

HDMI Compliance Testing with the BitifEye BIT-2100 Switch and Keysight N7010A Adapters

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Introduction

HDMI has four differential high-speed lanes. Three lanes are used for data (D0, D1, D2) and one lane is used for the clock (Ck).

Performing the electrical measurements to validate the HDMI interface requires specific connections to the oscilloscope. The test regimen for both HDMI 1.4 and HDMI 2.0 can be divided into two groups of measurement types: single-ended measurements and differential measurements. Data eye and data jitter measurements require the HDMI clock at the same time.

The critical measurements in HDMI 2.0 (data eye, data jitter, and clock jitter) require a complex channel model that implies a single-ended connection to make the required differential measurements. Although various approaches are available for completing the full test regimen, the most convenient approach is to use single-ended connections to the scope whether using differential probes or the termination adapters (N7010A). This guide addresses not only the convenience of using single-ended connections but also the time-saving switch matrix construct that enables one connection setup and no further reconnection.

While there is flexibility in the connections offered, Keysight has selected the HDMI clock lane to drive channels 1 and 3 (Ck+ to channel 1 and Ck- to channel 3), by default. The data lanes are routed to channels 2 and 4 (D+ to channel 2 and D- to channel 4). When connections are made this way, the test selection can be:

- all differential clock tests
- all single-ended clock tests
- all differential tests of the connected data lane
- all single-ended tests of the connected data lane

Testing another data lane requires reconnection of channels 2 and 4, or a switch matrix construct. If a switch box is used it must be compensated for in magnitude (loss) and in phase (skew). In all cases, it may be required that the untested data lanes be terminated. All of these connection requirements are addressed in this guide.

In This Guide

This guide describes how you can use the BitifEye BIT-2100 switch, along with the Keysight N5399C HDMI Electrical Performance Validation and Compliance software, N7010A active termination adapters, and N2809A PrecisionProbe kit, to perform sequential testing of all data lanes, one at a time, automatically.

Four main procedures are required:

- Perform DC and skew calibrations on the probe adapters.
- Configure the BIT-2100 switch.
- Set up the switch in the N5399C HDMI application.

- Use PrecisionProbe / PrecisionCable for AC response correction for signal paths.

For More Information

- Find the latest version of the BitifEye *BIT-2100 Series Switch System User Manual* at <http://www.bitifeye.com/>.
- Find the Keysight N5399C/N5399D HDMI Test Compliance Application Online Help at www.keysight.com/find/N5399C.

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Equipment required

Description	Critical specifications	Recommended model/part number
Keysight Infiniium oscilloscope	≥ 16 GHz bandwidth	Infiniium 90000 X-Series, Q-Series, V-Series, or Z-Series
Active termination adapter probes (4 required)		N7010A 
HDMI 2.0 TPA fixture		BitifEye BIT-1010-0200-0 HDMI Type A Source Test Plug Adapter Kit Wilder Technologies HDMIA2-TPA-12P or HDMIA2-TPA-6P
Phase-matched SMA cables (2 sets required)	25 ps	15443A
Short, semi-rigid or flexible coaxial cables for routing on switch box		Rosenberger 24/14 023A L99-001-000
SMA (f)-(f) or APC 3.5 mm adapters (3 pairs)	3.5 mm	
HDMI termination module or connecting terminations*	50 Ohm to 3.3 V	Wilder HDMI Termination Module model HDMI-TPA-T
Torque wrench	5/16", 5 in-lbs	8710-1582
PrecisionProbe software and cable calibration kit		N2809A
BitifEye BIT-2100 Series switch module: one 6x SPDT module and two 1x SP4T or two 1x SP6T modules		BitifEye BIT-2162A (6x SPDT) BitifEye BIT-2114A (1x SP4T) BitifEye BIT-2116A (1x SP6T)
Phase-matched cables for data lanes to switches (3 sets, optional)		15443A
<p>* Terminations can be done in several ways. The examples in this guide use a Wilder HDMI-TPA-T with a USB source, but you can also use N5380B probe heads with center pin to 3.3 volt supply. You can also use bias tees and a separate 3.3 V supply. The Wilder solution is the simplest and lowest cost.</p> <p>Connecting terminations may be optional if:</p> <ul style="list-style-type: none"> —Your device will work with a subset of the TMDS lanes connected. Most HDMI silicon has been shown to operate with minimal terminations. —You determine that your results are independent (that is, you do not see cross-talk degradation). 		

Performing a DC Calibration on N7010A Adapters

If the N7010A adapters have not yet had DC attenuation/offset and skew calibrations for the specific channels they are connected to, we recommend performing those calibrations now rather than interrupting the AC Response calibration procedure later.

- 1 Connect an N7010A adapter to each channel on the oscilloscope.
- 2 In the Infiniium application, open the Channel dialog box and select **Probe Cal...**, or click **Setup > Probe Calibration...**



Figure 1 No DC or Skew calcs performed yet

- 3 Click **Start Atten/Offset Cal...** and follow the instructions for connecting an SMA cable from the channel to Cal Out and running the calibration.
- 4 Click **Start Skew Cal...** and follow the instructions that appear.
- 5 Repeat **step 3** and **step 4** for each channel until all probe adapters have completed the DC and skew calcs.



Figure 2 DC and Skew calcs completed

Configuring the BIT-2100 Switch

- 1 Make sure the BIT-2100 switch is loaded with two SP4T (or SP6T) switch modules and one 6x SPDT module. The SP4T (or SP6T) modules belong in slots 3 and 5, and the 6x SPDT module belongs in slot 4. See [Figure 3](#).

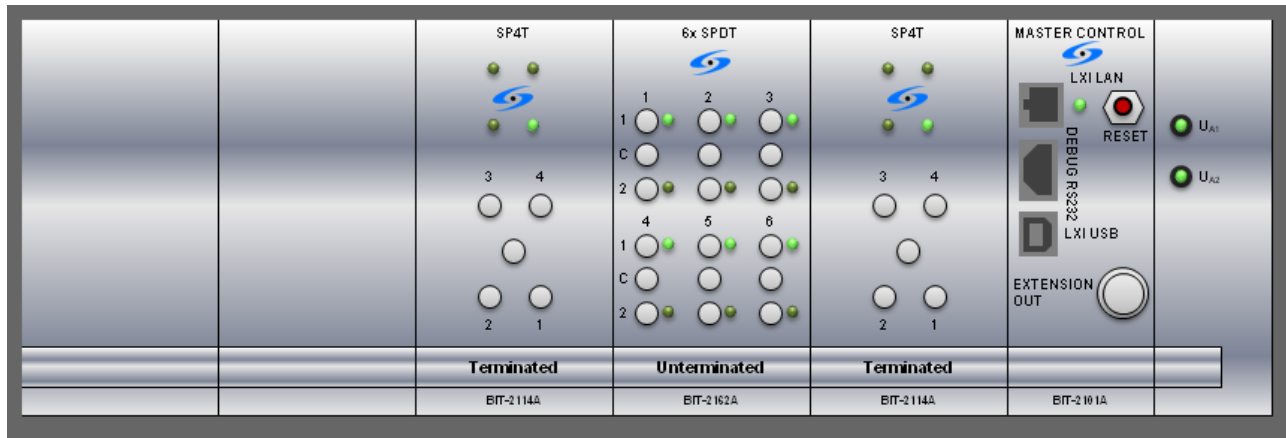


Figure 3 BitifEye BIT-2100 switch with two SP4T modules and one 6x SPDT module

NOTE

For help with this step, refer to the *BIT-2100 Series Switch System User Manual* chapter on mounting modules and setting addresses for each module.

- 2 Refer to [Figure 4](#) on page 9 to connect the cables on the BitifEye switch for HDMI testing as follows:
 - Using one of the 15443A SMA matched cable sets and a pair of (f)-(f) SMA/APC 3.5 mm adapters, route the center SMA of module 3 to channel 2 on the oscilloscope, and route the center SMA of module 5 to channel 4 (through the N7010A termination adapters).
 - Use the other matched cable set and two pairs of (f)-(f) SMA/APC 3.5 mm adapters to route from the clock signal (Ck+ and Ck-) to channels 1 and 3 of the oscilloscope (through the N7010A termination adapters) directly from the HDMI TPA.
 - Route the SMA cable breakouts from the HDMI TPA of the data lanes to the center (common) of the six SPDT switches.
 - Route the bottom SMA, port 2, of these switches to the HDMI termination.
 - Route the top SMA, port 1, of these switches to the SP4T switches. Route all of the D+ signals from the HDMI device under test to module 3 through the SP4T switches, and route the D- signals to module 5 as shown in [Figure 4](#).

