

ECE 3300
Electrical Circuits: Laboratory
Experiment 1 Pre-Reading
The Oscilloscope

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This Unit, and its associated experiment, introduces the student to the Rigol [MSO1104 oscilloscope](#) and its basic operation. The material presented here also applies to other Rigol MSO/DS Series oscilloscopes (e.g., the Rigol MSO1074 and Rigol DS1074 oscilloscopes).

Learning Objectives

By the end of this unit, the student should have an understanding of the use of the oscilloscope (scope) as a tool to display and measure acquired voltage waveforms. More specifically, the student should:

- Know how to reset the scope to its default factory settings.
- Identify the function of various knobs and keys on the scope's front panel.
- Have a working knowledge of the various menus and their associated softkeys.
- Interpret the scope's display.
- Be able to properly connect the scope's test probe to a circuit.
- Understand the connection between a circuit ground node and that of the scope.
- Determine the attenuation factor of the test probe.
- Be able to calibrate the test scope.
- Be able to set the scope to the probe's attenuation factor.
- Be able to adjust the scope settings to properly display an acquired voltage signal.
- Understand the concept of triggering and how it affects the stability of the displayed waveform of an acquired signal.
- Be able to use the scope to automatically measure the various attributes of a signal, including: amplitude, frequency, period, maximum, minimum, peak-to-peak, average, RMS, rise time, fall time and duty cycle.

- Be able to use the scope's cursor system to measure a signal's amplitude, peak-to-peak, frequency, period, maximum, and minimum.
- Be able to apply math functions on acquired signals.
- Be able to configure the scope for the XY operation mode.
- Be able to save the display to a file on the floppy disk.

Introduction

An **oscilloscope** (or **scope**) is an electronic test instrument that allows a voltage signal to be viewed as a two-dimensional graph of voltage amplitude (vertical axis) plotted as a function of time (horizontal axis).

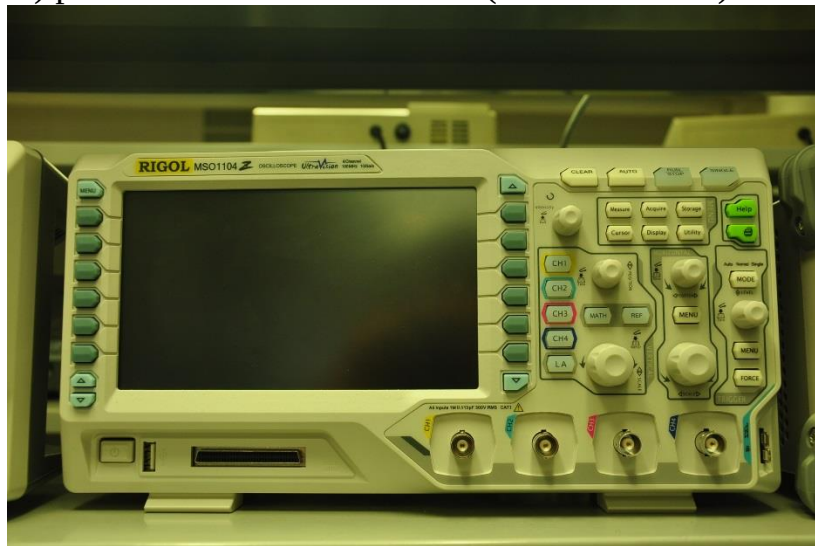


Figure 1 Four-Channel Oscilloscope (RIGOL MSO1104)

The Rigol MSO1104 scope (Figure 1) is a 4-channel digital technology scope. It allows the user to display up to 4 voltage signals, simultaneously. In addition to measuring the amplitude of a signal, this scope can (automatically) measure many attributes of a given signal including frequency, period, peak-to-peak, maximum, minimum, rise-time, fall-time, duty-cycle, root-mean-square (RMS) value and average (refer to the [unit on signal basics](#) for definitions).

The basic front panel control keys/buttons are shown in Figures 2 and Table 1. The Rigol MSO1104 scope is capable of saving the displayed plots and signal measurement value to current workstation or a flash drive. The flash drive can be loaded from the front panel of the scope, located beside the Power Switch button. The Rigol MSO1104 scope has physical knobs and “**softkeys**.”

