Introduction to the Digital Storage Oscilloscope[*]

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MECE 3320: Measurements & Instrumentation Lab Exercise

I.   Introduction

The 2532 Digital Storage Oscilloscope is a light-weight benchtop oscilloscope for viewing waveforms and taking measurements and also well suited for applications in service and repair.
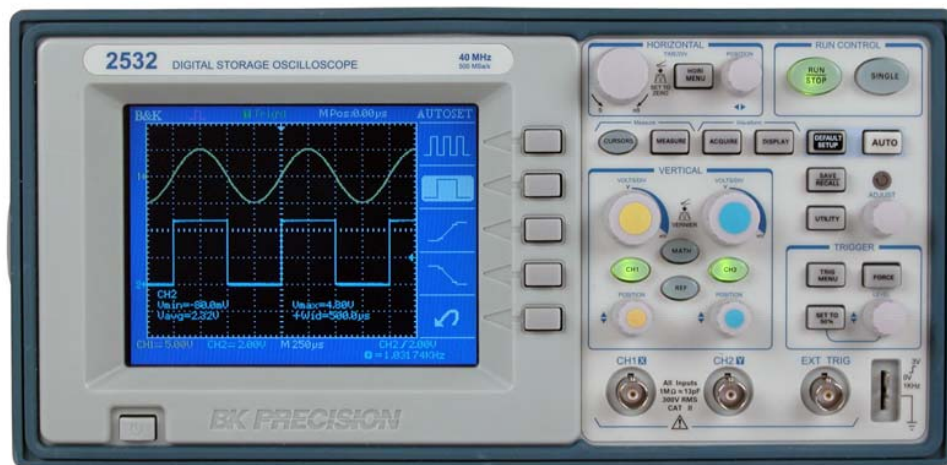

Figure 1. Model 2532 Digital Storage Oscilloscope.

The key features of this oscilloscope include:

⇨ 40 MHz bandwidth, 500MSa/s sample rate with color display

⇨ 4000 point record length for each channel

⇨ One touch automatic setup for ease of use (Auto)

⇨ Save/Recall setup and waveform data

⇨ Capture, save and analyze waveform data and measurement results with the included EasyScope Application Software

⇨ Cursors with readouts

⇨ Eleven automatic measurements

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[*]Reference: BK Precision 2532 Instruction Manual

⇨ Waveform averaging and peak detection

⇨ Math functions: +, -, / and operations

⇨ Fast Fourier Transformation (FFT)

⇨ Extensive Trigger capabilities: Pulse Width trigger, Video trigger capability with line-selectable triggering, External trigger

⇨ Variable persistence display

⇨ Built in trigger frequency counter

The oscilloscope is widely used to display the behavior of repetitive electrical signals. The oscilloscope samples an incoming analog signal and converts it into a digital signal using a built-in Analog-to-Digital (A2D) converter. The digital signal is then displayed on the Liquid Crystal Display (LCD) screen of the oscillosope. In general, on the display, the x-axis represents the time and the y-axis represents the voltage corresponding to the incoming signal.

II.   Overview and Procedures

The following subsections are designed to introduce the various features of the BK Precision 2532 oscilloscope. Please seek the TA's assistance if you require help in any these steps.

A.   Probe Compensation

Perform this adjustment to match your probe to the input channel. This should be done whenever you attach a probe to any input channel for the first time.
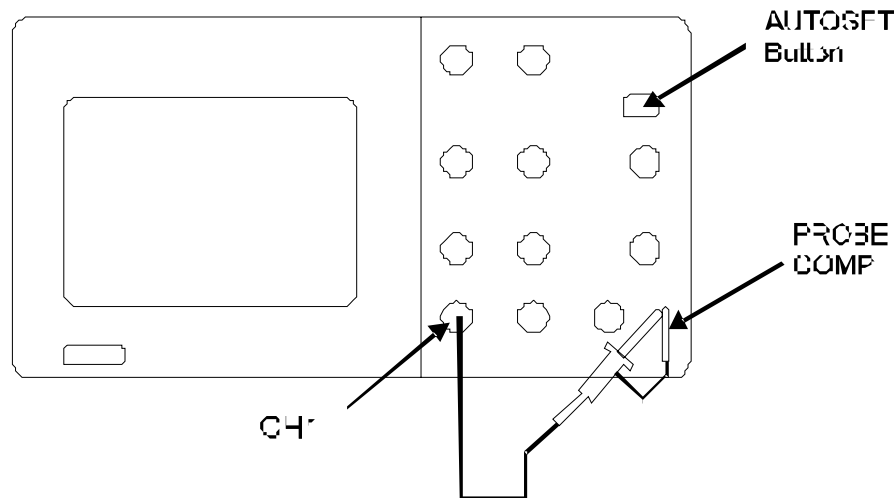
⇨ Set the Probe option attenuation in the channel menu to 10X. Set the switch to 10X on the probe and connect the probe to channel 1 on the oscilloscope. If you use the probe hook-tip, ensure a proper connection by firmly inserting the tip onto the probe.

