiprocessor Architecture from YOKOGAWA

Yokogawa introduced the first DSO with a parallel processor architecture as long ago as 1994. Every DSO manufactured by Yokogawa incorporates several high-speed processors especially designed for their purpose. Every channel has its own management intelligence, which processes the measured data at the highest of speeds. The DSO user therefore benefits from a constant display update rate of 60Hz, when a 10 kword memory length is selected, regardless of other settings!



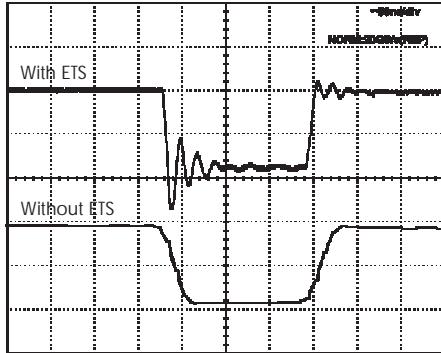
Single chip analogue amplifier with high accuracy and excellent thermal stability

Three super fast pipeline processors developed by Yokogawa for DSO applications. They are responsible for data acquisition, signal analysis and the display of the measurement data on the screen and thus ensure the highest possible data transfer rate

8

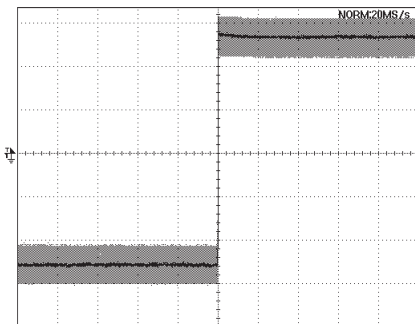
What modes of operation are usually available to a DSO user?

Equivalent Time Sampling (ETS)



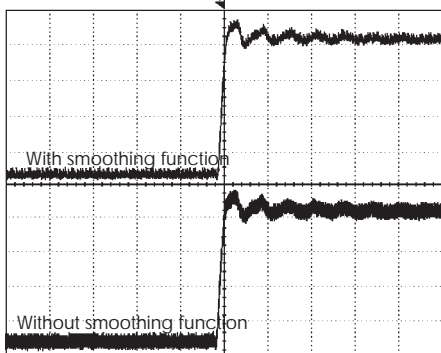
For repetitive signals, time shifted sampling of the waveform allows a higher sample rate than the maximum specified for the A/D converter.

Accumulate (Persistence)



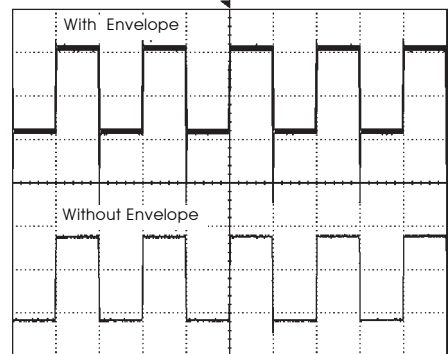
In this mode of operation, all waveforms remain visible on the display (similar to the persistence display on analogue storage oscilloscopes)

Smoothing function



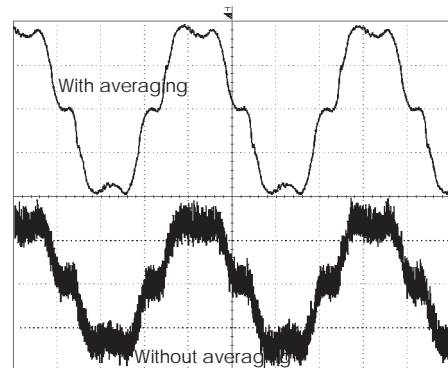
This function corresponds to digital filter-

Envelope



In this mode, the waveform is sampled at the maximum rate of the A/D converter irrespective of memory length or timebase setting. The display is a Max-Min representation.

