Revision 1.01
Feb-24, 2017

Universal Serial Bus Type-C™ Specification Revision 1.1

Keysight Method of Implementation (MOI) for USB Type-C™ Cables Assemblies Compliance Tests Using Keysight M937XA Multiport PXIe VNA

For Type-C to Type-C Passive Cable Assemblies

(Low Speed Signal)

Table of Contents

1. Revision History

Revision	Date	Remarks
01.00	2016/04/14	• Initial release • Spec 1.1 and compliance document 1.0
01.01	2017/02/24	• Updated required equipment

2. Purpose

This test procedure is provided for USB Type-C cable testing using the Keysight M937XA PXIe VNA per USB Type-C Cable and Connector Specification Revision 1.1 and Connectors and Cable Assemblies Compliance Document 1.0.
The test procedure is applied for Type-C to Type-C passive cable assemblies (Low Speed Signal).

3. References

- Universal Serial Bus Type-C Cable and Connector Specification Revision 1.1 (April 3, 2015)
- Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document 1.0 (October 6, 2015)

4. Required Equipment

Description	Test Equipment	QTY
Network Analyzer	Keysight M937XA PXIe Vector Network Analyzer ➢ Either M9370A (4.5 GHz), M9371A (6.5 GHz), M9372A (9 GHz), M9373A (14 GHz), M9374A (20 GHz) or M9375A (26.5 GHz) Note: The firmware of the M937XA with revision A.03.00 or later is required for operation.	6 ea.
Network Analyzer Software	➢ Option 010 (Time-domain Analysis) ➢ Option 551 (N-port Calibrated Measurements) Note: Only QTY 1 of these options needs to be ordered for one of the six M937xA modules when using a multiport configuration.	1 ea.
PXI Chassis	Keysight M9018A or M9019A PXIe 18-slot chassis	1 ea.
PXI Controller	Keysight M9037A High-performance embedded controller	1 ea.

	➢ Option M04 (4 GB Memory) ➢ Option WE3 or WE6 (Windows Embedded Standard 7 (32 bit) or (64 bit)	
Cable kits for multiport configuration	Keysight Y1242A Cable kits for multiport configuration	5 ea.
Accessory and tool kit	Keysight Y1281A accessory and tool kit for connector removal.	1 ea.
4-port ECal	Keysight N4431B (4-port, 13.5 GHz) or N4433A (4-port, 20 GHz) ➢ Option 010 (3.5 mm female connectors on all ports)	1 ea.
Test Fixture	USB Type-C official test fixtures and calibration standards	1 ea.
RF cable	3.5 mm or SMA cables of 20 GHz bandwidth or more Note: Refer to Configuration Guide of Digital Interconnect Test System Reference Solution (5992-1447EN) for cable examples.	12 ea.
50 ohm Terminator	Termination for unused differential pairs (ex. Keysight 909D-301, 3.5 mm male termination)	8 ea.
Compliance Tool	USB Type-C cable assembly compliance tool provided by USB-IF	1 ea.

Note: Refer to the M937XA Configuration Guide (5991-4885EN) for more detail at: http://www.keysight.com/find/pxivna.

Note: Fixtures for testing USB 3.1/Type-C connectors and cable assemblies are available for purchase through Luxshare-ICT.

http://web.luxshare-ict.com/en/ProductList.php?id1=22&id2=92

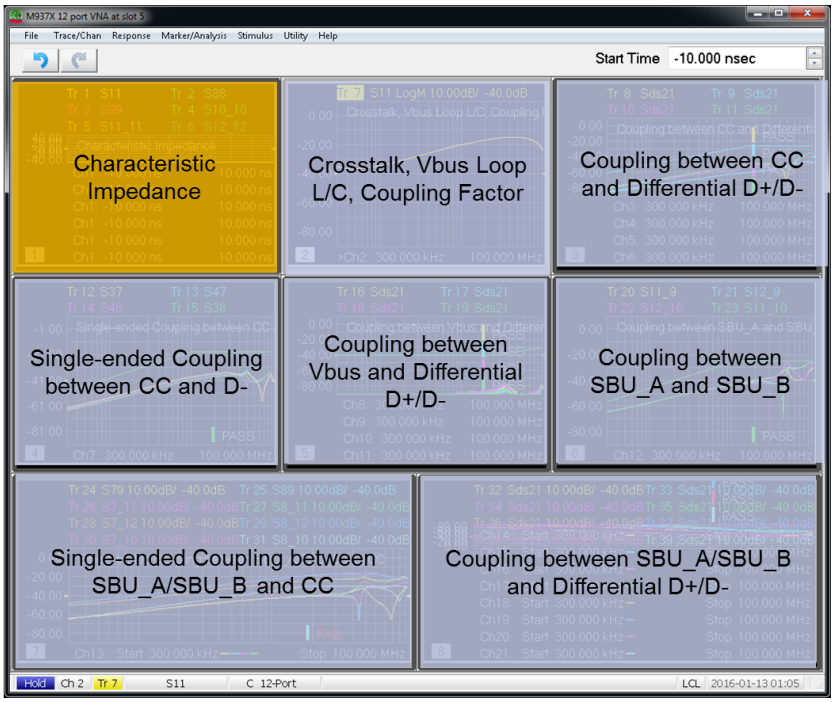
5. Test Procedure

5.1. Outline of Test Procedure

1. **Test System Setup**
   - Launch a 12-port VNA
   - Automatic setup by recalling a state file
2. **Calibration**
   - ECal Calibration and De-embedding
3. **Measurements**
   1. **Time-domain Measurements**
      - Characteristic Impedance
   2. **Frequency-domain Measurements**
      - V_{BUS} loop inductance and capacitance (L/C), coupling factor
      - Coupling between CC and differential D+/D-
      - Single-ended coupling between CC and USB D-
      - Coupling between V_{BUS} and differential D+/D-
      - Single-ended coupling between SBU_A and SBU_B
      - Single-ended coupling between SBU_A/SBU_B and CC
      - Coupling between SBU_A/SBU_B and differential D+/D-