⇨ Attach the probe tip to the PROBE COMP3V connector and the reference lead to the PROBE COMP Ground connector. Display the channel and then push theAUTOSET button.

⇨ Check the shape of the displayed waveform.

Over compensated   Correctly Compensated   Under compensated

⇨ If necessary, use a non-metallic tool to adjust the trimmer capacitor on the probe for to resemble the correctly compensated wave shape as much as possible. Repeat as necessary.

B.   Main Control Sections Overview

To use your oscilloscope effectively, you need to familiarize yourself with the following control sections. In performing these tasks, use the function generator to input a $500\,Hz$ sine wave signal.

⇨ Vertical System

⇨ Horizontal System

⇨ Trigger System

⇨ Acquisition System

⇨ Measurement System

C.   Vertical System

Each channel has a vertical control menu which appears after pressing the *CH1* or *CH2* button. The vertical controls are used to size and position the signals and to turn the waveform on or off. Below is a figure of the vertical system controls.

⇨ *Vertical POSITION knob*: Use the VERTICAL POSITION knobs to move waveforms up or down on the screen.

⇨ *Volts/Div knob*: Use the VOLTS/DIV knobs to control how the oscilloscope amplifies or attenuates the source signal. When you turn the VOLTS/DIV knob, the oscilloscope increases or decreases the vertical size of the waveform on the screen with respect to the ground level. Press the "Volt/div knob to toggle between "Coarse and "Fine adjustment of the Volt/Div setting.

⇨ *GND Coupling*: Use GND coupling to display a zero-volt waveform. Internally, the channel input is connected to a zero-volt reference level.

⇨ *Fine Resolution*: The vertical scale readout displays the actual Volts/Div setting while in the fine resolution setting. Changing the setting to coarse does not change the vertical scale until the VOLTS/DIV control is adjusted.

⇨ *Remove the Waveform from the display*: Push the CH1 or CH2 button to display the respective vertical menu. Push CH1 or CH2 button again to remove the waveform.

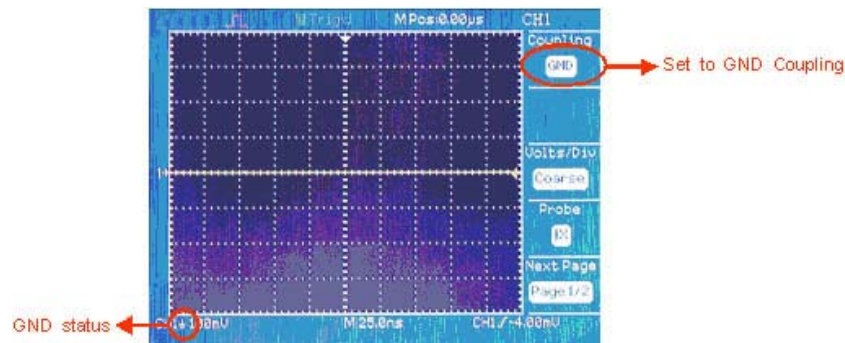⇨ *Setting up the coupling mode*: Apply a sine wave signal to CH1.

