Tutorial

Keysight™ MSO X 3012A Digital Channels

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This document is intended for instructional purposes at the Electrical Engineering and Computer Science Department of the University of Toledo.

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Keysight Mixed-Signal Oscilloscope (MSO) – Model X3012A

This document presents a tutorial on using the digital channels of the Keysight X 3012A Mixed Signal Oscilloscope (MSO). The front view of the MSO is presented in Figure 1. The X 3012A is shown in Figure 1 with a single channel of analog information on the upper half of the display and several channels of digital information on the lower half of the display.

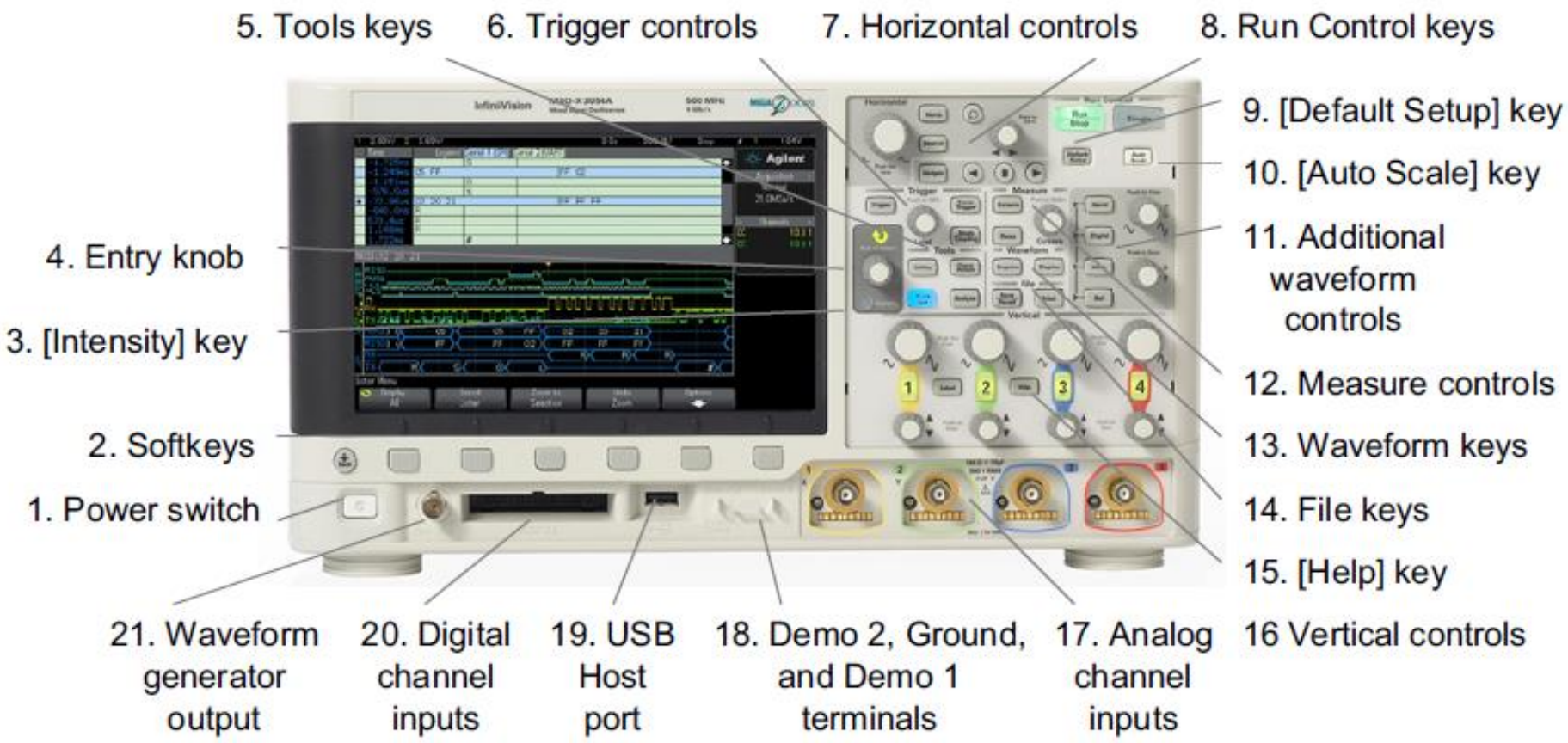


Figure 1. Front view of Keysight X3012A Mixed Signal O'scope

Overview

This tutorial aims to cover several introductory areas of digital logic signal observation and analysis. At the completion of this tutorial, you should know how to trigger on a digital signal, probe digital signals (logic levels, frequency and period), adjust a signal display attributes to be meaningful, enter or edit digital input labels, and transfer waveform data to the Keysight BenchVue utility (which is available in Embedded Systems lab) running on a PC for follow-up analysis and processing.

Safety Considerations

CAUTION ⚠ Do not float the oscilloscope chassis

Defeating the ground connection and "floating" the oscilloscope chassis will probably result in inaccurate measurements and may also cause equipment damage. The probe ground lead is connected to the oscilloscope chassis and the ground wire in the power cord. If you need to measure between two live points, use a differential probe with sufficient dynamic range.

WARNING **Always use a grounded power cord. Do not defeat the power cord ground.**

Tutorial

Let's start the tutorial by performing the steps in the order given.

- Boot the PC at your station if it is not already on with Windows already booted.
- Turn on the X 3012A by pressing the power button near the lower left corner of the display. The button should remain in the depressed position. To turn the oscilloscope off press the button a second time and the button should stay in the non-depressed position. Press the button a third time to turn on the oscilloscope. As the oscilloscope warms up and the built-in computer self-tests the system, a booting screen as shown in Figure 2 appears with the word Keysight (among other things).

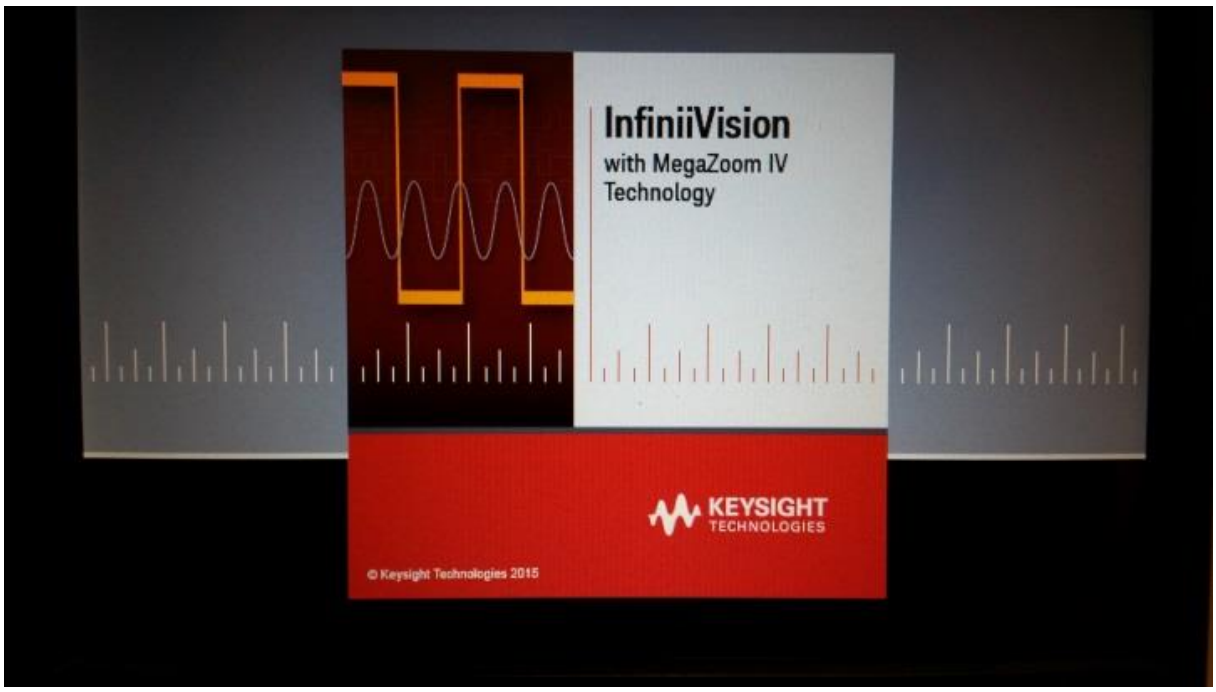


Figure 2. MSO Boot Screen

- Figure 3 illustrates the main parameters and adjustments for analysis of logic signals on digital channels on the Keysight X 3012A MSO. The softkeys as shown on the screen image can be accessed by pressing the *Digital* button on the oscilloscope interface.

