Tektronix

USB2.0 - Device

Universal Serial Bus Measurement

www.tektronix.com

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REVISION RECORD SHEET

Version	Completion Date	Initiator	Pages	Nature of Change
0.8	7-7-2014	S. Harrison	56	First Draft

DISCLAIMER OF WARRANTIES

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Signal Quality

(EL_2, EL_4, EL_5, EL_6, EL_7)

Specifying the Equipment-Signal Quality Tests for High Speed Devices for Upstream Testing

- Tektronix digital oscilloscope
- USB2SIGQUAL compliance test fixture
- Two SMA cables (phase matched)
- Host PC
- 1 meter USB2.0 cable

Typical Equipment Setup-Signal Quality Tests for High Speed Devices (Upstream Testing)

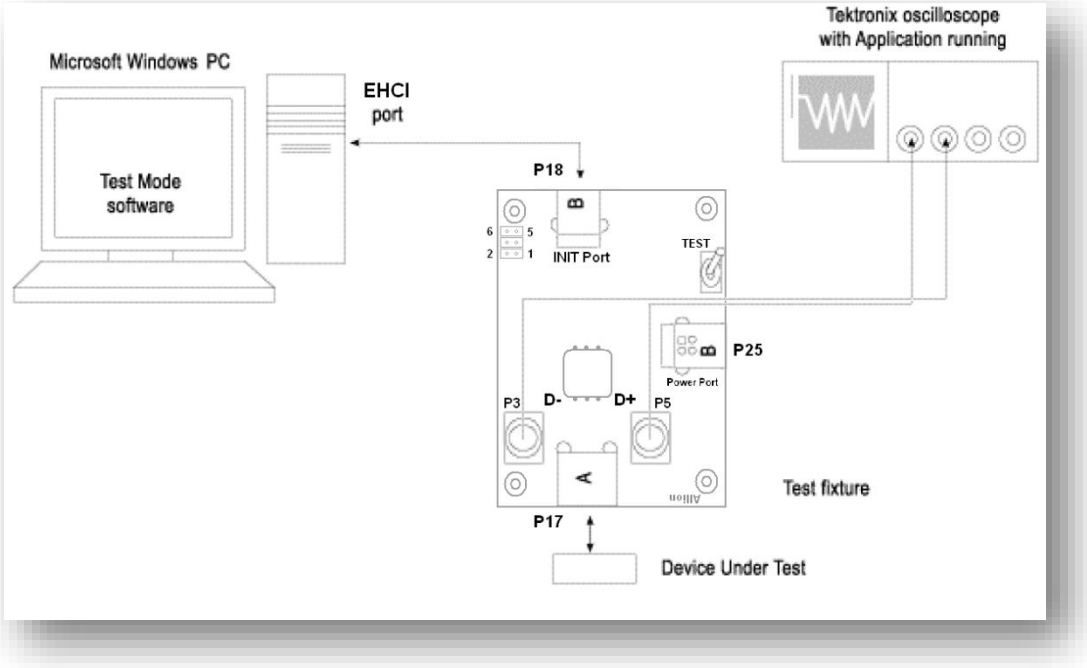


Figure 1: Equipment Setup for Signal Quality Measurement

To setup for the High Speed Signal Quality test, follow these steps:

1. Using the USB2SIGQUAL; Set the **SW4** switch to the position <u>not</u> labeled **TEST**.
2. Connect a standard USB cable between the Type B-INIT port **(P18)** and the host PC port.
3. Connect the Type A port **(P17)** of the test fixture to the Device Under Test.

4. Connect the two SMA cables from CH1 and CH2 of the oscilloscope to the SMA connections label P5 & P3 respectively.
5. Run the High-Speed Electrical Test Tool software on the host PC. EHCI_HSETT main menu shown in figure below.

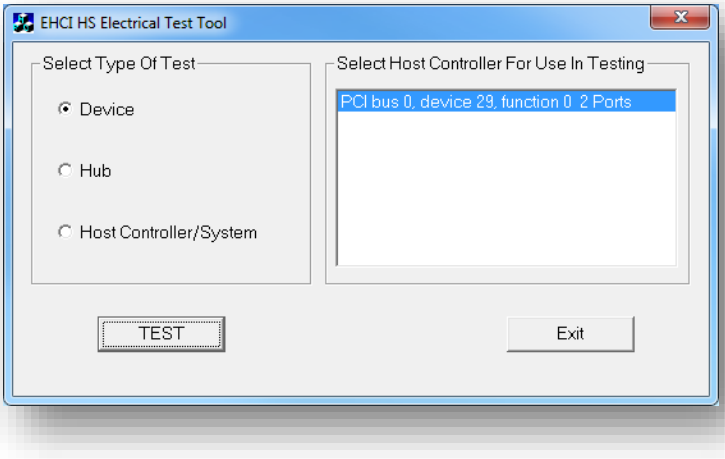


Figure 2: High-Speed Electrical Test Tool - Main Menu

6. Configure the device into the test mode from the host PC controller. Select TEST_PACKET from the Device Command dropdown menu and click EXECUTE.

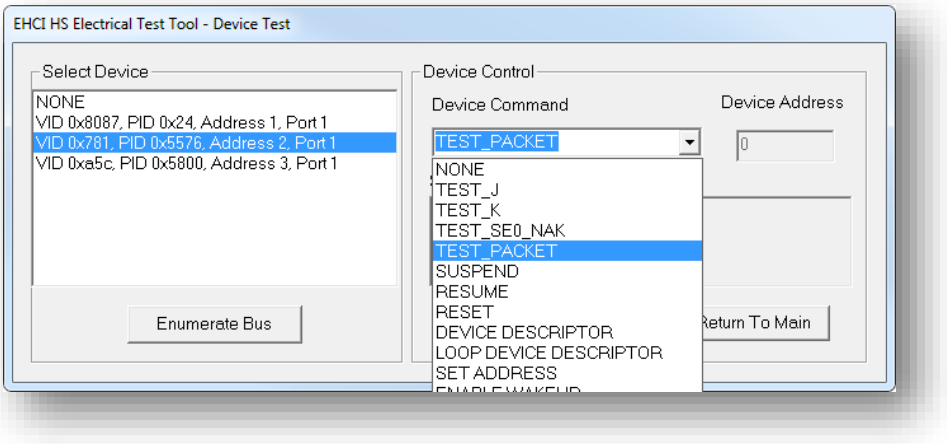


Figure 3: Test Device Packet

7. Set the switch **(SW4)** to the TEST position. This will isolate the unit under test while maintaining the bus power.

8. On the Tektronix scope, set your Math channel to **Ch1 - Ch2**

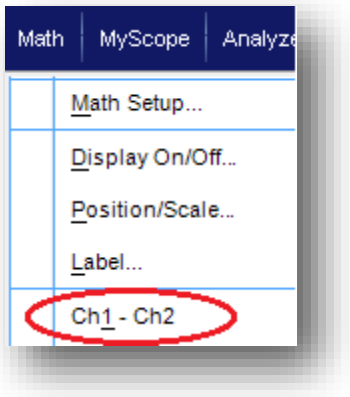


Figure 4: Math Setup

9. Adjust the scope Horizontal scale so that one complete packet is displayed

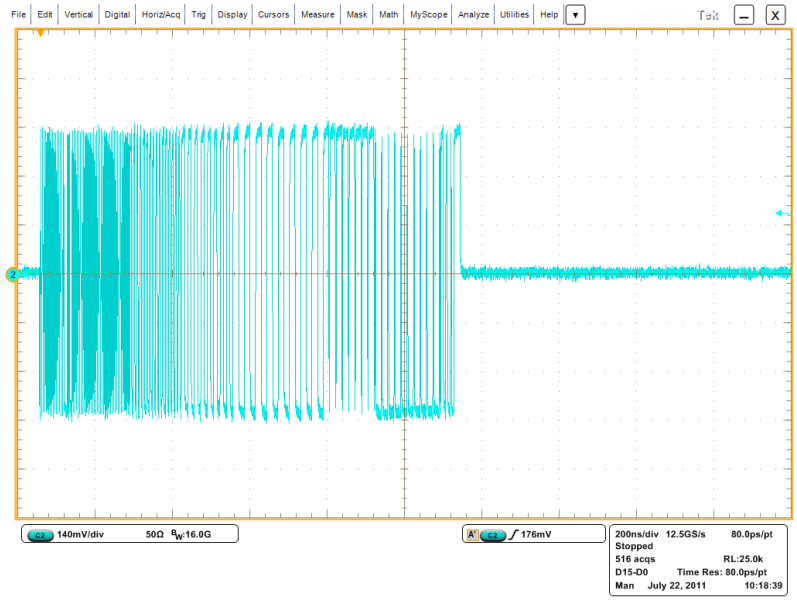


Figure 5: Test Packets

10. Save Math waveform as a CSV (*.csv) or Tek Waveform (*.wfm) for later processing.

Selecting and Configuring Measurements-Signal Quality Tests for High Speed Devices (Upstream Testing)

Launch USB Electrical Analysis Tool 2.0 (Download from USB.org)

11. From the application menu, select **Device/Host SQ (tab)**.

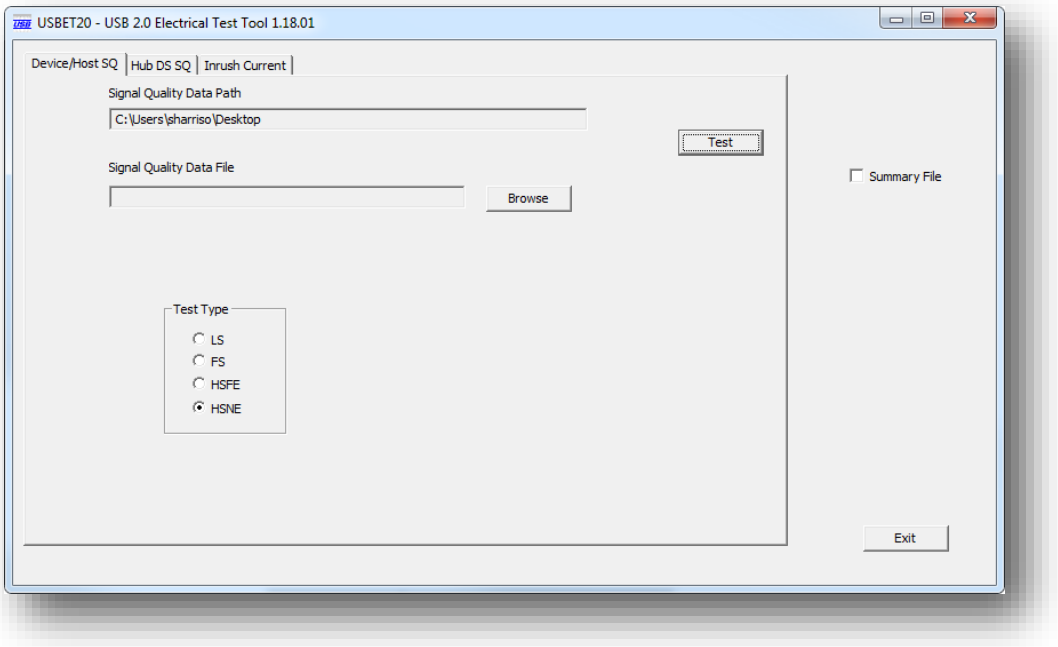


Figure 6: USBET20 Analysis Tool

12. Select the Test Type:

- HSFE (High Speed Far End) is a device with an 'A' connector on the end

- HSNE (High Speed Near End) is a device with a 'B' port on it.