    ⇛ Press *CH1* → *Coupling* → *AC*. Set AC coupling mode. Now the DC component of the signal is blocked.
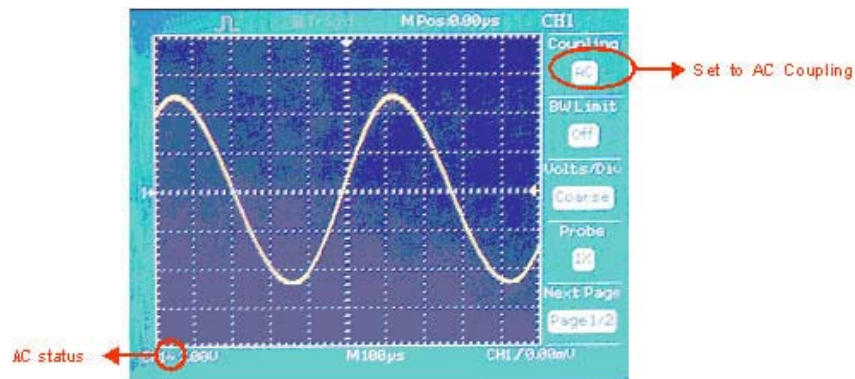
    ⇛ Press *CH1* → *Coupling* → *DC*. Set DC coupling mode. Both the AC and DC components of the signal will be passed on and displayed on the screen.
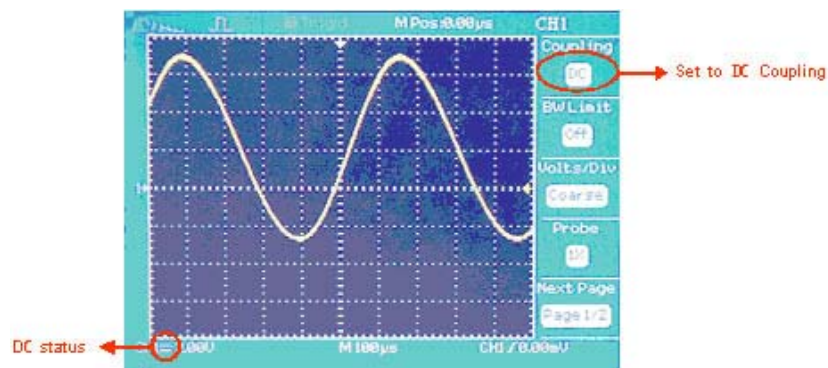

    ⇛ Press *CH1* → *Coupling* → *GND*. Select GROUND mode to disconnect the input signal.


⇨ *Volts/Div settings*: Vertical scaling can be adjusted in 2 modes, Coarse and Fine. The vertical sensitivity range is 2mV/div to 5V/div scale. Take CH1 for example.

    ⇛ Press *CH1* → *Volts/Div* → *Coarse*. This is the default setting of Volts/Divand it allows adjustment of the vertical scale in a 1-2-5-step sequence starting from 2mV/Div5mV/Div10mv/div up to 5V/Div.
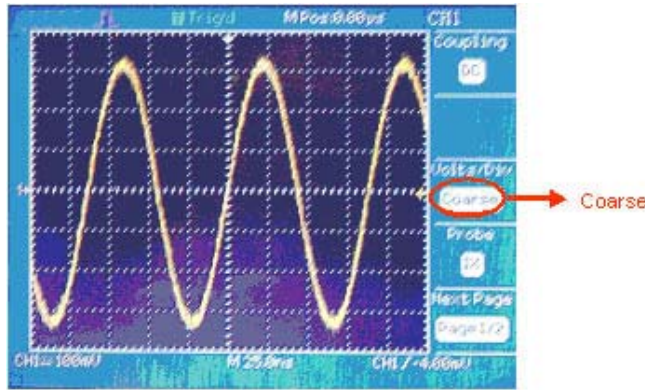
⇒ Press *CH1 → Volts/Div → Fine*. This setting changes the vertical scale to small steps between the coarse settings. It is useful when you need to adjust the vertical scale in small steps to set a specific value.
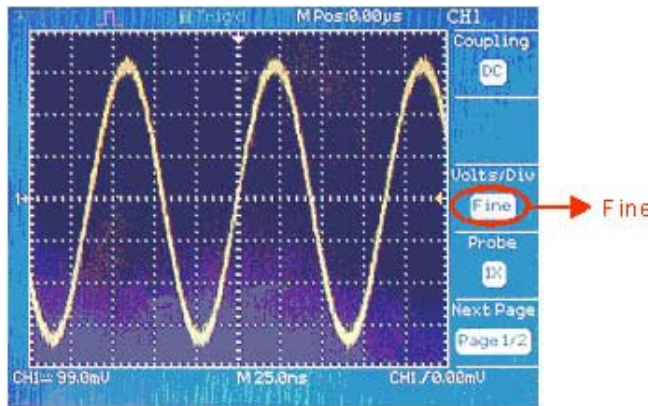