Each soft key, when pressed, performs the corresponding operation. Refer to Figure 2 and Table 1 for each **softkeys** function.

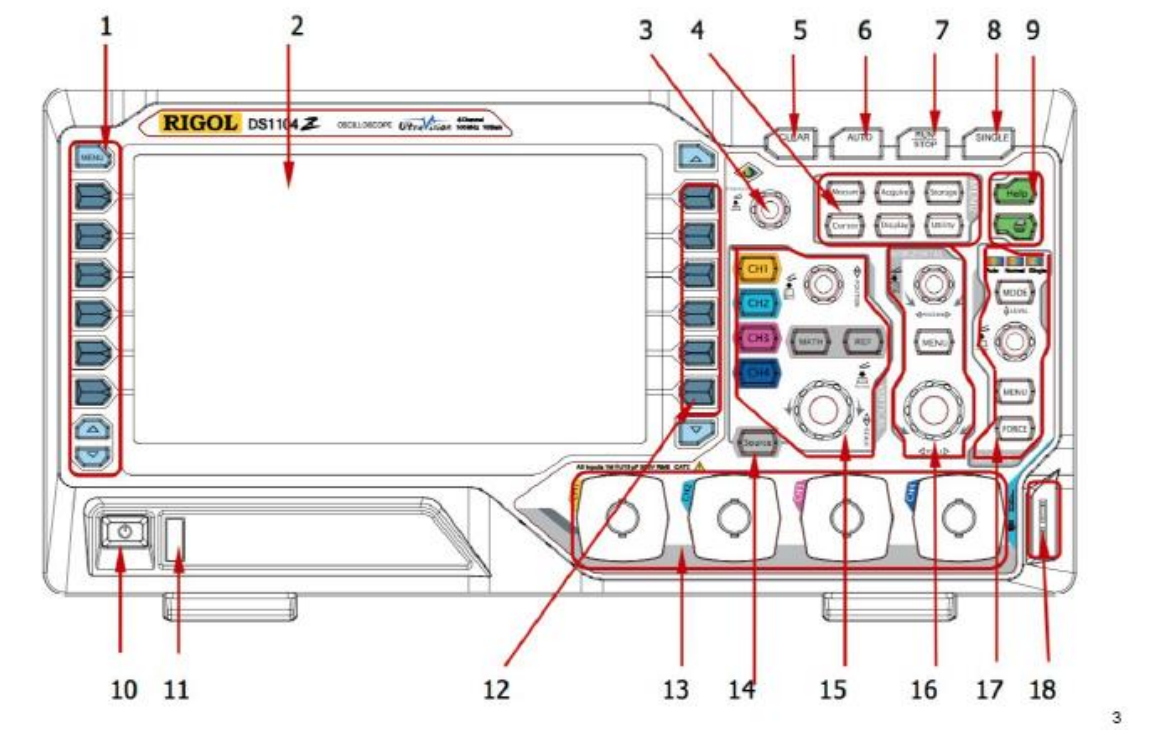


Figure 2 Basic front panel control keys/buttons

1 – Measurement Menu Softkeys	10 – Power switch
2 – LCD Display	11 – USB Host (USB drive, Power)
3 – Multifunction Knob	12 – Function Menu Softkeys
4 – Function Selection Keys	13 – Analog input channels (1-4)
5 – CLEAR button	14 – Function Generator Menu
6 – Auto button	15 – Vertical Controls / Channel Controls
7 – RUN/STOP button	16 – Horizontal Controls
8 – SINGLE button	17 – Trigger Controls
9 – Help & Print	18 – Probe compensation port

Table 1 Front panel descrption

Connecting a Voltage Signal

The Rigol MSO1104 scope has 4 input channels. It can accept up to four voltage signals for display and measurement. The input signal is connected to the scope through a (female) BNC connector (named after its “bayonet mount” locking mechanism and its two inventors; refer to Figure 3). The outer shield of the scope’s BNC connector is grounded to the metal enclosure of the instrument and to the ground of the electrical installation in the building. **A**

voltage to be measured must then be connected between the inner conductor of the BNC connector and the outer, grounded BNC shield.



Figure 3 A Scope's input BNC connector.