Time Domain **(normative)**

Frequency Domain **(normative)**

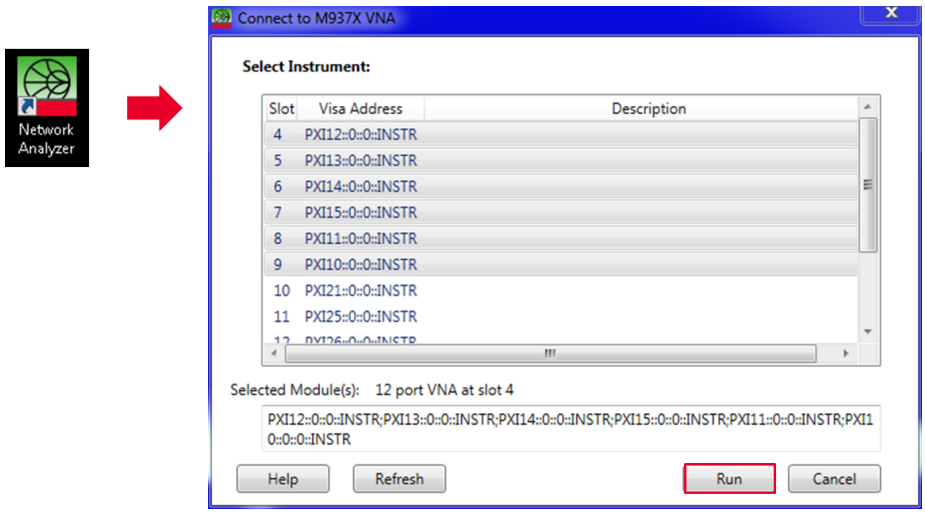


5.2. Test System Setup

This section describes how to set up parameters by recalling a state file of the 12-port M937XA that includes all the measurement settings necessary for USB Type-C cable assemblies (low speed signal) compliance tests. The state file for the 12-port M937XA can be downloaded at: http://www.keysight.com/find/pxivna_usbtype-c-cabcon.

5.2.1. Launch a 12-port VNA

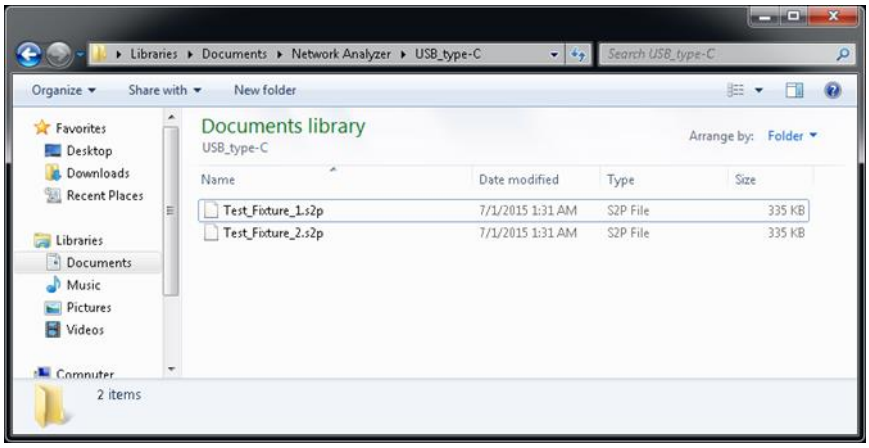
1. Double-click a shortcut icon "Network Analyzer" on desktop of the PXI controller
   For more details about installing the M937XA firmware, refer to the M937XA Startup Guide at: http://literature.cdn.keysight.com/litweb/pdf/M9370-90001.pdf
2. Select 6x PXI VNA modules to configure a 12-port VNA
3. Click "Run"



5.2.2. Save De-embedding Files

De-embedding Touchstone files of test fixtures (*.s2p) should be saved in the directory of the PXI controller in advance of recalling a state file. The file paths are pre-defined in the state file for all the measurements. The procedure of creating de-embedding files using the PLTS software is described in Appendix, "Creating Fixture De-embedding Files using PLTS AFR".

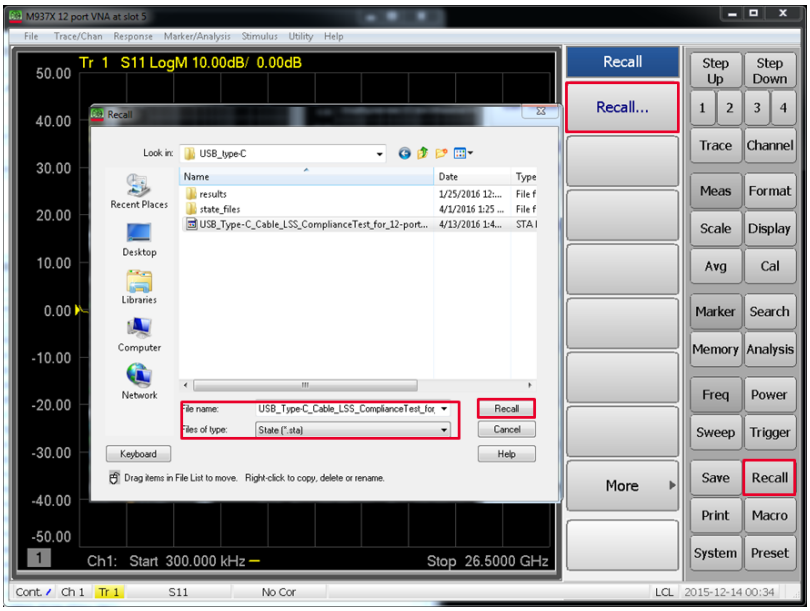
1. Rename 2-port Touchstone files of test fixtures (*.s2p) as:
   - "Test_Fixture_1.s2p" (Test Fixture - Side A)
   - "Test_Fixtures_2.s2p" (Test Fixture - Side B)
2. Save the two files under "C:/Users/Public/Documents/Network Analyzer/USB_Type-C/Test_Fixture_x.s2p" of the PXI controller



Note: In the following sections, steps using keys in Toolbar of the PXI firmware (on right screen) are highlighted in blue and **bold**, and softkeys are highlighted in **bold**.

5.2.3. Recall a State File

1. Click **Recall** > **Recall...**
2. Select "State (*.sta)" for Files of Type
3. Select a state file name ("USB_Type-C_Cable_LSS_ComplianceTest_for_12-port_M947xA.sta")
4. Click "Recall"



Note: When the number of ports in a multiport VNA is smaller than 12, an error message is shown when recalling a state file for a 12-port VNA.

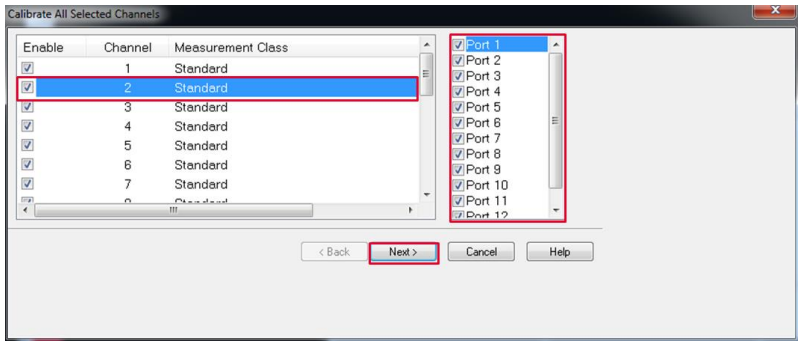
5.3. Calibration

The purpose of this step is to calibrate the RF effects such as delay, loss or mismatch of RF cables and test fixture traces before measurements. The effect of test cables is removed by full multiport calibration using the ECal module. The effect of test fixture is removed by de-embedding 2-port S-parameter data (*.s2p) of each trace.