D. Horizontal System

In performing these tasks, use the function generator to input a $500\,Hz$ sine wave signal. The horizontal controls change the horizontal scale and position of waveforms. The horizontal center of the screen is the time reference for waveforms. Changing the horizontal scale causes the waveform to expand or contract around the screen center. The horizontal position knob changes the position of the trigger point relative to the center of the screen. The center axis of the vertical scale is GND level. The readout on the top right corner shows the horizontal position. "M" stands for main time base, "W" stands for window time base (Zoom function, horizontal menu). The arrow on the top center scale shows the vertical position.
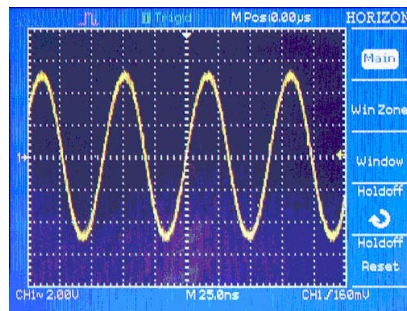
⇨ *Horizontal POSITION Knob*: Used to control the position of the trigger relative to the center of the screen. When the trigger point (downward arrow) moves outside the acquired waveform, (reaches the left or right edge of the screen) the instrument switches automatically to delayed sweep, indicated by the arrow pointing left or right instead of downwards. In delayed sweep mode, you can use the horizontal Time/Div knob to acquire more detail around the center of the screen.

⇨ *Time/Div Knob*: Used to change the horizontal time scale to magnify or compress the waveform. If waveform acquisition is stopped (using the RUN/STOP or SINGLE button), the SEC/DIV control expands or compresses the waveformPressing the Time/Div knob resets the horizontal position to zero. When the Time/DIV control is set to 100 ms/div or slower and the trigger mode is set to Auto, the oscilloscope enters the scan acquisition mode. In this mode, the waveform display updates from left to right. In this mode, trigger or horizontal position control of waveforms is disabled.
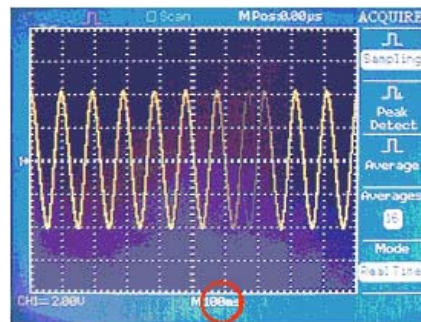

Time base set to
100ms/div

⇨ *Window Zone*: Define the zoom area of a waveform section. The Window time base setting cannot be set to a value slower than the main time base setting. Use the Window Zone option to define a segment of a waveform you want to see in greater detail. The Window time base setting cannot be set slower than the Main time base setting. Adjust the Horizontal Position and Time//Div controls to enlarge or minimize waveforms in the Window Zone.


Waveform needs
to be expanded

Waveform expanded after zoom
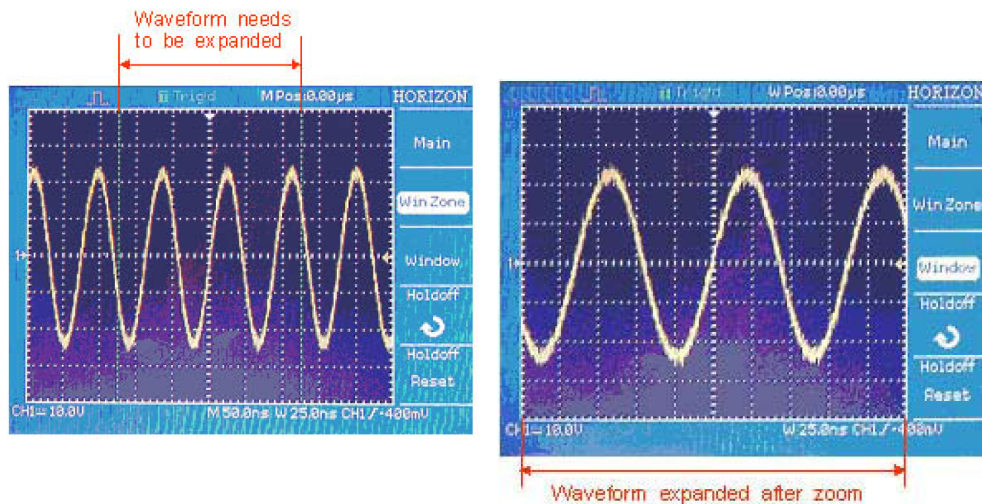
⇨ *Window*: Press to expand the zoom area to cover the whole screen.

