1 Introduction

The four-channel Keysight (ex-Agilent) MSO-X 3024A oscilloscopes have special triggering modes that allow them to capture I$^2$C and RS-232 serial data transfers and display them. These triggering modes should be used whenever looking at these signals rather than just using the standard edge triggering. This document briefly describes how to setup the scopes to acquire I$^2$C and RS-232 data and display it.

2 Viewing I$^2$C Transfers

To view I$^2$C or “Two-Wire” data transfers follow the steps below. If at any time during the setup you want to make a menu disappear from the screen, press the “Back” button near the lower right corner of the screen.

1. Turn on the scope and then turn on two of four input channels by pressing the buttons with numbers on them in the vertical section of controls until the traces appear on the screen (Fig. 1). In this example we’ll use channels 1 and 2.

   ![Figure 1: Keysight channel settings](image1)
   ![Figure 2: Keysight serial mode set for I$^2$C](image2)

2. Use the large knobs above the “1” and “2” buttons to adjust the input levels for both channels to 5 Volts per division. The levels for the channels are shown in the upper left part of the screen.

3. Use the small knobs below channel buttons to vertically position the two traces on the screen where both can be viewed.
4. Use the large knob in the horizontal section of the controls to change the horizontal sweep speed to 100μs (time/division). The sweep speed is shown in the upper right portion of the screen.

5. The small knob in the right part of the horizontal section changes the horizontal position of the displayed signal. First press the knob to center the signal on the screen, and then rotate the knob to move the small orange triangle at the top of the screen over closer to the left side of the screen. When an I²C signal is captured, it will be displayed with the starting point of the signal at this position.

6. Connect two scope probes to channels 1 and 2 of the scope and then connect the probe tips to the I²C clock and data lines on your project board. Either one can be attached to either signal but make note of which way they are connected. Connect the black ground lead of one of the probes to ground on the breadboard. Both probe’s ground leads can be connected to the breadboard ground but only one is required.

7. The Keysight scopes can have two stored configurations for working with serial signals like I²C. To setup a one for I²C, press the “Serial” button in right portion of the screen. This brings up the Serial Decode Menu along the bottom of the screen. Press the left soft key and it should show the two Serial selections. If Serial 1 doesn’t have the box next to it filled in with a blue square, press the button again to select it.

8. The label for the second softkey from the left shows the current protocol selection for the bus. If it doesn’t say “I²C”, press the softkey below the label to bring up a vertical menu for selecting the protocol type. Using the knob with the illuminated green arrow just to the right of the screen, select the “I²C” setting for Serial 1 as shown in Fig. 2.

9. Press the third softkey from the left labeled “Signals”. This brings up the screen shown in Fig. 3. The current settings for which channel is clock (SCL) and which is data (SDA) is shown along the bottom of the screen. Use the softkeys below the channel destinations and the selector knob to change these to match how you connected the probes to the hardware under test.

10. For each channel, press the “Threshold” softkeys and then use the selector knob to adjust the voltage thresholds. The thresholds need to be set to something around the middle of the zero to 5 volt range. Use the selector knob to set each of the thresholds to 2.4 to 2.6 Volts.

11. Press the “Trigger” button in the Trigger section of the controls. Press the “Trigger Type” soft key to bring up the vertical menu of triggering types, and use the selector knob to scroll down near the bottom and select “Serial 1”.

Figure 3: Keysight I²C input settings

Figure 4: Keysight I²C signal display
12. The “Trigger on:” softkey is used to select the \(^2\text{C}\) condition that will cause the scope to acquire data. For most purposes a “Start” condition works best. If the softkey doesn’t say “Start”, press it to bring up the “Trigger on:” menu and use the selector knob to set it for triggering on a \(^2\text{C}\) Start condition.

13. Press the “Mode/Coupling” button in the Triggers section of the controls. Use the left softkey that says Mode to set the triggering mode to “Normal”.

At this point the scope is configured to trigger on a \(^2\text{C}\) Start condition. Press the “Single” button in the upper right to put the scope in a state where it will wait for the next Start condition on the \(^2\text{C}\) bus and then capture the data. Do whatever is needed on your project board to get it to generate the \(^2\text{C}\) transfer, and once the data has been captured it will be displayed on the screen (Fig. 4). The bottom portion of the screen should show the contents of each byte in the the \(^2\text{C}\) transfer in hexadecimal. In addition it will mark various protocol bits in the transfer: S = Start, R = read, W = write, a = ACK.

The captured data can be expanded or shrunk horizontally using the horizontal scale control. If you shrink the data to try to see more of it, it may not show up since the scope only stored the part that was to be displayed. In this case you will have to repeat the acquisition of the data to capture more data. The smaller knob in the horizontal section can be used to move the display left or right to see all parts of the \(^2\text{C}\) data.