13. Browse to the Math waveform saved from the scope.

14. Press **Test.**

Packet Parameter Measurement
(EL_21, EL_22, EL_25)

Specifying the Equipment-Packet Parameter Measurement

- Tektronix digital oscilloscope
- One differential probe
- Host PC
- 1 meter USB2.0 cable

Typical Equipment Setup-Packet Parameter Measurement

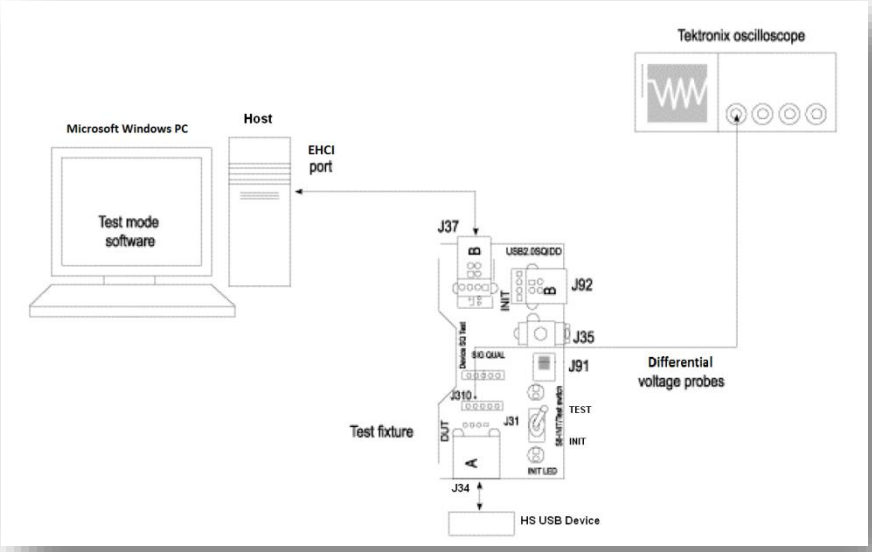


Figure 7: Equipment Setup for Packet Parameter Measurement

Test Fixture Setup

To set up the test fixture, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect the standard USB cable between the Device SQ Init port **(J37)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the device under test.
4. Apply the power to the test fixture.
5. Apply the power to the DUT.

6. Attach the differential probe near the device connector on the test fixture **(J31)**.

Oscilloscope Setup

7. Verify that SOFs (Start Of Frame packets) are being transmitted.
8. Go to scope trigger menu to trigger on:
   a. Width: The EOP is required to be NRZ 01111111 without bit stuffing. Since the only other traffic is SOF's, we can trigger on the EOP; 7 x 2.08ns = 14.56ns
   b. Edge: Since we are measuring at the device, its amplitude should be higher than from the host. Set the Edge trigger just below the nominal voltage of 400mV
9. In the HS Electrical Test Tool application- select SINGLE STEP SET FEATURE from the Device Command dropdown menu and click EXECUTE once.

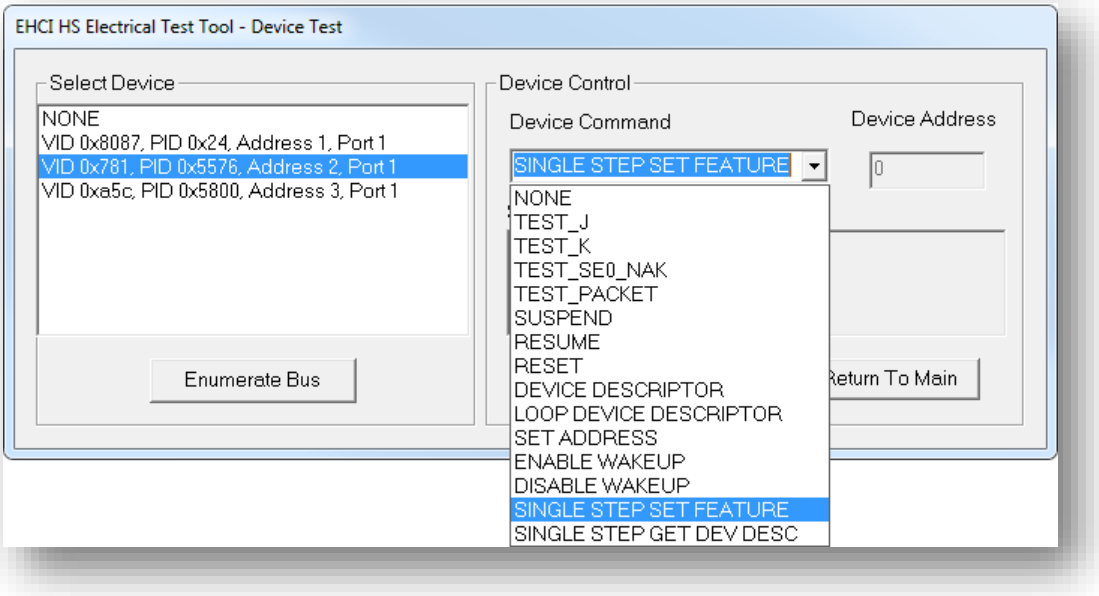


Figure 8: Device Single Step Set Feature

10. The oscilloscope capture should appear as follows:

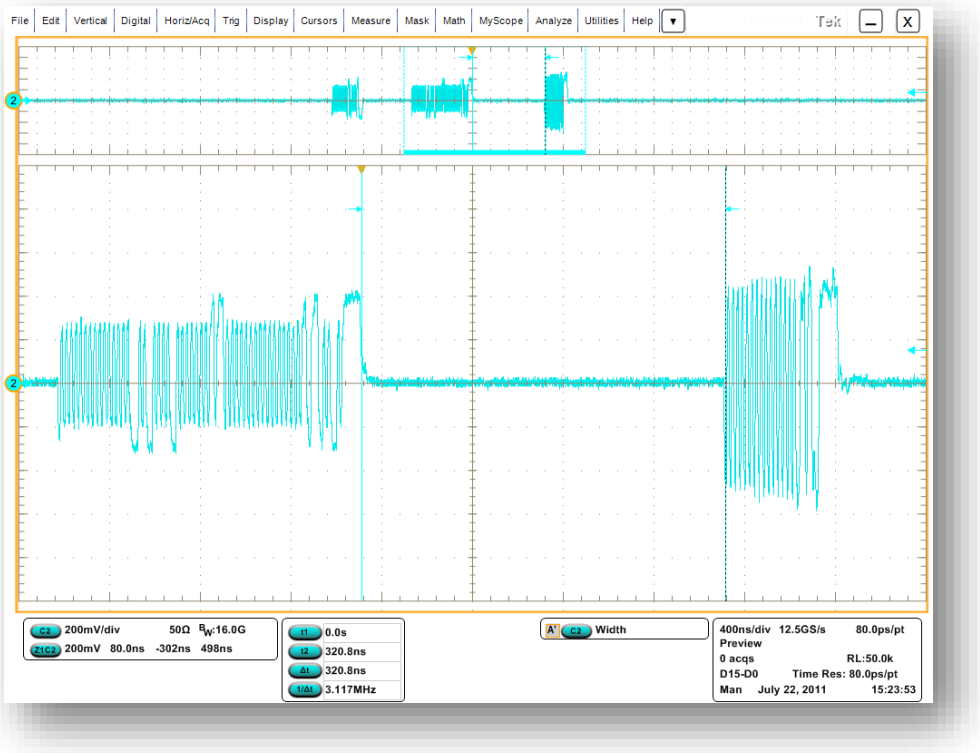


Figure 9: EL_22 Device inter-packet gap

The application can perform the following EL measurements:

1. High Speed Device: EL_21, EL_22, EL_25 (EOPII-InterPacketI&II)

- The application measures the synchronous bits (32) from the third packet. This is EL_21: The SYNC field for all transmitted packets (not repeated packets) must begin with a 32 bit SYNC field.

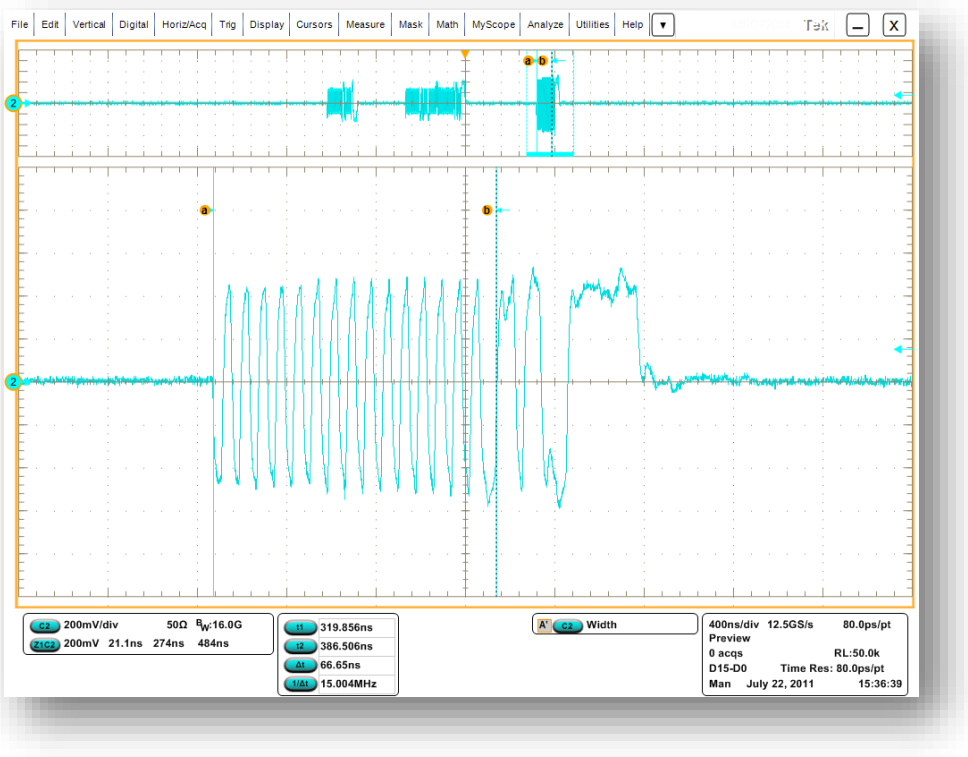


Figure 10: EL_21 Sync Field - Device Packet

- Transmitting after receiving a packet: EL_22 measures the inter-packet gap between the second (from host) and the third (from device in response to the host) of at least 8 bit times and not more than 192 bit times. As the signal is differential, the EOP can be a positive or a negative pulse

- The results consist of EL_25 EOP (End of Packet) width (number of bits) for all transmitted packets (except SOFs) must be an 8 bit NRZ byte of 01111111 without bit stuffing. Third packet on oscilloscope