Each scope input channel has an input resistance of $1\text{M}\Omega$, in parallel with an input capacitance of about 13 pF . Let us assume that the scope receives its input directly from a function generator source. Then, we say that the source “sees” the scope as a parallel RC load.

For low frequency signals, one could use an adapter (BNC male to dual binding post adaptor; refer to Figure 4) which would allow for two separate wires to connect the signal source to the scope. However, with such a connection scheme, the two wires might act as antennas which would pick up interference from a radio station or other source of radio frequency.

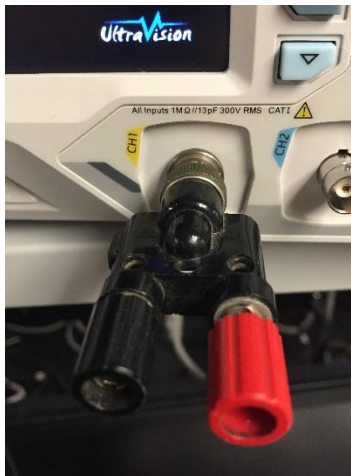


Figure 4 BNC male to dual binding post adaptor.

In order to protect the input to the scope from external interferences and unwanted high-frequency transient effects, a special test probe is used (refer to Figure 6). The cable of the probe is coaxial. It consists of an inner conductor that is shielded by an outer conductor. The outer shield connects to the ground of the scope and shields the inner conductor signal from external interference.

The test probe has a simple passive RC circuit that can be tuned in order to calibrate the probe to reduce the scope's own RC loading effects on the circuit being tested.

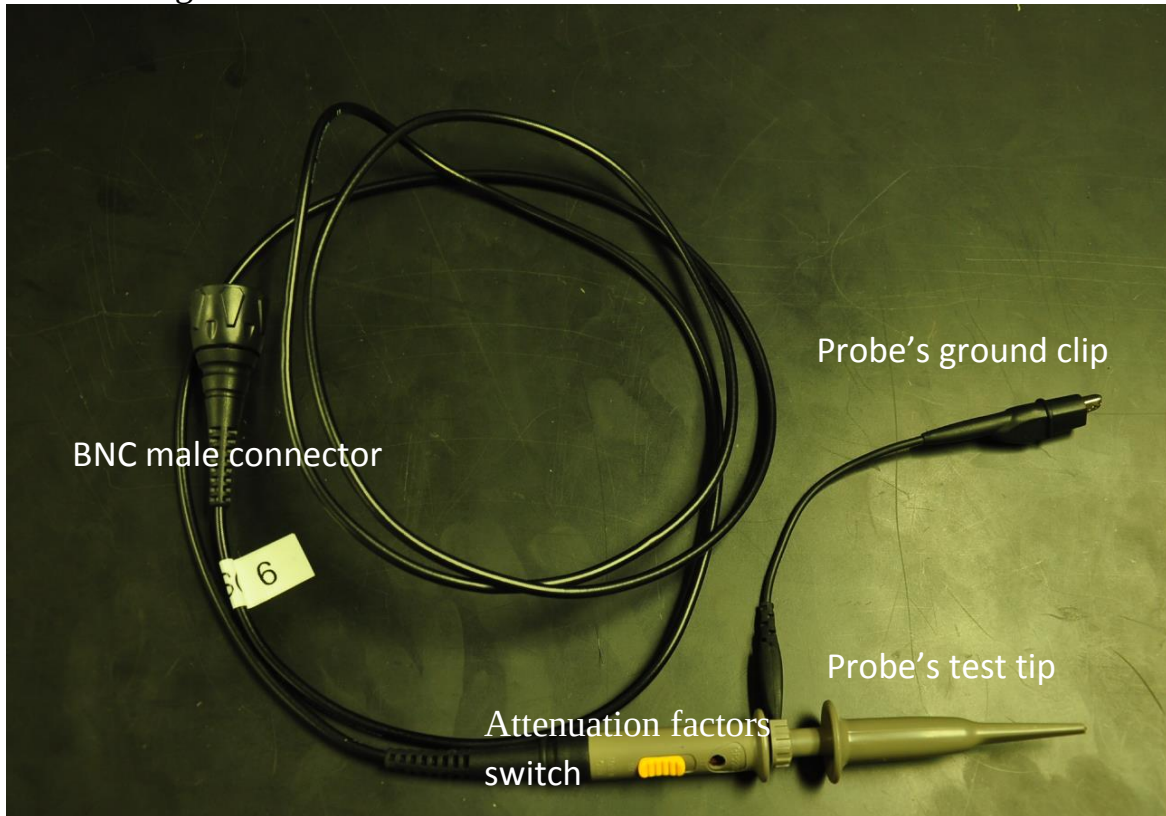


Figure 5 RIGOL MSO1104 10x / 1x (10:1/1:1) test probe.