3 Viewing RS-232 Transfers

The RS-232 communication standard actually only refers to the hardware and electrical characteristics of the signals, but over the years many people also use the term to refer to the timing and format of the signals. “True RS-232” uses signals that use positive and negative voltages like \(-8\) V for a logical 1, and \(+8\) V for a logical 0. In EE109 we often instead use what people sometimes call “TTL serial” which uses the same timing and signal format at normally used with RS-232 but uses \(+5\) V for a logical 1 and \(0\) V for a logical 0. The Keysight scopes can display TTL serial signals in the same manner as the true RS-232 ones by making a couple changes to the settings. To view TTL serial signals, follow the steps below but look for places where it says to make changes for viewing the TTL serial signals.

To view RS-232 data transfers follow the steps below. If at any time during the setup you want to make a menu disappear from the screen, press the “Back” button near the lower right corner of the screen.

1. Turn on the scope and then turn on input channel 1 by pressing the button with number 1 on it in the vertical section of controls until the trace appear on the screen (Fig. 5).

![Figure 5: Keysight channel settings](image)

2. Use the large knobs above the “1” button to adjust the input levels for the channel to 5 Volts per division. The levels for the channels are shown in the upper left part of the screen.

![Figure 6: Keysight serial mode set for RS-232](image)
3. Use the small knobs below channel buttons to vertically position the yellow trace in about the middle of the screen.

4. Use the large knob in the horizontal section of the controls to change the horizontal sweep speed to 1ms (time/division). The sweep speed is shown in the upper right portion of the screen.

5. The small knob in the right part of the horizontal section changes the horizontal position of the displayed signal. First press the knob to center the signal on the screen, and then rotate the knob to move the small orange triangle at the top of the screen over closer to the left side of the screen. When an RS-232 signal is captured, it will be displayed with the starting point of the signal at this position.

6. Connect a scope probe to channel 1 of the scope and then connect the probe tip to the source of the RS-232 data. Connect the black ground lead of the probe to ground on the breadboard.

7. The Keysight scopes can have two stored configurations for working with serial signals like RS-232. To setup a one for RS-232, press the “Serial” button in right portion of the screen. This brings up the Serial Decode Menu along the bottom of the screen as shown in Fig. 6. Press the left soft key and it should show the two Serial selections. If Serial 1 doesn’t have the box next to it filled in with a blue square, press the button again to select it.

8. The label for the second softkey from the left shows the current protocol selection for the bus. If it doesn’t say “UART/RS232”, press the softkey below the label to bring up a vertical menu for selecting the protocol type. Using the knob with the illuminated green arrow just to the right of the screen, select the “UART/RS232” setting for Serial 1.

9. Press the third softkey from the left labeled “Signals”. The serial data triggering mode is designed to look at two RS-232 data streams at the same time, and one is called the Tx or transmitted data and the other is the Rx or received data. For looking at just one data stream either can be used but for this example we’ll use the Rx channel.

The labels above the softkeys show which scope channels are assumed to have the Rx and the Tx data connected to them. If the number below the Rx label is not 1, press that softkey and use the knob to change the channel setting to 1.

10. For the Rx channel, press the “Threshold” softkey and then use the selector knob to adjust the voltage threshold. The threshold should be set to something around the 0 volts for true RS-232 since the signals go both positive and negative. For TTL serial, set to around +2.5V.

11. Press the “Back” button to get back to the Serial Decode Menu and then press the “Bus Config” softkey. This brings up the screen shown in Fig. 7.
12. On the Bus Configuration Menu, use the softkeys to set the RS-232 communications parameters.
   - #Bits = 8
   - Parity = None
   - Baud rate = whatever you are using
   - Polarity = Idle low for true RS-232, idle high for TTL serial
   - Bit Order = LSB

13. Press the “Trigger” button in the Trigger section of the controls to bring up the Trigger Menu.

14. Press the “Trigger Type” softkey to bring up the vertical menu of triggering types, and use the selector knob to scroll down near the bottom and select “Serial 1”.

15. Press the “Trigger Setup” softkey to bring up the UART/RS232 Trigger Setup Menu.

16. The “Trigger” softkey is used to select the RS-232 condition that will cause the scope to acquire data. For most purposes we want to trigger on the RS-232 “start bit” that indicates the beginning of the data transfer. We’re using the Rx channel so if it doesn’t say “Rx Start” on the label, press the softkey to bring up the “Trigger” menu and use the selector knob to set it for triggering on an “Rx Start Bit”.

17. Press the “Mode/Coupling” button in the Triggers section of the controls. Use the left softkey that says Mode to set the triggering mode to “Normal”.

   At this point the scope is configured to trigger on a RS-232 start bit. Press the “Single” button in the upper right to put the scope in a state where it will wait for the next start bit and then capture the data. Do whatever is needed on your project board to get it to generate the RS-232 transfer, and once the data has been captured it will be displayed on the screen (Fig. 8). The bottom portion of the screen should show the contents of each byte in the the RS-232 transfer in hexadecimal. The hex values only show the 8-bits contents, not the start or stop bits.

   The captured data can be expanded or shrunk horizontally using the horizontal scale control. If you shrink the data to try to see more of it, it may not show up since the scope only stored the part that was to be displayed. In this case you will have to repeat the acquisition of the data to capture more data. The smaller knob in the horizontal section can be used to move the display left or right to see all parts of the RS-232 data.