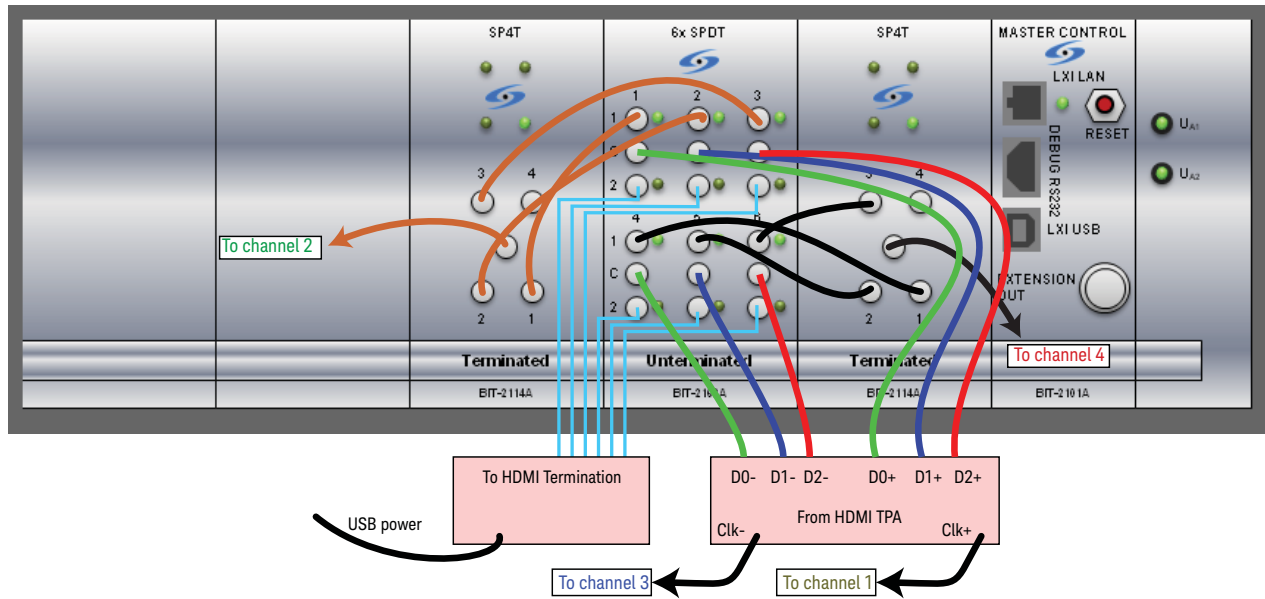


Figure 4 Cable connections on the BitifEye BIT-2100 switch for HDMI testing

Setting Up the Switch in the N5399C HDMI Software

The N5399C HDMI software running on an Infiniium oscilloscope needs a connection to the switch in order to control it. Three types of connections are possible:

- USB cable between switch and oscilloscope
- LAN (both oscilloscope and switch connected to LAN)
- LAN cable between switch and oscilloscope

This chapter assumes you will use the first type, a USB cable connection. The LAN connection types are described in [Appendix A](#), “Using a LAN Connection”.

Now that the BIT-2100 switch is configured, you need to configure the testing environment for the HDMI software.

Configure the switching paths

You can configure the switching paths either automatically or manually. If you cabled the switches as shown in **Figure 4** on page 9, you can configure the paths automatically as described here. If you cabled the switches differently than shown in **Figure 4**, you need to manually set up the switch matrix to match the cabling (see **Appendix B**, “Configuring Paths Manually”).

- 1 Connect the USB cable between the switch and the oscilloscope.
- 2 Start the HDMI application from the Infiniium application (**Analyze > Automated Test Apps > N5399C/N5399D HDMI Test App**).
- 3 Drag the HDMI Test window to the bottom of your screen, leaving the menu bar accessible.
- 4 Click **Tools > Switch Matrix...**
- 5 In the Configure Switch Matrix Settings dialog box, select **On** to make the grayed-out sections active.
- 6 Select **Automatically select drivers and paths**.
- 7 Select the **BitifEye BIT2100** model and click **Connect...** The Connect To BitifEye BIT2100 dialog box appears.

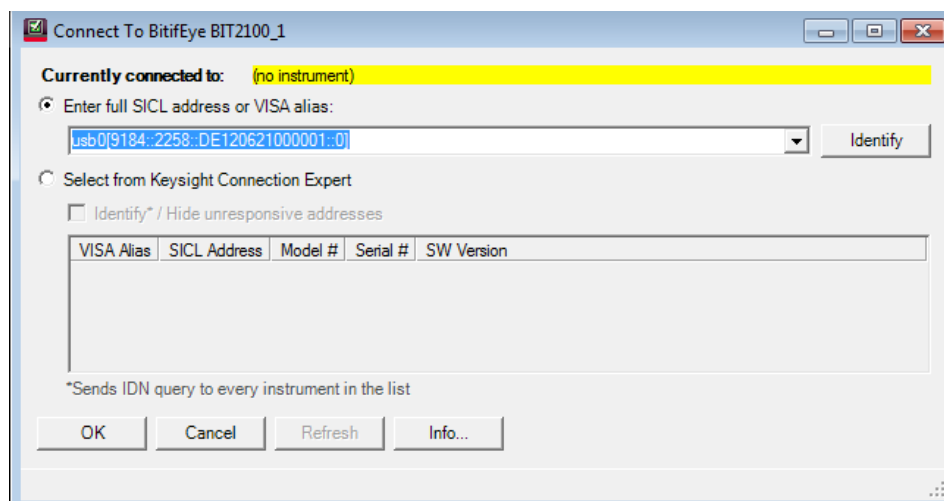


Figure 5 Connecting to the switch matrix

- 8 Select the **Select from Keysight Connection Expert** button and click the SICL address that shows a USB device.

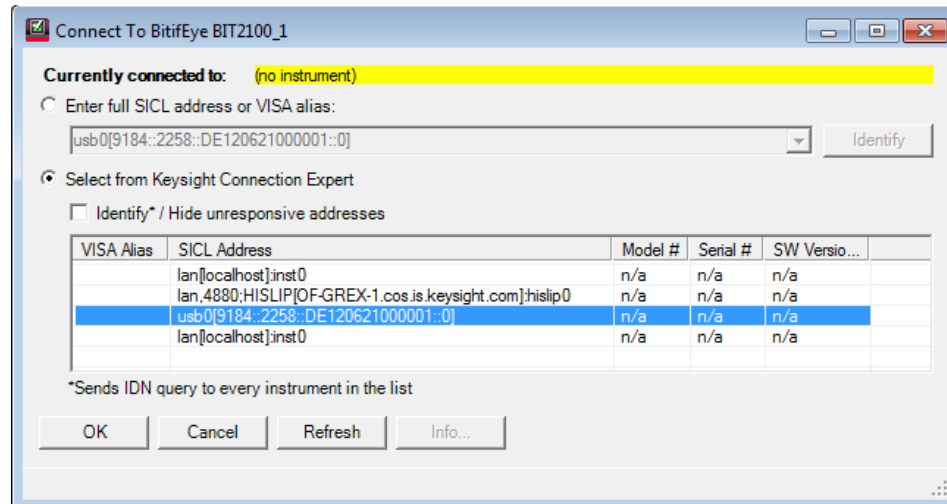


Figure 6 Selecting the USB device

9 Click **OK**.

10 Click **Next>>** to go to the Signal Paths tab.

Using PrecisionProbe for AC Response Correction for Signal Paths

Now that the switch is configured and is controllable, you need to calibrate each of the six paths.

PrecisionCable calibration will compensate the path loss vs. the frequency of each path, plus the skew, so it is critical to the operation of the switch.

- 1 Open the Channel 2 dialog box.



Figure 7 Infiniium Channel dialog box

- 2 Click **Setup...** in the PrecisionProbe/PrecisionCable field. The Channel 2 PrecisionProbe/PrecisionCable dialog box appears.