Most test probes are designed for 1x (or 1:1) and 10x (or 10:1) attenuation factors. The test probes in the lab have 10x attenuation. For Auto-probes (e.g., RIGOL MSO1104 passive probe), the RIGOL MSO1104 scope can detect the probe's attenuation constant and automatically scales the acquired waveform amplitude to undo the attenuation. For other, more basic probes, the user would have to set the attenuation factor manually, using the **Intensity** knob. When the user selects a particular input channel, by pressing particular channel select key, a sub menu is displayed under "**Probe**" catalog, refer to figure 6. The user can adjust the attenuation factor, to match that of the probe, using the **Intensity** knob.

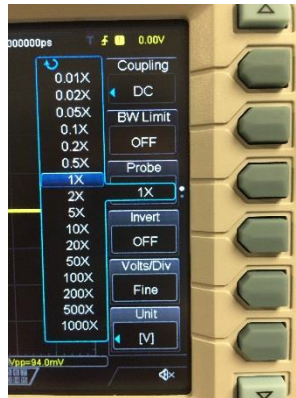


Figure 6 Attenuation factor adjustment

The alligator clip (ground connector) of the probe **must** be connected to the **ground node of the circuit being tested**; normally the ground node is the negative terminal of the input source (e.g., function generator's negative terminal). Figure 7 depicts two probe placements for measuring voltage in a simple circuit. The figure on the right shows the correct connection of the probe. On the other hand, the connection in the figure on the left should not be attempted; it shorts the second component by connecting both of its terminals to the ground node. The voltage signal across component 1 can be measured by the scope as the difference between the source signal and component 2 voltage signal. Refer to the section on Math Functions below to find out how the scope can display the difference between two input signals.

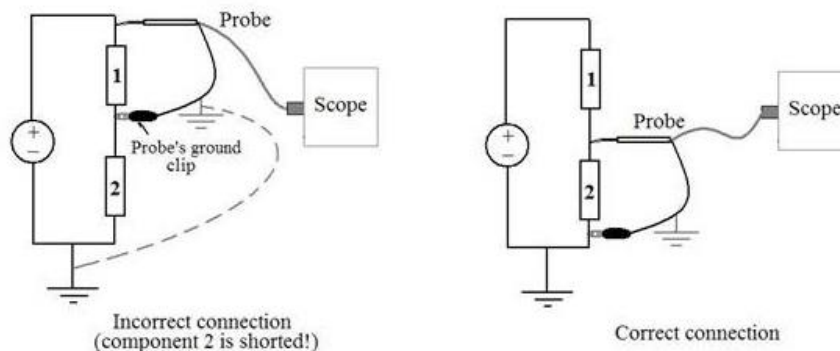


Figure 7 Connecting the test probe to measure a node's voltage.

Interpreting the Display

The oscilloscope display (a sample display is depicted in Figure 8) contains displayed waveforms, setup information, measurement results, and other info.