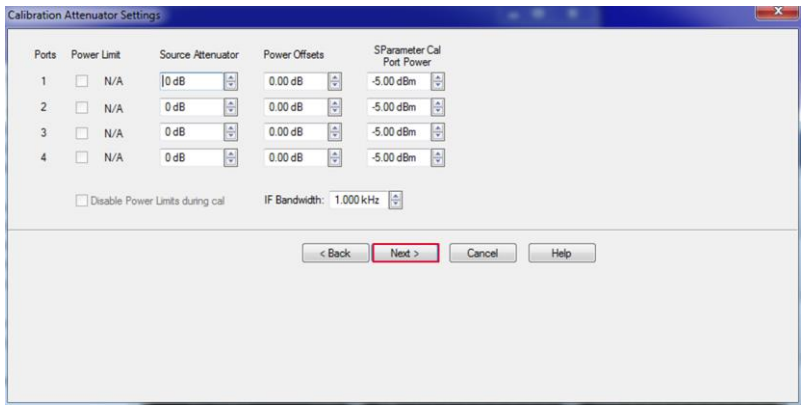
5.3.1. Perform Multiport Calibration using ECal

Full multiport calibration is performed by using the 4-port ECal Module (i.e. N4433A) at the end of RF cables connected to test ports of the M937XA multiport VNA.

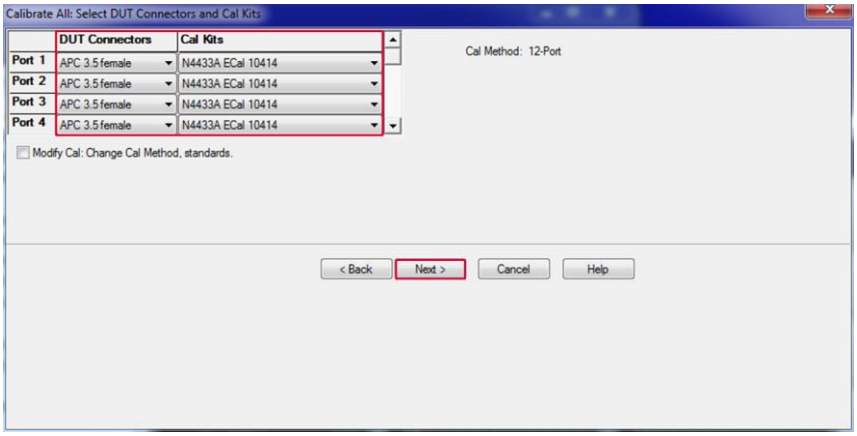
1. Click **Cal** > **Start Cal** > **Cal All Wizard…** to launch calibration wizard
2. Select Channel 2
3. Check all ports (Port 1 to Port 12) on right
4. Click “Next >”



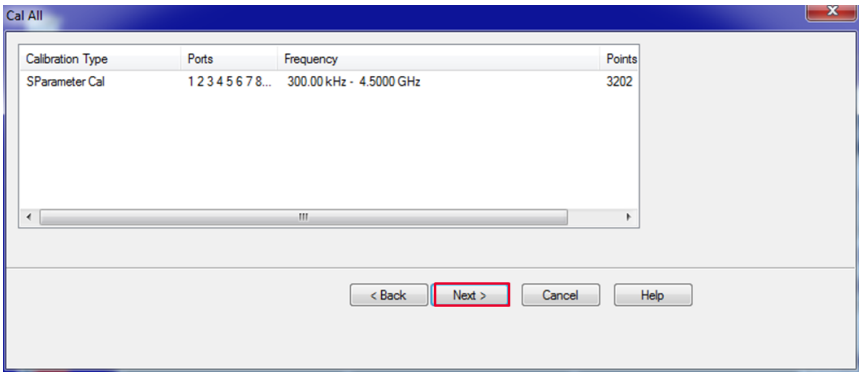
5. Click “Next >”



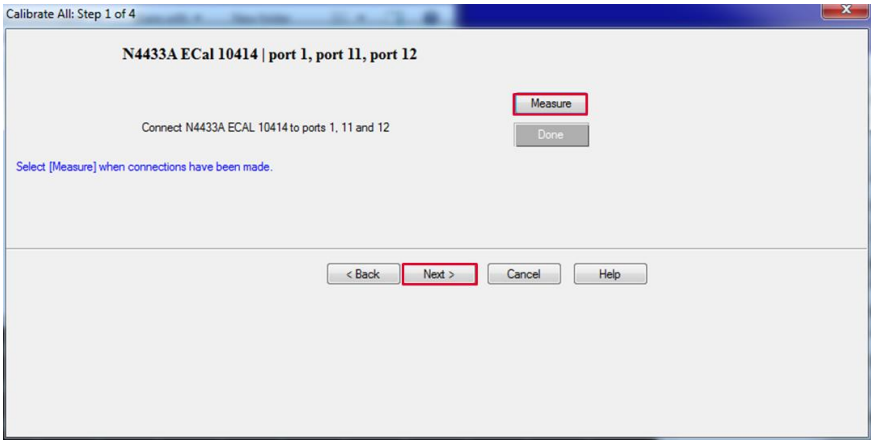
6. Select “APC 3.5 female” of DUT Connectors for all ports (Port 1 to Port 12)
7. Select “N4433A ECal xxx” of Cal Kits for all ports (Port 1 to Port 12)
8. Click “Next>”



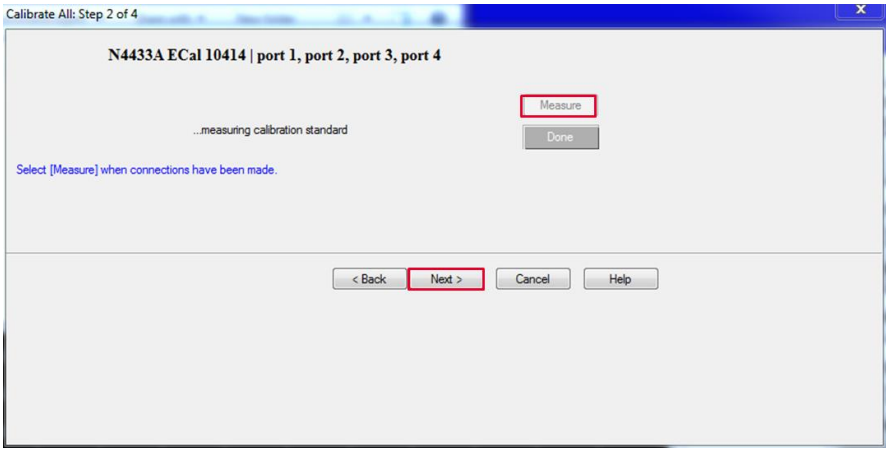
9. Click “Next>”



