Familiarization of Digital Storage Oscilloscope

By

Manjunath S Koparde
Junior Technical Superintendent
Under the guidance of
Prof. Naveen Kadayinti
Electronic Laboratory
Department of EECE, IIT Dharwad

Introduction

- Digital storage oscilloscope commonly known as DSO is display device used to display, measure the connected signals.

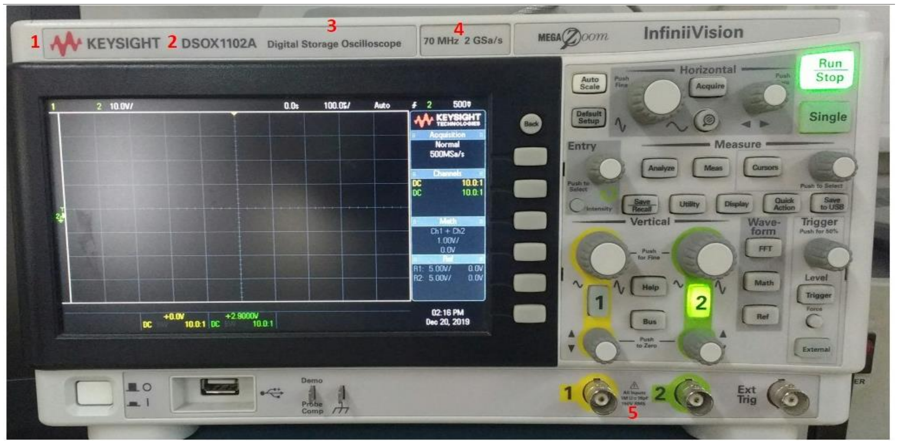
- Digital storage oscilloscope the name itself indicates he DSO not only display the waveforms it can store and analyze the signals.

- The DSO KEYSIGHT DSO1102A can measure frequency upto 70 MHz, it can simultaneously analyze two input signals.

- Rather than processing the signals in an analog fashion, the DSO converts them into a digital format using an analog to digital convertor (ADC).

- The DSO can store waveforms and can be retrieved at any point. Since the waveform is stored in a digital format, the data can be processed either within the oscilloscope itself, or even by a PC connected to it.

