Getting Started

MSO/DPO Series Oscilloscopes

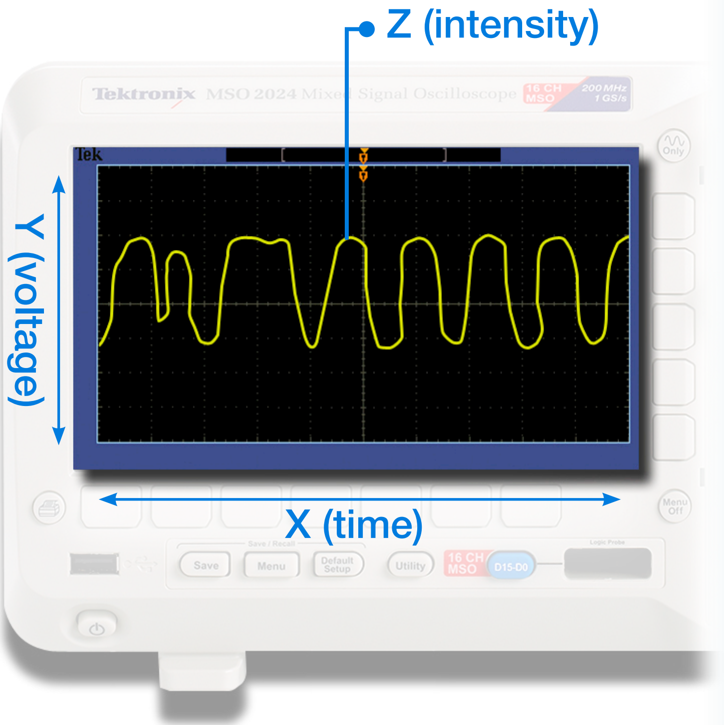
Basic Concepts

001-1523-00

What is an oscilloscope?

An oscilloscope is a device that draws a graph of an electrical signal.

In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity or brightness of a waveform is sometimes called the Z axis.


Z (intensity)
Y (voltage)
X (time)
Tektronix MSO 2024 Mixed Signal Oscilloscope
16 CH MSO
200 MHz 1 GS/s
Tek
Save
Menu
Default Setup
Utility
D15-D0
Only
Menu Off

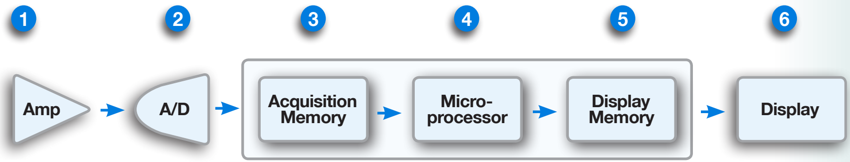
Tektronix

How does a digital oscilloscope work?

1. The signal travels through the probe to the vertical **amplifier.**
2. Next, an **analog-to-digital converter (A/D)** digitizes the signal by sampling the signal at discrete points in time and converting the signal's voltage at these points into digital values called sample points.
3. The sample points from the A/D are stored in **acquisition memory** as waveform points. Together, the waveform points comprise one waveform record.

   The number of waveform points used to create a waveform is called the record length.

   The trigger determines the start and stop points of the record.
4. The signal path includes a **microprocessor,** which measures the signal and formats it for display.
5. 6. The signal then passes through the **display memory** and is displayed on the oscilloscope **display.**

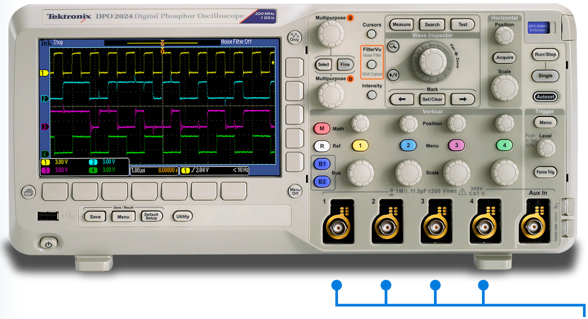


1
2
3
4
5
6
Amp
A/D
Acquisition Memory
Micro-processor
Display Memory
Display

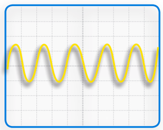
What are the differences between an MSO and a DPO Oscilloscope?

Digital Phosphor Oscilloscope (DPO)

A DPO has only one type of input - typically two or four analog channels.