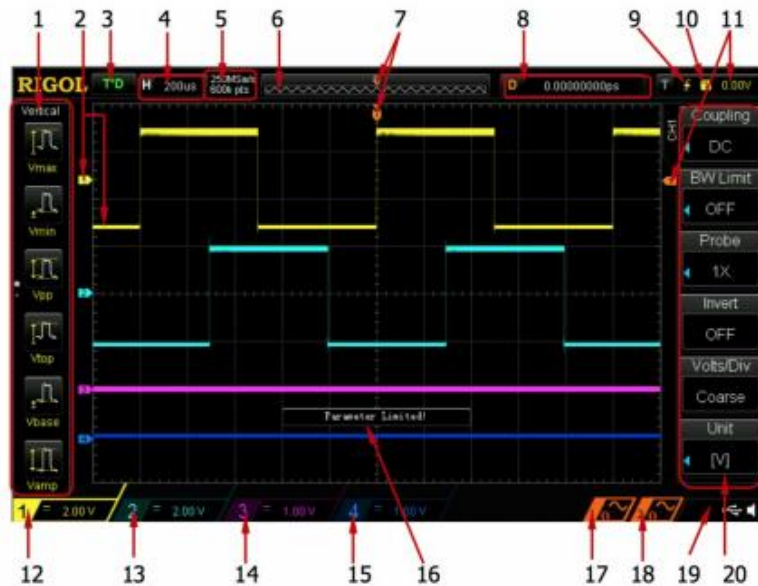


Figure 8 The oscilloscope display

1 – Auto Measurement Items	11 – Trigger Level
2 – Channel Label/Waveform	12 – CH1 Vertical Scale
3 – Operational Mode	13 – CH2 Vertical Scale
4 – Horizontal Time Base	14 – CH3 Vertical Scale
5 – Sample Rate / Memory Depth	15 – CH4 Vertical Scale
6 – Waveform Memory	16 – Message Box
7 – Trigger Position	17 – Source 1 waveform
8 – Horizontal Position	18 – Source 2 waveform
9 – Trigger Type	19 – Notification Area
10 – Trigger Source	20 – Operation Menu

Table 2 The oscilloscope display description

Triggering

Triggering must be used by the scope in order to display a stationary periodic signal. Without triggering, multiple traces of the waveform are drawn in different places, giving a drifting image on the display. Thus, triggering allows the scope to synchronize the trace of a periodic waveform on the display by always plotting complete signal cycles with respect to a predefined time reference point on the display.

The triggering system on the RIGOL MSO1104 scope is fairly complicated. In this laboratory course, we need not worry about all available triggering modes and their configurations. In fact, after the **Auto** key is pressed, the RIGOL MSO1104 scope adopts an **Auto, edge** triggered mode. Here, one of the input channel signals is chosen as the **trigger source**. Then, the trigger occurs on a **rising slope** and at a specific signal voltage level (**trigger level**). For example the square waveform shown in Figure 8 is triggered by a zero Volt trigger level and a rising edge on channel 1. This information is displayed on the right hand side of the status line at the top of the display.

Note: In some cases, the user may adjust the DC bias of the signal on the channel that serves as the trigger source. This may cause the trigger level to go beyond the triggering signal voltage range. Here, the signal trace becomes unstable on the display; it will look like a mixture of several sinusoids. To fix this problem, the user may press the **Scale** key to automatically reset the trigger level. Alternatively, the **Trigger Level** knob (refer to Figure 9) can be manually operated to readjust the trigger level.



Figure 9 Trigger adjustment knob

Saving the Display to USB drive

The Rigol oscilloscope supports saving a screenshot as a PNG image file onto a USB drive. The drive must be formatted as FAT32, must be less than 8GB, and must be plugged into the front USB port before turning the unit on.

Pressing the print button () will capture the screen

Math Functions

The RIGOL MSO1104 scope allows the user to apply math functions on selected input waveforms. For example, the scope can subtract or multiply the two signals acquired on channels 1 and 2, and display the resulting waveform. Also, the scope can integrate or differentiate the signal acquired on any input channel, or the signal resulting from applying math functions. Figure 10 shows a square signal and its integral.



Figure 10 Integral of a Square function

The **Math** functions softkeys and its **Settings** appear at the left side of the display, after the **Math** key is pressed. Press the **operation** to ON to display settings applicable to the selected math function (e.g., to change the vertical scaling). The scope automatically scales math functions for optimum vertical scale and offset.

Making Automatic Measurements

The scope can make automatic measurements on any input channel or any running math function. Those measurements include amplitude, frequency, period, maximum, minimum, peak-to-peak, average, RMS, rise time, fall time and duty cycle; refer to the scope's manual, pp. 5-36 to 5-44, or the [unit on signal basics](#) for definitions of those measurements. To make automatic measurements, press the **Measure** key (see Figure 11 for key location) to display the automatic measurement.



Figure 11 A section of the front panel showing the Measure key.