- The below information tells how to check the specification of DSO,



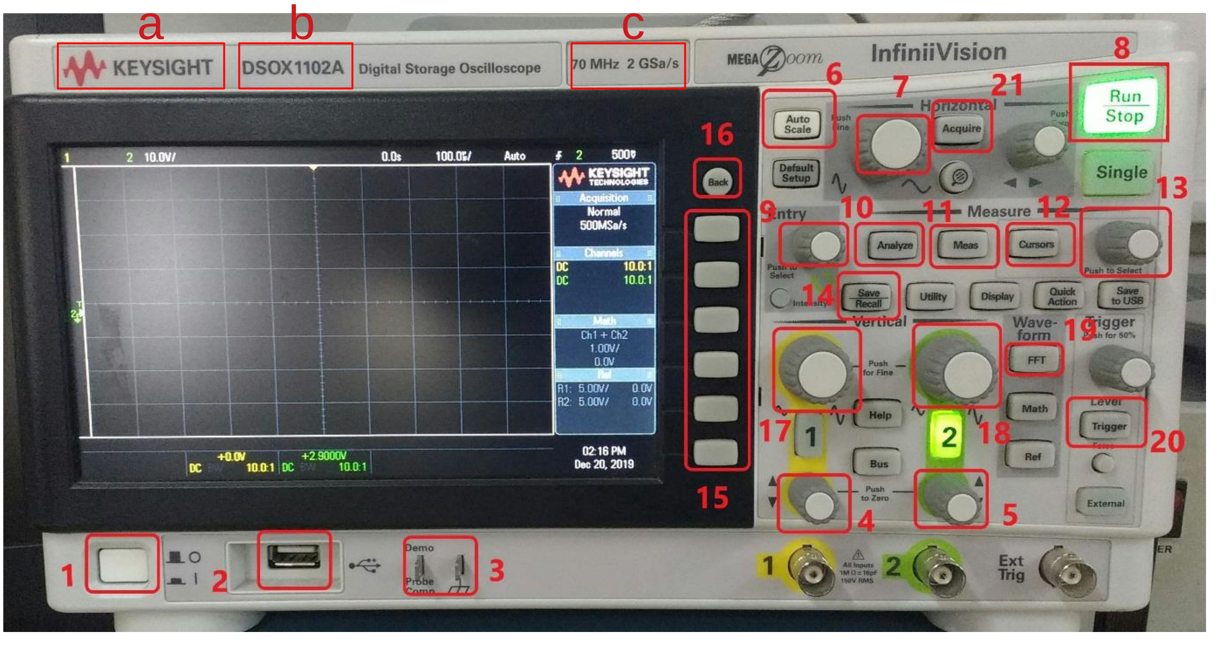
Something Interesting

A big step in the development of **oscilloscopes** was made in 1897, when a German physicist Karl Ferdinand Braun invented a cathode ray tube (CRT). A British company called A. C. Cossor which was the **first** company in the **world** that adapted this technology, presented their **first oscilloscope** in 1932.

a. KEYSIGHT is the manufacturer of the DSO and DSOX1102A is the model number, there are different manufacturers available for DSO in the market. Based on the user requirement the model number varies.

b. It's about the model number, based on options available and more advanced features the model number varies.

c. Frequency of operation, the DSOX1102A can work upto 70MHz, DSO starting from mili hertz to giga hertz are available in the market. It can scan the input analog signal at 2Gs/s.

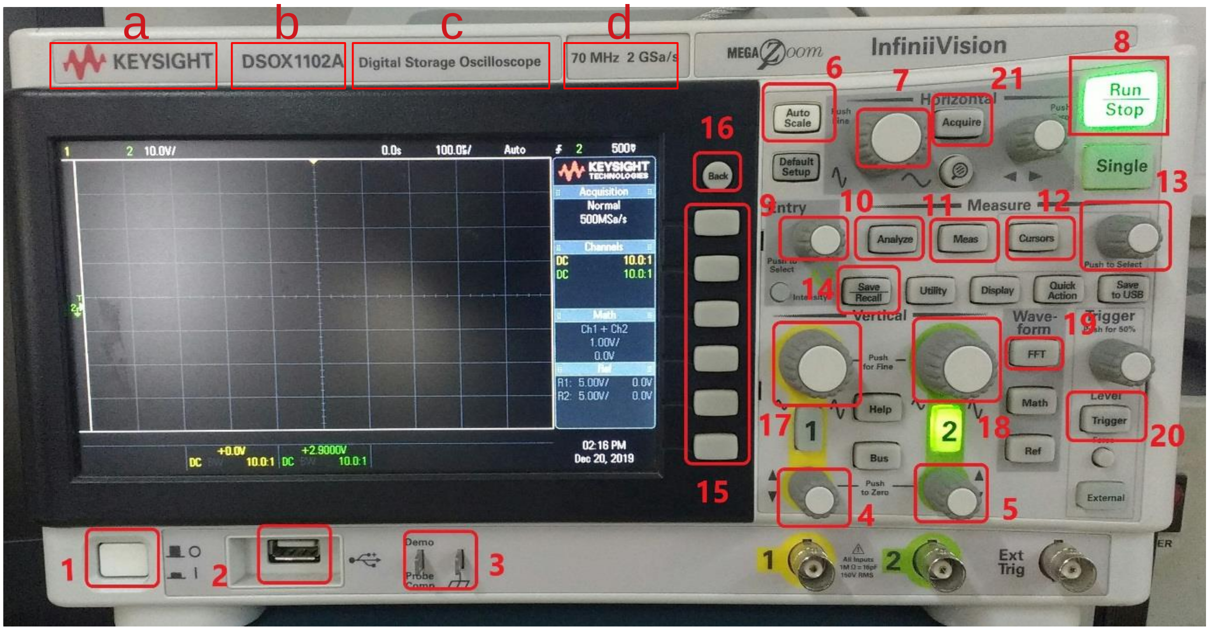


The scope has two input channel where we provide the signal to be measured, the DSO can plot and measure two signals simultaneously. The other input is for external trigger purpose.