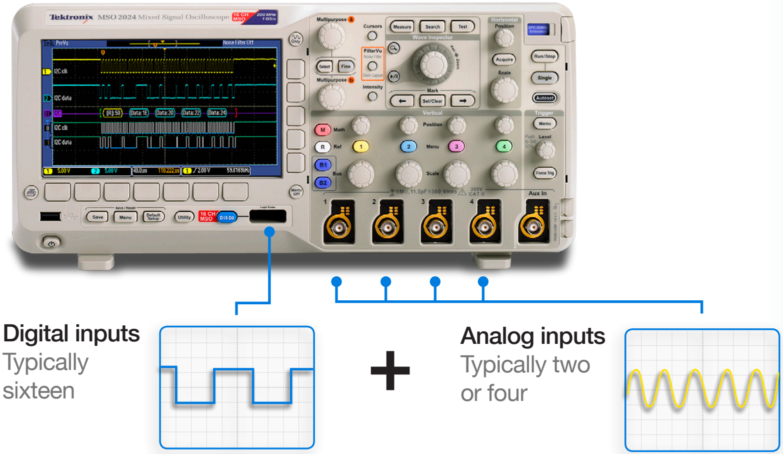


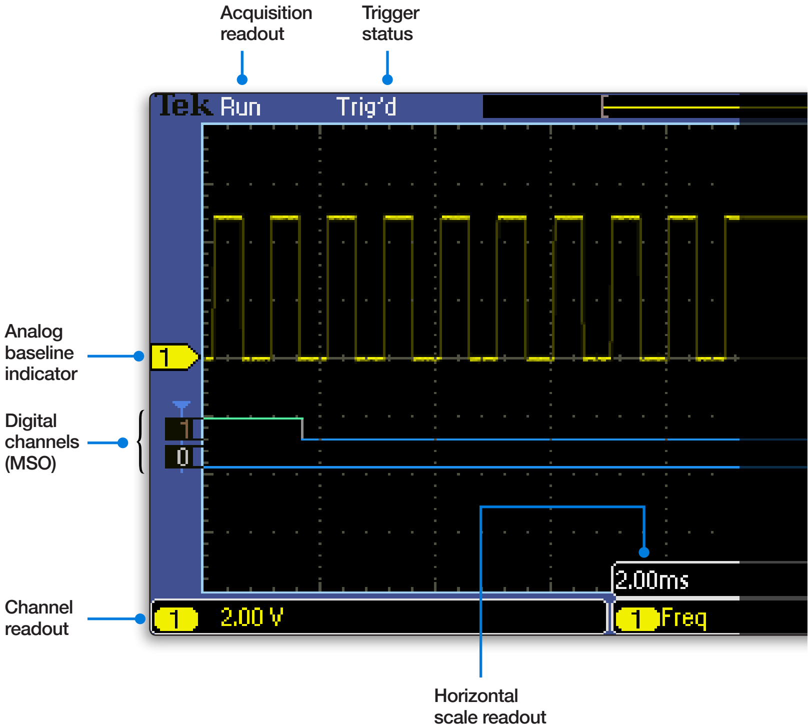
Analog inputs only
Typically two or four



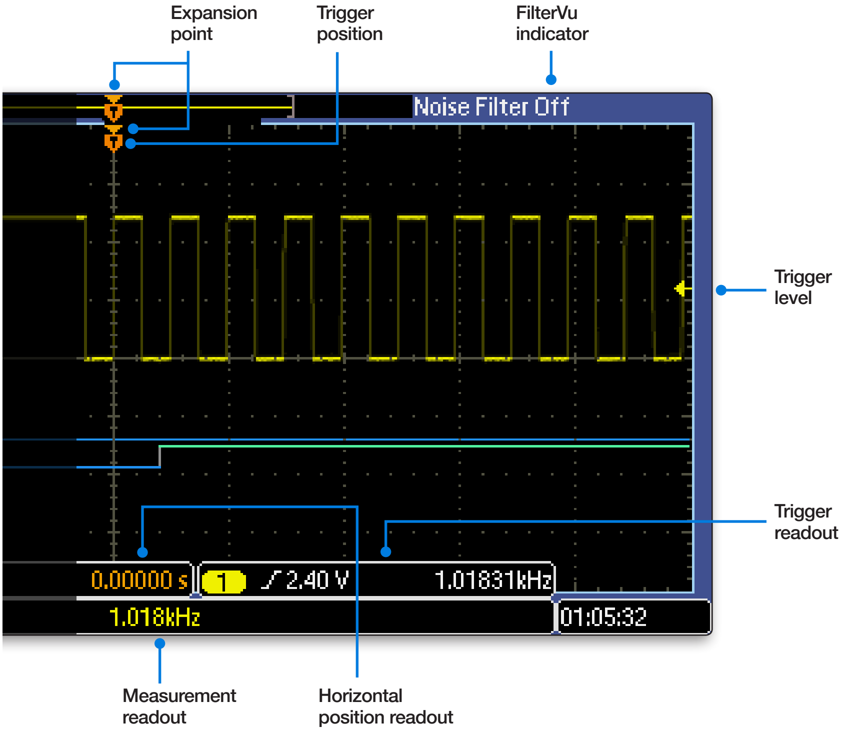
Mixed Signal Oscilloscope (MSO)

An MSO has two kinds of inputs - typically two or four analog channels, and a larger number (typically sixteen) of digital channels for advanced digital measurements. Applications include characterization and debugging of analog-to-digital converters (ADCs), digital-to-analog converters (DACs), and control systems.