Interpreting the Digital Waveform Display

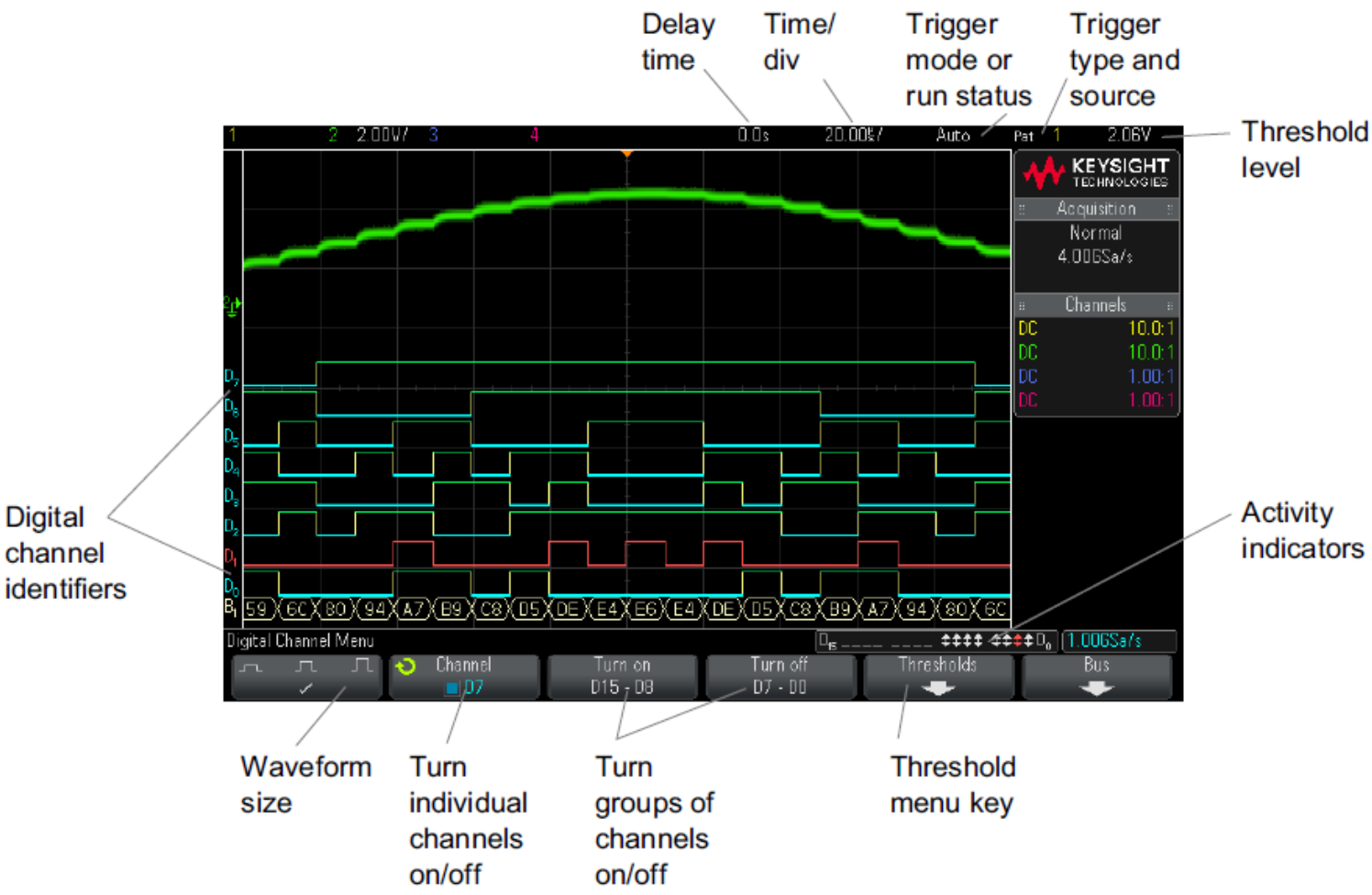


Figure 3. Typical Display with Digital Channels

- Locate the digital probes that should already be attached to the oscilloscope. If not attach them as shown in Figure 4.

Figure 4. Digital Probe Connection to MSO

- The probes look similar to those shown in Figure 5. The MSO has two logic analyzer probes, one for digital inputs zero through seven and the other for eight through sixteen. Both logic analyzer probes are shown below in Figure 6. This tutorial will utilize five of the 16 digital inputs, which will be referred to as D0, D1, D2, D3 and D4 for channels 0, 1, 2, 3, and 4, respectively.

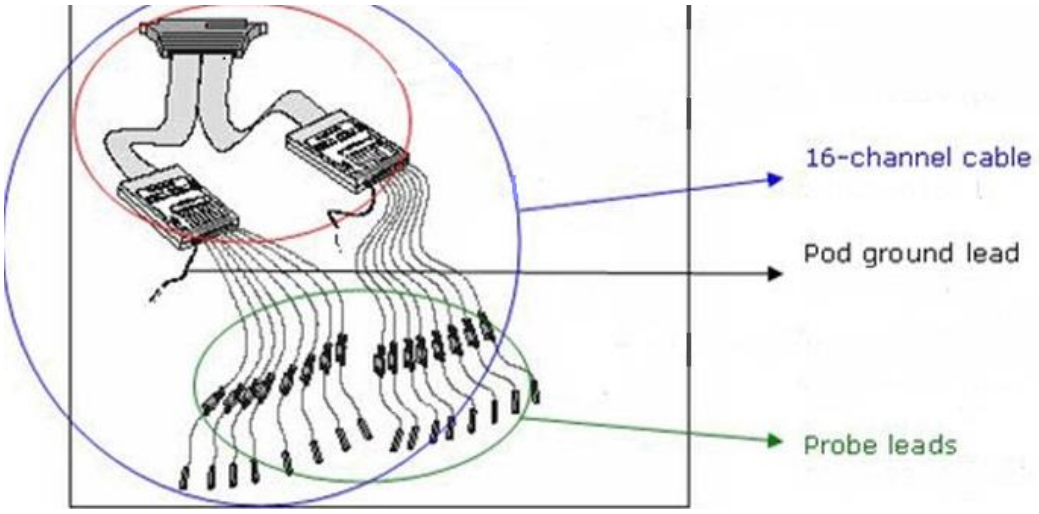


Figure 5. Logic Analyzer Probes

- Figure 6 illustrates both analog and digital channels displayed together on the Keysight X 3012A MSO screen. The analog channels are displayed at the top of the screen while the digital channels are displayed below them. It should become clear upon viewing Figure 7 what the differences between analog and digital channels are.

Digital Channels Shown with Analog Channels

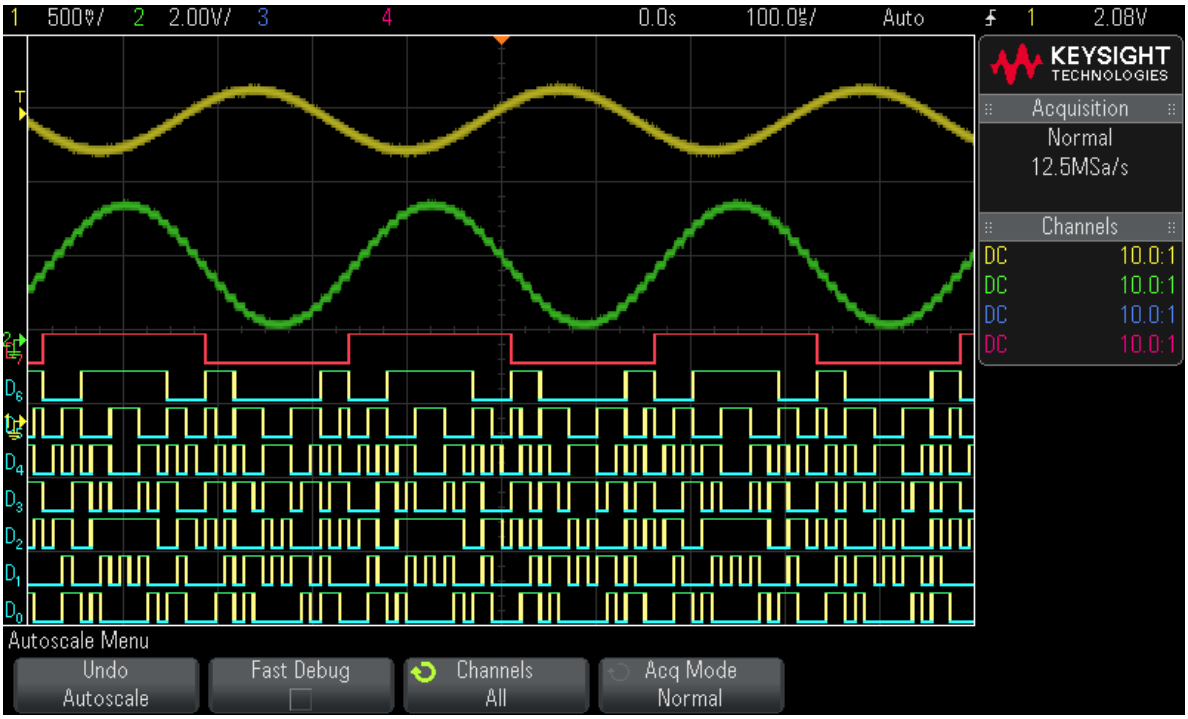


Figure 6. Analog and Digital Waveforms

Configuring Digital Channels

A logic analyzer is essentially a multiple channel digital storage scope with many ways to trigger as a troubleshooting aid; it allows the experimenter to observe numerous digital signals at various points in time and thus make decisions based upon such observations.