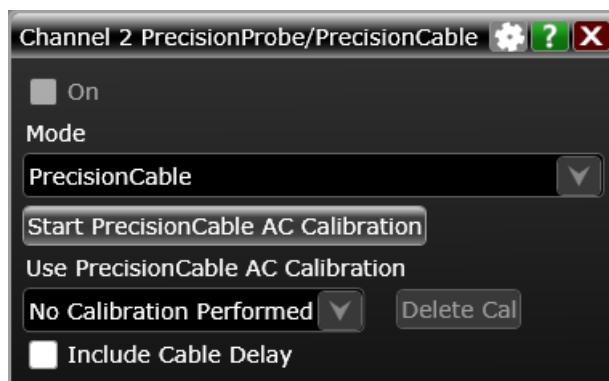


Figure 8 Starting PrecisionCable

- 3 Click **Start PrecisionCable AC Calibration** to start the PrecisionCable Wizard.
- 4 Read the PrecisionCable Wizard initial screen and click **Next >** to open the Connect Trigger step of the wizard.

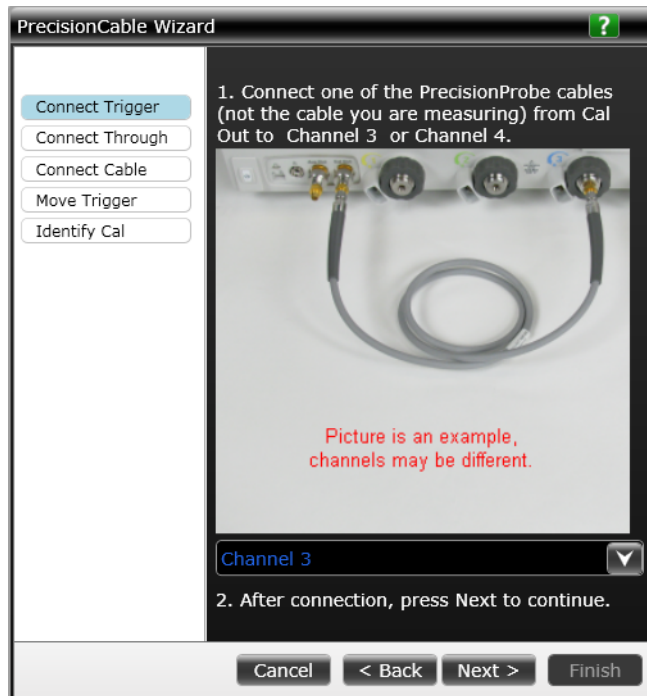


Figure 9 PrecisionCable Wizard – Connect Trigger

- 5 In the wizard's Connect Trigger screen (**Figure 9**), follow the instructions to connect a cable from Cal Out to channel 3. You will need to temporarily remove the N7010A adapter. Click **Next >** to advance to the Connect Through step.
- 6 In the Connect Through screen of the wizard, the example picture is not correct for your test scenario. You need to connect only one cable (not two) directly into channel 2 (not channel 1) from Aux Out.

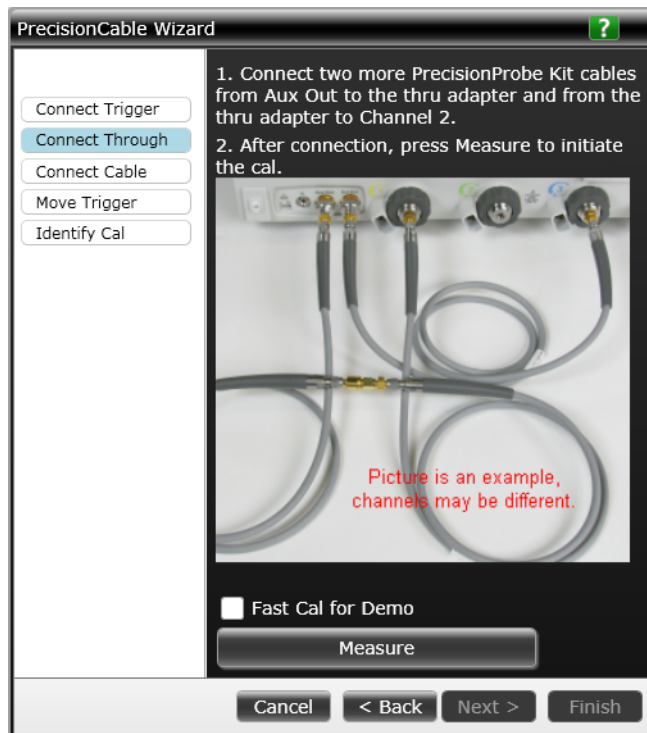


Figure 10 PrecisionCable – Connect Through screen

- 7 After making the correct connection, click **Measure** and wait for the calibration to complete.
- 8 Click **Next >** to advance to the Connect Cable step.

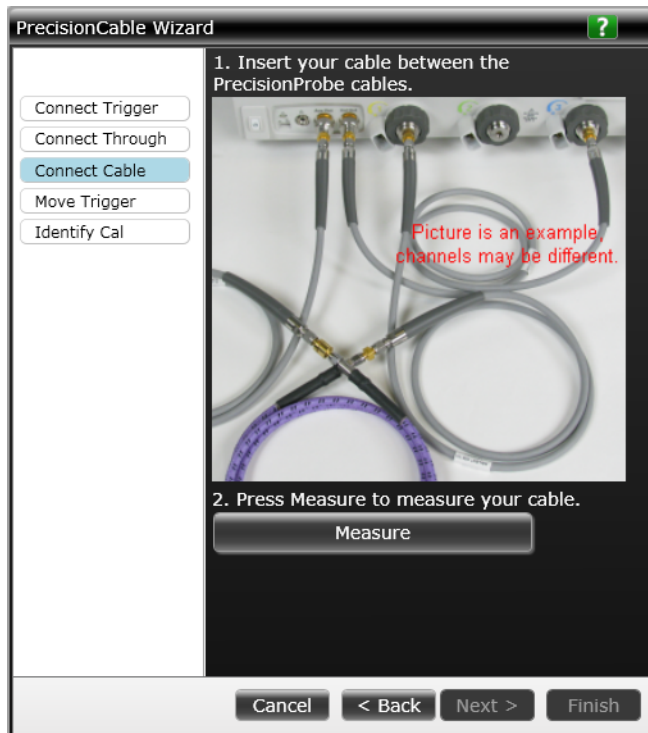


Figure 11 PrecisionCable– Connect Cable

- 9 The example picture in the Connect Cable screen in **Figure 11** also does not reflect your test scenario. It shows a purple cable that represents your switch matrix path, but it does not have the N7010A in place. You must put the N7010A adapter back onto channel 2.
- 10 Connect the cable from Aux Out to the common of the particular SPDT switch of the path you are calibrating. The example picture in **Figure 12** uses D0+.
- 11 Connect the cable coming out of the SP4T common to the N7010A adapter on channel 2, as shown in **Figure 12**. This second measurement will determine the difference between the reference measurement and the one with the N7010A adapter and the path. This difference provides you with a total, absolute correction.



Connect to Aux Out

Connect to adapter on channel 2

Figure 12 Channel 2 and Aux Out connections

- Click the buttons in the switch matrix you saved to change the currently set switch path. See Figure 13.