Acquisition readout
Trigger status
Analog baseline indicator
Digital channels (MSO)
Channel readout
Horizontal scale readout
Tek Run
Trig'd
1
0
2.00 V
2.00ms
Freq


Expansion point
Trigger position
FilterVu indicator
Noise Filter Off
Trigger level
Trigger readout
0.00000 s
1
2.40 V
1.01831kHz
1.018kHz
01:05:32
Measurement readout
Horizontal position readout

Vertical

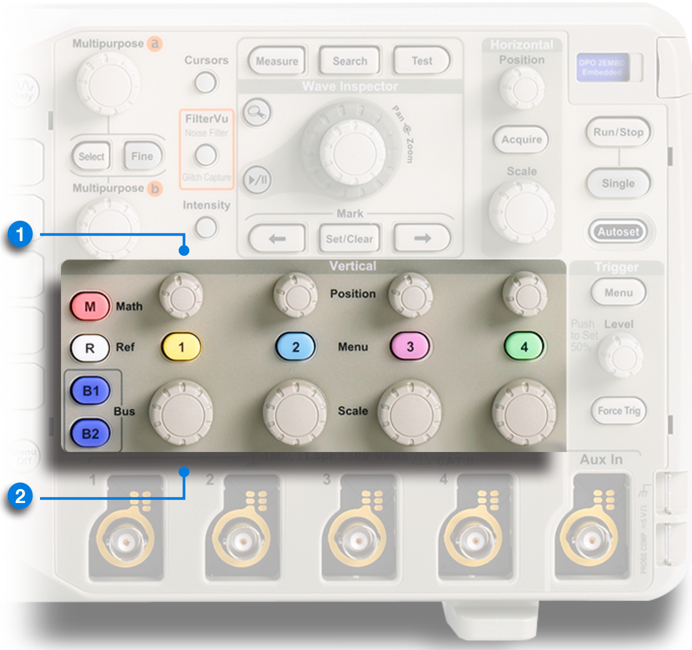
Vertical

What are Vertical Controls used for?

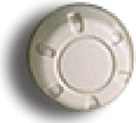
You can change the vertical position of waveforms by moving them up or down on the display. To compare data, you can align a waveform above another or you can align waveforms on top of each other.

You can change the vertical scale of a waveform. The waveform display will contract or expand around the ground reference level.

Vertical Controls



Tektronix®

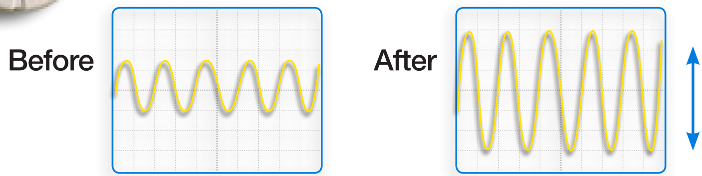


1 Position knob

Moves the waveform up and down on the display.

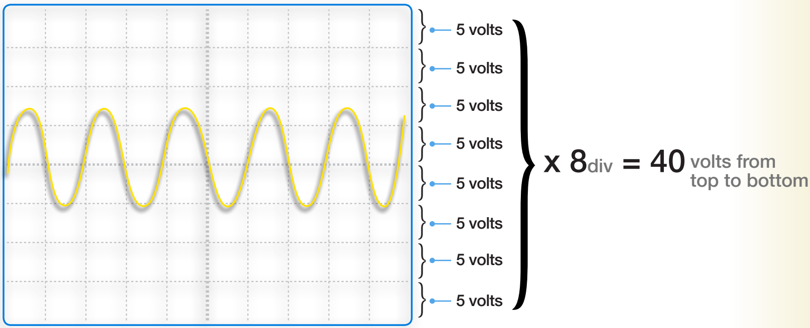
2 Scale (volts-per-division)

Varies the size of the waveform on the screen.



The volts/div setting is a scale factor.

If the volts/div setting is 5 volts, then each vertical division represents 5 volts and an entire screen of 8 divisions can display 40 volts from top to bottom.

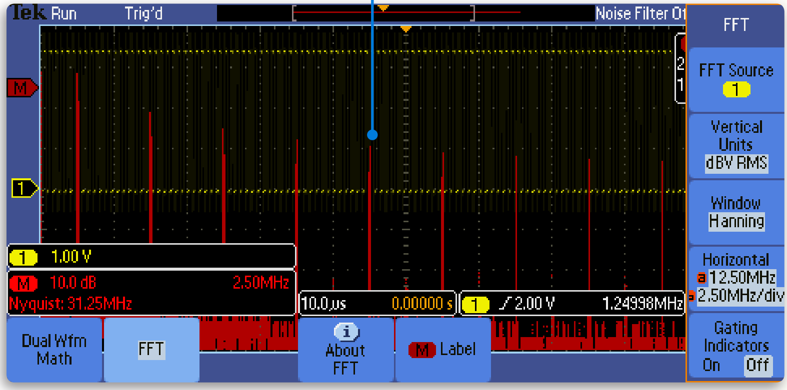


What is Fast Fourier Transform (FFT) used for?

You can use the FFT Math mode to convert a time-domain signal into its frequency components (spectrum). You can use FFT for the following kinds of analysis: analyzing harmonics, characterizing noise, testing impulse response, and analyzing vibration.

The MSO/DPO2000 Series FFT is calculated from 5000 points on the display. The resulting FFT spectrum goes from DC (0 Hz) to one-half the sample rate.

Frequency component



Additional information in about FFT

Horizontal scale in frequency per division

Frequency at the center graticule

Window type: Allows you to trade off the frequency resolution and amplitude accuracy that you will see in the FFT spectrum.