We will use the logic analyzer (digital input channels of the MSO) to observe of the output signals from ports PF2, PF3 and PF4 of the Tiva Launchpad as configured for Lab Project 1. Figure 7 shows Switch and LED interfaces on the Tiva LaunchPad evaluation board.

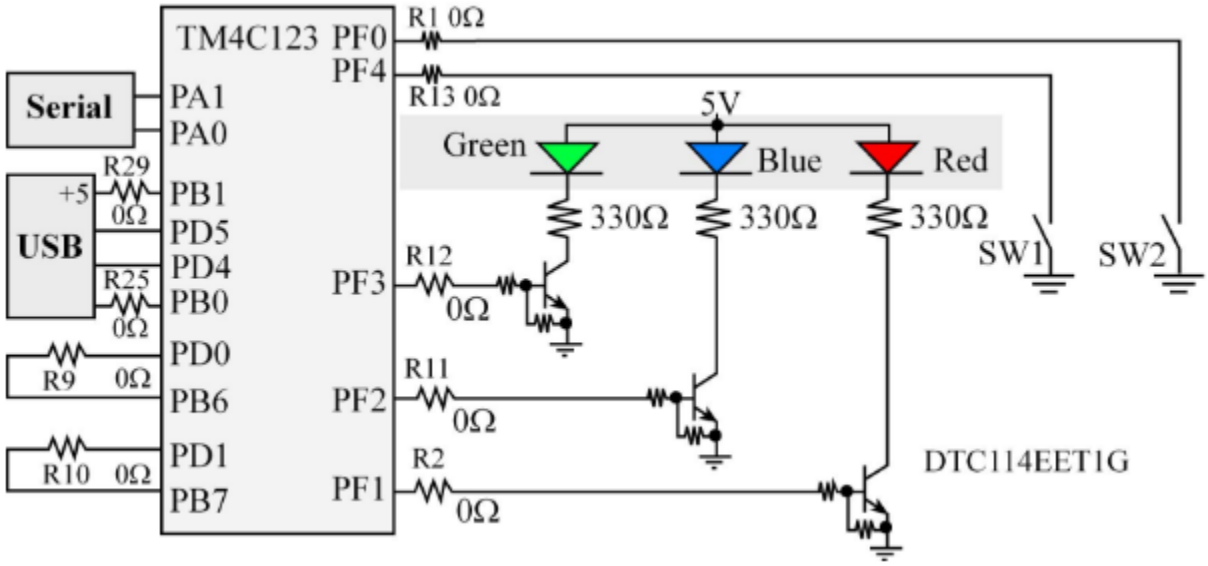
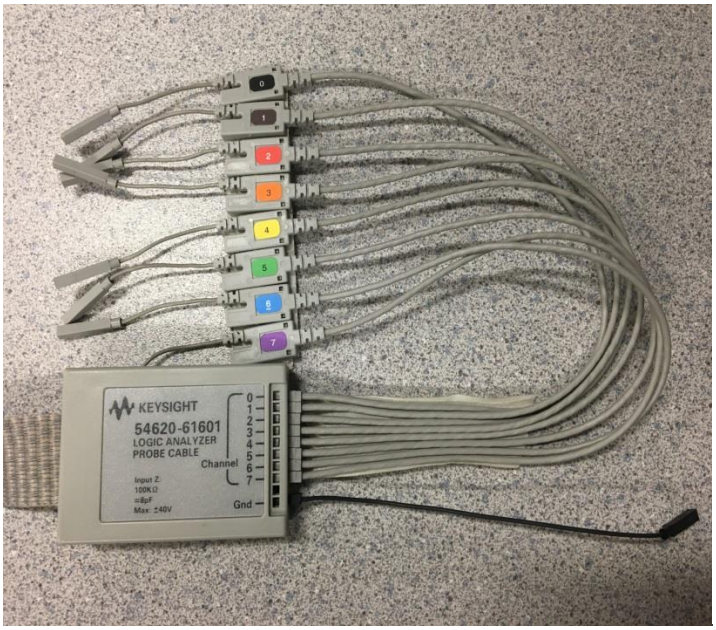
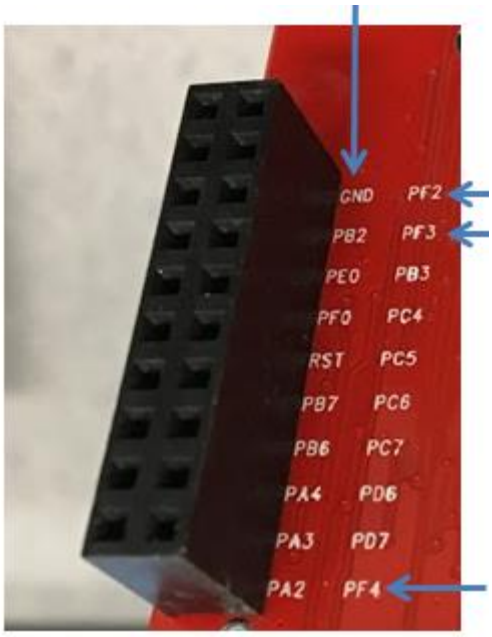


Figure 7. ***Switch and LED interfaces on the Tiva LaunchPad Evaluation Board.***

Make the following connections from the Tiva Launchpad ports PF2, PF3 and PF4 (connector picture with ports labels shown below) to the digital input channels 0 through 2 (D0-D2) of the digital logic analyzer probe (see below for a picture) of the MSO:

- The GND of the LaunchPad to the GND connection wire (color in black) of the analyzer probe
- The port labeled ‘PF2’ of the LaunchPad to digital input 0 (D0) of MSO
- The port labeled ‘PF3’ of the LaunchPad to digital input 1 (D1) of MSO
- The port labeled ‘PF4’ of the LaunchPad to digital input 2 (D2) of MSO





Next, perform the following actions through the front panel of the MSO:

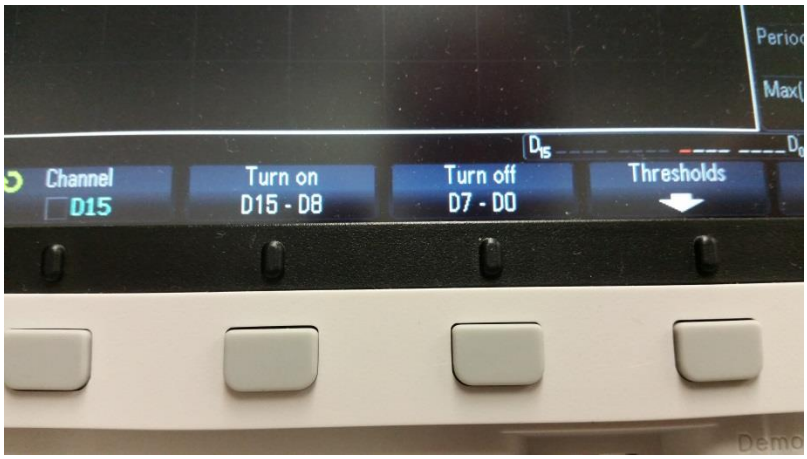
- Verify the threshold level of the digital channels is set to TTL using the following steps:
  - Press the key **Digital**

  - Press the button underneath the *Thresholds* option at the bottom of the screen

- Verify D7-D0 is set to TTL (1.4V)

- Turn on digital channels D0 ,D1 and D2 using the following steps:
  - Press the key **Digital**

  - Verify that D7-D0 is turned 'ON' and D15-D8 is turned 'OFF'