Press the **Source** softkey to select the channel or running math function on which measurements will be made. Press the one item of the left side menu and display a particular signal measurement. In Figure 12, **Measure** was used

to display frequency, period and Max voltage for the displayed square waveform.

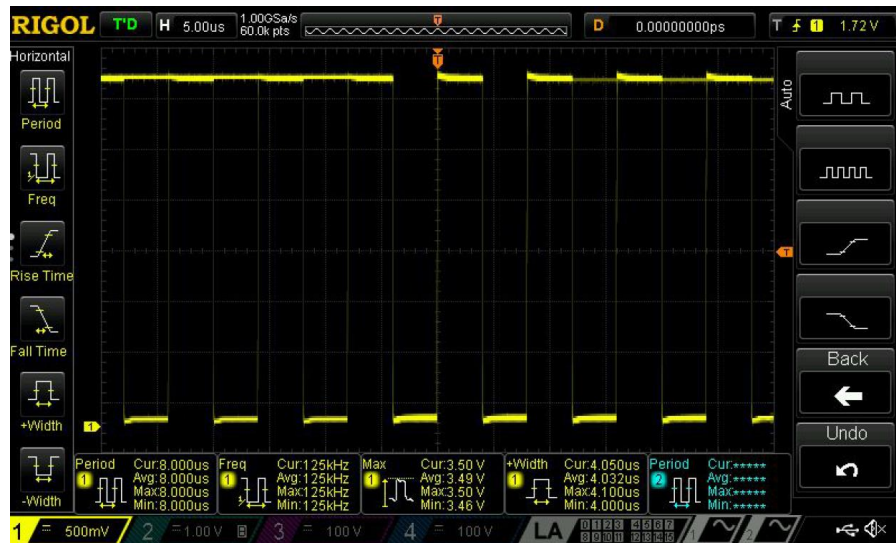


Figure 12 Auto measurement display

The scope is capable of averaging the acquired signal, over multiple cycles (triggers), to reduce signal noise. This allows the displayed waveform to look sharp. This allows the user to perform more accurate automatic (**Measure**) and cursor-based measurements. Averaging is applied by pressing the **Acquire** key and Select '**average**' in '**mode**' function. Refer to Fig 13. The number of triggers being averaged is displayed in the # **Avgs** softkey. The number in # **Avgs** can be adjusted by turning the **Intensity** knob. Values can be set in increments of powers of 2 (e.g., 2, 4, 8, 16, 32, 64, and so on). 2 is the default value for # **Avgs**. The higher # **Avgs** is, the more noise is removed from the acquired signal. On the other hand, increasing # **Avgs** causes slower response of the displayed waveform to signal changes. In most cases, setting # **Avgs** to 8 is a good compromise. Signal averaging is reset (to no averaging) upon pressing the **Auto** key.

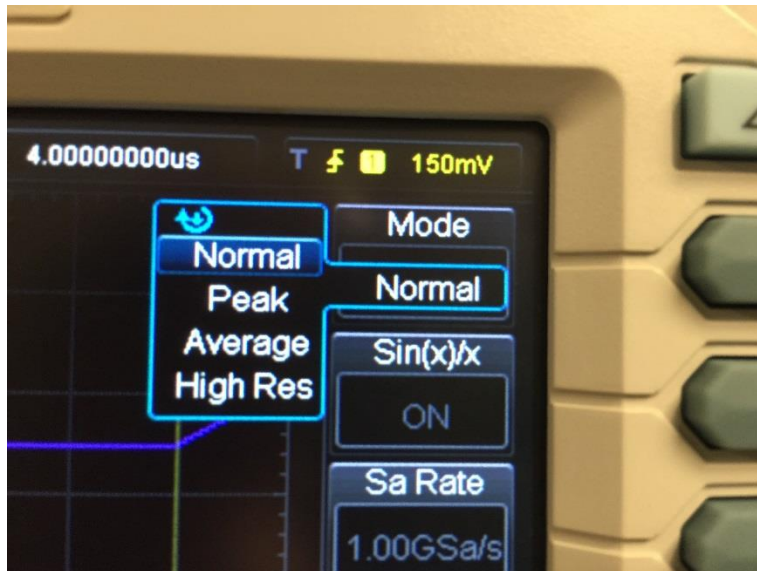


Figure 13 Average mode

Cursor Measurements

The scope has a pair of horizontal sliding cursors and a pair of vertical sliding cursors. The horizontal cursors are used to reference time. The vertical cursors are used to reference voltage. As the cursors move, the scope displays their numerical values in the Measurement Line of the display. The difference between the horizontal cursor pair can also be displayed (similarly for the vertical cursor pairs). The cursors can be activated by pressing the **Cursor** key and can be controlled using the **Intensity** knob (refer to Figure 14), and its menu refer to figure 15



Figure 14 . The Intensity knob and the Cursor key.