Vertical scale in dB per division (0 dB = 1VRMS)

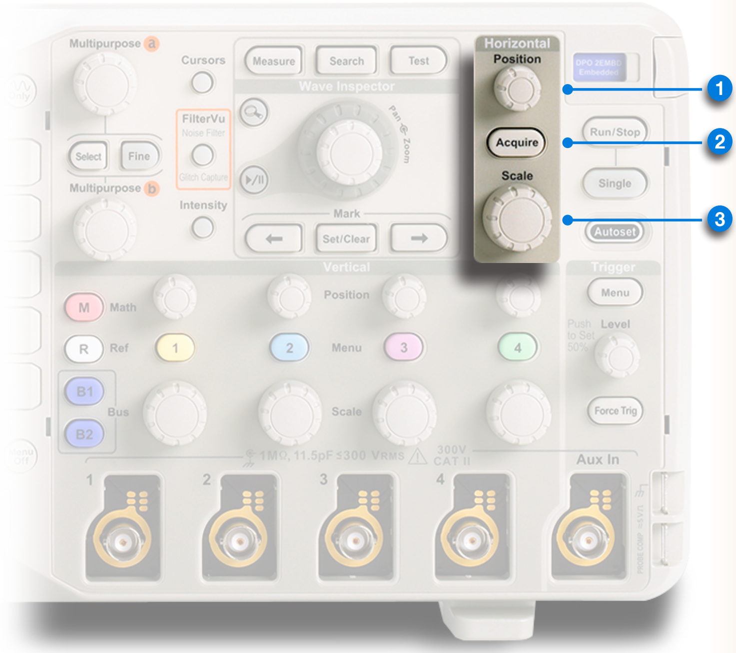
Horizontal

What are Horizontal Controls used for?

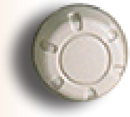
You can adjust the Horizontal Position control to view waveform data before the trigger, after the trigger, or some of each.

When you change the horizontal position of a waveform you are changing the time between the trigger and the center of the display. This moves the waveform to the right or left on the display.

Horizontal Controls



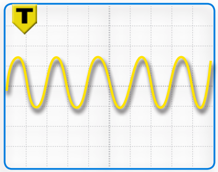
Tektronix



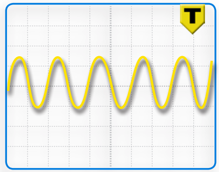
1 Position knob

Adjusts the horizontal position of all channel and math waveforms. The resolution of this control varies with the time base setting.

Before
Example:
Post trigger
acquisition



After
Example:
Pre-trigger
acquisition

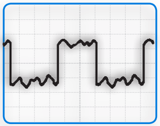


2 Acquire button

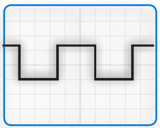
Determines how the oscilloscope processes the digitized signal before displaying it.

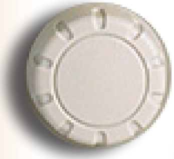
There are two acquisition modes: Sample and Average.

Sample mode: Samples are taken in evenly-spaced intervals to construct the waveform. This mode accurately represents signals most of the time.



Average mode: Several waveforms are acquired and averaged point-by-point to obtain the average voltage at each time sample in the acquisition. This mode is used to reduce random noise.

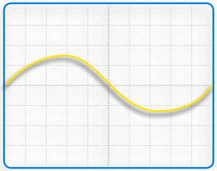




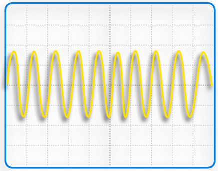
3 Scale knob

The scale knob (sec/div) setting varies the rate at which the waveform is drawn across the screen.