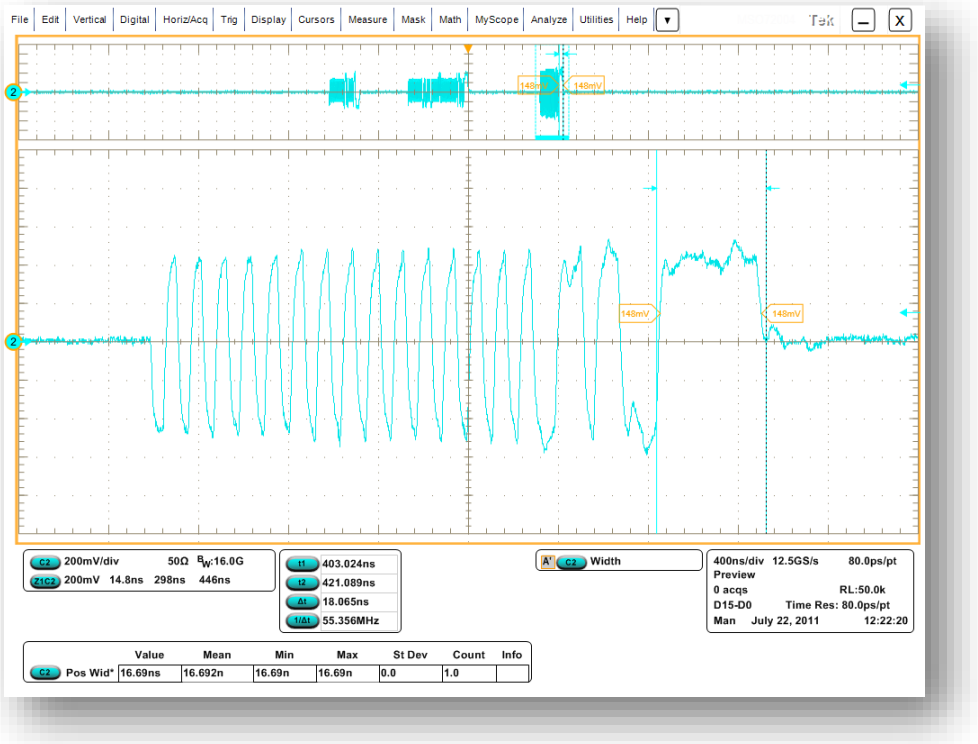


Figure 11: EL_25 EOP in Device's Packet

Packet Parameter Single Step Measurement

1. The Scope should still be setup from previous measurement. Press ‘Step’ from EHCI HS Electrical Test Tool

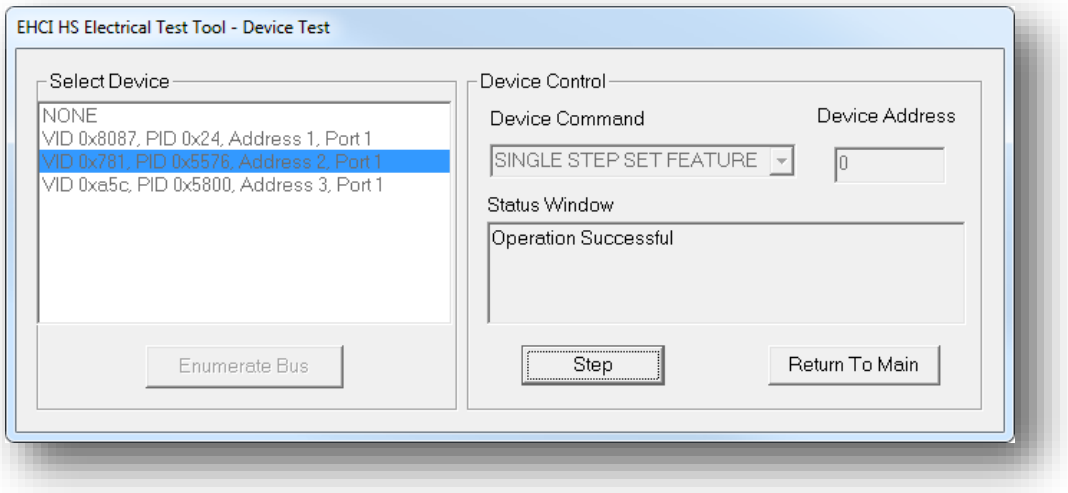


Figure 12: EHCI Packet Param Step

2. The scope should acquire the two packets as seen in the following figure.

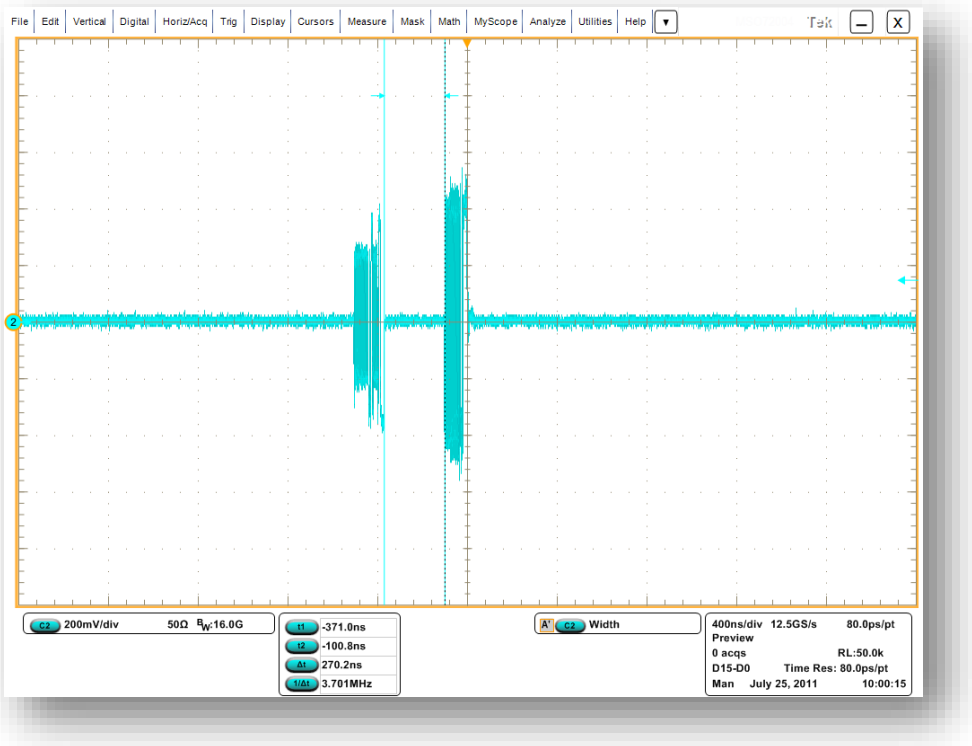


Figure 13: Single Step Set Feature - Second Step

3. The results consist of EL_22 inter-packet gap between the first (from host) and the second (from device in respond to the host's) packets shown on the oscilloscope. The application measures the number of bits (8-192 : 16.64ns – 399.36ns) between the packets

Suspend Measurement
(EL_38, EL_39)

Specifying the Equipment-Suspend Measurement

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- Two single-ended probes
- Host PC
- 1 meter USB cable

Typical Equipment Setup-Suspend Measurement

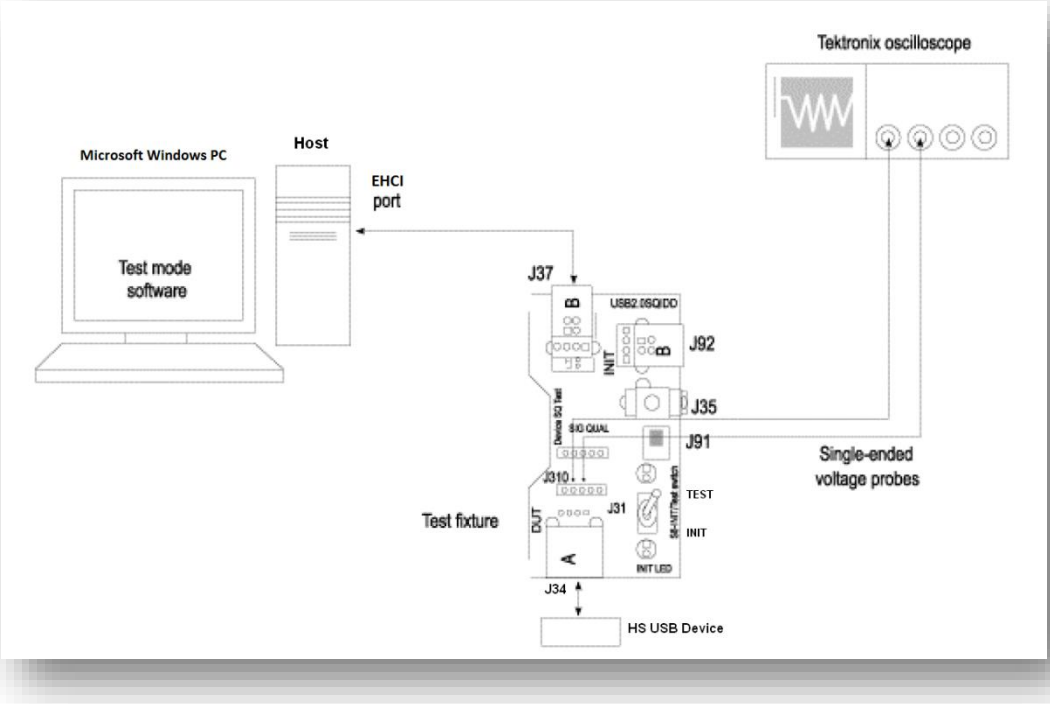


Figure 14: Equipment Setup for Suspend Measurement

Test Fixture Setup

To set up for the Suspend test, follow these steps:

1. Set the S6 switch to the **Init** position.

3. Connect the standard USB cable between the Device SQ Init port **(J37)** and the host PC port.

4. Connect the A receptacle from the Device SQ test port **(J34)** of the test fixture to the Device Under Test.

5. Connect the single-ended probes of the oscilloscope to the D+ and D– pins **(J31)**.

Selecting and Configuring Measurement-Suspend Measurement

1. Set the scope to trigger on the **Rising** edge at 2.5V of the D+ line. When suspended, the D+ pull-up resistor will bring the voltage to between 3.0 – 3.6 volts.
2. In the EHCI Electrical Test Tool application- select SUSPEND from the Device Command dropdown menu and click EXECUTE once.

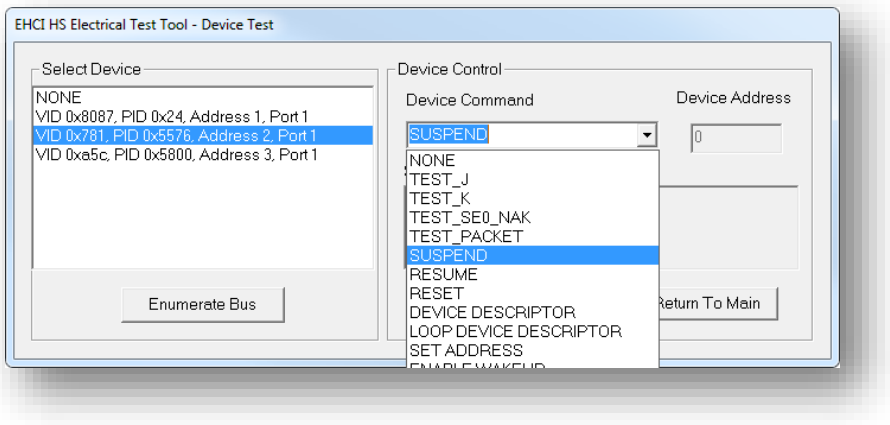


Figure 15: Device Suspend

3. The captured suspend transition should appear as in the following figure.

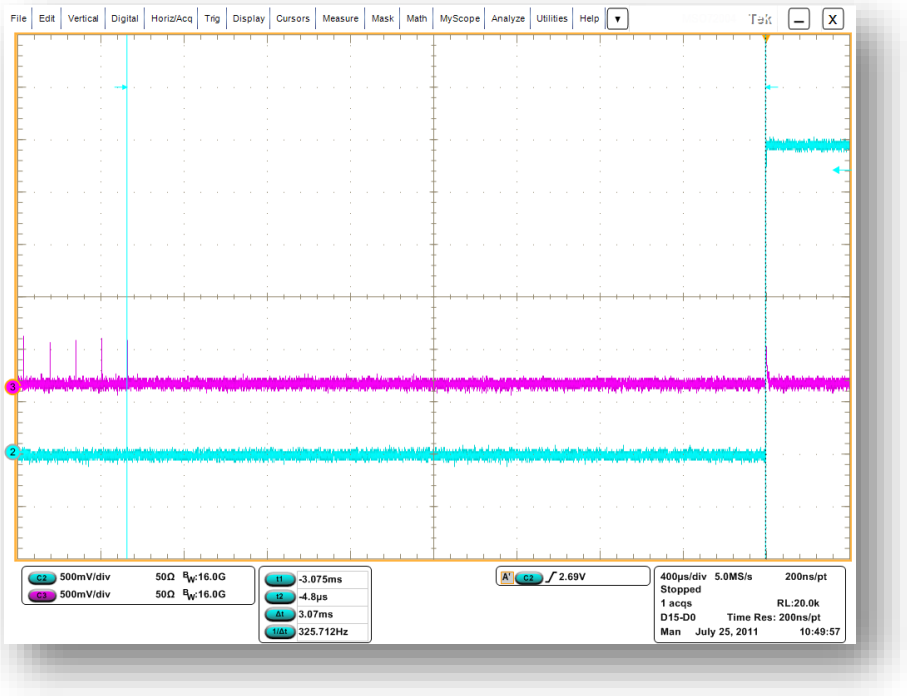


Figure 16: Device Respond to Suspend from High-Speed

4. The result contains EL_38, which is the time interval from the end of last SOF packet issued by the host to when the device attached its full speed pull-up resistor on D+. This is the time between the last SOF packet and the rising edge transition to full speed J-state. Time should be between 3.000 ms and 3.125 ms.