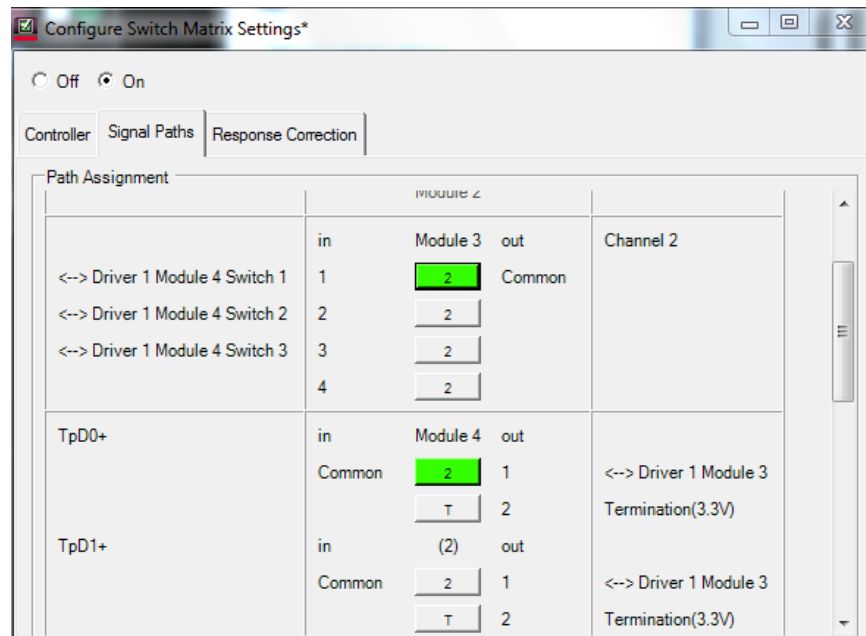


Figure 13 Updated switch matrix

- 13 Click **Measure** in the wizard, then click **Next >** when the measurement is complete.
- 14 When the process is complete, you will be prompted to enter a calibration file name. Choose a name that is easily identifiable, such as **D0_plus**.

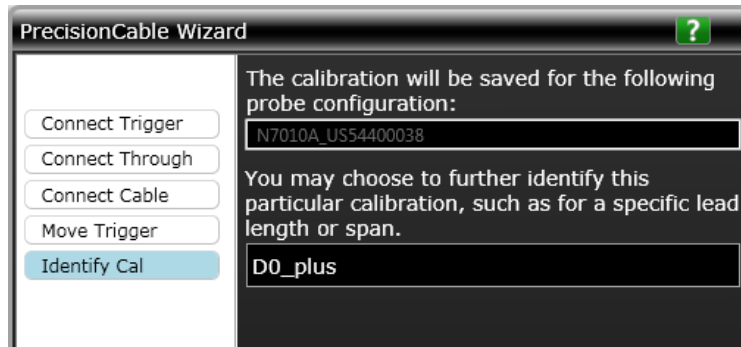


Figure 14 Assigning a cal file name

- 15 Click **Next >** and **Cal Another Cable** until you have calibrated the other two paths of D+ data lanes. Use consistent naming, such as **D1_plus** and **D2_plus**.

Remember that you need to move the physical cables and update the switch matrix for each path, just as you did for the D0_plus path. You will connect Aux Out to switch 2 common for D1+, and Aux Out to switch 3 common for D2+.

- 16 When you are done calibrating all three paths, click **Finish**.
- 17 Review the calibration files for quality.

As you review your own results, note a few things in the screen in **Figure 15**:

- The response should decrease monotonically. For example, a sharp narrow band that changes quickly indicates a cable connection problem. Use a torque wrench to tighten the connection.
- Notice the 6 dB of loss at 15 GHz. This loss would be a benchmark for all channels. The greater the loss to compensate for, the more susceptible to noise your measurements will be.
- Setting the bandwidth to 16 GHz makes a flat result up to about 14 GHz.



Figure 15 PrecisionCable response

- 18 Repeat this procedure on channel 4 for the D- lanes. Assign identifiable names such as **D0_minus**, **D1_minus**, and **D2_minus**.

Remember, as with the D+ lanes, you need to move the cables and update the switch matrix for each path.

- 19 Calibrate the cables being used by the clock lines by repeating path calibration for channels 1 and 3. Use clear names such as **Clk_plus** and **Clk_minus**.
- Start the PrecisionProbe wizard.
 - At the Connect Through screen, connect AuxOut directly into channel 1 (Figure 16).



Figure 16 Connecting channel 1 and Aux Out for the clock

- c At the Connect Cable screen, connect the **Clk+** cable into channel 1, through the N7010A adapter.



Figure 17 Connecting the Clk+ cable into channel 1, using the N7010A adapter

- d Complete the path calibration steps for channels 1 and 3.

When all calibration is complete, your mapping will be:

- **Clk_plus** in channel 1
- **D0_plus, D1_plus, and D2_plus** in channel 2
- **Clk_minus** in channel 3
- **D0_minus, D1_minus, and D2_minus** in channel 4

Assigning cal files to the paths

Next, you need to assign these calibration files to the paths in the HDMI application:

- 1 In the HDMI software application, choose **Tools > Switch Matrix...** and click the Response Correction tab.

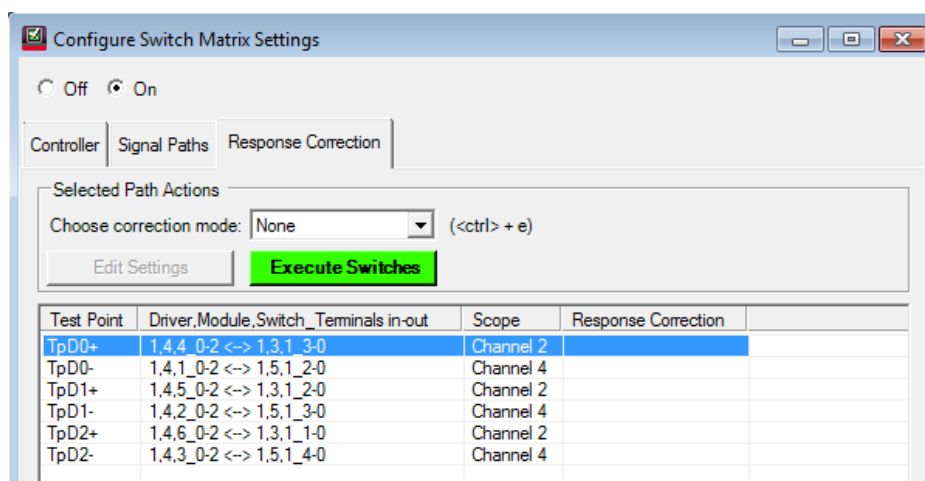


Figure 18 Response correction calibration

- 2 For each row, select the PrecisionProbe correction mode. A new dialog box appears:

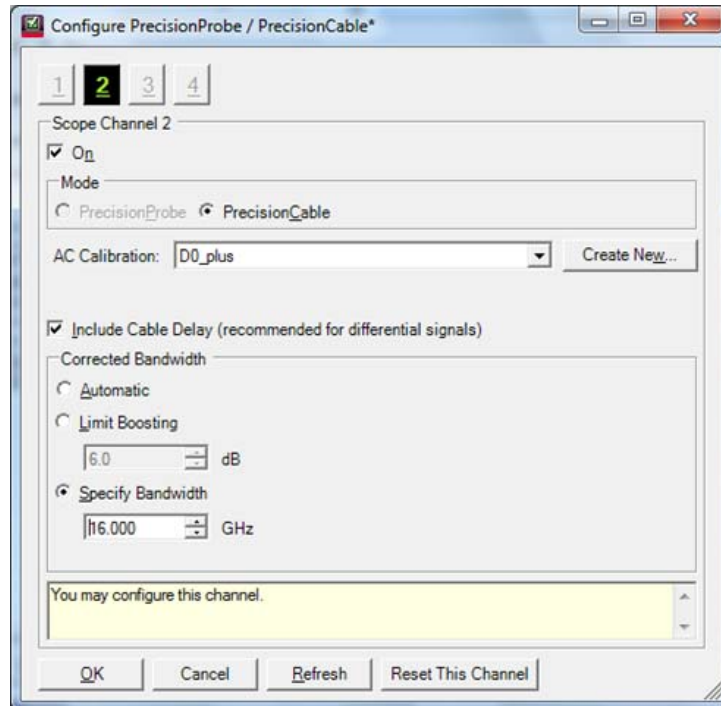


Figure 19 Settings for use of the PrecisionCable calibration file

- 3 Select **Include Cable Delay** (Figure 19) to minimize skew on each line, and specify **16 GHz** of bandwidth because the HDMI application sets the bandwidth of the measurement to 13 GHz. You do not want the combination of this response and the oscilloscope response to produce a lower bandwidth.

NOTE

If the **Include Cable Delay** and **Specify Bandwidth** controls are grayed out, you may need to clear the **On** check box (Figure 19) and re-select it.

- 4 Click **OK**. Notice that the settings appear in the response column in the table under the Response Correction tab.