To enable the channel we have to press "1" or "2" as per our requirement. If the button turns green it means the channel has been enabled. In the above picture channel 2 is enabled and channel 1 is disabled.

Trigger in DSO: It establishes the time reference for waveform display and measurement. It specifies the logical condition or waveform feature which defines the origin of the display's time axis. This time origin is called the Trigger Point and is often just referred to as the trigger.

Oscilloscopes normally define the trigger as the point at which the waveform transitions a specified voltage called the trigger level. The trigger control implements analog and logic triggers individually or in combination and supports auto triggers, glitch, hold-off and post-trigger filters, cross-triggers and parameter and signal condition tracking.



1. DSO can be switched On/Off using the button. Please consider the following points,

a. Initially DSO take few seconds to load, hence patience is requested.
b. Please do not play with the button as it may damage the equipment.

2. It is the USB slot where we can connect pen drive to store our waveforms in different file formats. Please go-through the procedure to save your waveform,

a. Press save & recall button (no.14 in the above picture).
b. Press save button (using keys adjacent, no.15 in picture), select the file format using entry knob (using keys adjacent, no.9 in picture).
c. Give the file name by pressing file name button.
d. Select setting if you wish to change the color of output waveform to be saved.
e. Finally press “Press to Save” button to save your waveform.

Note: Please use FAT/FAT32 file formatted USB drive for better connectivity.

3. The slot where we connect the probe to calibrate the probe. Please follow the procedure,

a. Connect the probe to channel “1” or “2” and connect the other end of probe to probe check terminal (please refer below mentioned picture for better understanding).
b. Proper square wave with 5.0 Vp-p, 1KHz signal should appear on screen if the probe is working fine else you observe some attenuation or distortion in signal if probe is defective.

4. The knob is used to move the waveform vertically; we use this knob to center align the waveform for better visibility. Each channel has its own vertical alignment knob.

   Knob marked with no. 4 is used to vertically align channel “1” signal only.

5. The knob is used as above but it is meant for channel “2” only.

6. The button Auto scale is used to scale the input signal, by pressing the button the DSO recognizes the incoming signal and scales the signal and chooses appropriate trigger such that it can be comfortably viewed on the screen.

7. Its horizontal scale knob, usually whenever we connect high frequency signal, we find difficult to recognize the signal due to its appearance hence we use horizontal scale knob to scale it until we visualize proper waveform. It is common knob for both the channels.

8. Pressing “RUN/STOP” button captures the signal i signle event capture mode, the menu is useful in debugging aperiodic signals.

Something Interesting

The Digital Storage Oscilloscope, DSO was invented by Walter LeCroy after producing high-speed digitizers for the research centre CERN in Switzerland. Walter LeCroy later founded the LeCroy Corporation.

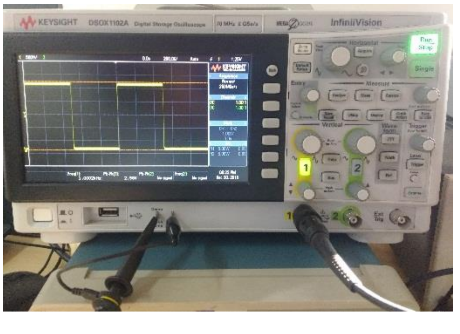
9. Its entry knob mainly used in menu selection, (ex. If you want to change the measurement than we use the knob to scroll into the menu list of measurement).

10. Press this key to access analysis features like trigger level setting, measurement threshold setting, Video trigger automatic set up and display, or digital voltmeter.

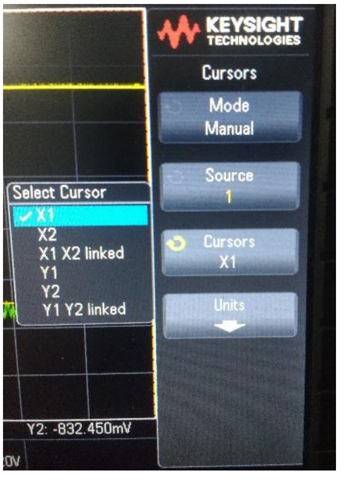
11. The measurement button through which multiple measurement options are available, please refer the below mentioned procedure for measurement selection,

a. Press the measurement button, select the source, channel “1” or “2” which you want to measure. Scroll can be made using entry knob (no. 09).
b. Next click on “Type” will find list of measurement options using entry knob scroll until you select the what you want to measure, then press the entry knob to select the measurement.
c. As soon as you select the measurement the values start displaying at the bottom of the display screen.
d. At last you can find “Clear Meas” option, by selecting you can clear all your previous measurement selections.