Resume Measurement
(EL_40)

Specifying the Equipment-Resume Measurement

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- Two single-ended probes
- Host PC
- 1 meter USB cable

Typical Equipment Setup-Resume Measurement

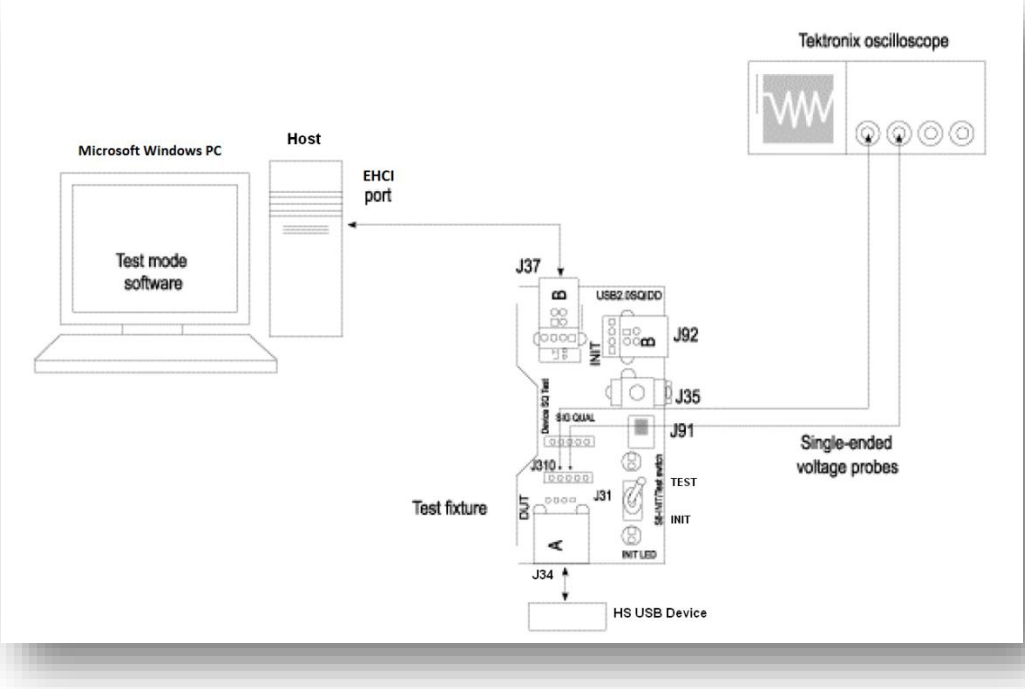


Figure 17: Equipment Setup for Resume Measurement

Test Fixture Setup

To set up for the Resume test, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect the standard USB cable between the Device SQ Init port **(J37)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the device under test.

4. Connect the single-ended probes of the oscilloscope to the D+ and D– pins **(J31)**.

Continuing from the SUSPEND measurement

Selecting and Configuring Measurement-Resume

1. Set the scope to trigger on the **Falling** edge at 2.5V of the D- line. This is to trigger on the D- line resuming from suspended state.
2. In the EHCI Electrical Test Tool application- select RESUME from the Device Command dropdown and click EXECUTE once. This will resume the device from suspend state.

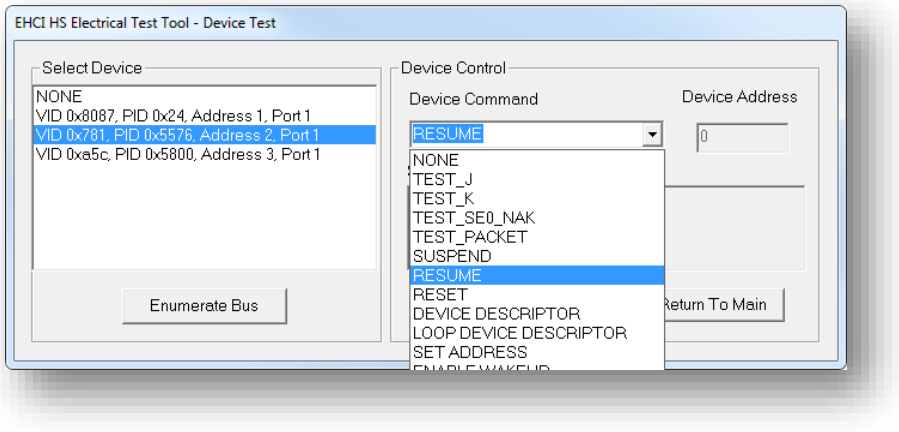


Figure 18: Device Resume

3. The result consists of the time between the falling edge of D+ and the First SOF. This should not exceed 3.0ms. The device should resume the HS operation, which is indicated by the presence of HS SOF packets (with 400mV nominal amplitudes) following the K State driven by the host controller.

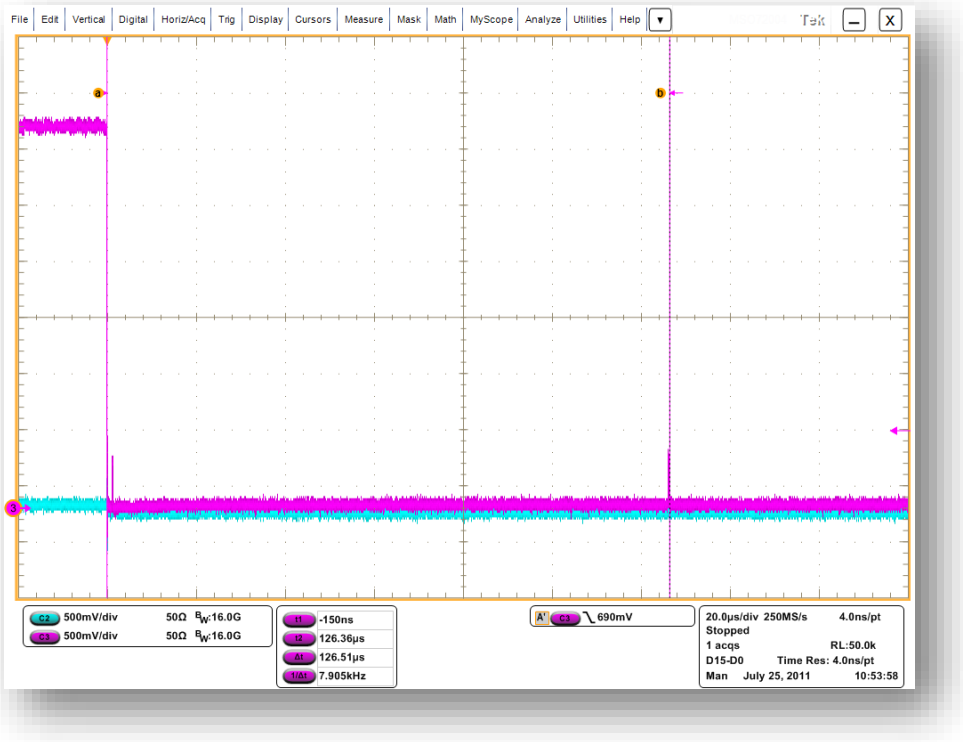


Figure 19: Device Resume to High-Speed (EL_40)

4. EL_40: If a device is in the suspend state, and was operating in high-speed before being suspended, then device must transition back to high-speed within two bit times from the end of resume signaling. *USB2.0 Spec: 7.1.7.7*

   Note: Measuring devices transition back to high-speed isn't practical, therefore we measure EL_41: After resuming a port, the host must begin sending SOFs within 3ms of the start of the idle state.

Reset from High Speed Measurement
(EL_27)

Specifying the Equipment-Reset from High Speed Measurement

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- Two single-ended probes
- Host PC
- 1 meter USB cable

Typical Equipment Setup-Reset from High Speed Measurement

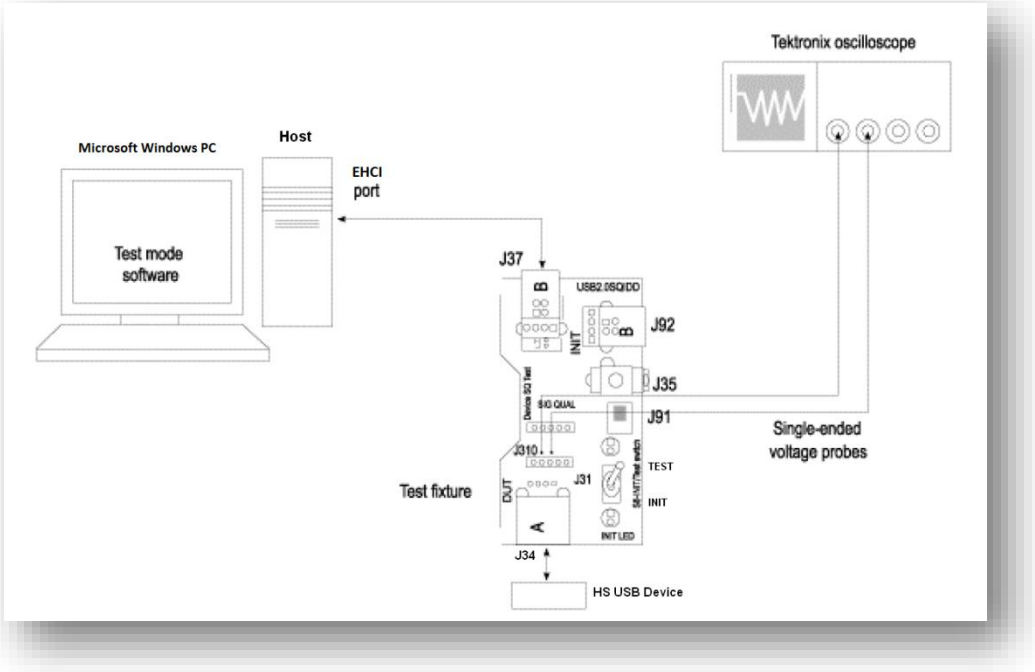


Figure 20: Equipment Setup in Reset from High Speed Measurement

To set up for the Reset from High Speed test, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect the standard USB cable between the Device SQ Init port **(J37)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the device under test.
4. Connect the single-ended probes of the oscilloscope to the D+ and D– pins **(J31)**.

Selecting and Configuring Measurement-Reset from High Speed Measurement

1. In the EHCI Electrical Test Tool application- select RESET from the Device Command dropdown menu and click EXECUTE once.