⇨ *Holdoff*: You can use Holdoff to produce a stable display of complex waveforms. During the holdoff time the oscilloscope will not trigger until the holdoff time has expired. For a pulse train, you can adjust the holdoff time so the oscilloscope triggers only on the first pulse in the train. If you want to change the holdoff time, do the following: 1. Press the HORI MENU button to show the Horizontal Menu; 2. Press Holdoff; 3. Adjust the ADJUST knob to change the holdoff time until the waveforms triggers reliably.
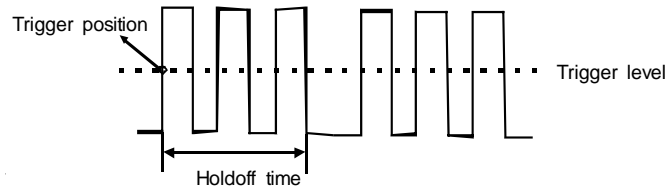

E.   Trigger System

The trigger determines when the oscilloscope starts to acquire data and display a waveform. The oscilloscope acquires data while waiting for the trigger condition to occur. After it detects a trigger, the oscilloscope continues to acquire enough data so that it can draw the waveform on the display. Below are the trigger section controls:
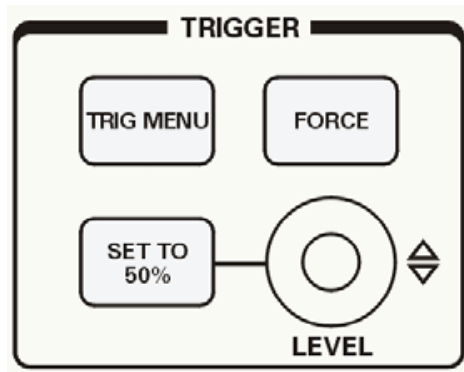
⇨ *LEVEL Knob*: Set the trigger level.

⇨ *SET TO 50% Button*: Use the SET TO 50% button to stabilize a waveform quickly. The oscilloscope automatically sets the Trigger Level about halfway between the minimum and maximum voltage levels. This is useful when you connect a signal to the EXT TRIG BNC and set the trigger source to Ext or Ext/5.

⇨ *FORCE Button*: Use the FORCE TRIG button to complete the current waveform acquisition regardless of whether or not the oscilloscope detects a trigger. This is useful for SINGLE acquisitions and Normal trigger mode.

⇨ *TRIG MENU Button*: Press the "TRIG MENU" Button to display the TRIG MENU.

⇒ *Signal Source*: You can use the Trigger Source options to select the signal that the oscilloscope uses as a trigger. The source can be any signal connected to the CH1 or CH2 connectors, the EXT TRIG connector or the AC power line.
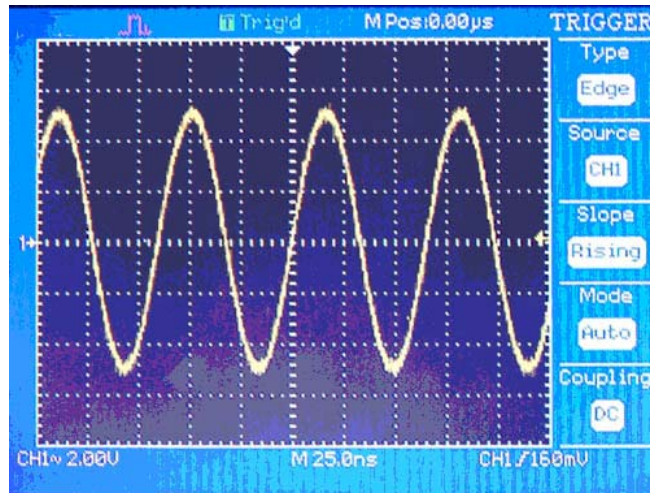
⇒ *Trigger Type*: The 2530 series supports three types of Trigger signalsEdgeVideo and Pulse Trigger. Edge trigger can be used with analog and digital circuits. An edge trigger occurs when the trigger input passes through a specified voltage level with the specified slope. Pulse trigger is used to find pulses with certain pulse widths. Video is used to trigger on fields or lines for standard video waveforms.

⇒ *Position*: The horizontal position control establishes the time between the trigger position and the screen center. You can adjust the HORIZONTAL POSITION control to view waveform data before the occurrence of the trigger, after the trigger, or any point in between. When you change the horizontal position of a waveform, you are changing the time between the trigger and the actual center of the display. (This appears to move the waveform to the right or left on the display.). Use a pretrigger setting to acquire waveforms leading up to a trigger event. Use a post trigger setting when you want to acquire waveforms that follow an event. When the trigger point (downward arrow) moves outside the acquired waveform, (reaches the left or right edge of the screen) the instrument switches automatically to delayed sweep, indicated by the arrow pointing left or right instead of downwards. In delayed sweep mode, you can use the horizontal time/Div knob to acquire more detail around the center of the screen.