12. Cursors are horizontal and vertical markers that indicate X-axis values and Y-axis values on a selected waveform source. You can use cursors to make custom voltage, time, phase, or ratio measurements on oscilloscope signals. Cursor information is displayed in the right-side information area.



a. X cursors are vertical dashed lines that adjust horizontally and can be used to measure time (s), frequency (1/s), phase (°), and ratio (%). When used with the FFT math function as a source, the X cursors indicate frequency. In XY horizontal mode, the X cursors display channel 1 values (Volts or Amps).



b. Y cursors are horizontal dashed lines that adjust vertically and can be used to measure Volts or Amps, dependent on the channel Probe Units setting, or they can measure ratios (%). When math functions are used as a source, the measurement units correspond to that math function. The Y cursors adjust vertically and typically indicate values relative to the waveform's ground point, except math FFT where the values are relative to 0 dB. In XY horizontal mode, the Y cursors display channel 2 values (Volts or Amps).

c. Fig. 01 indicates the cursor menu. When you press the cursor option the cursor menu appears. Please follow the below procedure for using cursor in measurement,

1. Select the source (channel 01 or 02).
2. Next select the cursor X1, X2 for time (s), frequency (1/s), phase (°), and ratio (%) and Y1, Y2 for volts or amps.
3. Using the Knob no. 13 you can set the points you wish to measure.
4. The measured value appears below the screen. The measure value ΔX will be the difference between X1 and X2. The measure value ΔY will be the difference between Y1 and Y2.

13. The knob is used to vary the cursor pointer, by pressing the knob you can directly read the values of all the cursor pointers.

13. As explained earlier the "SAVE/RECALL" is used to save the waveforms into the USB and stored signals can be recalled for analysis.

13. These six buttons are used for selections, used is various measurement options

13. Its "back" button, the button can be pressed to return from any menu.

13. Its vertical scaling knob used to scale the signal vertically, its dedicated for ch. No. 01.

13. Its vertical scaling knob used to scale the signal vertically, its dedicated for ch. No. 02.

13. FFT is used to compute the fast Fourier transform using analog input channels. FFT takes the digitized time record of the specified source and transforms it to the frequency domain. When the FFT function is selected, the FFT spectrum is plotted on the oscilloscope display as magnitude in dBV versus frequency.

The readout for the horizontal axis changes from time to frequency (Hertz) and the vertical readout changes from volts to dB. Use the FFT function to find crosstalk problems, to find distortion problems in analog waveforms caused by amplifier non-linearity, or for adjusting analog filters. Please refer following for FFT key usage,

a. FFT Span/Center – FFT Key
b. FFT window - [FFT] > Settings > Window (Hanning, Flat Top,
c. Rectangular, Blackman Harris.
d. FFT vertical units - [FFT] > Settings > Vertical Units (Decibels, VRMS)
e. FFT auto setup - [FFT] >Settings - Auto Setup
f. FFT waveform, scale - [FFT] > Scale – Knob No. 09.
g. FFT waveform, offset - [FFT] > Offset – Knob No. 09.

FFT Measurement

The number of points acquired for the FFT record can be up to 65,536, and when frequency span is at maximum, all points are displayed. Once the FFT spectrum is displayed, the frequency span and center frequency controls are used much like the controls of a spectrum analyzer to examine the frequency of interest in greater detail. Place the desired part of the waveform at the center of the screen and decrease frequency span to increase the display resolution. As frequency span is decreased, the number of points shown is reduced, and the display is magnified.

While the FFT spectrum is displayed, use the [FFT] and [Cursors] keys to switch between measurement functions and frequency domain controls in FFT Menu.