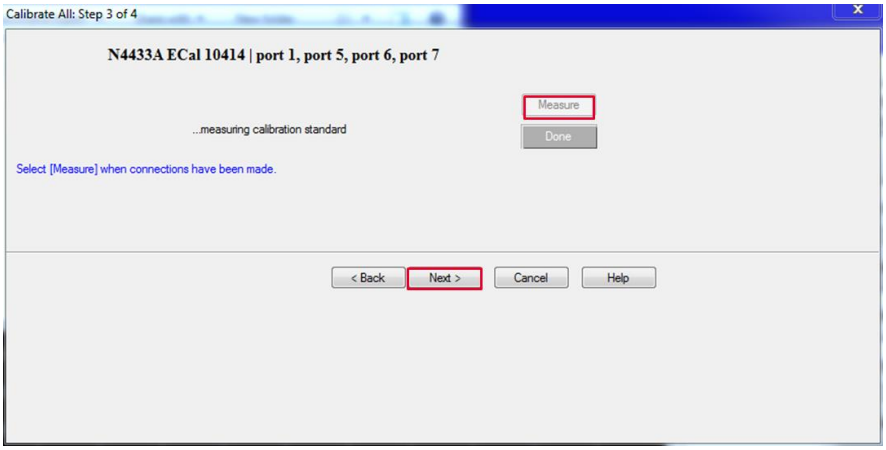
10. Connect port 1, port 11 and port 12 of the VNA to ECal ports.
11. Click “Measure” to start calibration measurements
12. Click “Next>” after the measurements are completed



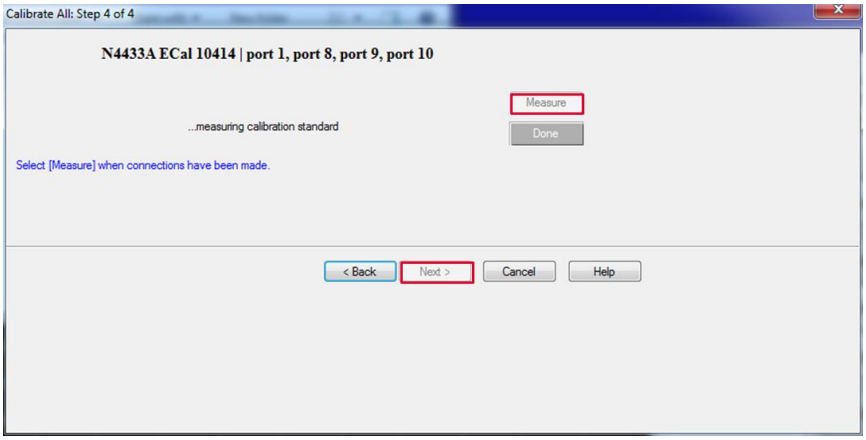
13. Connect port 1, port 2, port 3 and port 4 of the VNA to ECal ports.
14. Click “Measure” to start calibration measurements
15. Click “Next>” after the measurements are completed



16. Connect port 1, port 5, port 6 and port 7 of the VNA to ECal ports.
17. Click “Measure” to start calibration measurements
18. Click “Next>” after the measurements are completed

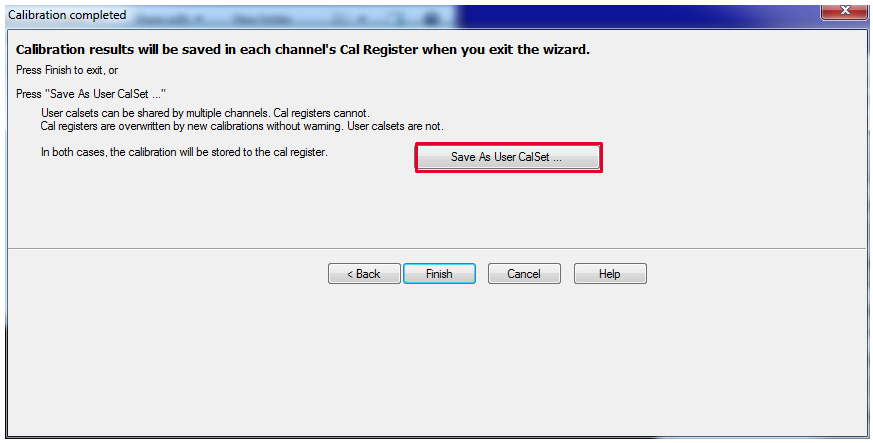


19. Connect port 1, port 8, port 9 and port 10 of the VNA to ECal ports.
20. Click “Measure” to start calibration measurements
21. Click “Next>” after the measurements are completed



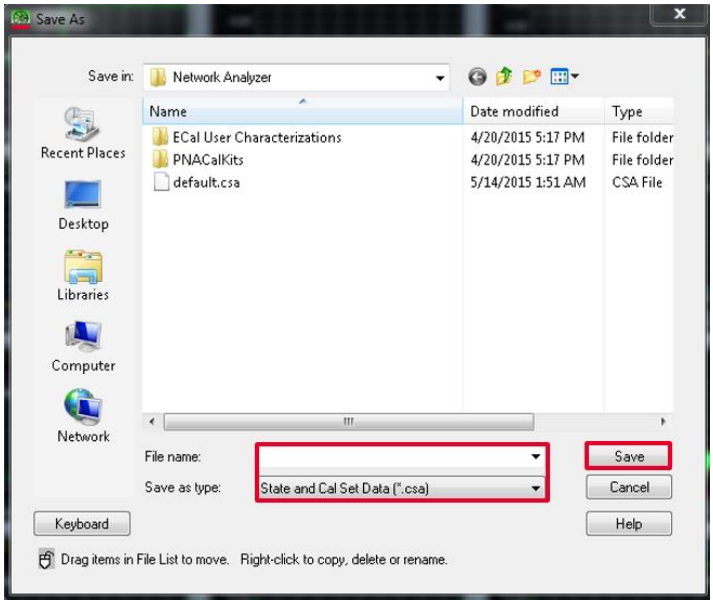
22. Click “Save As User CalSet…”
23. Enter CalSet name

24. Click “Save”



5.3.2. Save a State File including Cal Set Data

1. Click **Save** > **Save As...**
2. Select “State and Cal Set Data (*.csa)” of “Save as type”
3. Enter a file name
4. Click “Save”



5.4. Measurement

5.4.1. Connect VNA and test fixtures

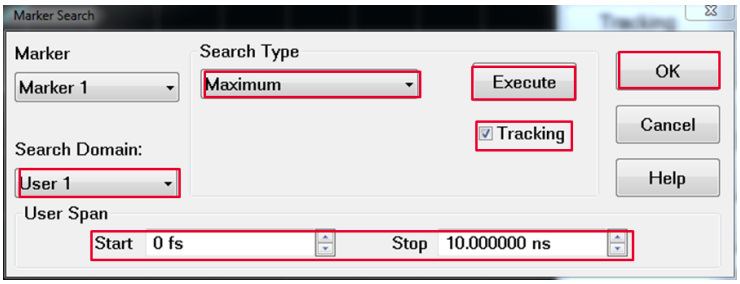
All RF test cables from the 12-port VNA should be connected to the ports of test fixtures. Since multiport calibration is performed for all test items in the previous section, further connection & disconnection of test cables are not needed. Connection of the VNA's ports and fixture ports are listed below. Note that unused ports of test fixtures should be terminated with 50-ohm terminations.