⇒ *Slope & Level*: The Slope and Level controls help to define the trigger. The Slope option (Edge trigger type only) determines whether the oscilloscope finds the trigger point on the rising or the falling edge of a signal. The TRIGGER LEVEL knob controls where on the edge the trigger point occurs.
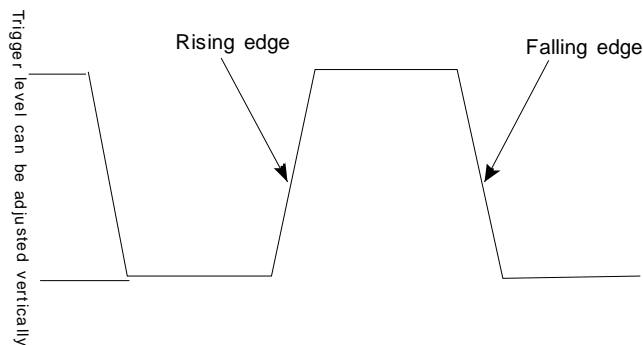
F.   Acquisition System

When you acquire a signal, the oscilloscope digitizes the signal and displays the resulting waveform on the screen. The acquisition mode defines how the signal is digitized, and the time base setting affects the time span and level of detail in the acquisition. The sampling rate adjusts automatically to a value suitable for each selected Time/Div scaling factor. Push the ACQUIRE button to access the Acquisition menu.

Acquire button
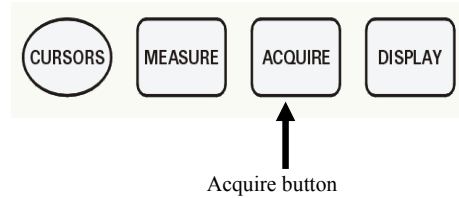
There are 3 acquisition modes: Sample, Peak Detect and Average.

⇨ *Sampling*: In this acquisition mode, the oscilloscope samples the signal in evenly spaced intervals to reconstruct the waveform. This mode accurately represents the signal most of the time. This mode does not capture rapid variations in the signal that may occur between samples. This can result in aliasing and may cause narrow pulses to be missed. In these cases, you should use the Peak Detect mode to acquire data.
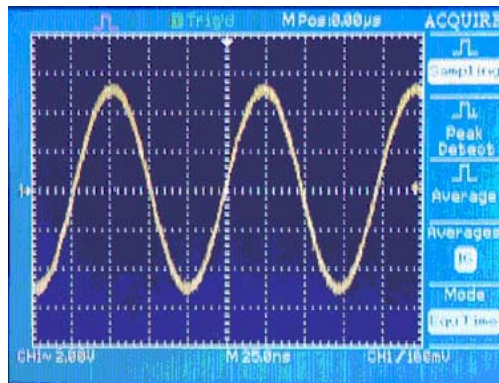
⇨ *Peak Detect*: Peak Detect finds the maximum and minimum values of a signal. In this way, the oscilloscope can acquire and display narrow pulses, which may have otherwise been missed in Sample mode. Noise will appear to be higher in this mode.
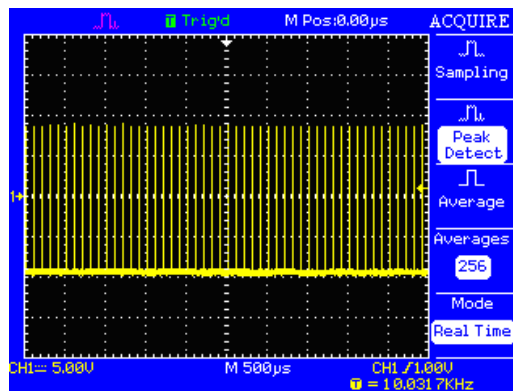
⇨ *Average*: The oscilloscope acquires several waveforms, averages them, and displays the resulting wave-form.
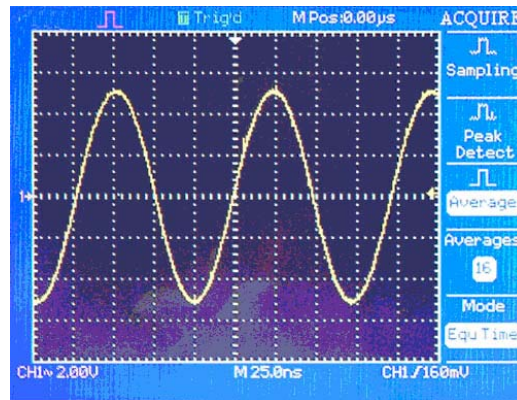
G. Measurement System

There are several ways to take measurements. You can use the graticule, the cursors, or make an automated measurement.