Before
Example:
1 sec

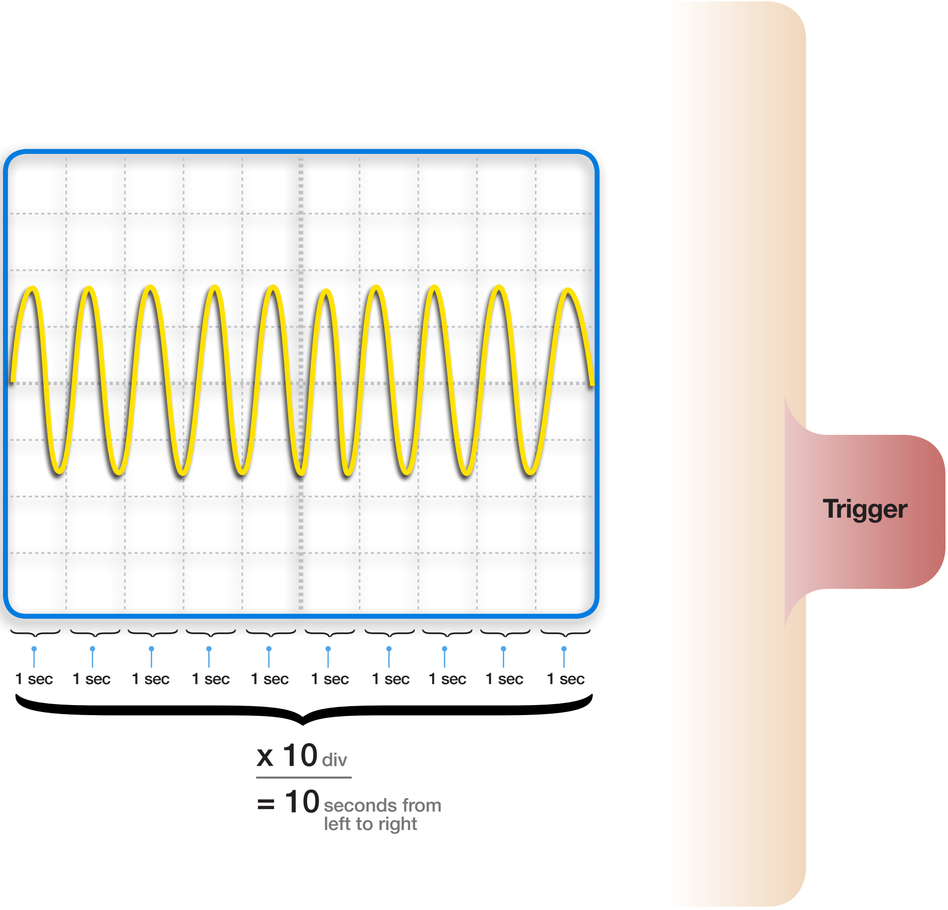


After
Example:
10 sec



The sec/div setting is a scale factor.

If the sec/div setting is 1 second, then each horizontal division represents 1 division and an entire screen of 10 divisions can display 10 seconds from left to right.


Trigger
1 sec
1 sec
1 sec
1 sec
1 sec
1 sec
1 sec
1 sec
1 sec
1 sec
x 10 div
= 10 seconds from left to right

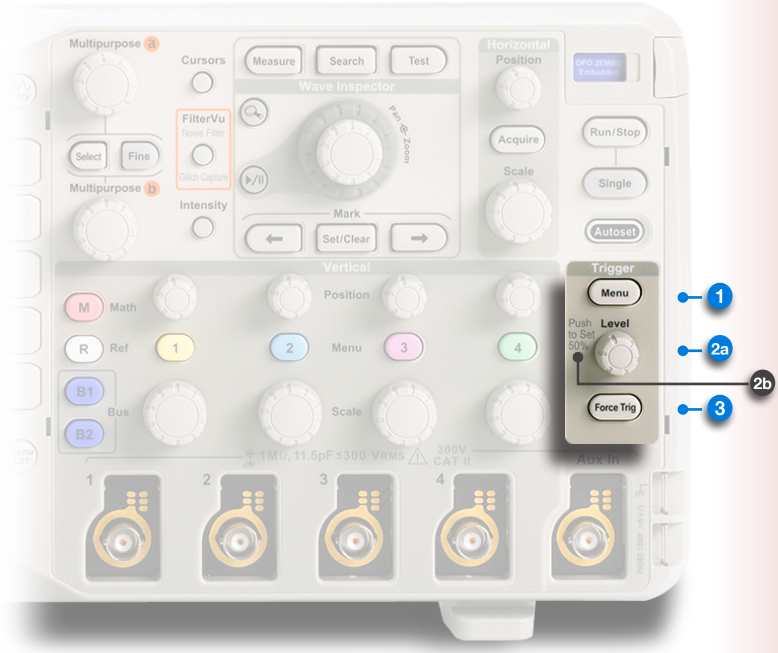
Trigger

What are Trigger Controls used for?

Trigger controls allow you to capture single-shot waveforms and stabilize repetitive waveforms.

Imagine the jumble on the screen that would result if each time the waveform was drawn across the screen, the drawing began at a different part of the signal. The trigger ensures the same part of the waveform is drawn each time, making repetitive waveforms appear stationary.

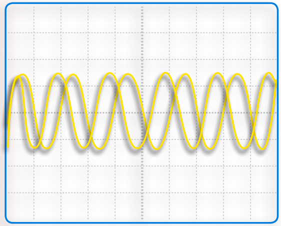
Trigger Controls



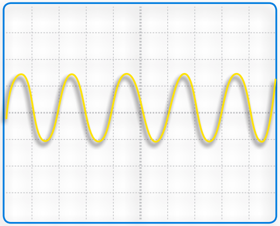
Tektronix

What does a Trigger do?

When the signal matches the trigger setting, the oscilloscope captures the signal and displays it around the trigger point. Edge triggering is used most often; it captures the signal as it passes through a specified voltage level on a rising or falling edge.



Untriggered display

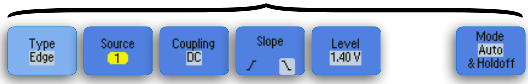


Triggered display

Menu

1 Trig Menu

Displays the Trigger Menu



5a 5b 5c 5f

5a Type

Cycles through different trigger types

Edge triggers are the simplest and most commonly used trigger type, with both analog and digital signals. An edge trigger event occurs when the trigger source passes through a specified voltage level in the specified direction.

Pulse width triggering, allows you to monitor a signal indefinitely and trigger on the first occurrence of a pulse with a duration (pulse width) that is outside the specified limits.

Runt triggering allows you to define two levels (or thresholds). A trigger occurs when a pulse crosses one, but not both thresholds.

Logic triggering allows you to trigger on any logical combination of available input channels – especially useful in verifying the operation of digital logic.