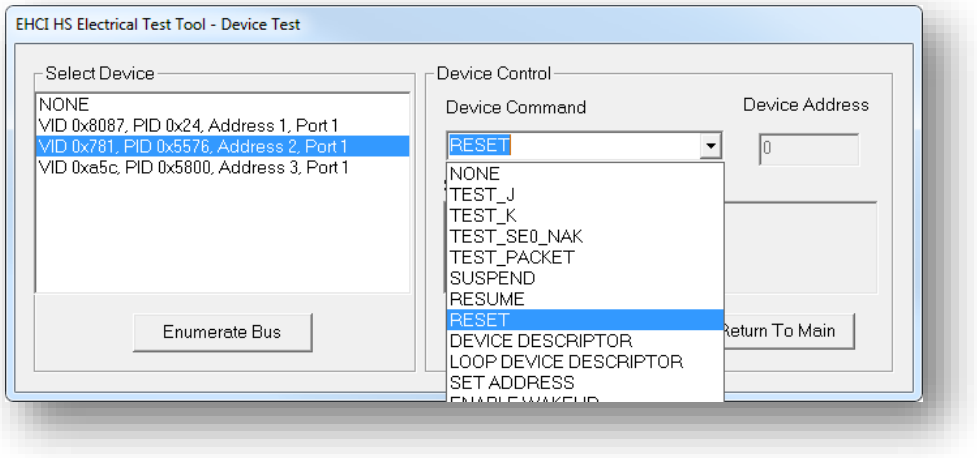


Figure 21: Device Reset

2. The results contain the time between the beginning of the last SOF before the reset and the start of the device Chirp-K. The device should transmit a chirp handshake following the reset. It should be between 3.1ms and 6ms. EL_27

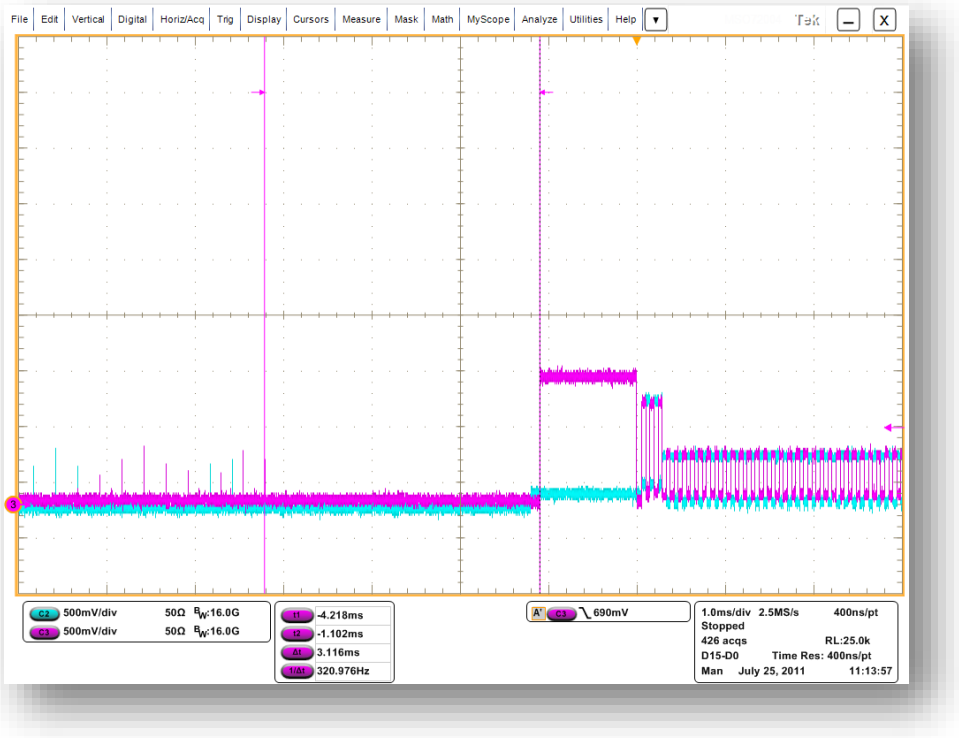


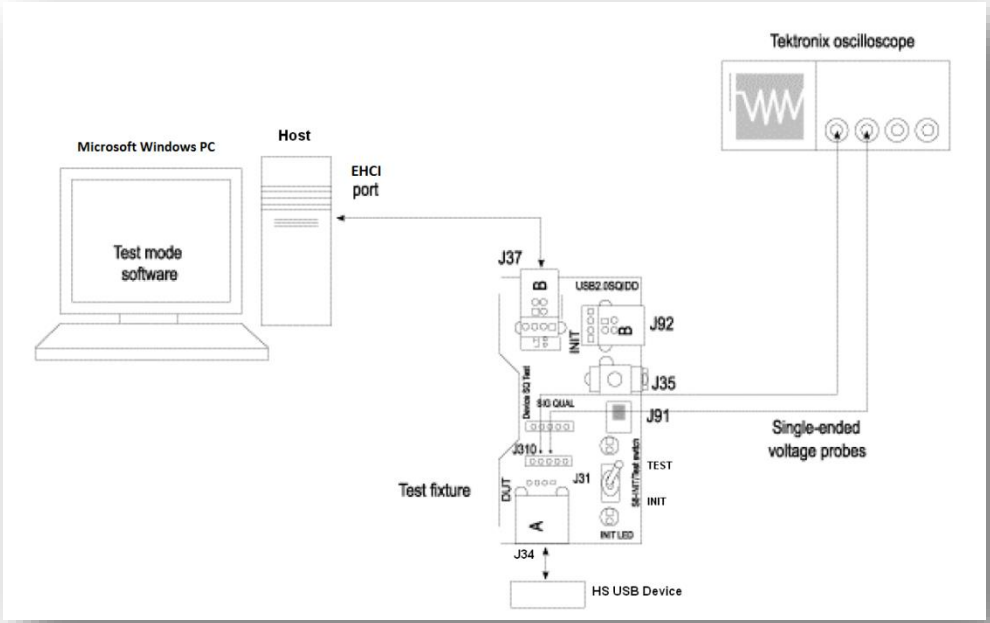
Figure 22: Device Chirp-K in Response to Reset from High-Speed (EL_27)

Reset from Suspend Measurement
(EL_28)

Specifying the Equipment-Reset from Suspend Measurement

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- Two single-ended probes
- Host PC
- 1 meter USB cable

Typical Equipment Setup-Reset from Suspend Measurement



To set up for the Reset from Suspend test, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect one end of a standard USB cable to the B receptacle Device SQ Init port **(J37)** and the other end to the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the Device Under Test.
4. Connect the single-ended probes of the oscilloscope to the D+ and D– pins.

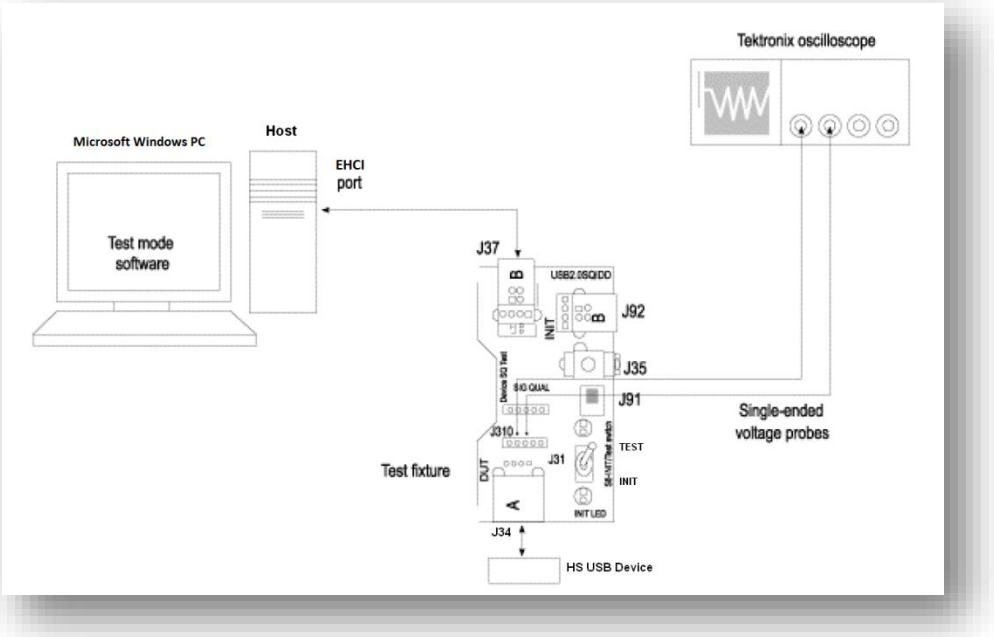


Figure 23: Equipment for Reset from Suspend Measurement

Continuing from the SUSPEND measurement

Selecting and Configuring Measurement-Reset from Suspend Measurement

1. Set the scope to trigger at 2.0 volts on the **Falling** edge of D+.
2. In the EHCI Electrical Test Tool application- select RESET from the Device Command dropdown menu and click EXECUTE once.

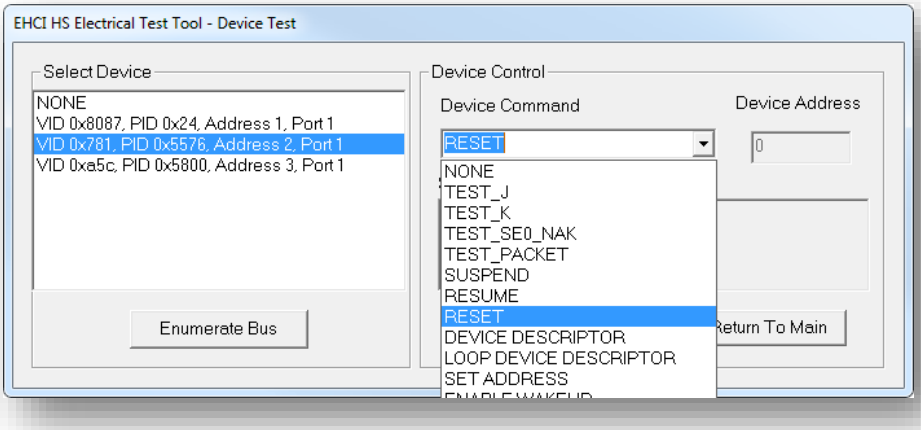


Figure 24: Device Reset

3. The device responds to the reset with the Chirp-K. The results contain the time between the falling edge of the D+ and the start of the device Chirp-K. It should be between 2.5us and 6ms.

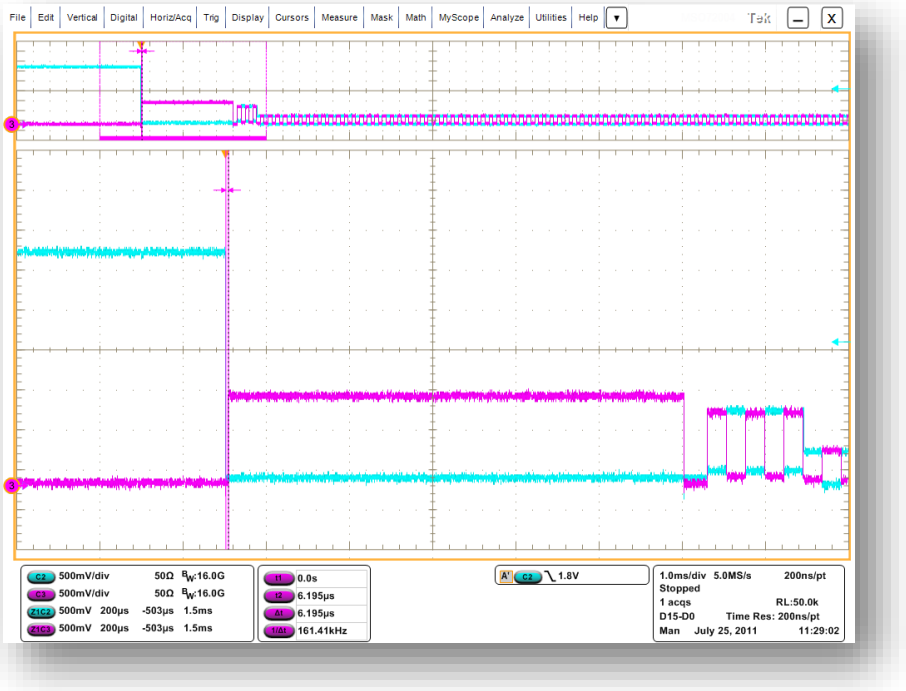


Figure 25: Device Reset from Suspend (EL_28)

Chirp Measurement
(EL_29, EL_31)

Specifying the Equipment-Chirp

The following equipment is needed to test Chirp measurement:

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- Two single-ended probes
- Host PC
- 1 meter USB cable

Typical Equipment Setup-Chirp

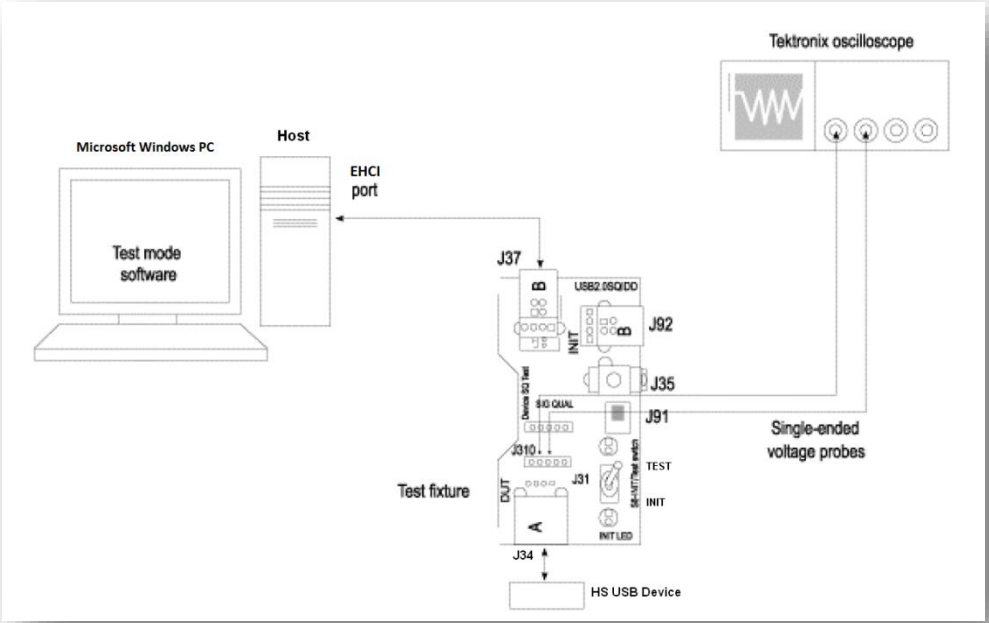


Figure 26: Equipment Setup for Chirp Measurement

To set up the equipment for the Chirp test, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect the standard USB cable between the Device SQ Init port **(J37)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the device under test.
4. Connect the single-ended probes to D- and D+ on the test fixture pins **J31**.