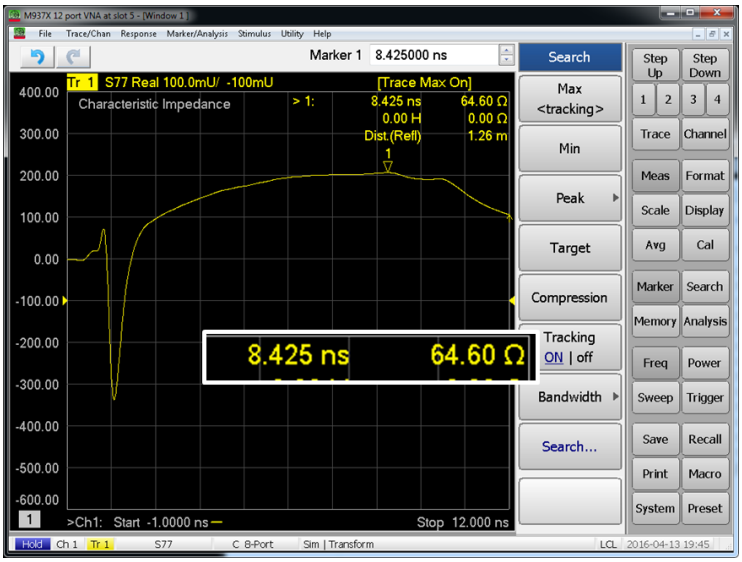
VNA Ports	Test Fixture A Side	Cable Assembly		Test Fixture B Side	VNA Ports
	Type-C (Receptacle)	Type-C (Plug)	Type-C (Plug)	Type-C (Receptacle)	
Port 1	D+	⇔		D+	Port 2
Port 3	D-	⇔		D-	Port 4
Port 5	V_{BUS}	⇔		V_{BUS}	Port 6
Port 7	CC1	⇔		CC1	Port 8
Port 9	SBU1	⇔		SBU2	Port 10
Port 10	SBU2	⇔		SBU1	Port 12

5.4.2. Characteristic Impedance

Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.

1. Select Trace 1 (S77) of Channel 1 in Window 1
2. Click **Trace** > **Trace Max** and turn on to maximize the trace
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Click **Scale** > **Autoscale**
5. Click **Search** > **Search…**
6. Select "User 1" for Search Domain
7. Enter the span range in time domain depending on DUT's cable length (ex. Start = 0 ns, Stop = 10 ns)
8. Select "Maximum"
9. Check "Tracking"
10. Click "Execute" to search for the max impedance value in the range
11. Click "OK"





Note: Y-axis values on left of the screen do not represent impedance values in ohms.

12. Click **Search** > **Min** to search for the minimum impedance value
13. Confirm measured characteristic impedance is within the specification

Trace Number	Type	Spec
Trace 1 to 2 (S77, S88)	CC unshielded or shielded wires	32 to 93 ohm
Trace 3 to 6 (S99, S10_10, S11_11, S12_12)	SBU unshielded or shielded wires	32 to 53 ohm

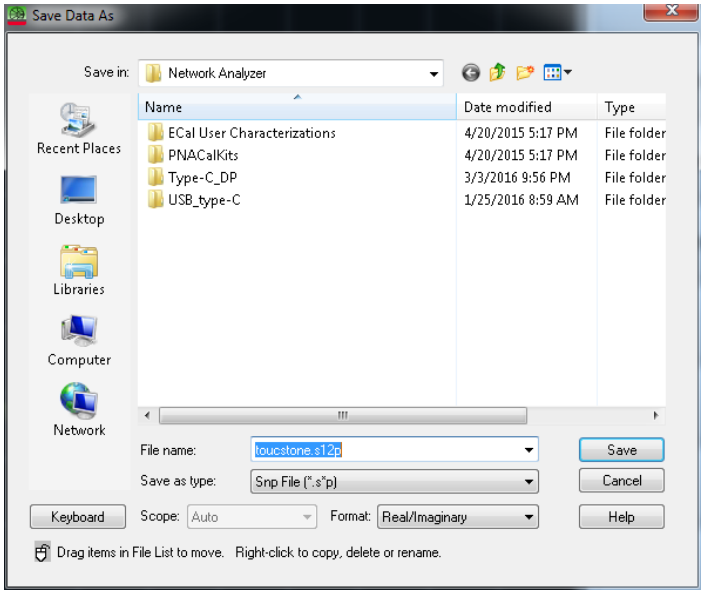
14. Activate traces and repeat above step 4 to step 12 for Trace 2 to Trace 6 (S88 to S12_12) of Channel 1 in Window 1

5.4.3. Crosstalk, V_{BUS}, Loop inductance, capacitance, Coupling Factor

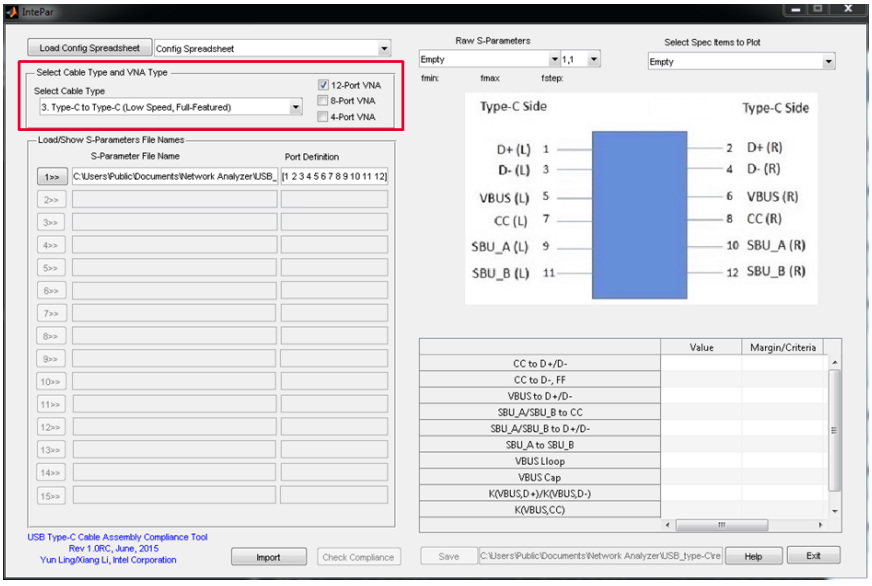
Crosstalk, V_{BUS} loop inductance, V_{BUS} capacitance and coupling factor performance are checked with the standard tool (*CableComp Tool*) provided by USB-IF. One 12-port Touchstone file (*.s12p) is created and saved with the PXI VNA firmware, and then imported to the compliance tool for pass/fail judgement.