Setup-and Hold triggering allows you to capture setup and hold violations.

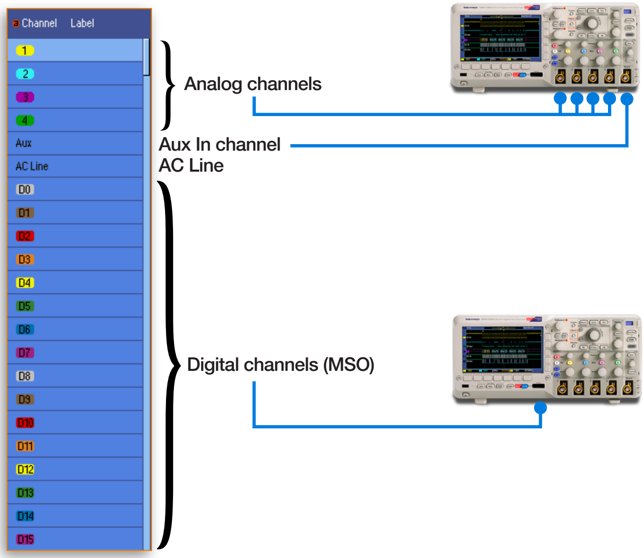
Rise/Fall Time Triggering allows you to selectively trigger on fast or slow edges.

Video trigger on specified fields or lines of a composite video signal.

Bus trigger is used when there are various parallel or serial bus conditions.

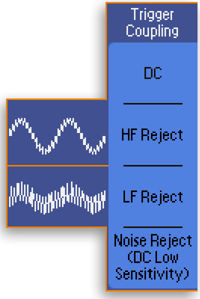
5b Source

Determines which signal is compared to the trigger settings.



5c Coupling

High frequency, low frequency, and noise rejection trigger coupling are useful for eliminating noise from the trigger signal to prevent false triggering.



DC Passes all components of the signal

HF Reject attenuates the high frequency components of the signal

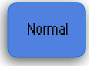
LF Reject attenuates the low frequency components of the signal

Noise Reject adds hysteresis to the trigger circuitry to reduce the chance of falsely triggering on noise

5d Mode

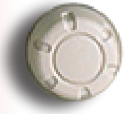
Determines whether or not the oscilloscope draws a waveform based on a signal condition.

In **Auto** mode the scope displays a signal, even without a trigger.



In **Normal** mode the scope only displays a signal if the input signal reaches the set trigger point; otherwise the last acquired waveform remains on the display.

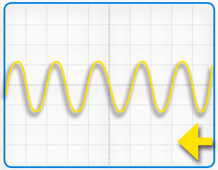
After a trigger is detected, the scope acquires and displays one waveform.



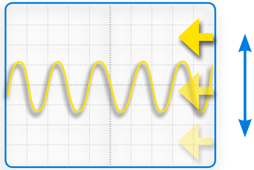
2a Level

When you use an Edge or Pulse trigger, the Level knob sets the amplitude level that the signal must cross to acquire a waveform.

Before



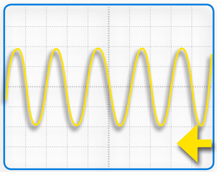
After



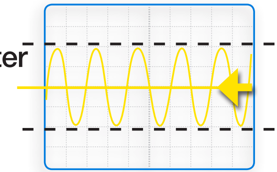
2b Set to 50% (Push to Set)

The trigger level is set to the vertical midpoint between the peaks of the trigger signal.

Before



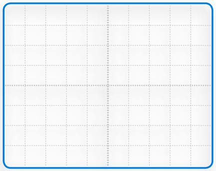
After



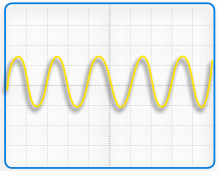
3 Force Trig

Completes an acquisition regardless of an adequate trigger signal. This button has no effect if the acquisition is already stopped.

Before



After



Probing basics

Choose a probe that exceeds the signal's bandwidth by 5 times for accurate reconstruction of the signal.

Remember to connect the probe's ground clip to a known ground in the circuit under test. Measuring a signal requires two connections: the probe tip connection and the ground connection.

Don't forget to compensate passive voltage probes to the oscilloscope.

Probe connections

Tektronix

1 CH1 BNC

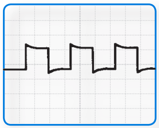
To connect the probe, align the slot in the probe connector with key on the BNC, push to connect and twist to the right to lock the probe in place.

2 Probe comp connector

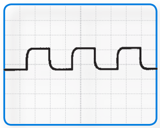
Connect the probe tip to the bottom connector and the ground to the top connector labeled ground.

Verify your probe is compensated correctly

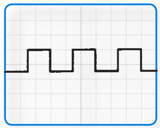
Check the shape of the displayed waveform.