Decreasing the effective sampling rate by selecting a greater time/div setting will increase the low frequency resolution of the FFT display and also increase the chance that an alias will be displayed. The resolution of the FFT is the effective sample rate divided by the number of points in the FFT. The actual resolution of the display will not be this fine as the shape of the window will be the actual limiting factor in the FFTs ability to resolve two closely space frequencies. A good way to test the ability of the FFT to resolve two closely spaced frequencies is to examine the sidebands of an amplitude modulated sine wave.

For the best vertical accuracy on peak measurements:

Make sure the probe attenuation is set correctly. The probe attenuation is set from the Channel Menu if the operand is a channel.

Set the source sensitivity so that the input signal is near full screen, but not clipped.

Use the Flat Top window.

Set the FFT sensitivity to a sensitive range, such as 2 dB/division.

For best frequency accuracy on peaks:

• Use the Hanning window.

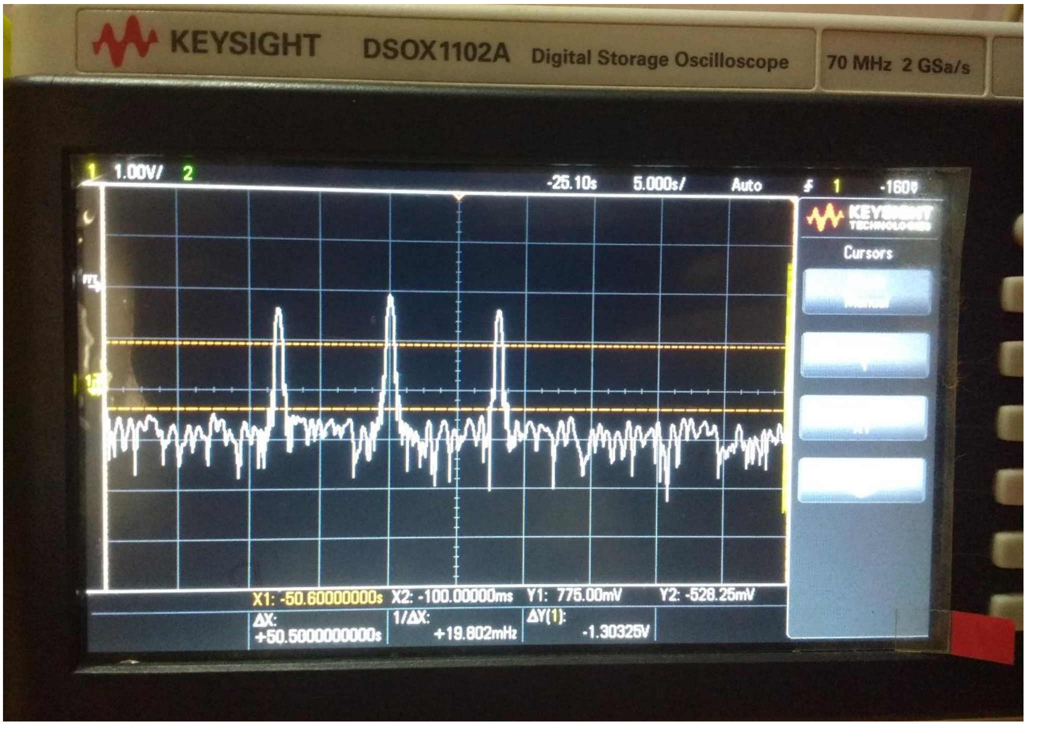
• Use Cursors to place an X cursor on the frequency of interest.

• Adjust frequency span for better cursor placement.

• Return to the Cursors Menu to fine tune the X cursor.

Example on FFT

The experiment illustrates the frequency domain analysis of Amplitude modulation, as here from left the first impulse tells the fc-fm, the middle one shows the center frequency fc and the last one is fc+fm. (fc is carrier frequency and fm is modulate frequency of amplitude modulation).