Note: The port Z conversion is turned off so the measurement is performed based on 50 ohm port impedance required by the standard tool.

1. Select Trace 7 of Channel 2 in Window 2
2. Click **Trigger** > **Single** to trigger measurement sweep once
3. Click **Save** > **Save Data As…**
4. Select “Snp File (*.s*p)” for “Save as type”
5. Enter File name with the file extension of “*.s12p” (ex. touchstone.s12p) to represent a 12-port Touchstone file.
6. Click “Save”

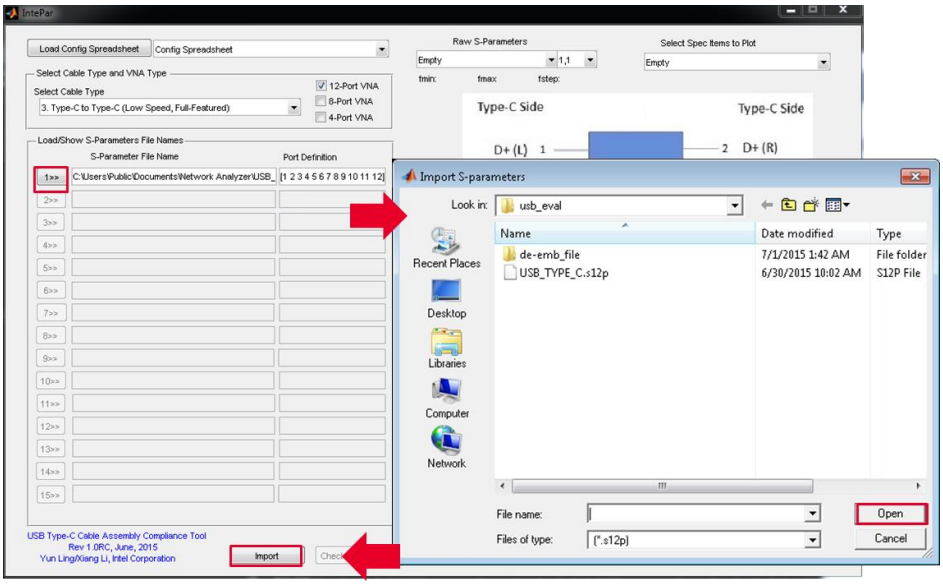


7. Launch USB Type-C Cable Assembly Compliance Tool
8. Select Cable Type (ex. “3. Type-C to Type-C (Low Speed, Full-Featured)”)
9. Check “12-Port VNA”

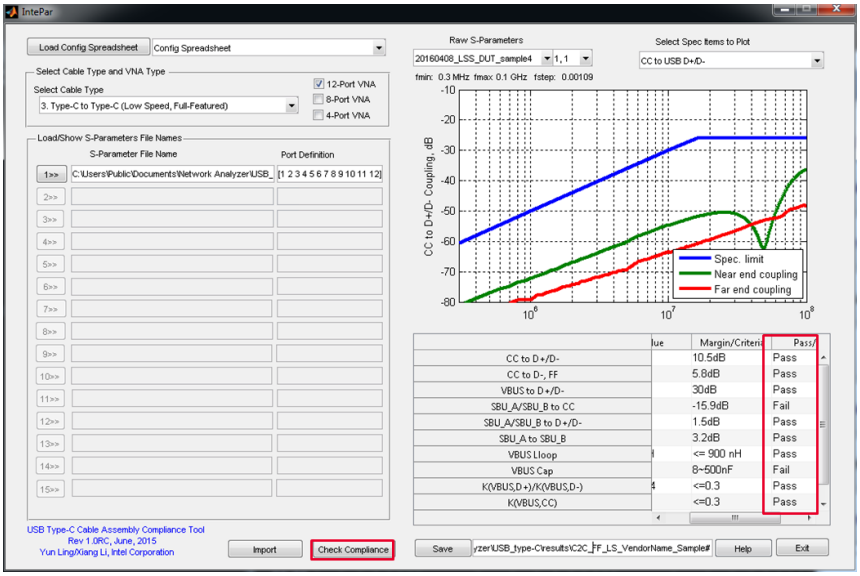


10. Click “1>>” to load 12-port Touchstone file (*.s12p)

11. Select a file name of saved 12-port Touchstone file (*.s12p) and click “Open”
12. Click “Import”



13. Click “Check Compliance”
14. Measurement results (pass/fail judgment) are shown.



5.4.4. Coupling between CC and Differential D+/D-

1. Select Trace 8 (CC(L)->D+/D-) of Channel 3 in Window 3
2. Click **Trace** > **Trace Max** to maximize the trace
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm measured coupling is within the specification

Start Frequency	Stop Frequency	Start Limit	Stop Limit

0.3 MHz	1 MHz	-60.5 dB	-50 dB
1 MHz	10 MHz	-50 dB	-30 dB
10 MHz	16 MHz	-30 dB	-26 dB
16 MHz	100 MHz	-26 dB	-26 dB

5. Repeat above steps for Trace 9 (CC(L)->D+/D-(R)), Trace 10 (CC(R)->D+/D-(L)), and Trace 11 (CC(R)->D+/D-(R))

5.4.5. Single-ended Coupling between CC and D-

1. Select Channel 7 of Window 4
2. Click **Display** > **Windows** > **More** > **Maximize** to show all traces of Window 4 (Trace 12 to 15)
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm all the measured coupling is within the specification
   A. USB 2.0 Type-C Cable Assembly

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	1 MHz	-48.5 dB	-38 dB
1 MHz	10 MHz	-38 dB	-18 dB
10 MHz	100 MHz	-18 dB	-18 dB

   B. Full-featured Type-C Cable Assembly

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	1 MHz	-58 dB	-27.5 dB
1 MHz	11.8 MHz	-27.5 dB	-26 dB
11.8 MHz	100 MHz	-26 dB	-26 dB

   Note: It is necessary to update the limit table of Trace 12 to 15 when measuring full-featured Type-C cable assemblies. Click **Analysis** > **Limits** > **Limit Table** to show the limit table and update limit values for all traces.