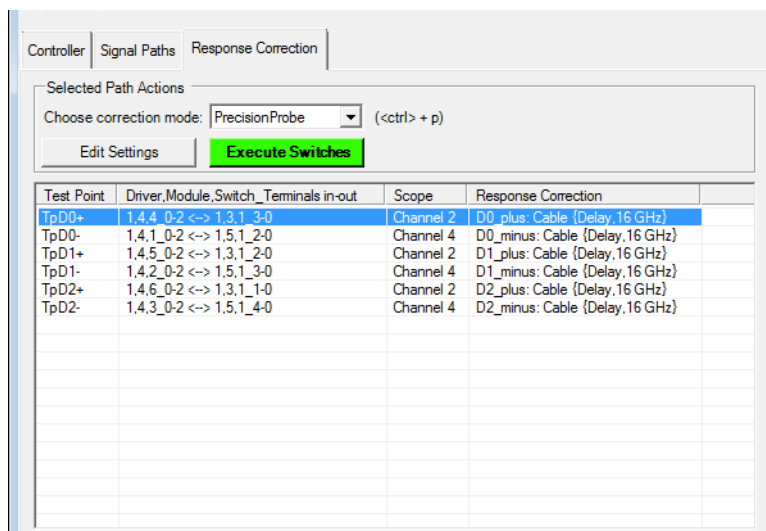


Figure 20 Response correction calibration file assignments

- 5 Use the Configure PrecisionProbe / PrecisionCable dialog box (**Tools > PrecisionProbe/PrecisionCable...**) to enter clock cable information for channels 1 and 3. Select Channels 1 and 3, select the **Clk_plus** and **Clk_minus** files respectively, and make the cable delay and bandwidth selections as you did in **step 3**.

Running Tests to Verify the Setup

Now that you have set up the switch, you should run some tests to ensure the setup is working properly.

Configure the switching operation

- 1 Click **Analyze > Automated Test Apps > N5399C /N5399D HDMI Test App** to start the N5399C HDMI compliance application.

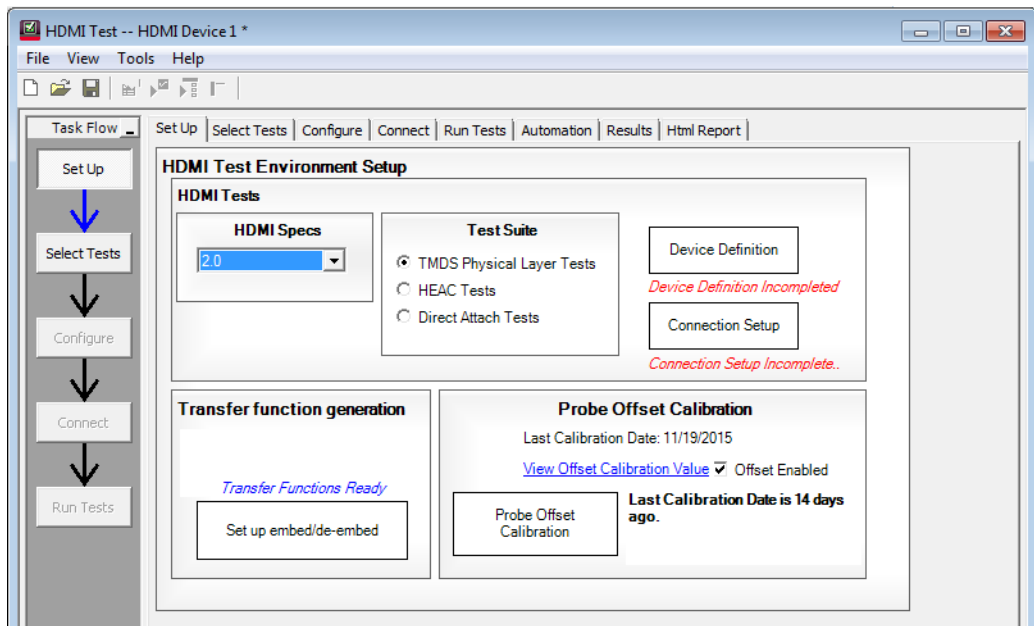


Figure 21 HDMI Test setup screen

- Click the **Connection Setup** box to open the Test Connection Setup dialog box.

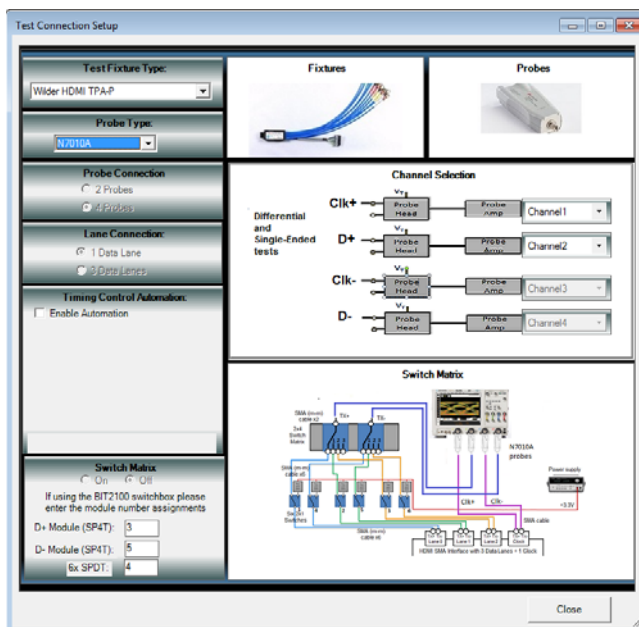


Figure 22 Test Connection Setup dialog box

- Select the Test Fixture Type (**Wilder HDMI TPA-P** in **Figure 22**) and the Probe Type (**N7010A**).

If you are using the FlexEDID or QD 980 for the EDID emulation, select the Enable Automation check box and select the driver.

You will need to set up the switch matrix modules in the lower left area of the dialog box if you enable automation.

- Close the Test Connection Setup dialog box to return to the HDMI Test dialog box.

1 Configure, Set Up, Calibrate

As an example, **Figure 23** shows HDMI set-up selections for fall time of the clock, D0, D1, and D2.

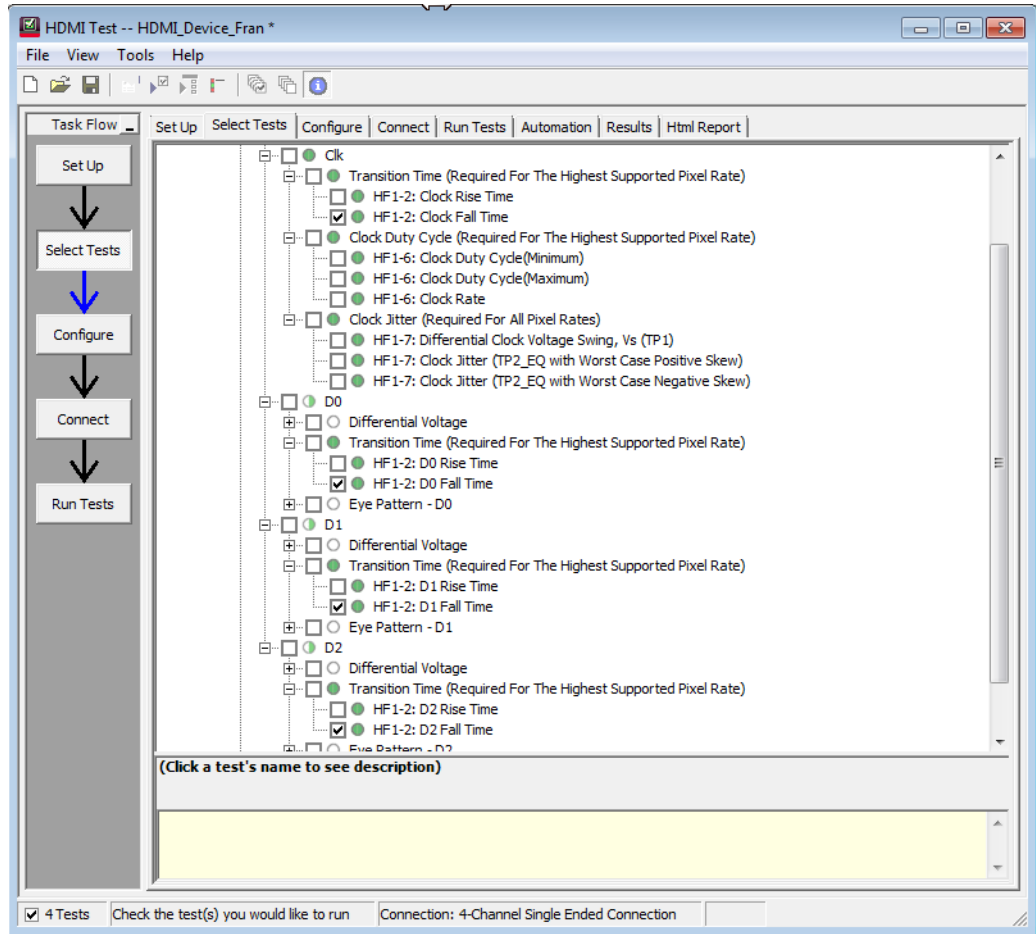


Figure 23 HDMI Test–Set Up tab

The Connect tab of the HDMI Test would look like the one in **Figure 24**.