Something Interesting

Hand-drawn oscillograms : The earliest method of creating an image of a waveform was through a laborious and painstaking process of measuring the voltage or current of a spinning rotor at specific points around the axis of the rotor, and noting the measurements taken with a galvanometer. By slowly advancing around the rotor, a general standing wave can be drawn on graphing paper by recording the degrees of rotation and the meter strength at each position.

20. A trigger setup tells the oscilloscope when to acquire and display data. For example, you can set up to trigger on the rising edge of the analog channel 1 input signal.

You can use any input channel or the Ext Trig input BNC as the source for most trigger types

Changes to the trigger setup are applied immediately. If the oscilloscope is stopped when you change a trigger setup, the oscilloscope uses the new specification when you press [Run/Stop] or [Single]. If the oscilloscope is running when you change a trigger setup, it uses the new trigger definition when it starts the next acquisition.

In addition to the edge trigger type, you can set up triggers on pulse widths and video signals. In the oscilloscope, you can also set up triggers on patterns, rising and falling edge transition times, and setup and hold violations.

Please refer following for Trigger key usage,

a. Trigger level - Turn the trigger Level knob.
b. Trigger type - Trigger Type (Edge, Pulse Width, Video, Serial 1, Pattern*, Rise/Fall Time*, Setup and Hold*)
c. Edge trigger - [Trigger] > Trigger Type, Edge
d. Pulse width trigger - Trigger Type, Pulse Width
e. Video trigger - Trigger Type, Video
f. Pattern trigger - Trigger Type, Pattern
g. Rise/fall edge transition time trigger - Trigger Type, Rise/Fall Time
h. Setup and hold violation trigger - Trigger Type, Setup and Hold

Serial bus trigger - Trigger Type, Serial 1

Trigger Mode, Coupling, Reject, Holdoff Features

a. Trigger mode - Mode You can also configure the [Quick Action] key to toggle between the Auto and Normal trigger modes.

a. Auto trigger mode - Mode, Auto If the specified trigger conditions are not found, triggers are forced and acquisitions are made so that signal activity is displayed on the oscilloscope. The Auto trigger mode is appropriate when:
    - Checking DC signals or signals with unknown levels or activity.

• When trigger conditions occur often enough that forced triggers are unnecessary.

c. Normal trigger mode - Mode, Normal Triggers and acquisitions only occur when the specified trigger conditions are found. The Normal trigger mode is appropriate when:

• You only want to acquire specific events specified by the trigger settings.

• Making single-shot acquisitions with the [Single] key. Often with single-shot acquisitions, you must initiate some action in the device under test, and you do not want the oscilloscope to auto-trigger before that happens. Before initiating the action in the circuit, wait for the trigger condition indicator Trig'd? to flash.

d. When in the Normal trigger mode and no triggers are occurring, you can force a trigger to acquire and display waveforms (which may show why triggers are not occurring).

21. When selecting the oscilloscope acquisition mode, keep in mind that samples are normally decimated (thrown away) at slower time/div settings. At slower time/div settings, the effective sample rate drops (and the effective sample period increases) because the acquisition time increases and the oscilloscope's digitizer is sampling faster than is required to fill memory

For example, suppose an oscilloscope's digitizer has a sample period of 1 ns (maximum sample rate of 1 GSa/s) and a 1 M memory depth. At that rate, memory is filled in 1 ms. If the acquisition time is 100 ms (10 ms/div), only 1 of every 100 samples is needed to fill memory.

a. Acquisition mode - [Acquire] > Acq Mode
b. Normal acquisition mode - [Acquire] > Acq Mode, Normal
c. Peak detect acquisition mode - [Acquire] > Acq Mode, Peak Detect
d. Averaging acquisition mode - [Acquire] > Acq Mode, Averaging, [Acquire] > Avgs
e. High resolution acquisition mode - [Acquire] > Acq Mode, High Resolution