- Press the button underneath the *Channel* option at the bottom of the screen

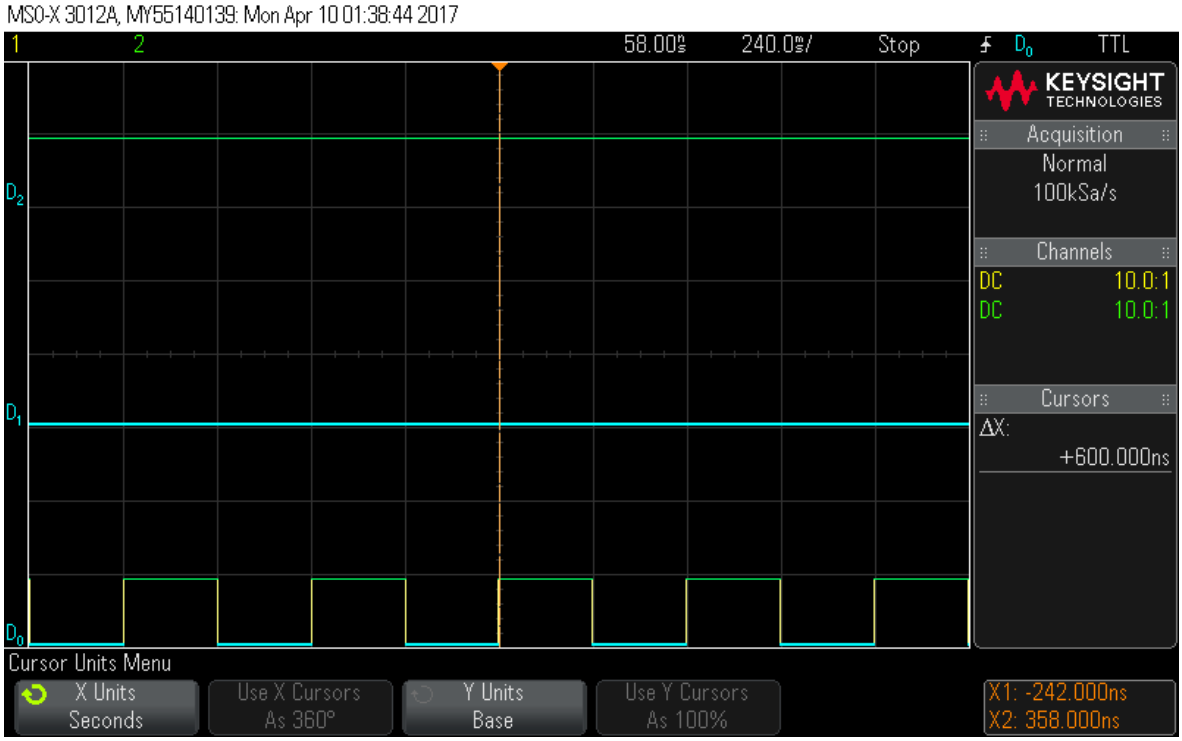
- Using the **Entry** knob,  deselect D3 through D7 and keep D0, D1 and D2 selected

- Press the key **Autoscale**
  - The *Autoscale* key automatically determines which channels have activity and will turn these channels on and scale them to display the signals properly.

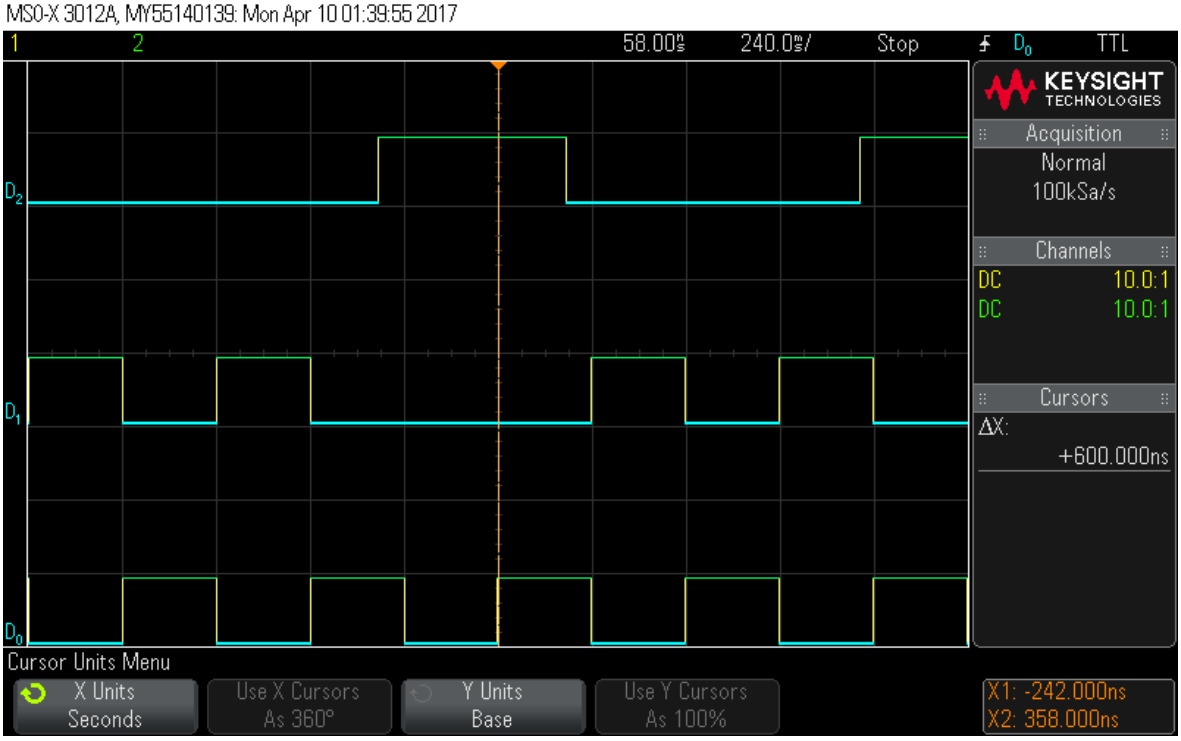
- Press the key **Single**
  - The *Single* key allows a user to make single-shot acquisitions of a waveform being displayed on the MSO. This is useful when viewing trigger conditions as well as analyzing a given waveform.

If the previous steps are done correctly, the MSO should auto-recognize the digital inputs on channels D0, D1 and D2. Three waveforms (two straight and one square) should appear similar to those shown in Figure 8 below.

Note: press the SW1 switch on the Tiva LaunchPad to generate the waveforms in Figure 8(b).



(a) **Three Digital Waveforms on Channels D0, D1 and D2**



(b) Three Digital Waveforms on Channels D0, D1 and D3

Figure 8. MSO Digital Channels D0, D1 and D2 Connected to Tiva Launchpad Ports PF2, PF3 and PF4

Digital Signal Adjustments

Using the same set of waveforms shown in Figure 8, manipulate the size, Time/Div, and turn one or more signals 'OFF' and then back 'ON.' The step-by-step instructions on signal adjustment shown below were taken directly from the *Keysight InfiniiVision 3000 X-Series Oscilloscopes User's* Guide. [1]

To change the displayed size of the digital channels

1 Press the **[Digital]** key.

2 Press the size (⎍ ⎍ ⎍) softkey to select how the digital channels are displayed.

The sizing control lets you spread out or compress the digital traces vertically on the display for more convenient viewing.

Change the size of either D0 or D1 using the steps listed to the left. What is your observation? How does the signal change? What adjustment is this similar to for analog waveform 'size' adjustment?

To switch a single channel on or off

1 With the Digital Channel Menu displayed, rotate the Entry knob to select the desired channel from the popup menu.

2 Push the Entry knob or press the softkey that is directly below the popup menu to switch the selected channel on or off.

Practice turning D0 'OFF' and then back 'ON' using the steps listed to the left. Why is it important to be able to turn digital signals 'ON' and 'OFF'?

To switch all digital channels on or off

1 Press the **[Digital]** key to toggle the display of digital channels. The Digital Channel Menu is displayed above the softkeys.

If you want to switch the digital channels off, and the Digital Channel Menu is not already displayed, you must push the **[Digital]** key twice to switch the digital channels off. The first push displays the Digital Channel Menu, and the second push switches the channels off.

Practice turning D0 and D1 'OFF' simultaneously using the steps listed to the left. Next, turn D0 and D1 back 'ON'.

Lastly, locate the **Time/Div** knob and rotate it counter-clockwise and clockwise. Observe the waveform during various Time/Div intervals.

- How is the waveform changing?
- Why might it be useful to increase the Time/Div setting in some cases and decrease it in others?

Channel Labeling

Assigning a meaningful label as the name of a signal on a particular digital channel helps the user to identify with a specific waveform readily. For example, the default label of digital input channel number one is D1, but the input signal hooked up to D1 may be referred to as the 'Clock' in real life. It would benefit the user to change this label to better identify with the MSO waveforms being observed.

The steps listed below outline the procedure to define a new label and were taken directly and adapted from the *Keysight InfiniiVision 3000 X-Series Oscilloscopes User's* Guide. [1]

Defining a New Label

1. Press the **Label** key.

2. Press the **Channel** softkey; then, turn the Entry knob or successively press the softkey to select channel D0, D1 or D2 for label assignment. The digital channels D0, D1 and D2 will be relabeled to TEST1, TEST2 and TEST3 respectively by implementing the steps below. The channel does not have to be turned on to have a label assigned to it. If the channel is turned on, its current label will be highlighted.

3. Press the **Spell** softkey; then, turn the Entry knob to select the first character in the new label. In the case of this example the first letter would be 'T'.

Turning the Entry knob selects a character to enter into the highlighted position shown in the "New label =" line above the softkeys and in the **Spell** softkey. Labels can be up to ten characters in length.

4. Press the **Enter** softkey to enter the selected character and to go to the next character position.

5. You may position the highlight on any character in the label name by successively pressing the **Enter** softkey.

6. To delete a character from the label, press the **Enter** softkey until the letter you want to delete is highlighted, then press the **Delete Character** softkey.