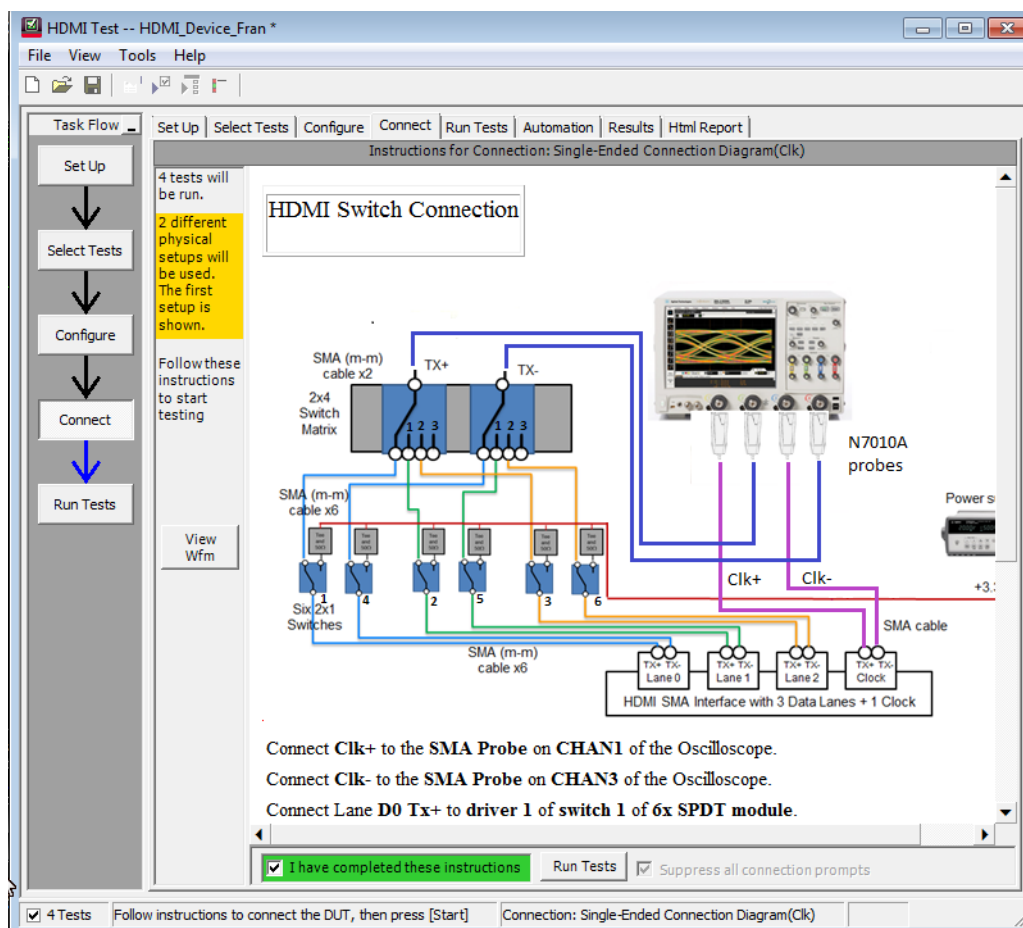


Figure 24 HDMI Test–Connect tab

After you select the check box at the bottom of this screen to show you have completed these instructions, click **Run Tests**.

1 Configure, Set Up, Calibrate

When the tests are complete, click the Html Report tab to see the overall result (Figure 25).

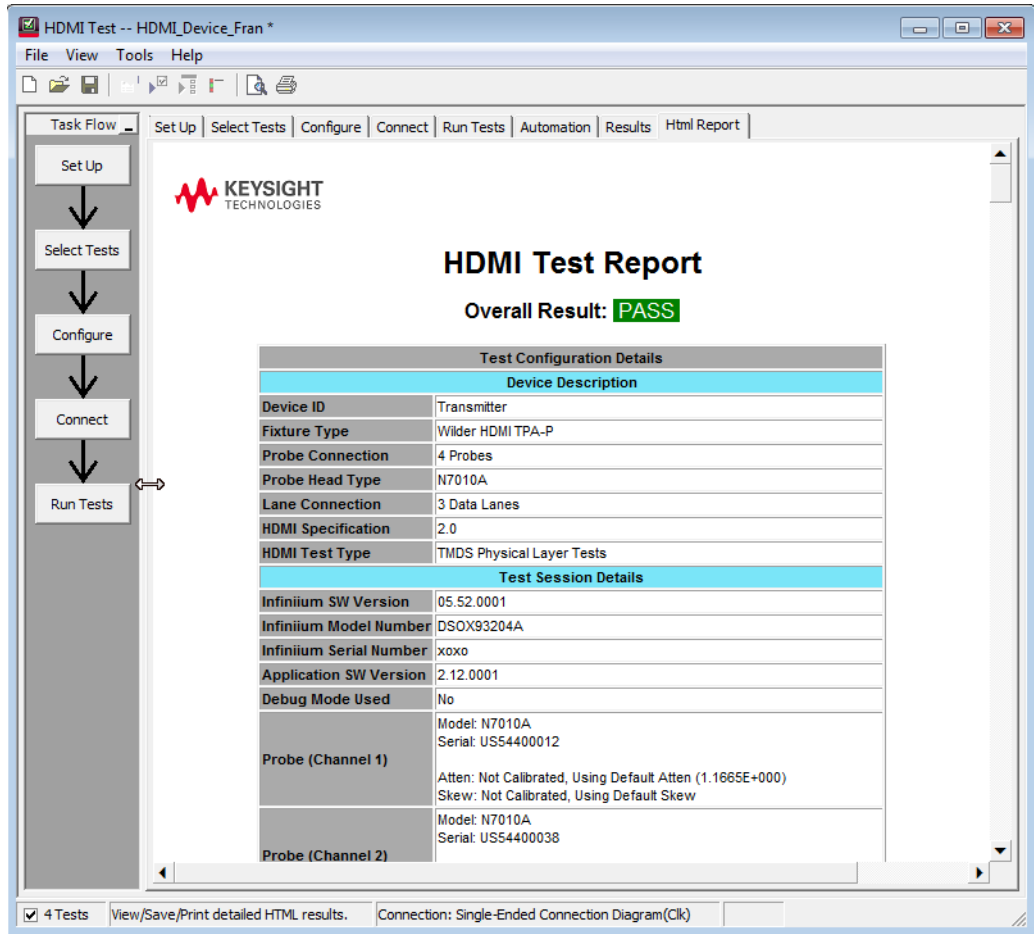


Figure 25 HDMI Test–Html Report tab

A Using a LAN Connection

If you prefer to use a LAN connection rather than a USB to connect the oscilloscope to the switch, you can either connect both the oscilloscope and the switch to the LAN, as described in this appendix, or connect a LAN cable between the switch and the oscilloscope.

Oscilloscope and switch both connected to a LAN

- 1 Assuming the oscilloscope is already connected to the LAN, connect the switch to the LAN, press the LXI LAN Reset button on the switch for the oscilloscope to re-acquire its IP address, and wait 2 minutes.
- 2 Click **IO > Connection Expert** from the bottom right area of your oscilloscope.