5.4.6. Coupling between V_{BUS} and Differential D+/D-

1. Select Trace 16 (Vbus(L)->D+/D-(L)) of Channel 8 in Window 5
2. Click **Trace** > **Trace Max** to maximize the trace
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm the measured coupling is within the specification

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	1 MHz	-40 dB	-40 dB
1 MHz	30 MHz	-40 dB	-40 dB
30 MHz	100 MHz	-40 dB	-30 dB

5. Repeat above steps for Trace 17 (Vbus(L)->D+/D-(R)), Trace 18 (Vbus(R)->D+/D-(R)), and Trace 19 (Vbus(R)->D+/D-(L))

5.4.7. Single-ended Coupling between SBU_A and SBU_B

1. Select Channel 12 of Window 6
2. Click **Display** > **Windows** > **More** > **Maximize** to show all traces of Window 4 (Trace 20 to Trace 23)
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm all the measured coupling (Trace 20 to Trace 23) is within the specification

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	1 MHz	-56.5 dB	-46 dB
1 MHz	10 MHz	-46 dB	-26 dB
10 MHz	11.2 MHz	-26 dB	-25 dB
11.2 MHz	100 MHz	-25 dB	-25 dB

5.4.8. Single-ended Coupling between SBU_A/SBU_B and CC

1. Select Channel 13 of Window 7
2. Click **Display** > **Windows** > **More** > **Maximize** to show all traces of Window 7 (Trace 24 to Trace 31)
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm all the measured coupling (Trace 24 to Trace 31) is within the specification

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	1 MHz	-65 dB	-55 dB
1 MHz	18 MHz	-55 dB	-30 dB
18 MHz	100 MHz	-30 dB	-30 dB

5.4.9. Coupling between SBU_A/SBU_B and Differential D+/D-

1. Select Trace 32 (SBU_A(L)->D+/D-(L)) of Channel 14 in Window 8
2. Click **Trace** > **Trace Max** to maximize the trace
3. Click **Trigger** > **Single** to trigger measurement sweep once
4. Confirm the measured coupling is within the specification

Start Frequency	Stop Frequency	Start Limit	Stop Limit
0.3 MHz	30 MHz	-80 dB	-40 dB
30 MHz	100 MHz	-40 dB	-40 dB

5. Repeat above steps for the following traces in Window 8.

Channel #	Trace #	Trace Name
15	33	SBU_A(L)->D+-(R)
16	34	SBU_B(L)->D+-(L)
17	35	SBU_B(L)->D+-(R)
18	36	SBU_A(R)->D+-(L)
19	37	SBU_A(R)->D+-(R)
20	38	SBU_B(R)->D+-(L)
21	39	SBU_B(R)->D+-(R)

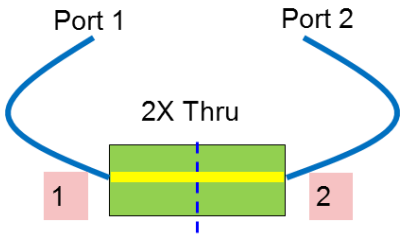
6. [Appendix] Creating Fixture De-embedding Files using PLTS AFR

The procedure to create de-embedding Touchstone files (*.s2p) of test fixtures is introduced in the section using the Automatic Fixture Removal (AFR) function of Keysight Physical Layer Test System (PLTS).

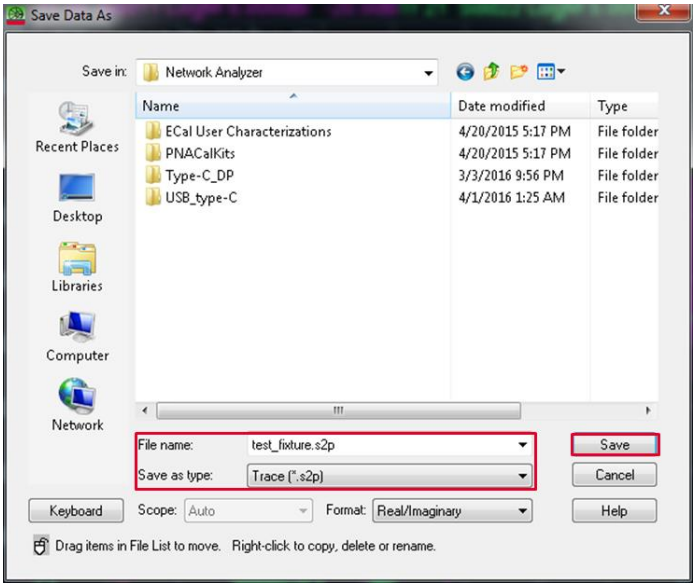
6.1. 2x Thru Standard Measurement

A 2-port Touchstone file (*.s2p) of 2X Thru standard should be measured and saved with the PXI VNA first. Full 2-port calibration with the ECal module is performed for the whole frequency range required for the USB Type-C low speed signal cable test (300 kHz to 4.5 GHz).

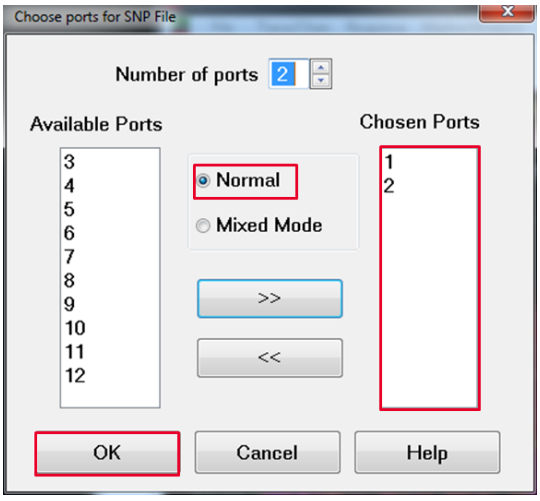
1. Click **Preset**
2. Click **Freq** > **Stop** and enter "4.5 GHz"
   Note: When created de-embedding files are used for Type-C to Type-C high speed signal cable compliance test, the stop frequency should be set to 15 GHz or above to cover the required frequency range.
3. Click **Sweep** > **Number of Points** and enter "1,601"
4. Click **Cal** > **Start Cal** to launch calibration wizard
5. Select "Use Electronical Calibration (ECal)" and click "Next >"
6. Check Port 1 and Port 2, and click "Next >"
7. Connect the VNA's port 1 and 2 to the Ecal ports, then click "Measure" to complete calibration measurements.
8. Connect the PXI VNA's port (port 1 to 2) to 2x Thru standard with RF test cables.