Over-compensated

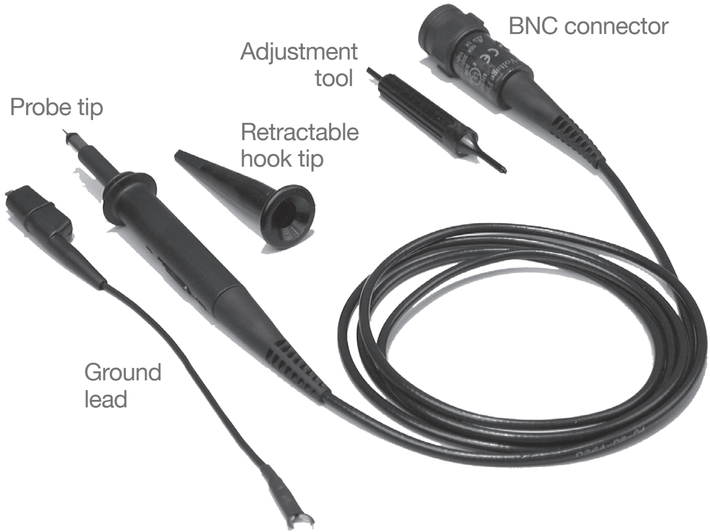


Under-compensated



Compensated Correctly

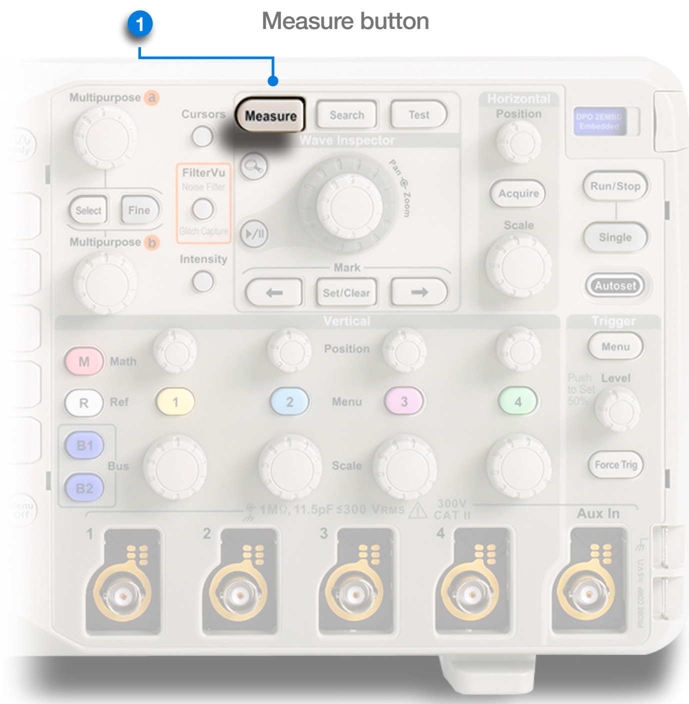
Standard P2221 MSO/DPO Analog Probe



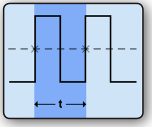
Measurements

The oscilloscope can help you to analyze your waveform through measurements. There are several ways to take measurements. You can use the graticule, the cursors, or automatic measurements.

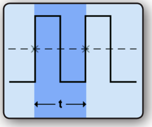
Automatic measurements use on-screen readouts to show measurement results. These readouts are updated periodically as the oscilloscope acquires new data.


1
Measure button
Multipurpose a
Cursors
Measure
Search
Test
Wave Inspector
Pan Zoom
Horizontal
Position
DPO 2EMBD Embedded
FilterVu
Noise Filter
Glitch Capture
Select
Fine
Multipurpose b
Intensity
Acquire
Scale
Run/Stop
Single
Autoset
Mark
Set/Clear
Vertical
Trigger
M
Math
Position
Menu
Push to Set 50%
Level
R
Ref
1
2
Menu
3
4
B1
Bus
Scale
Force Trig
B2
1MΩ, 11.5pF ≤300 VRMS
300V CAT II
Aux In
1
2
3
4

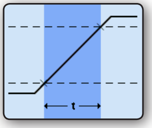
The following automatic measurements are available:



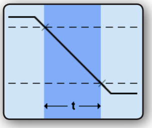
Frequency (Hertz) = $\left(\frac{1}{t}\right)$
Frequency is the reciprocal of Period. Frequency is measured over the first cycle.



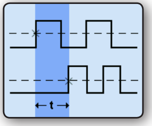
Period (seconds) = t
Period is the time required to complete the first cycle. The first cycle is the time between the first two positive crossings, or the first two negative crossings, at the Mid Reference level.



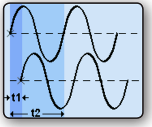
Rise Time (seconds) = t
Rise Time is the time required for the first rising edge to rise from the Low Reference level to the High Reference level.



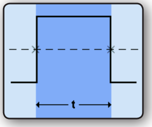
Fall Time (seconds) = t
Fall Time is the time required for the first falling edge to fall from the High Reference level to the Low Reference level.



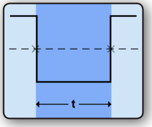
Delay (seconds) = t
Delay is the time between the first occurrences of the specified Mid Reference crossings of two waveforms.



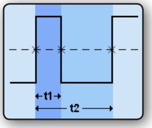
Phase (°) = $\left(\frac{t1}{t2}\right)$ **x 360 °**
Phase is the ratio of the Delay between the first Mid Reference crossings of two waveforms (t1) to the Period of the source (t2) waveform. Phase is expressed in degrees. 360 degrees comprise one cycle.