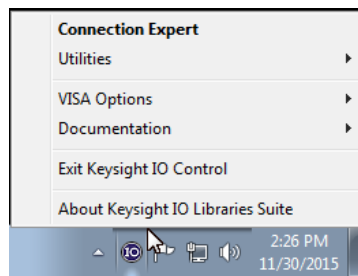


Figure 26 Keysight IO Libraries Suite

- 3 Locate and click the BIT2100 instrument in the left side of the Instruments tab. If you do not see BIT2100 in the list of instruments, go to **“Using a USB connection to determine the VISA address”** on page 30.

NOTE

Figure 27 shows IO Libs version 17.X. If you have an earlier version, the interface will look different.

- 4 Take note of the SICL address for later reference.

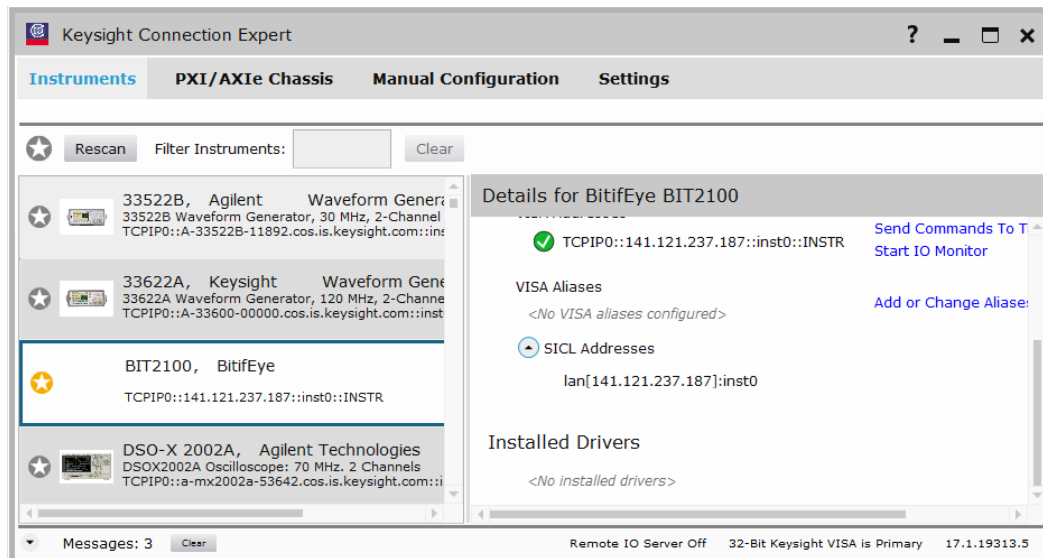


Figure 27 Using Keysight Connection Expert (Keysight IO Libraries) to find the switch

Using a USB connection to determine the VISA address

If Connection Expert is unable to locate the switch, which may happen when there are too many instruments on a large network, you can use a USB connection to find the IP address:

- 1 Connect the USB cable between the switch and the oscilloscope. You will see the VISA address in the Connection Expert:

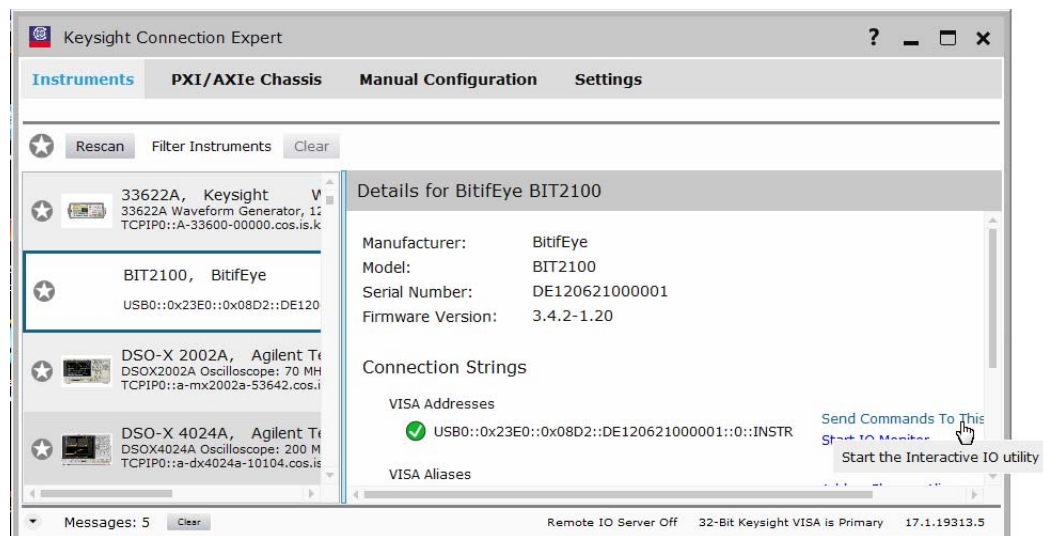


Figure 28 VISA address

- 2 Click **Send Commands To This Instrument** (Figure 28) to start the Interactive IO utility.
- 3 In the Command field, enter the **:NET:IP?** command and click **Send & Read** to find the IP address of the switch. Use the right-click menu to copy the address.

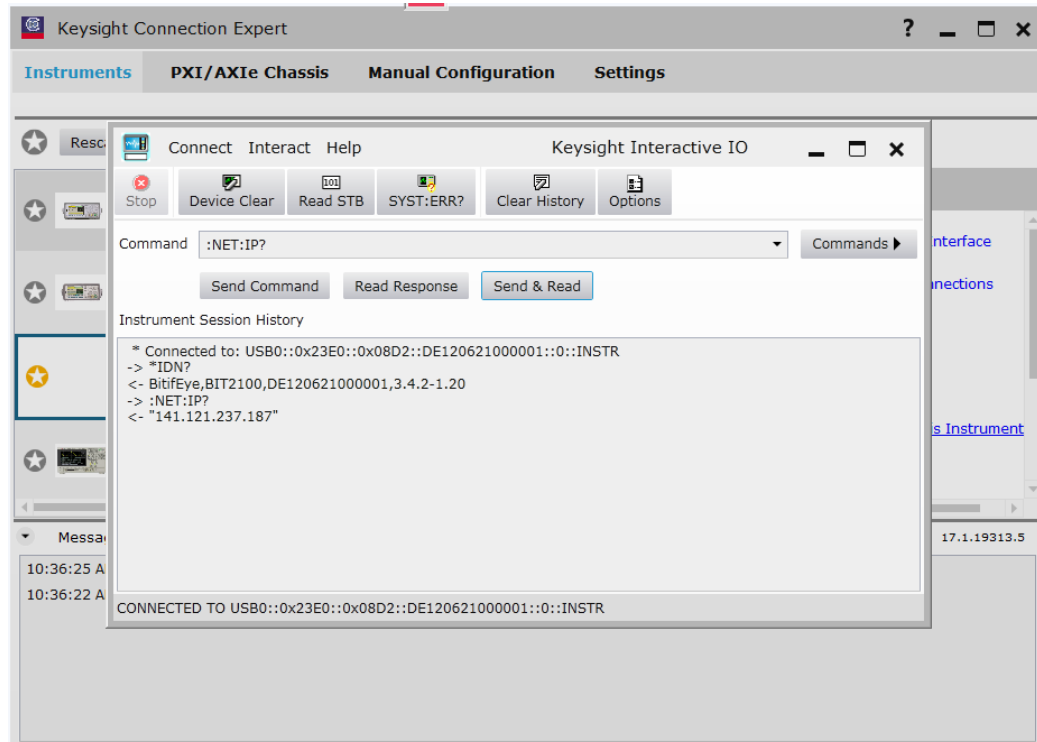


Figure 29 Finding the IP address using USB cable and Keysight IO Libraries

- 4 Close the Keysight Interactive IO window.
- 5 In the Keysight Connection Expert, click the Manual Configuration tab and paste the copied IP address into the Hostname or IP address field.