9. Click **Trigger** > **Single**
10. Click **Save** > **Save Data As…**
11. Select "Trace (*.s2p)" for "Save as type"
12. Enter a file name
13. Click "Save"

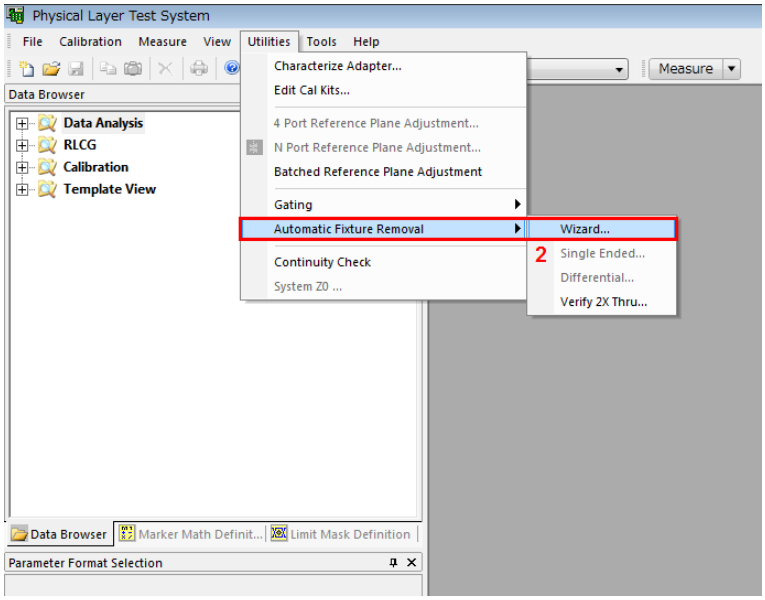


14. Check “Normal”
15. Chose port 1 and port 2 (Number of ports is “2”)
16. Click “OK”

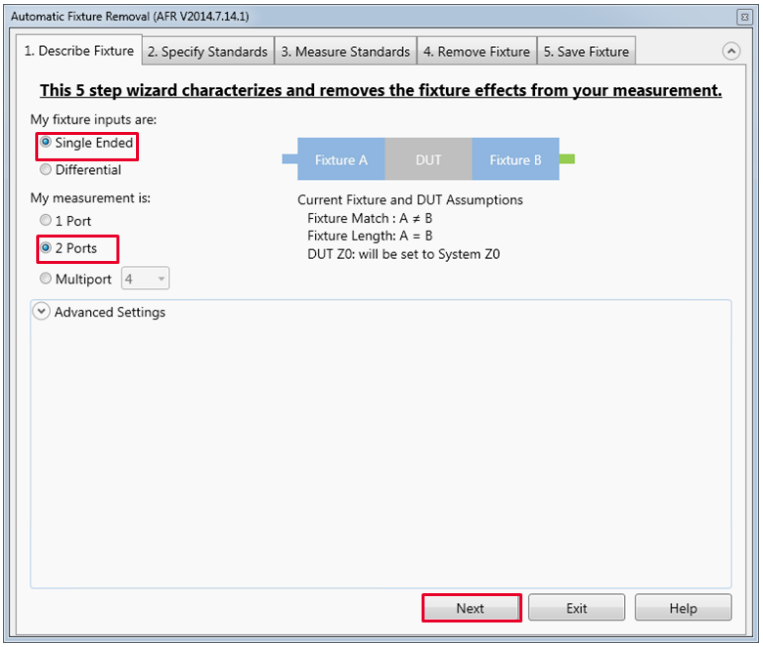


6.2. Creating De-embedding files with AFR

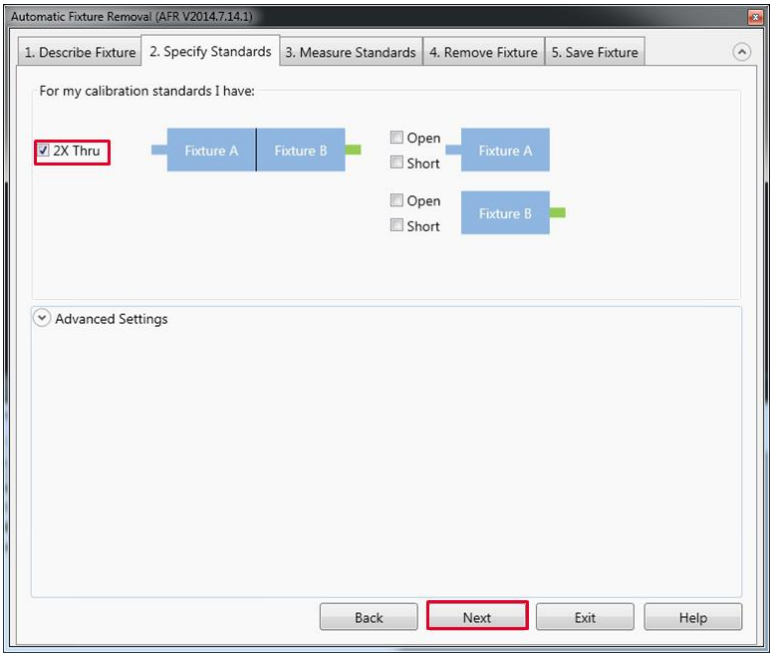
1. Launch Keysight PLTS Software
2. Click Utilities > Automatic Fixture Removal > Wizard



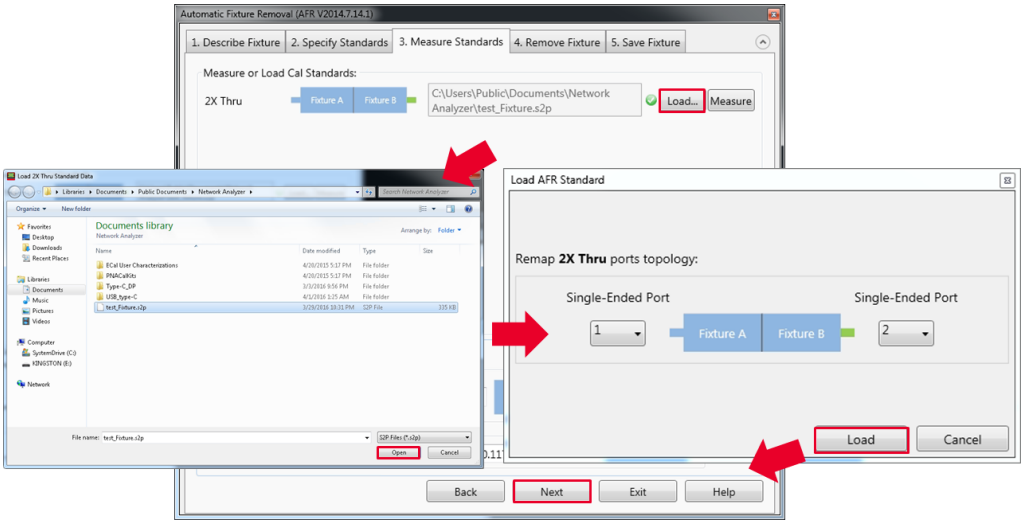
3. Select “Single Ended” and “2 Ports”
4. Click “Next”



5. Check “2X Thru”
6. Click “Next”



7. Click “Load…”
8. Select the measured Touchstone file (*.s2p) and click “Open”
9. Click “Load”
10. Click “Next



11. Select “5.Save Fixture” tab
12. Select “Touchstone” and “PNA Format”
13. Enter “Test_Fixture”
14. Click “Browse…” and enter directory (ex. “C:/Users/Public/Documents/Network Analyzer/USB_type-C”)
15. Enter a base file name, “Test_Fixture”

16. Click “Save Fixture Files” to save the two generated Touchstone files (*.s2p).
17. Click “Exit”