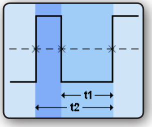
Positive Pulse Width (seconds) = t
Positive Pulse Width is the time between the Mid Reference crossings of the first positive pulse.



Negative Pulse Width (seconds) = t
Negative Pulse Width is the time between the Mid Reference crossings of the first negative pulse.

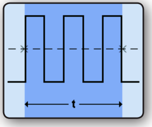


Positive Duty Cycle (%) = $\left(\frac{t1}{t2}\right)$ **x 100%**
Positive Duty Cycle is the ratio of the Positive Pulse Width (t1) to the Period (t2). Positive Duty Cycle is measured over the first cycle.



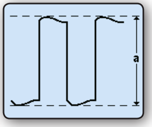
Negative Duty Cycle (%) = $\left(\frac{t1}{t2}\right)$ x 100%

Negative Duty Cycle is the ratio of the Negative Pulse Width (t1) to the Period (t2). Negative Duty Cycle is measured over the first cycle.



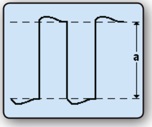
Burst Width (seconds) = t

Burst Width is the time from the first Mid Reference crossing to the last Mid Reference crossing.



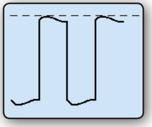
Peak-to-peak (Volts) = a

Peak-to-peak is the difference between the Max value and the Min value.



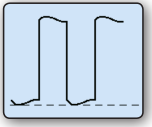
Amplitude (Volts) = a

Amplitude is the difference between the High value and the Low value.

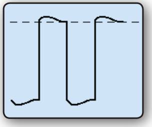


Max (Volts)

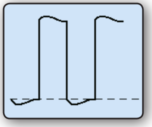
Max is the maximum value.



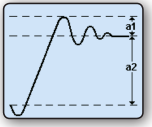
Min (Volts)
Min is the minimum value.



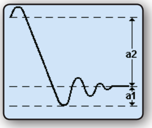
High (Volts)
If the High-Low Method is Histogram, High is the highest density of points above the midpoint of the waveform. If the High-Low Method is Min-Max, High is equal to Max.



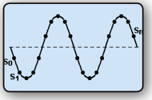
Low (Volts)
If the High-Low Method is Histogram, Low is the highest density of points below the midpoint of the waveform. If the High-Low Method is Min-Max, Low is equal to Min.



Positive Overshoot (%) = $\left(\frac{a1}{a2}\right)$ **x 100%**
Positive Overshoot is the difference between Max and High (a1), divided by Amplitude (a2).

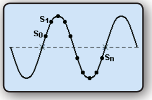


Negative Overshoot (%) = $\left(\frac{a1}{a2}\right)$ **x 100%**
Negative Overshoot is the difference between Min and Low (a1), divided by Amplitude (a2).



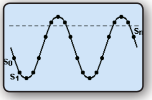
Mean (Volts) $= \dfrac{(S_0 + S_1 + \ldots + S_n)}{n}$

Mean is the arithmetic mean value over the entire record.



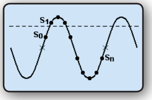
Cycle Mean (Volts) $= \dfrac{(S_0 + S_1 + \ldots + S_n)}{n}$

Cycle Mean is the arithmetic mean value. Cycle Mean is calculated over the first cycle.



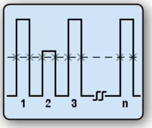
RMS (Volts) $= \sqrt{\dfrac{(S_0^2 + S_1^2 + \ldots + S_n^2)}{n}}$

RMS is the true Root Mean Square value over the entire record.



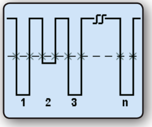
Cycle RMS (Volts) $= \sqrt{\dfrac{(S_0^2 + S_1^2 + \ldots + S_n^2)}{n}}$

Cycle RMS is the true Root Mean Square value. Cycle RMS is calculated over the first cycle.

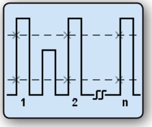


Positive Pulse Count = n

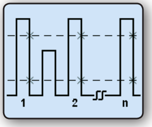
Positive Pulse Count is the number of positive pulses that rise above the Mid Reference level.



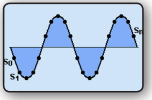
Negative Pulse Count = n
Negative Pulse Count is the number of negative pulses that fall below the Mid Reference level.



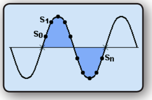
Rising Edge Count = n
Rising Edge Count is the number of positive transitions from the Low Reference value to the High Reference value.



Falling Edge Count = n
Falling Edge Count is the number of negative transitions from the High Reference value to the Low Reference value.



Area (Volt-seconds) = $(S_0 + S_1 + \ldots + S_n)$ x (sample interval)
Area is the area under the curve, calculated by integrating the samples. The area measured above ground is positive. The area measured below ground is negative.



Cycle Area (Volt-seconds) = $\underline{(S_0 + S_1 + \ldots + S_n)}$ x (sample interval)
Cycle Area is the area under the curve, calculated by integrating the samples in the first cycle. The area measured above ground is positive. The area measured below ground is negative.

For the most current information visit our website at
tektronix.com/oscilloscopes