Selecting and Configuring Measurement-Chirp

5. Set the scope to trigger at 2.0 volts on the **Falling** edge of D+.
6. In the EHCI Electrical Test Tool, click Enumerate and observe the chirp signal on the oscilloscope. This will resume the device from suspend state.
7. Instead of enumerating the device, an alternative method to generate the chirp signal, is to disconnect and reconnect the Device Under Test to the port

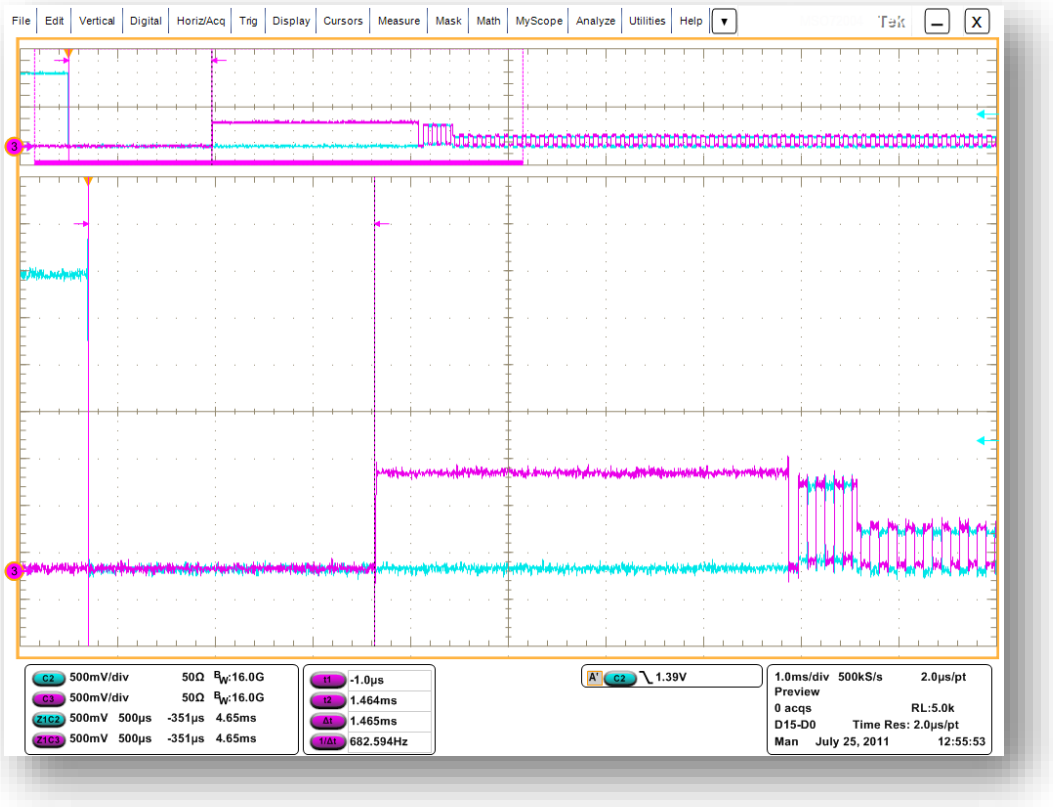


Figure 27: Device Chirp-K Latency (EL_29)

8. The EL_29 checks the device's CHIRP-K duration. The assertion time should be between 1.0ms and 7.0ms.
9. EL_31: When a device detects a valid Chirp K-J-K-J-K-J sequence, the device must disconnect the D+ pull-up resistor (1.5k-ohm). It's evident by the 800mV to 400mV drop in amplitude. The time from the last J pair to the drop in amplitude must be less than 500us.

Device Test J/K, SE0_NAK
(EL_8, EL_9)

Specifying the Equipment-J/K & SE0_NAK

- Digital Volt Meter
- TDSUSBF compliance test fixture

Typical Equipment Setup-J/K and SE0_NAK

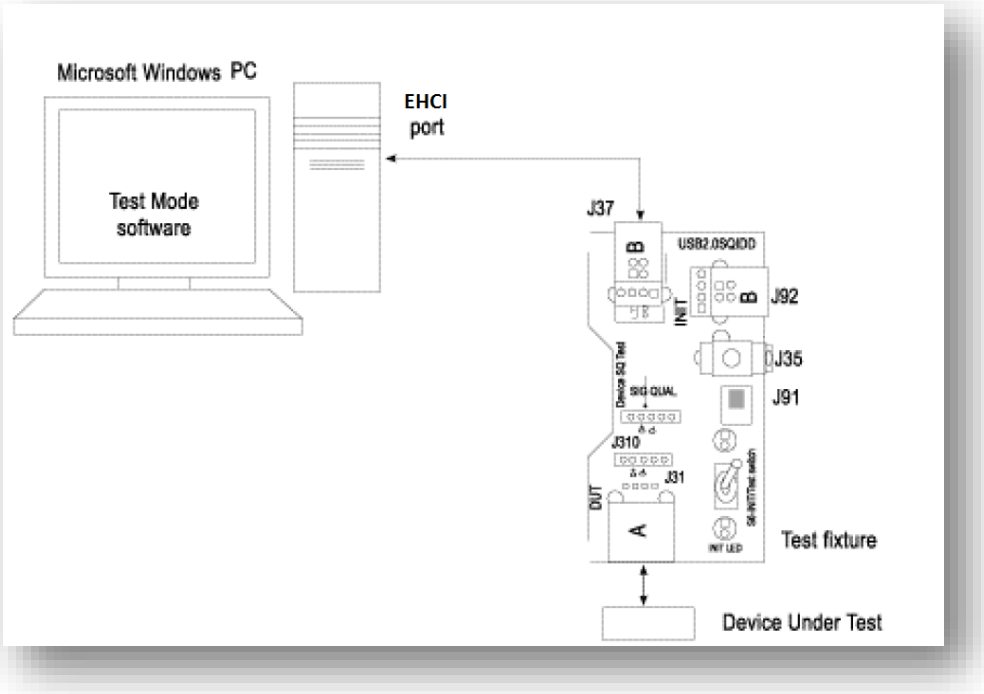


Figure 28: Equipment Setup for J/K, SE0_NAK Test

To set up the equipment for J/K & SE0_NAK, follow these steps:

1. Set the S6 switch to the Init position.
2. Connect a standard USB cable between the B receptacle Device SQ Init port **(J37)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device SQ test port **(J34)** to the device under test.
4. On the HS Electrical Test Tool application - Device Test menu, select TEST_J from the Device Command dropdown menu. Click EXECUTE once to place the device into TEST_J test mode.

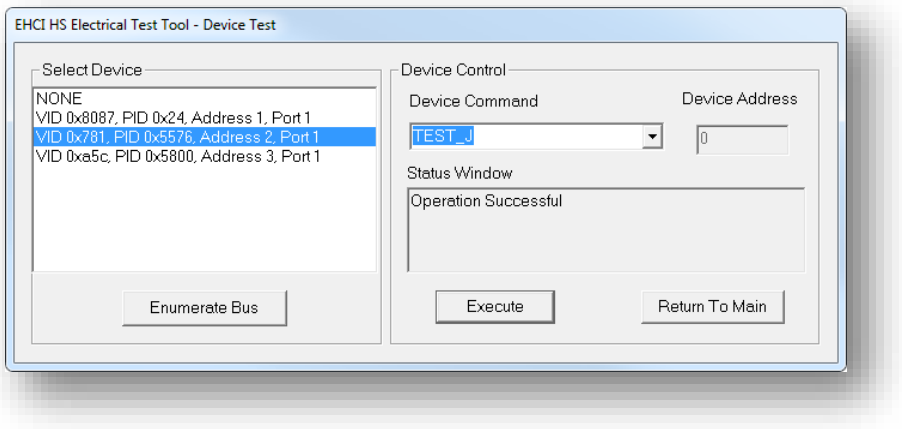


Figure 29: Device TEST_J

5. Connect the single-ended probes to D- and D+ on the test fixture pins **J310**.

6. Switch the test fixture into the TEST position. D+ output voltage must be 400mV +/-10% while D- = 0 +/-10mV.

7. Return the Test switch to the NORMAL position. Cycle the device power. Click Enumerate Bus once to force enumerate the device. This restores the device to normal operation.

8. On the HS Electrical Test Tool application - Device Test menu, select TEST_K from the Device Command dropdown menu. Click EXECUTE once to place the device into TEST_K test mode.

9. Switch the test fixture into the TEST position. D- output voltage must be 400mV +/-10% while D+ = 0 +/-10mV.

10. Return the Test switch to the NORMAL position. Cycle the device power. Click Enumerate Bus once to force enumeration of the device. This restores the device to normal operation.

11. On the HS Electrical Test Tool application - Device Test menu, select TEST_SE0_NAK from the Device Command dropdown menu. Click EXECUTE once to place the device into TEST_SE0_NAK test mode.

12. Switch the test fixture into the TEST position. D+ and D- output voltage must be 0V +/- 10mV.

Device Receiver Sensitivity
(EL_16, EL_17, EL_18)

Specifying the Equipment-Receiver Sensitivity

- Tektronix AWG5000/AWG7000
- Two SMA cables w/ 5x attenuators
- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- One differential probe

Typical Equipment Setup-J/K and SE0_NAK

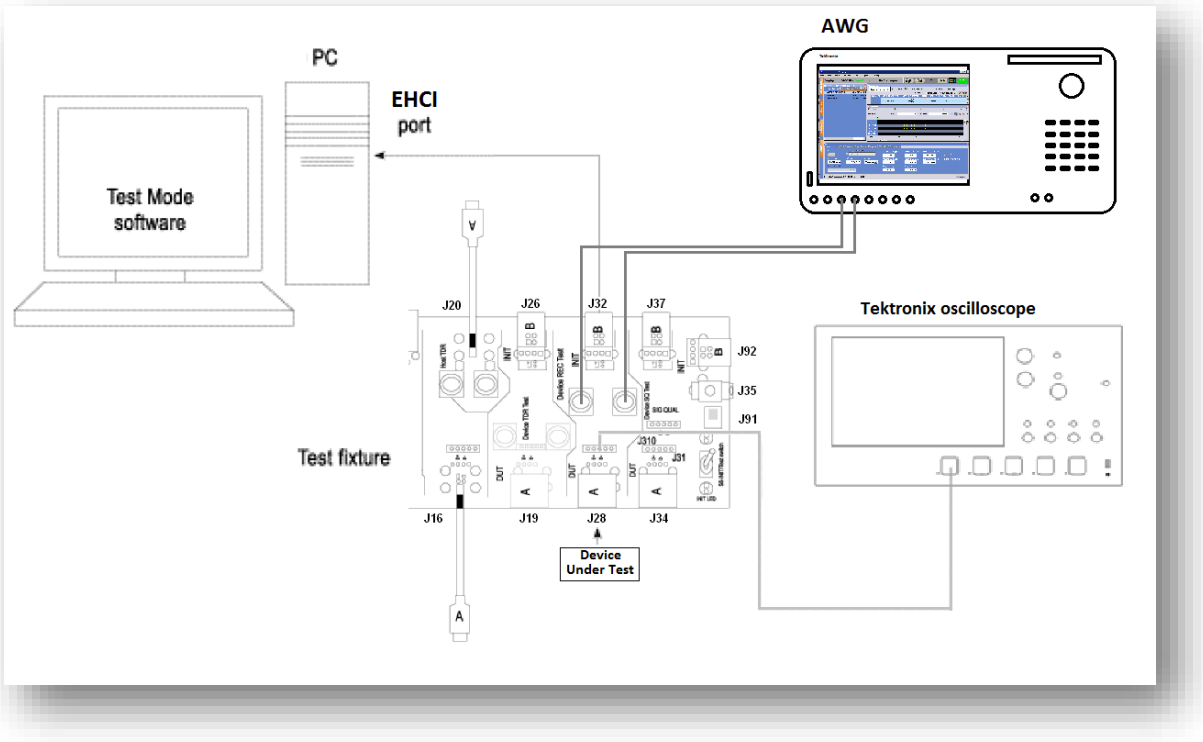


Figure 30: Equipment Setup for Receiver Sensitivity

To set up the equipment for Receiver Sensitivity, follow these steps:

1. Set the S6 switch to the **Init** position.
2. Connect a standard USB cable between the B receptacle Device REC Init port **(J32)** and the host PC port.
3. Connect the A receptacle (marked DUT) from the Device Rec test port **(J28)** to the device under test.