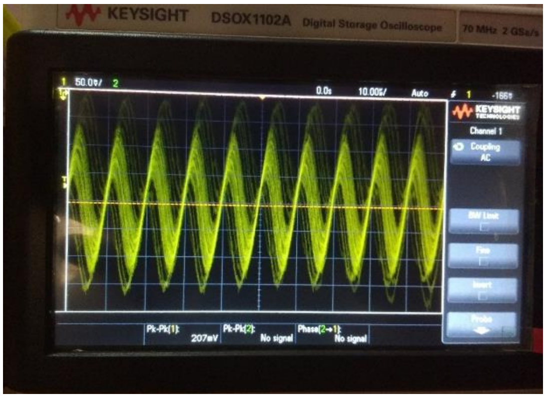
Normal Acquisition Mode: Normal acquisition mode is the default mode for oscilloscopes. The ADC samples and the scope decimates down to the desired number of points and plots the waveform. It's best to use normal acquisition mode for day-to-day debugging tasks because it gives a good general representation of your signal. It's a very safe mode to use, and has no significant caveats.

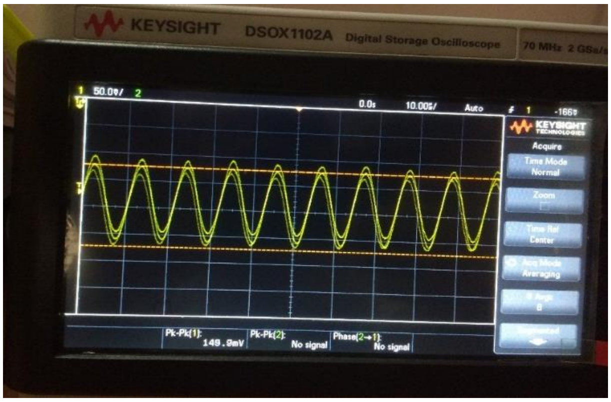
Averaging Acquisition Mode: Averaging acquisition mode is probably the second most commonly used mode. Averaging mode takes multiple waveform captures and averages them together. The main benefit of averaging acquisition mode is that it averages out the random noise on your signal; this allows you to see just the underlying signal. For example, clamp-on current probes are notoriously noisy. Therefore, using averaging mode will help give you more insight into what your current waveform actually looks like.

This mode should only be used under certain circumstances or you could get misinformation on the screen. Averaging acquisition mode should be used only with periodic signals and with a stable oscilloscope trigger. If the signal is aperiodic, the displayed signal will not be valid data—just a conglomeration of changing signals over time. If there's a glitch in the signal, it will be hidden by the continuous averaging.

Averaging mode is a great acquisition mode for viewing or characterizing very stable periodic waveforms, but it must be used appropriately.

The below image illustrate the averaging mode, the first image is of the signal continuously fluctuating which is very difficult to analyze. The second image is averaged one were the signal appears steady.





High-Resolution Mode: High-resolution mode is another form of averaging. However, instead of waveform-to-waveform averaging, it is point-to-point averaging. Essentially, the ADC oversamples the signal and averages neighboring points together. This mode uses a real-time boxcar averaging algorithm that helps reduce random noise. It also can yield a higher number of bits of resolution.

High-resolution mode isn't as effective at reducing random noise as the averaging mode discussed earlier, but it has some distinct advantages. Because high-resolution mode doesn't depend on multiple captures, it can be used with aperiodic signals and unstable triggers. This makes high-resolution mode much better than averaging mode for general-purpose debugging. However, averaging mode does a more complete job of removing random noise from the oscilloscope trace. High-resolution mode is a useful mode for maximizing the bits of resolution on the scope.

Peak-Detect Acquisition Mode: Peak-detect acquisition mode functions similar to high-resolution mode. The ADC oversamples the signal and selectively chooses which points to display. But, instead of averaging these points together, peak-detect mode chooses the highest and the lowest points and plots them both. This is useful because it can provide insight into any unusually high or low points that might be otherwise hidden. Peak-detect mode is best used for detecting glitches or viewing very narrow pulses.

Like high-resolution mode, at fast sweep speeds, the ADC won't be able to oversample the waveform. Therefore, peak-detect mode is best used at moderate sweep speeds. In addition, using peak-detect mode can give a distorted view of the true signal by plotting the highest and lowest points in a given sampling period.

Zoom Button Just below the Acquire button there is a zoom button, press this button if you need to zoom in particular part of a signal. The event you press this button the display divides in two part, the top half displays the normal time/div and the bottom half displays a faster zoom time/div window.