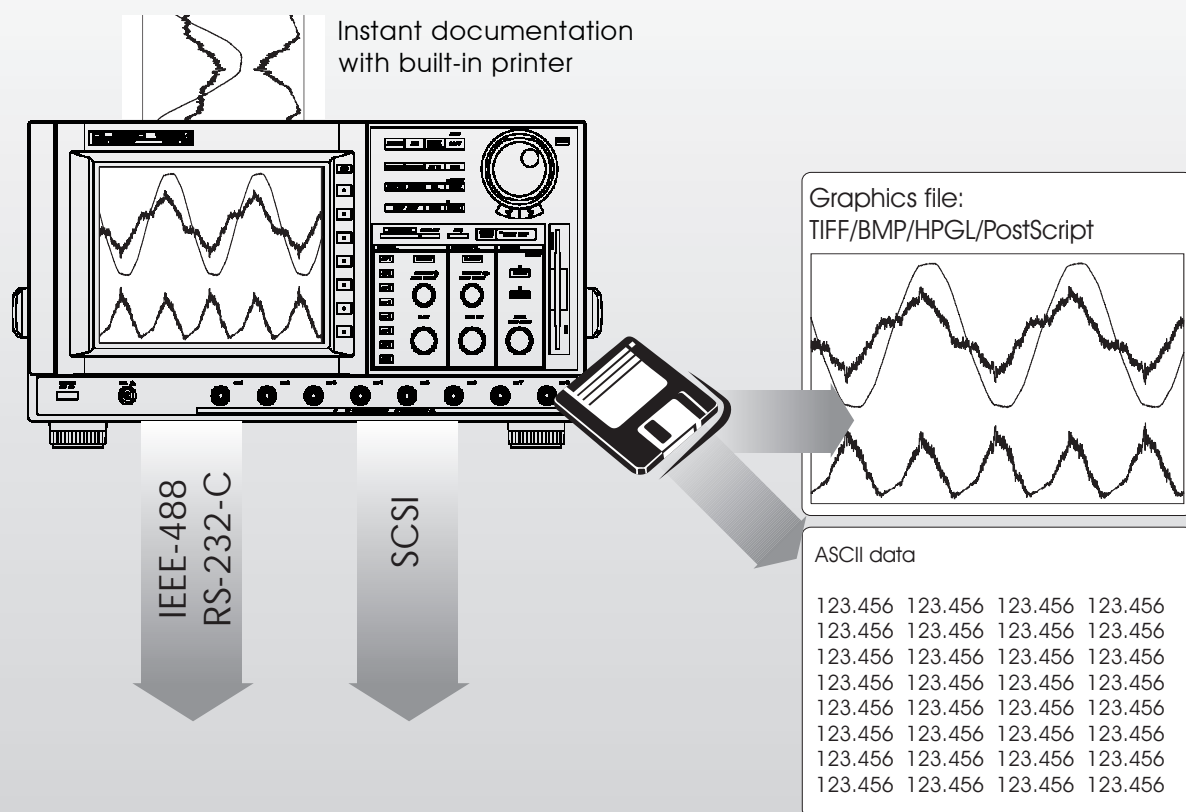
Average



The averaging function suppresses random signal components i.e. the signal can be displayed without the noise.

How can the results obtained by a modern DSO be exported?

9



The measurement is finished - what next?

It should be possible to obtain a recording of the measurement results in various forms. A paper record can be rapidly produced on site by using the built-in printer. If the results are required for use by a pc or for later interpretation on the DSO, they can be stored on a Floppy disk, either in a graphics file or in numerical form. Direct saving of the measurement data is therefore also possible in ASCII format. All file formats can be read and processed by most Windows programs. If a DSO has a larger acquisition memory, it is not feasible to save all the measurement data on a floppy disk, due to the size limitation. It is therefore preferable to use a SCSI device for storing hundreds of kilobytes or even megabytes of data.