4. Connect the differential probe to the test fixture at J25.

5. On the signal generator, select the MIN-ADD1.AWG setup file. This generates IN packets with a 12-bit SYNC field.

6. Turn on channel 1 on the AWG.

7. On the HS Electrical Test Tool application - Device Test menu, select TEST_SE0_NAK from the Device Command dropdown menu. Click EXECUTE once.

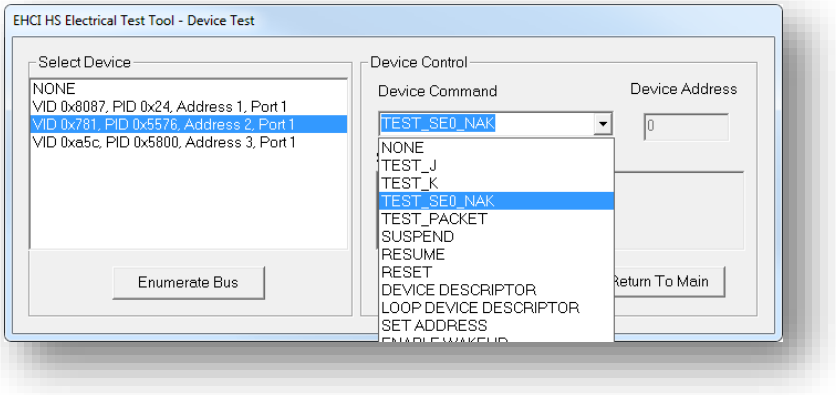


Figure 31: Device TEST_SE0_NAK

8. Place the Test Switch S6 into the TEST position.

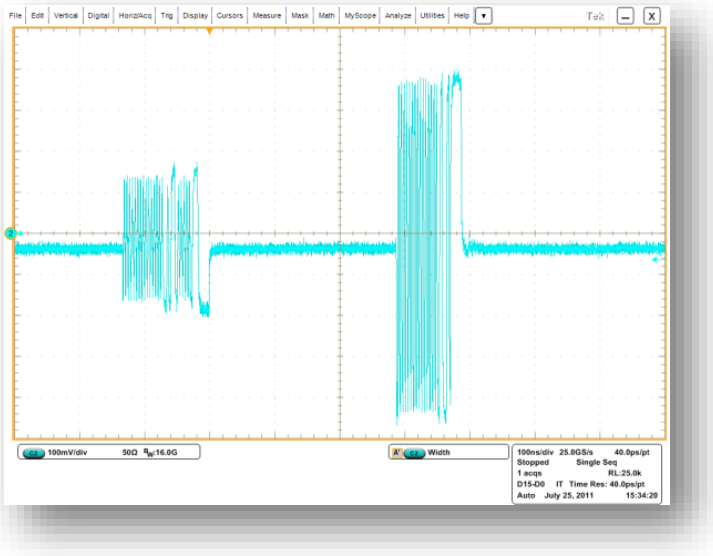


Figure 32: Results of the Receiver Sensitivity Measurement

9. On the data generator, load and run IN-ADD1.AWG setup file.

10. Reduce the amplitude of the data generator packets while monitoring the NAK response from the device on the oscilloscope.

11. Once the NAK packets begin to become intermittent, increase the amplitude till response is stable.

    EL_17: A high speed capable device must implement a transmission envelope detector that does not indicate squelch (reliably receives packets) when a receiver exceeds +/-150mV differential amplitude. Amplitude measured from the AWG is EL_17.

12. Measurements should be made from the midpoint plateau (zero voltage) to the Positive Peak and the midpoint plateau to the Negative Peak

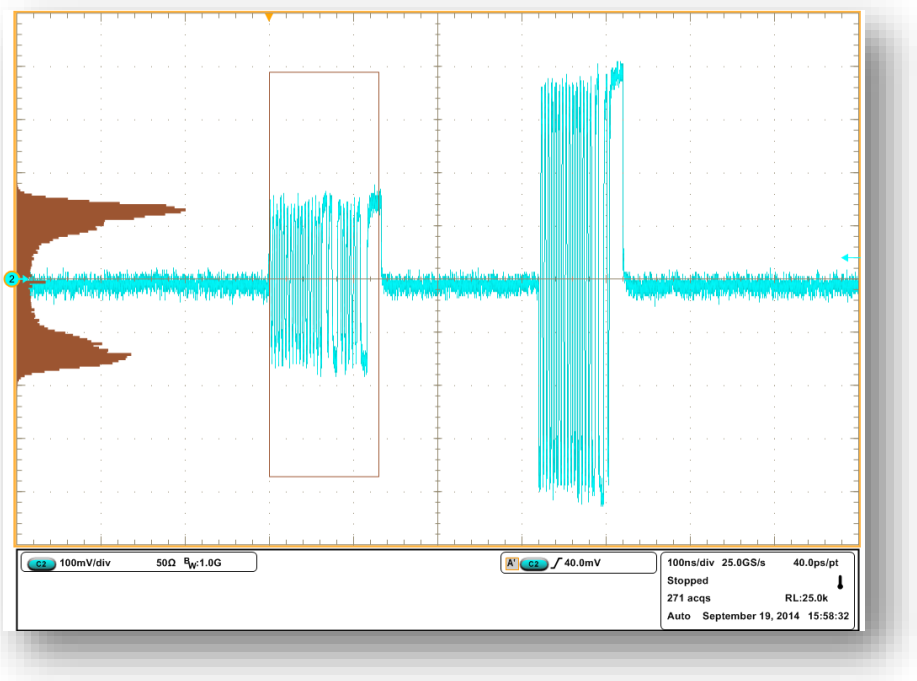


Figure 33: Measuring Differential Voltage Level - Zero to Positive Peak

13. Now reduce the amplitude on the AWG in small steps until the receiver ceases to respond with NAK. This is the squelch level of the receiver.

EL_16: A high speed capable device must implement a transmission envelope detector that indicates squelch (i.e. never receives packets) when a receivers input falls below +/- 100mV amplitude.

14. Measurements should be made from the midpoint plateau (zero voltage) to the Positive Peak and the midpoint plateau to the Negative Peak

Legacy USB Compliance Tests

In addition to the high-speed electrical tests prescribed in this document, the device under test must also pass the following compliance tests applicable to high-speed capable device:

- Low/Full Speed Signal Quality
- Inrush Current

Signal Quality Tests for Full/Low Speed Devices

Specifying the Equipment-Full Speed Signal Quality Tests for Upstream Testing

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- 5 x USB Hubs (One of them Full-Speed)
- 6 x Five Meter USB Cables
- 1 Full Speed USB Certified Device
- Three single-ended voltage probes

Typical Equipment Setup-Full Speed Signal Quality Tests for Upstream Testing

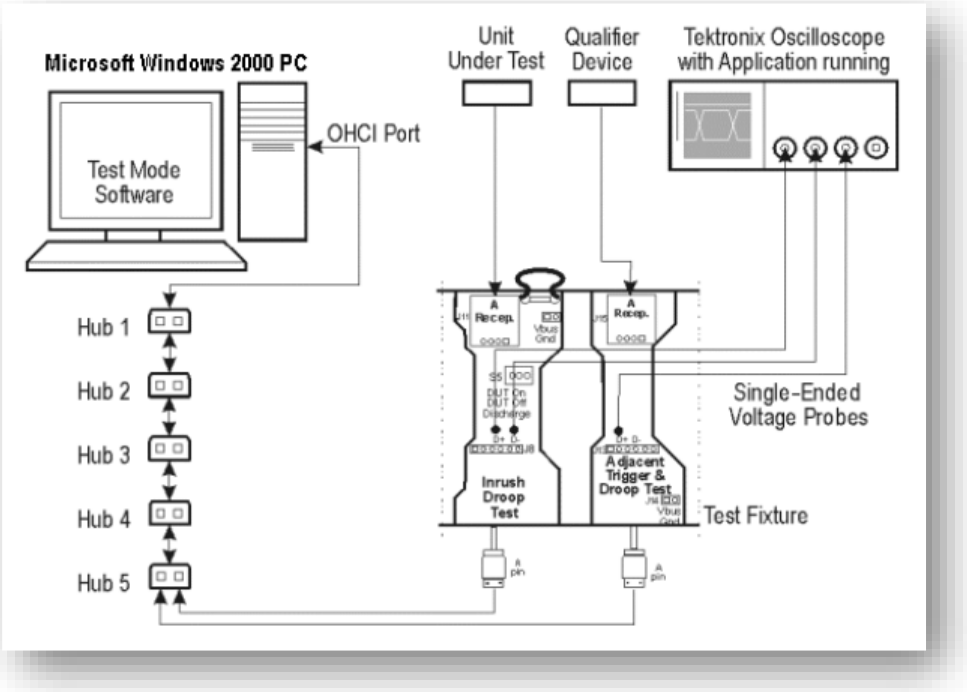


Figure 34: Equipment Setup for Full Speed Signal Quality Measurement

To set up for Upstream, follow these steps:

1. Connect the USB Device Under Test (DUT) to the A type USB receptacle of the Inrush Droop section on the test fixture.

2. Connect the Qualifier device to the Adjacent Trigger and Droop section of the test fixture.

3. Connect Ch1 of the D+ probe to the D+ pins on the Inrush Droop section of the test fixture.

4. Connect Ch2 of the D– probe to the D– pins on the Inrush Droop section of the test fixture.

5. Connect the D+ (D- for Low speed) pin of the Adjacent Trigger and Droop Section of the test fixture to Ch3 as shown in the previous figure.

6. Hub #1 is required to be a High Speed Hub and Hub #2 is required to a Full Speed Hub. All Hubs should be self-powered.