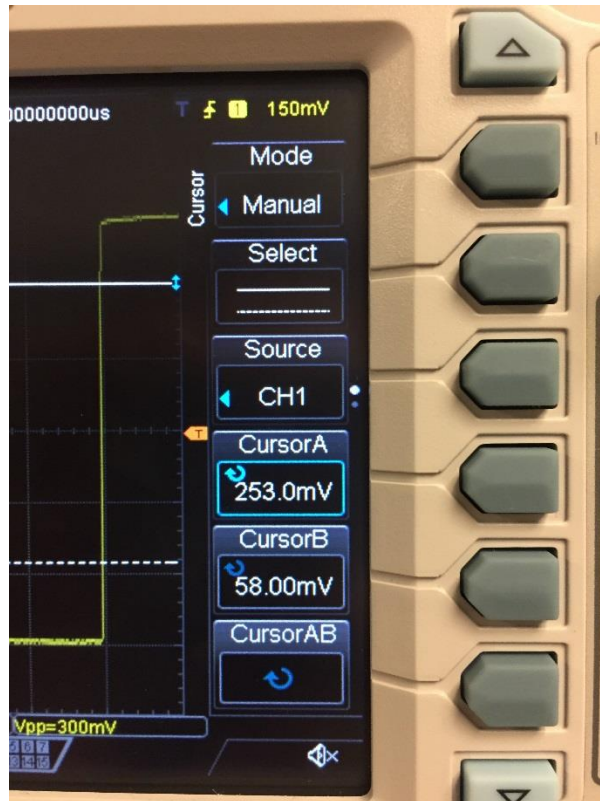


Figure 15 Cursor measurement menu

The following is a brief procedure for making cursor measurements:

1. Connect a signal to one of the scope's input channels and press the **Auto** key.
2. Press the **Cursor** key. This will activate the cursor functions \
3. Press the **Mode** softkey to select **Normal** (this allows voltage and time cursor-based measurements)
4. Press the **Source** softkey to select a channel or math function for the cursor measurement.
5. Switching **Horizontal line (X axis) mode** and **Vertical line (Y axis) mode** by pressing 2nd softkey.
6. When in **Horizontal (X axis)** mode. Press the **Cursor A** softkey to select the X1 cursor and adjust its position using the **Intensity** knob. Similarly, press the **Cursor B** softkey to select the X2 cursor for adjustment.
7. When in **Vertical (X axis)** mode Press the **Cursor A** softkey to select the Y1 cursor and adjust its position using the **Intensity** knob. Similarly, press the **Cursor B** softkey to select the Y2 cursor for adjustment.

8. Pressing the **Cursor AB** softkey allows the X1/X2 cursor pair to move together (similarly for the Y1/Y2 cursor pair).

XY Mode of Operation

In the XY mode, the scope can be used to plot one varying voltage waveform against another. In other words, the XY mode converts the scope from a volts-versus-time display to a volts-versus-volts display using two input channels (Channel 1 is the X-axis input and Channel 2 is the Y-axis input). This scope mode is especially useful for graphing V-I (voltage-versus-current) characteristic curves for components such as resistors and diodes, as well as phase shift between signals utilizing the Lissajous patterns. As it relates to electrical engineering, the [Lissajous patterns](#) [after the French mathematician Jules Antoine Lissajous (1822-1880)] are two-dimensional plots of one sinusoidal signal against another. For sinusoids of equal frequencies, the patterns allow the measurement of the phase difference. The **XY** mode is invoked by pressing the **Menu** in horizontal section, and choose **XY** in time base function. Refer to figure 16



Figure 16 The XY mode