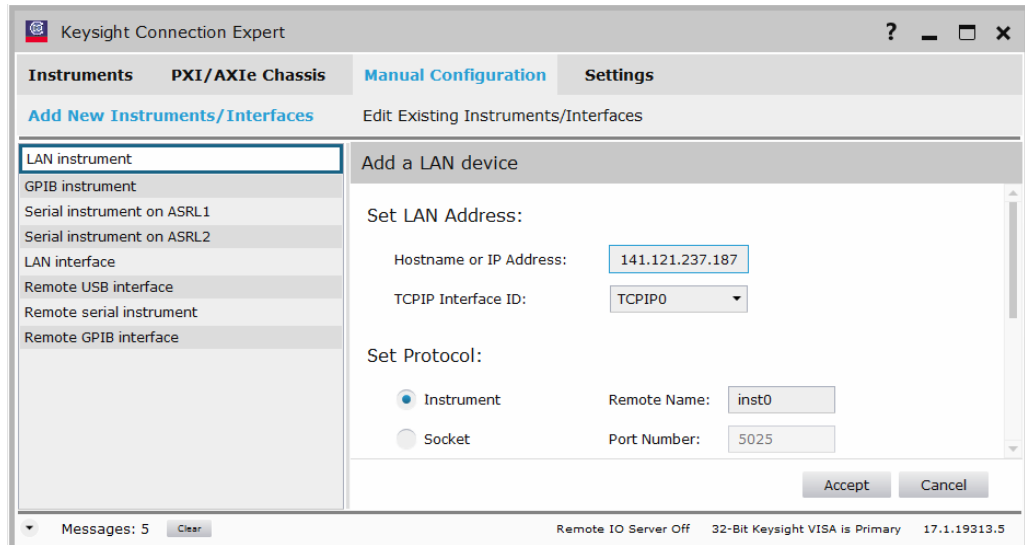


Figure 30 Copy the IP address into the **Hostname or IP Address** field

6 Click **Test This VISA Address**.

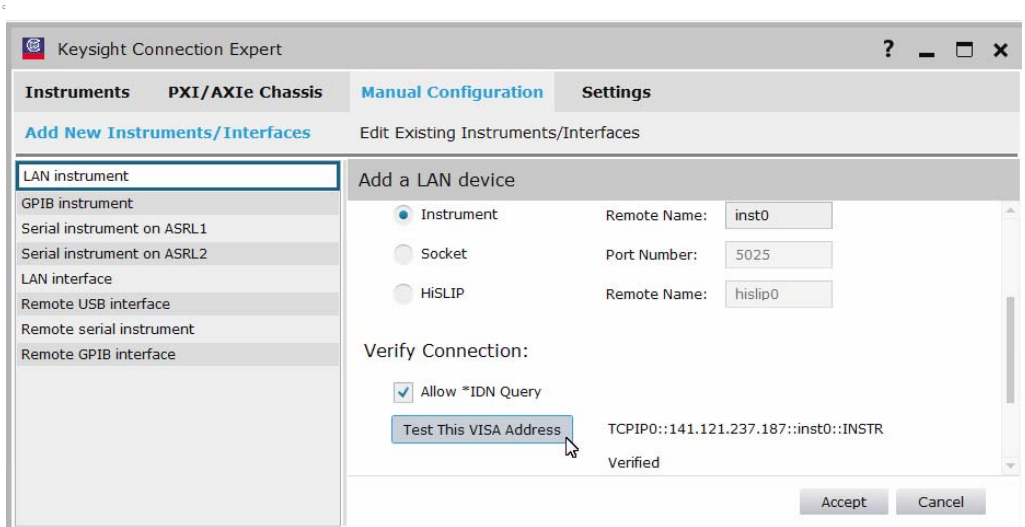


Figure 31 **Test This VISA Address**

7 Click **Accept**.

B Configuring Paths Manually

If you want to connect your cables in a different way than described in this guide, follow these steps to manually set up the switch matrix.

- 1 Connect the USB cable between the switch and the oscilloscope.
- 2 Start the HDMI application from the Infiniium application (**Analyze > Automated Test Apps > N5399C/N5399D HDMI Test App**).
- 3 Drag the HDMI Test window to the bottom of your screen, leaving the menu bar accessible.
- 4 Click **Tools > Switch Matrix...**
- 5 Select **On** to make the grayed-out sections active.
- 6 Select **Manually perform these tasks**.
- 7 Select the model of the switch (BitifEye BIT2100).
- 8 Click **Add**.
- 9 Click **Connect...**
- 10 Select the Signal Paths tab, then use **Figure 32** as an example when setting up your switch matrix. Before you begin setting the switches, read these helpful tips:
 - Start with module 4, putting the HDMI inputs into the switch matrix.
 - Click the blue text **in** and **out** to toggle between them. For example, assume you want module 4 to be configured as a set of 1 in and 2 out, though it defaults as 2 in and 1 out.
 - Because the switches are active at this point, you can click any of the boxes in the middle (Switch) column to control the switch.
 - When you have a valid path to channel 2 or channel 4, the box will appear as green for channel 2 and red for channel 4.

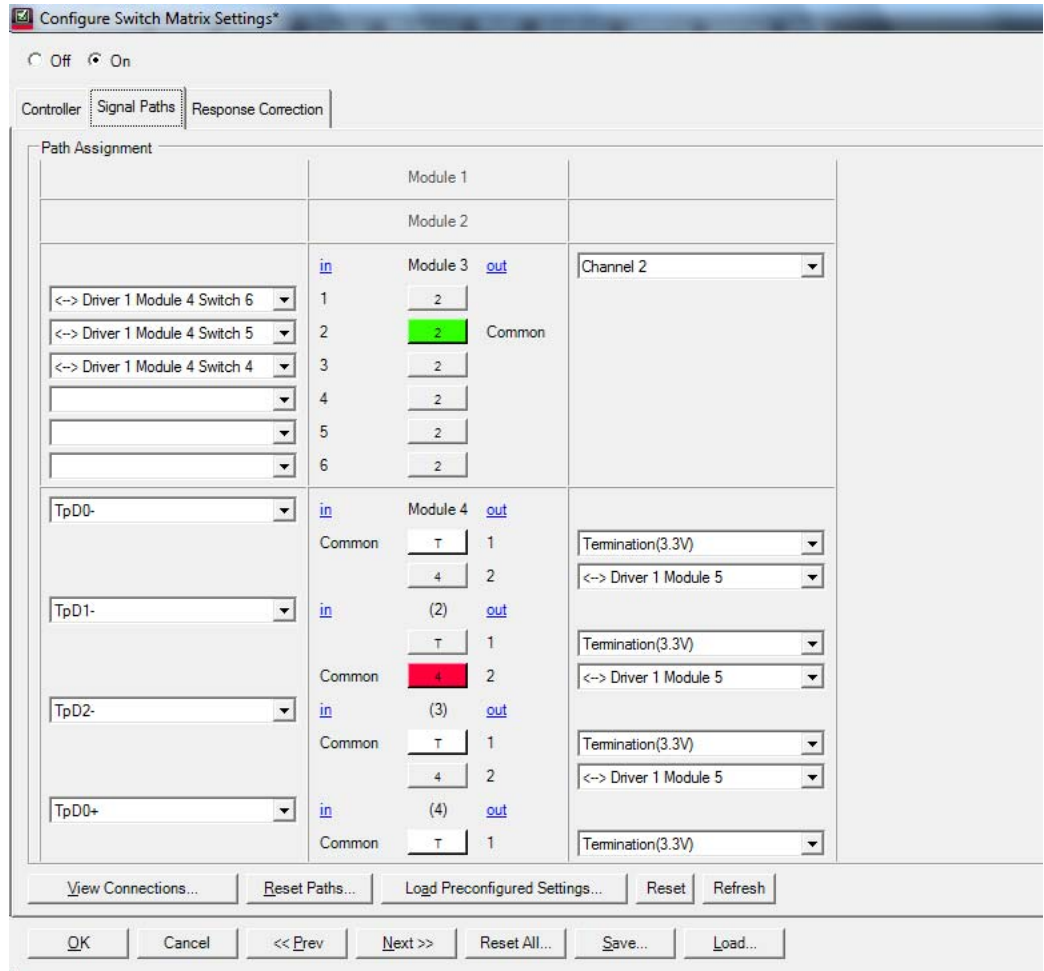


Figure 32 Switch definition showing module 3 and part of module 4 configuration

- 11 Click **Save...** at the bottom of the dialog box to save your configuration for future use. Choose a name that is easy to remember.
- 12 Close the Configure Switch Matrix Settings dialog box.

NOTE

If your switch settings do not appear when you open the dialog box, click **Reload** to load the saved file.



This information is subject to change without notice.

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