7. When you are done entering characters for the label, press the **Apply New Label** softkey to assign the label to the selected channel.

Upon becoming familiar with steps 1-7 above, practice relabeling D0, D1 and D2 to TEST1, TEST2 and TEST3, respectively. If done correctly your labels should look similar to those shown in Figure 9.

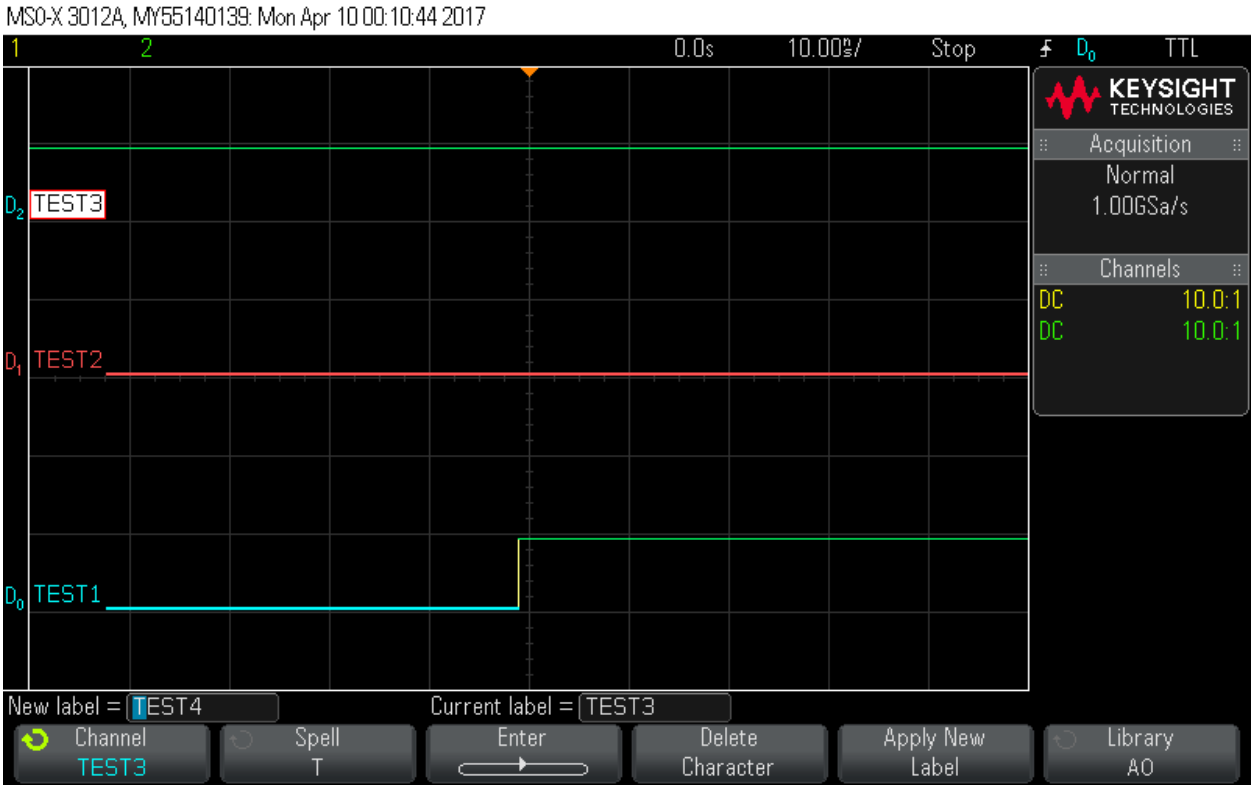


Figure 9. Channel Labeling of D0, D1 and D2

Cursors

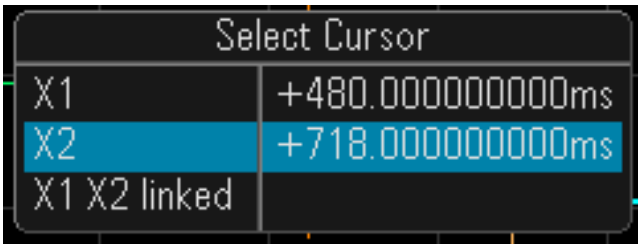
1. Use the same square wave signals previously used at the D0 (TEST1), D1 (TEST2) and D2 (TEST3) inputs to practice the use of cursors. Be sure to press the **Single** key in order to 'freeze' the waveforms in time.

2. Once the two square waves are present on the oscilloscope screen, press the **Cursors** key. The Cursors box in the right-side information area appears, indicating that cursors are 'ON'. (Press the **Cursors** key again when you want to turn cursors 'OFF'.)

3. In the Cursors Menu, press **Mode**; then, select the *Manual* option. In the *Manual* mode, ΔX, 1/ΔX, and ΔY values are displayed. ΔX is the difference between the X1 and X2 cursors and ΔY is the difference between the Y1 andY2 cursors.

4. Push the **Cursors** knob; then, turn the **Cursors** knob to select the desired cursor, **X1, X2, X1 X2 linked, Y1, Y2, or Y1 Y2 linked.** The **X1** and **X2** cursors denote vertical cursor lines while the **Y1** and **Y2** cursors denote horizontal cursor lines. The **X1 X2 linked** and **Y1 Y2 linked** selections let you adjust both cursors at the same time, while the delta value remains the same. This can be useful, for example, for checking pulse width variations in a pulse train. The currently selected cursor(s) display brighter than the other cursors.

For this particular example, the **X1** and **X2** cursors will be utilized. The menu that appears when the **Cursors** knob is pushed is shown below.



5. First, select the **X1** cursor by turning the **Cursor** knob to place the blue highlight over **X1**. To finalize your selection, either push the **Cursors** knob again or wait about five seconds for the popup menu to disappear. Use the **Cursor** knob to position the **X1** cursor at the first visible high-to-low transition point in either the TEST1 or TEST2 square waveforms.

6. Next, select the **X2** cursor by turning the **Cursor** knob to place the blue highlight over **X2**. To finalize your selection, either push the **Cursors** knob again or wait about five seconds for the popup menu to disappear.

7. Lastly, use the **Cursor** knob to position the **X2** cursor over the next high-to-low transition point of the same waveform used for **X1**. Consult Figure 10 for a visual example of the previously described steps. Notice that the distance between cursors **X1** and **X2** represents ΔX and is the period of the waveform. The reciprocal of ΔX is the frequency of the waveform. In this particular example, the period is equal to 484 ms and the frequency is equal to 2.066 Hz. These values are also displayed at the bottom right of the image shown in Figure 10.