1. Graticule Measurement

This method allows you to make a quick, visual estimate. For example, you might look at a waveform amplitude and determine that it is a little more than 100 mV. You can take simple measurements by counting the major and minor graticule divisions involved and multiplying by the scale factor. For example, if you counted five major vertical graticule divisions between the minimum and maximum values of a waveform and knew you had a scale factor of 100 mV/division, then you could easily calculate your peak-to-peak voltage as follows: $5 \ divisions \times 100 \ mV/division = 500 \ mV$.

2. Cursor Measurement

This method allows you to take measurements by moving the cursors, which always appear in pairs, and reading their numeric values from the display readouts. Access the Cursor menu by pressing the Cursor button.

Menu	Setting	Comment
Type	Voltage Time Off	Select and display the measurement cursors. The horizontal cursor measures amplitude and the vertical cursor measures time and frequency.
Source	CH1 CH2 MATH REFA REFB	Select the wave form source to be measured by the cursors
Cur1 ↻		Activate Cursor 1. Use the ADJUST knob to adjust the cursor position
Cur2 ↻		Activate Cursor 2. Use the ADJUST knob to adjust the cursor position.

⇨ *Voltage Cursor*: Voltage cursors appear as horizontal lines on the display and measure the vertical parameters.

⇨ *Time Cursor*: Time cursors appear as vertical lines on the display and measure the horizontal parameters.

⇨ *Moving the Cursors*: Use the ADJUST knob to move cursor-1 and cursor-2. Cursors can be moved when the cursor menu is displayed.

3. Auto Measurement

When you take automatic measurements, the oscilloscope does all the calculating for you. Because this method relies on the digital samples of the waveform, this method is more accurate than graticule or cursor measurements. Press the *MEASURE* button. There are 11 types of measurements available. You can display up to five measurements at a time. To define each of the 5 measurements, do the following:

⇨ Press one of the five option buttons corresponding to measurement 1 5 . This will open a submenu.

⇨ Enter the Source of the measurement and the measurement type.

⇨ Press the bottom option button to turn the measurement on.

If you want to display all eleven measurements at once, select *All Mea* from the submenu.

III.   FFT Spectrum Analyzer

The FFT process mathematically converts a time-domain signal into its frequency components. You can use the Math FFT to analyze the following type of signals:

⇨ Characterize noise in DC Power supplies.

⇨ Test the impulse response of filters and systems.

⇨ Analyze vibration.

⇨ Analyze harmonics in power lines.

⇨ Measure harmonic content and distortion in a system.

FFT Option	Set	Introduction
Source	CH1 CH2	Select the channel to which you want to apply the FFT operation
Window	Hanning Hamming Rectangular Blackman	Select the FFT window type
FFT ZOOM	1X 2X 5X 10X	Changes the horizontal magnification of the FFT display
Scale	Vrms dBVrms	Set Vrms to be the Vertical Scale unit Set dBVrms to be the vertical Scale unit
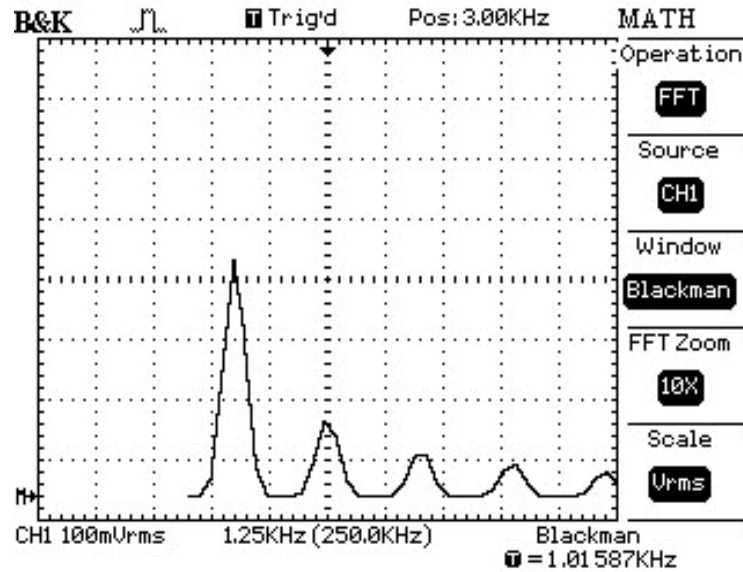
In this example the position at the center graticule is $3kHz$ (Pos: $3.00kHz$), the frequency of the second harmonic. The vertical scale is set to $100mV_{rms}/Div$ and the horizontal scale is set to $12.5kHz$ ($1.25kHz$ × 10 zoom factor). The window type is Blackman. To use the Math FFT mode, you need to perform the following tasks:

⇨ Set up the source YT (time-domain) waveform.

  ⇛ Press AUTOSET to display a YT waveform.

  ⇛ Turn the VERTICAL POSITION knob to move the YT waveform to the center vertically (zero divisions).

  ⇛ Turn the HORIZONTAL POSITION knob to position the part of the YT waveform that you want to analyze in the center eight divisions of the screen. The oscilloscope calculates the FFT spectrum using the center 1024 points of the time-domain waveform.

  ⇛ Turn the VOLTS/DIV knob to ensure that the entire waveform remains on the screen.

  ⇛ Turn the Time/DIV knob to provide the resolution you want in the FFT spectrum.

  ⇛ If possible, set the oscilloscope to display many signal cycles. To set up the FFT display, follow these steps:

    ∗ Push the MATH MENU button.
    ∗ Set the Operation option to FFT.
    ∗ Select the Math FFT Source channel.

⇨ Displaying the FFT Spectrum.

  ⇛ Press the MATH MENU button to display the Math Menu. Use the options to select the Source channel, Window algorithm, and FFT Zoom factor. You can display only one FFT spectrum at a time.

⇨ Select an FFT window.

  ⇛ Windows reduce spectral leakage in the FFT spectrum. The FFT assumes that the YT waveform repeats forever. With an integral number of cycles the YT waveform starts and ends at the same

amplitude and there are no discontinuities in the signal shape A non-integral number of cycles in the YT waveform causes the signal start and end points to be at different amplitudes. The transitions between the start and end points cause discontinuities in the signal that introduce high-frequency transients. There are 4 FFT windows. Each window has trade-offs between frequency resolution and amplitude accuracy. Your source waveform characteristics along with your measurement priorities help determine which window to use. Use the following guidelines to select the best window.

Window	Characteristics	Application/ Measurement
Rectangular	Best frequency resolution, worst magnitude resolution. This is essentially the same as no window.	Symmetric transients or bursts. Equal-amplitude sine waves with fixed frequencies. Broadband random noise with a relatively slowly varying spectrum.
Hanning/ Hamming	Better frequency, poorer magnitude accuracy than Rectangular. Hamming has slightly better frequency resolution than Hanning.	Sine, periodic, and narrow-band random noise. Asymmetric transients or bursts.
Blackman	Best magnitude, worst frequency resolution.	Single frequency waveforms, to find higher order harmonics.

⇨ Magnifying and Positioning an FFT Spectrum.

⇛ You can magnify and use cursors to take measurements on the FFT spectrum. The oscilloscope includes an FFT Zoom option to magnify horizontally. To magnify vertically, you can use the vertical controls.

⇨ Measuring an FFT Spectrum Using Cursors.

⇛ You can take two types of measurements on FFT spectrums: magnitude (in dB) and frequency (in Hz). Magnitude is referenced to 0 dB, where 0 dB equals 1 $Vrms$. You can use the cursors to take measurements at any zoom factor. Use horizontal cursors to measure magnitude and vertical cursors to measure frequency. Make sure to select the MATH as source in the cursor menu. The options display the delta between the two cursors, the value at cursor 1 position, and the value at cursor position. Delta is the absolute value of cursor-1 minus cursor-2.

Some Important Notes about FFT:

⇨ The FFT of a waveform that has a DC component or offset can cause incorrect FFT waveform magnitude values. To minimize the DC component, choose AC Coupling on the source waveform.

⇨ To display FFT waveforms with a large dynamic range, use the dBVrms scale. The dBVrms scale displays component magnitudes using a log scale.

⇨ The Nyquist frequency is the highest frequency that any real-time digitizing oscilloscope can acquire without aliasing. This frequency is half that of the sample rate, provided it is within the analog bandwidth of the oscilloscope. Frequencies above the Nyquist frequency will be under sampled, which causes aliasing.