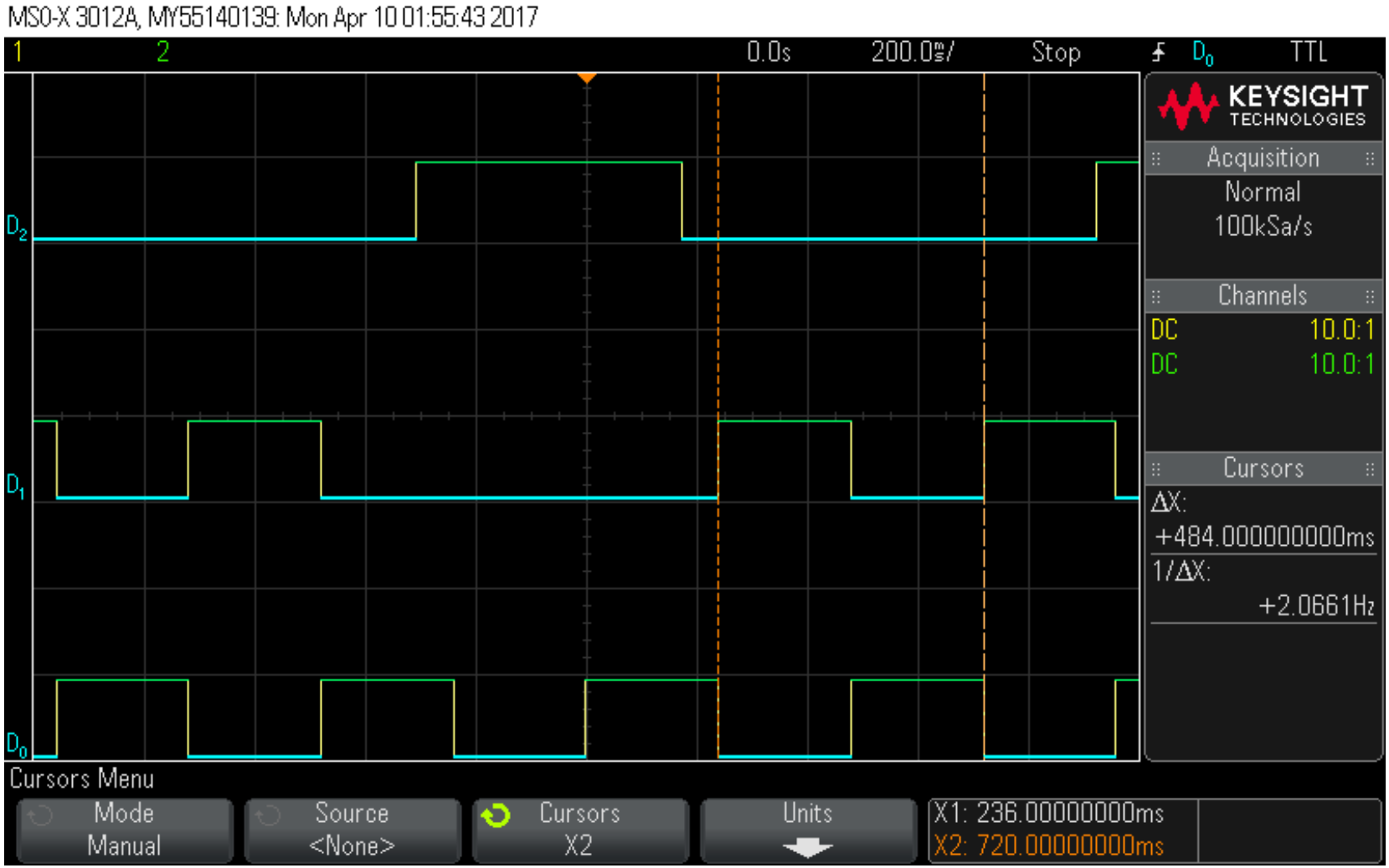


Figure 10. Cursor Placement

Triggering Modes

Triggering refers to the satisfaction of a condition (such as a signal changing its level from low-to-high or vice versa) which is used to initiate the capture of logic signals being monitored through the digital channels. Trigger indicates the use of a certain attribute of a logic signal or signal set being monitored. Triggering can be based on

- a specific signal changing levels (transitions from low-to-high indicating rising edge or high-to-low indicating a falling edge),
- a specific signal attaining a certain level (logic low vs. logic high) or
- a set of signals assuming a specific value combination (pattern trigger).

Set the triggering mode of the Keysight MSO-X 3012A to "*edge then edge*" trigger using the steps below.

- Press the key *Trigger*
- Press the button underneath the *Trigger Type* option
- Select the *edge then edge* option using the selection knob to the right of the screen
- Next, press the button underneath the *Sources* option
- Press the button *Arm A* option Select *D2*
- Press the button *Slope A* option Select *Rising*
- Press the button *Trigger B* option Select *D2*
- Press the button *Slope B* option Select *Falling*
- Press the key labelled as *Single*.
- Press SW1 on the Tiva LaunchPad and release.

Adjust the result to display at least one cycle or more. Were you successful in implementing the above steps and does your result make sense? Consult Figure 11 to visualize what the correct operation of the circuit should look like. Verify your results with your lab instructor.

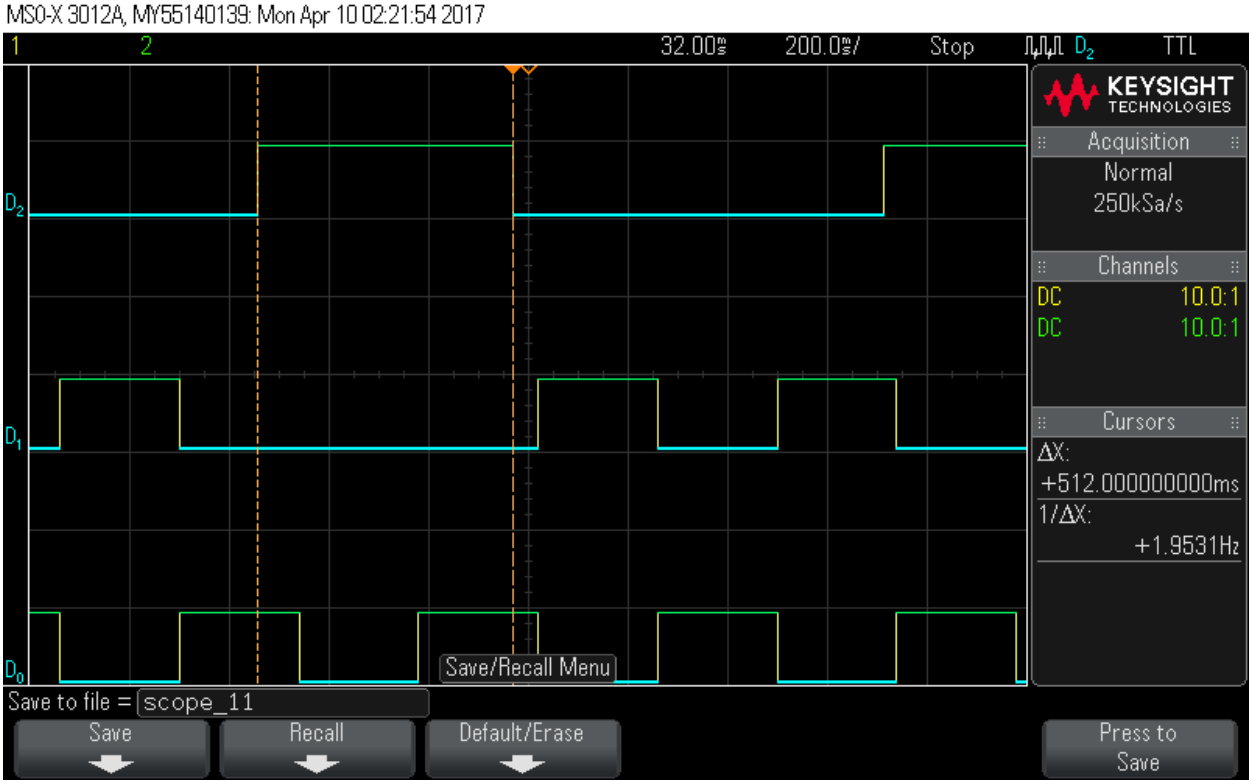


Figure 11. "Edge then Edge" trigger

Saving Information

The Keysight MSO-X 3012A allows users to save information using two different methods. A waveform can be captured and saved from the oscilloscope to a connected computer or by utilizing the on-board USB slot. The BenchVue utility is the software on the computer that the MSO communicates with and it allows waveforms to be saved to a desired location. The USB saving option can be used when it is only necessary to save oscilloscope data to a removable media drive. The steps listed below outline the steps to save a waveform and were taken directly from *Keysight InfiniiVision 3000 X-Series Oscilloscopes User's* Guide. [1]

USB Drive

1. Insert storage medium of choice into the front USB port of the MSO. Press the **Save/Recall** key.

2. In the Save/Recall Menu, press the **Save** softkey.

3. In the Save Menu, press the **Format** softkey and turn the Entry knob to select **PNG 24-bit image(*.png)**

4. Press the **Save** to softkey, then select the desired saving location.

5. Once a location is specified, press the **File Name** softkey to change the name of the file.

6. Finally, press the **Press to Save** softkey.
A message indicating whether the save was successful is displayed.

BenchVue Utility

1. Make sure the MSO is turned 'ON.'

2. Open the Keysight BenchVue program installed on the computer.

3. The oscilloscope icon should appear at the bottom right of the BenchVue welcome screen if there is an established connection between the computer and MSO. Double-click this icon to bring up the main screen of the BenchVue utility. See Figure 12 for reference.

4. In order to capture the waveform/s displayed on the oscilloscope, the 'Get Current Screen' button shown at the top left of the BenchVue interface must be selected. The button is circled in Red in Figure 12.

5. To save a waveform once it has been captured to the BenchVue utility, select the save icon at the bottom right of the screen and then select 'Save Image'. The icon is circled in blue in Figure 12.

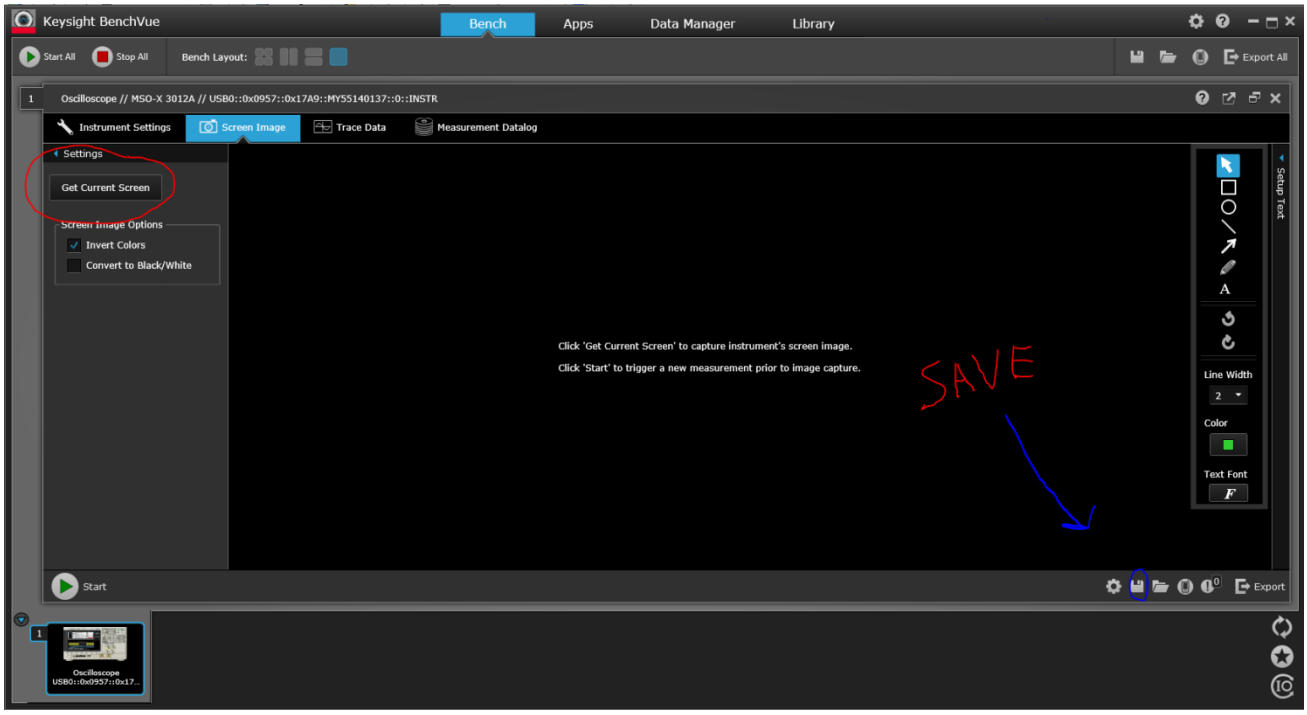


Figure 12. BenchVue Utility Graphical User Interface (GUI)

6. Save the file as the desired name and to the location of choice. Refer to Figure 13.

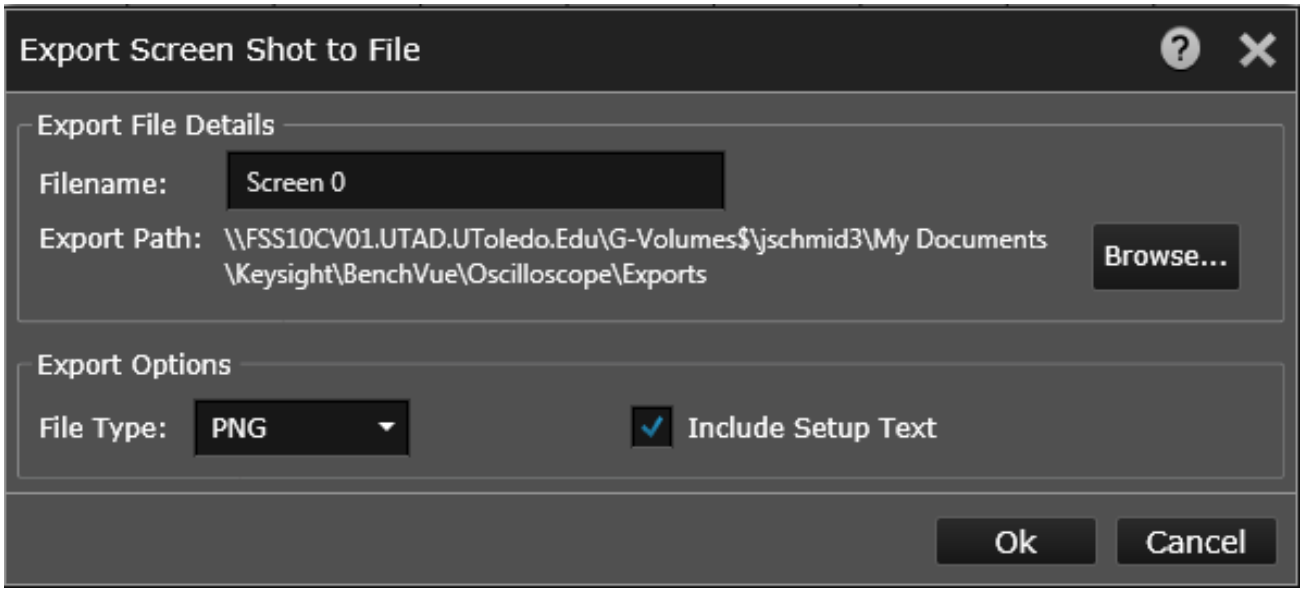


Figure 13. Saving Menu

APPENDIX

Keysight MSO Interface Explained

The table below outlines the various components of the oscilloscope interface shown in Figure 14. All page references mentioned in the table can be found in the *Keysight InfiniiVision 3000 X-Series Oscilloscopes User's Guide.* [1]

[1] Keysight InfiniiVision 3000 X-Series Oscilloscopes User's Guide. (2013). In (Eighth ed., Vol. One, pp. 1-430). Colorado Springs, Colorado: Keysight Technologies.

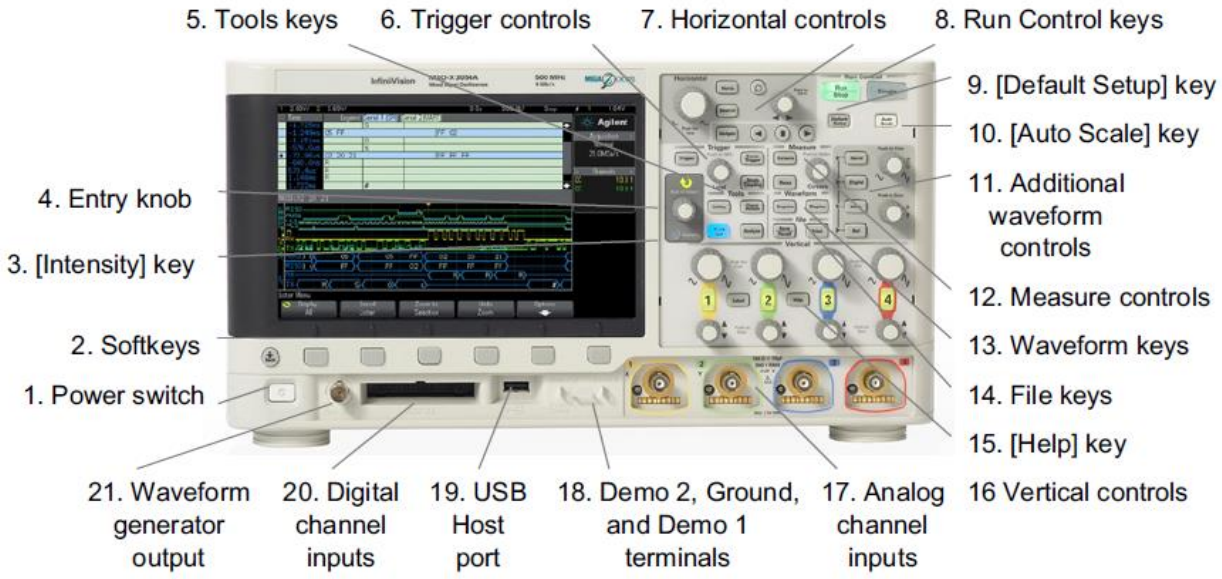
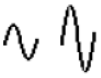


Figure 14. Keysight MSO Overview

1.	Power switch	Press once to switch power on; press again to switch power off. See "Power-On the Oscilloscope" on page 27.
2.	Softkeys	The functions of these keys change based upon the menus shown on the display directly above the keys. The Back/Up key moves up in the softkey menu hierarchy. At the top of the hierarchy, the Back/Up key turns the menus off, and oscilloscope information is shown instead.
3.	**[Intensity]** key	Press the key to illuminate it. When illuminated, turn the Entry knob to adjust waveform intensity. You can vary the intensity control to bring out signal detail, much like an analog oscilloscope. Digital channel waveform intensity is not adjustable. More details about using the Intensity control to view signal detail are on "To adjust waveform intensity" on page 127.
4.	Entry knob	The Entry knob is used to select items from menus and to change values. The function of the Entry knob changes based upon the current menu and softkey selections. Note that the curved arrow symbol above the entry knob illuminates whenever the entry knob can be used to select a value. Also, note that when the Entry knob symbol appears on a softkey, you can use the Entry knob, to select values. Often, rotating the Entry knob is enough to make a selection. Sometimes, you can push the Entry knob to enable or disable a selection. Pushing the Entry knob also makes popup menus disappear.
5.	Tools keys	The Tools keys consist of: ▪ **[Utility]** key – Press this key to access the Utility Menu, which lets you configure the oscilloscope's I/O settings, use the file explorer, set preferences, access the service menu, and choose other options. See Chapter 20, "Utility Settings," starting on page 287. ▪ **[Quick Action]** key – Press this key to perform the selected quick action: measure all snapshot, print, save, recall, freeze display. and more. See "Configuring the [Quick Action] Key" on page 302. ▪ **[Analyze]** key – Press this key to access analysis features like trigger level setting, measurement threshold setting, Video trigger automatic set up and display, mask testing (see Chapter 15, "Mask Testing," starting on page 237), or the DSOX3PWR power measurement and analysis application. ▪ **[Wave Gen]** key – Press this key to access waveform generator functions. See Chapter 17, "Waveform Generator," starting on page 253.
6.	Trigger controls	These controls determine how the oscilloscope triggers to capture data. See Chapter 10, "Triggers," starting on page 139 and Chapter 11, "Trigger Mode/Coupling," starting on page 173.

7.	Horizontal controls	The Horizontal controls consist of: ▪ Horizontal scale knob – Turn the knob in the Horizontal section that is marked  to adjust the time/div (sweep speed) setting. The symbols under the knob indicate that this control has the effect of spreading out or zooming in on the waveform using the horizontal scale. ▪ Horizontal position knob – Turn the knob marked ◀▶ to pan through the waveform data horizontally. You can see the captured waveform before the trigger (turn the knob clockwise) or after the trigger (turn the knob counterclockwise). If you pan through the waveform when the oscilloscope is stopped (not in Run mode) then you are looking at the waveform data from the last acquisition taken. ▪ **[Horiz]** key – Press this key to open the Horizontal Menu where you can select XY and Roll modes, enable or disable Zoom, enable or disable horizontal time/division fine adjustment, and select the trigger time reference point. ▪ Zoom key – Press the zoom key to split the oscilloscope display into Normal and Zoom sections without opening the Horizontal Menu. ▪ **[Search]** key – Lets you search for events in the acquired data. ▪ **[Navigate]** keys – Press this key to navigate through captured data (Time), search events, or segmented memory acquisitions. See "Navigating the Time Base" on page 58. For more information see Chapter 2, "Horizontal Controls," starting on page 47.
8.	Run Control keys	When the **[Run/Stop]** key is green, the oscilloscope is running, that is, acquiring data when trigger conditions are met. To stop acquiring data, press **[Run/Stop]**. When the **[Run/Stop]** key is red, data acquisition is stopped. To start acquiring data, press **[Run/Stop]**. To capture and display a single acquisition (whether the oscilloscope is running or stopped), press **[Single]**. The **[Single]** key is yellow until the oscilloscope triggers. For more information, see "Running, Stopping, and Making Single Acquisitions (Run Control)" on page 181.
9.	**[Default Setup]** key	Press this key to restore the oscilloscope's default settings (details on "Recall the Default Oscilloscope Setup" on page 29).
10.	**[Auto Scale]** key	When you press the **[AutoScale]** key, the oscilloscope will quickly determine which channels have activity, and it will turn these channels on and scale them to display the input signals. See "Use Auto Scale" on page 30.

11.	Additional waveform controls	The additional waveform controls consist of: ▪ **[Math]** key – provides access to math (add, subtract, etc.) waveform functions. See Chapter 4, "Math Waveforms," starting on page 71. ▪ **[Ref]** key – provides access to reference waveform functions. Reference waveforms are saved waveforms that can be displayed and compared against other analog channel or math waveforms. See Chapter 5, "Reference Waveforms," starting on page 99. ▪ **[Digital]** key – Press this key to turn the digital channels on or off (the arrow to the left will illuminate). When the arrow to the left of the **[Digital]** key is illuminated, the upper multiplexed knob selects (and highlights in red) individual digital channels, and the lower multiplexed knob positions the selected digital channel. If a trace is repositioned over an existing trace the indicator at the left edge of the trace will change from **D**nn designation (where nn is a one or two digit channel number from 0 to 15) to **D***. The "*" indicates that two channels are overlaid. You can rotate the upper knob to select an overlaid channel, then rotate the lower knob to position it just as you would any other channel. For more information on digital channels see Chapter 6, "Digital Channels," starting on page 103. ▪ **[Serial]** key – This key is used to enable serial decode. The multiplexed scale and position knobs are not used with serial decode. For more information on serial decode, see Chapter 7, "Serial Decode," starting on page 121. ▪ Multiplexed scale knob – This scale knob is used with Math, Ref, or Digital waveforms, whichever has the illuminated arrow to the left. For math and reference waveforms, the scale knob acts like an analog channel vertical scale knob. ▪ Multiplexed position knob – This position knob is used with Math, Ref, or Digital waveforms, whichever has the illuminated arrow to the left. For math and reference waveforms, the position knob acts like an analog channel vertical position knob.
12.	Measure controls	The measure controls consist of: ▪ Cursors knob – Push this knob select cursors from a popup menu. Then, after the popup menu closes (either by timeout or by pushing the knob again), rotate the knob to adjust the selected cursor position. ▪ **[Cursors]** key – Press this key to open a menu that lets you select the cursors mode and source. ▪ **[Meas]** key – Press this key to access a set of predefined measurements. See Chapter 14, "Measurements," starting on page 209.

13.	Waveform keys	The **[Acquire]** key lets you select Normal, Peak Detect, Averaging, or High Resolution acquisition modes (see "Selecting the Acquisition Mode" on page 187) and use segmented memory (see "Acquiring to Segmented Memory" on page 193). The **[Display]** key lets you access the menu where you can enable persistence (see "To set or clear persistence" on page 129), clear the display, and adjust the display grid (graticule) intensity (see "To adjust the grid intensity" on page 131).
14.	File keys	Press the **[Save/Recall]** key to save or recall a waveform or setup. See Chapter 18, "Save/Recall (Setups, Screens, Data)," starting on page 269. The **[Print]** key opens the Print Configuration Menu so you can print the displayed waveforms. See Chapter 19, "Print (Screens)," starting on page 281.
15.	**[Help]** key	Opens the Help Menu where you can display overview help topics and select the Language. See also "Access the Built-In Quick Help" on page 44.
16.	Vertical controls	The Vertical controls consist of: ▪ Analog channel on/off keys – Use these keys to switch a channel on or off, or to access a channel's menu in the softkeys. There is one channel on/off key for each analog channel. ▪ Vertical scale knob – There are knobs marked  for each channel. Use these knobs to change the vertical sensitivity (gain) of each analog channel. ▪ Vertical position knobs – Use these knobs to change a channel's vertical position on the display. There is one Vertical Position control for each analog channel. ▪ **[Label]** key – Press this key to access the Label Menu, which lets you enter labels to identify each trace on the oscilloscope display. See Chapter 9, "Labels," starting on page 133. For more information, see Chapter 3, "Vertical Controls," starting on page 61.

17.	Analog channel inputs	Attach oscilloscope probes or BNC cables to these BNC connectors. With the InfiniiVision 3000 X-Series oscilloscopes, you can set the input impedance of the analog channels to either 50 Ω or 1 MΩ. See "To specify channel input impedance" on page 64. The InfiniiVision 3000 X-Series oscilloscopes also provide the AutoProbe interface. The AutoProbe interface uses a series of contacts directly below the channel's BNC connector to transfer information between the oscilloscope and the probe. When you connect a compatible probe to the oscilloscope, the AutoProbe interface determines the type of probe and sets the oscilloscope's parameters (units, offset, attenuation, coupling, and impedance) accordingly.
18.	Demo 2, Ground, and Demo 1 terminals	▪ Demo 2 terminal – This terminal outputs the Probe Comp signal which helps you match a probe's input capacitance to the oscilloscope channel to which it is connected. See "Compensate Passive Probes" on page 32. With certain licensed features, the oscilloscope can also output demo or training signals on this terminal. ▪ Ground terminal – Use the ground terminal for oscilloscope probes connected to the Demo 1 or Demo 2 terminals. ▪ Demo 1 terminal – With certain licensed features, the oscilloscope can output demo or training signals on this terminal.
19.	USB Host port	This port is for connecting USB mass storage devices or printers to the oscilloscope. Connect a USB compliant mass storage device (flash drive, disk drive, etc.) to save or recall oscilloscope setup files and reference waveforms or to save data and screen images. See Chapter 18, "Save/Recall (Setups, Screens, Data)," starting on page 269. To print, connect a USB compliant printer. For more information about printing see Chapter 19, "Print (Screens)," starting on page 281. You can also use the USB port to update the oscilloscope's system software when updates are available. You do not need to take special precautions before removing the USB mass storage device from the oscilloscope (you do not need to "eject" it). Simply unplug the USB mass storage device from the oscilloscope when the file operation is complete. **CAUTION: ⚠ Do not connect a host computer to the oscilloscope's USB host port.** Use the device port. A host computer sees the oscilloscope as a device, so connect the host computer to the oscilloscope's device port (on the rear panel). See "I/O Interface Settings" on page 287. There is a second USB host port on the back panel.
20.	Digital channel inputs	Connect the digital probe cable to this connector (MSO models only). See Chapter 6, "Digital Channels," starting on page 103.

21.	Waveform generator output	Outputs sine, square, ramp, pulse, DC, or noise on the Gen Out BNC. Press the **[Wave Gen]** key to set up the waveform generator. See Chapter 17, "Waveform Generator," starting on page 253.