7. Run the High-Speed Electrical Test Tool software on the host **PC**.

8. If the device is connected correctly, it should be enumerate on the bottom of the HSETT as shown below.

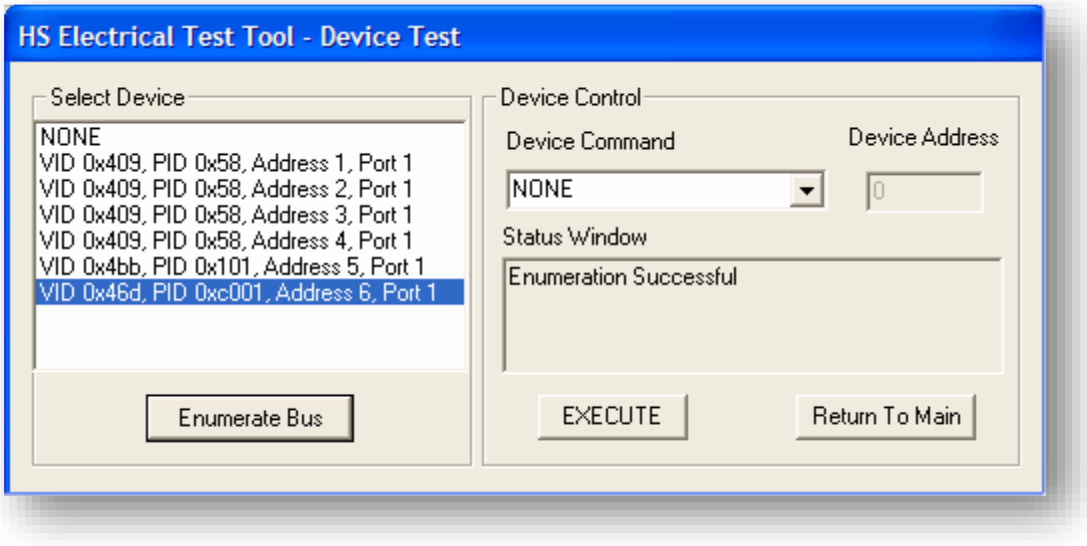


Figure 35: Full-Speed Electrical Test Tool Enumeration

9. Select the LOOP DEVICE DESCRIPTOR option in the Device Command pull down menu and click EXECUTE.

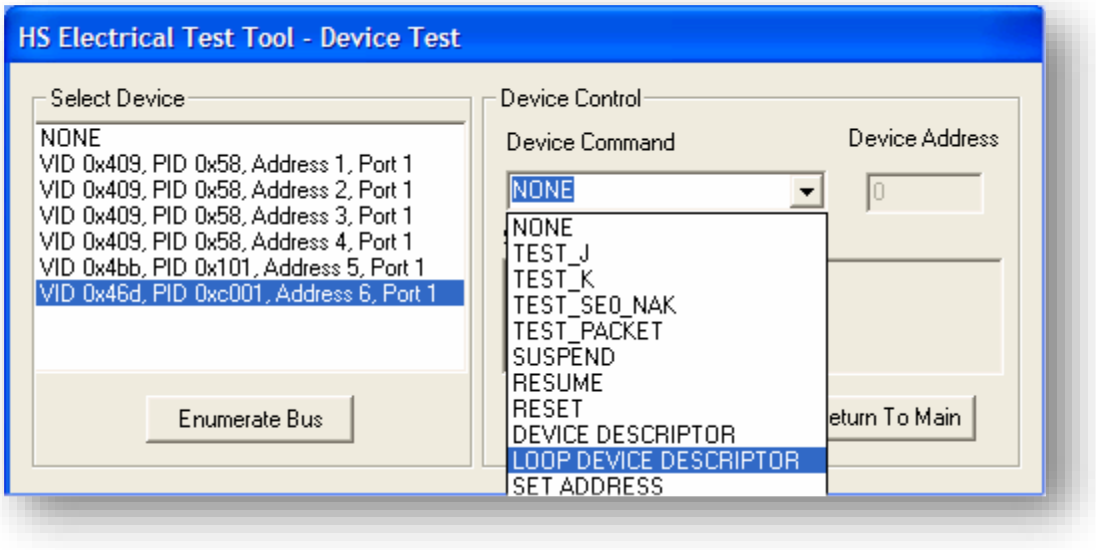


Figure 36: Loop Device Descriptor for Signal Quality Full Speed (Upstream)

10. Set the scope to trigger on **Pattern** 001x; where Ch1 & Ch2 are low and Ch3 (Qualifier Device) is high.

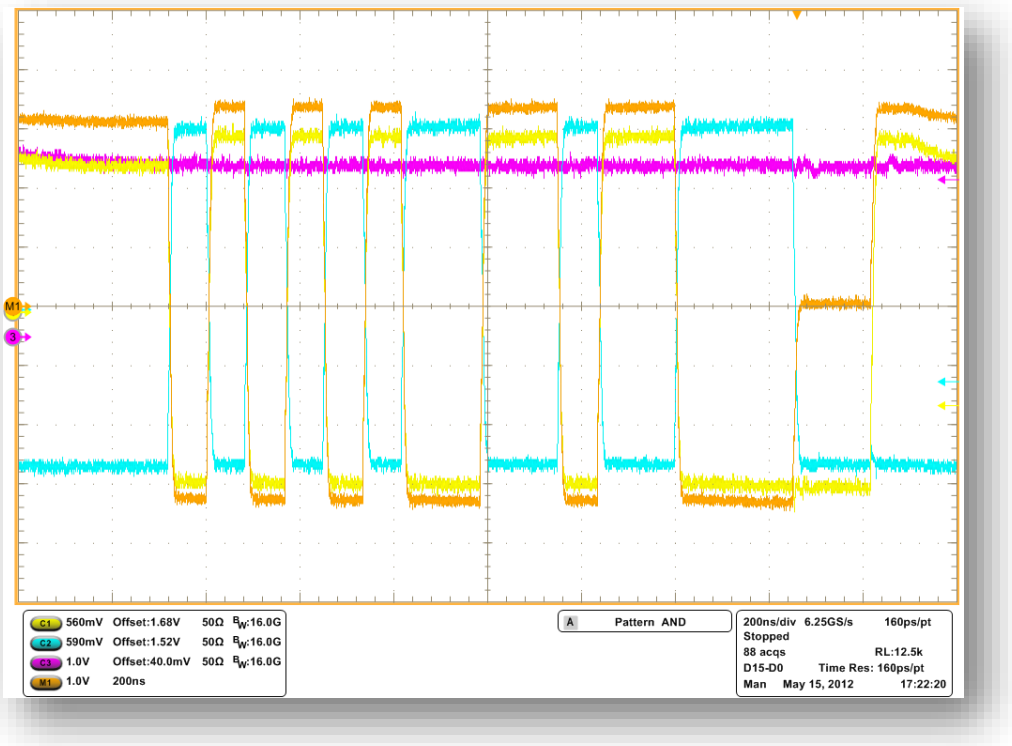


Figure 37: Full Speed Signal Quality trigger

11. Save the waveforms
12. Open USBET20 (download from USB.org)
13. Select the **Device/Host SQ** tab.
14. Browse for your file you saved and select Test

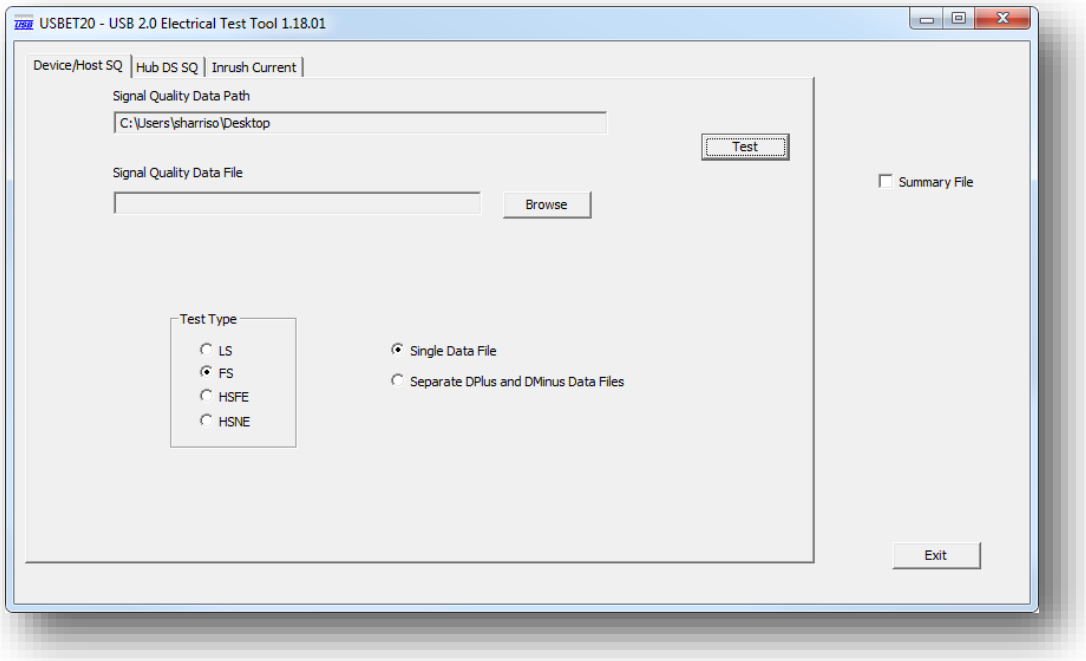


Figure 38: USBET Analysis Tool

Inrush Current Test for a Device

Specifying the Equipment-Full Speed Inrush Current Test

- Tektronix digital oscilloscope
- TDSUSBF compliance test fixture
- One TCP202 current probe

Typical Equipment Setup-Inrush Current Test

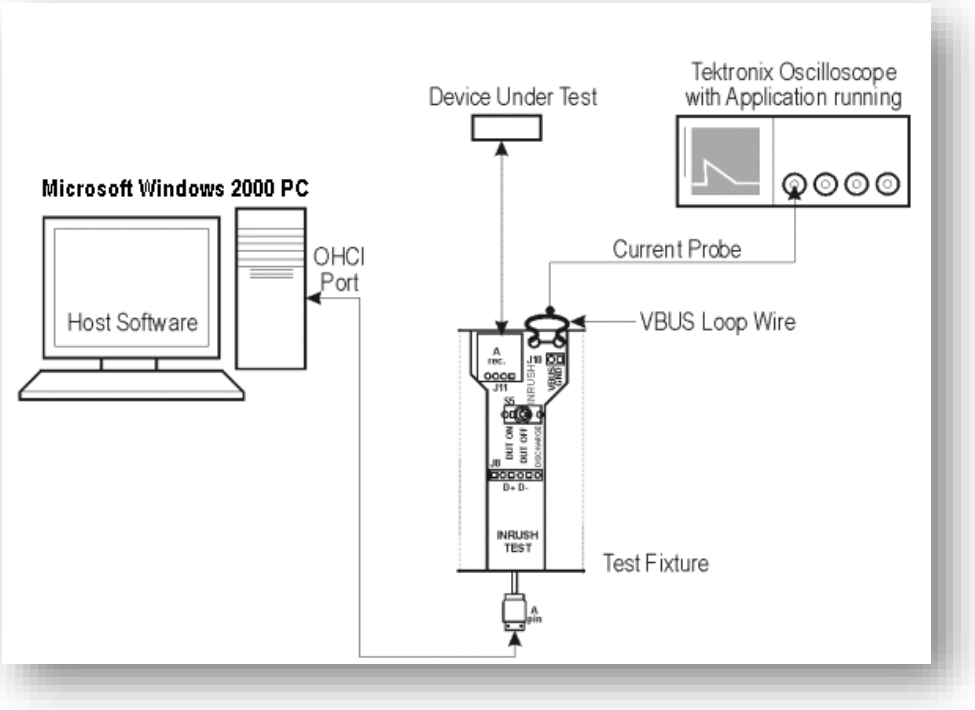


Figure 39: Equipment Setup for Full Speed Inrush Current Test

To set up the equipment for Inrush test, follow these steps:

1. Connect the current probe between the V_{BUS} Loop Wire on the Inrush section on the Test fixture and Ch1 of the oscilloscope.
2. Connect the Device Under Test to the A USB Receptacle of the Inrush section on the SQiDD fixture.
3. Place Switch on SQiDD board to position 3 (**DISCHARGE**) - shorting VBUS to Gnd on DUT to discharge device capacitance.
4. Unplug DUT.

5. Place Switch on SQiDD board to position 1 (**DUT ON**) - Switching VBUS on.
6. Plug in DUT to the SQiDD board. Do not use the switch on the fixture to open/close V_{bus} with the DUT attached since the switch bounce will cause errors in the actual inrush current measurement.
7. Save the Waveform after acquiring

Note: If there is no inrush event found, i.e. the current never rises above 100 mA, the result is considered a failure. A minimum of 1µF (microfarad) is required on all USB peripherals as required by the "Device Capacitance ECN"

8. Open USBET20 (download from USB.org)
9. Select the **Inrush Current** tab.
10. Browse for your file you saved and select Test

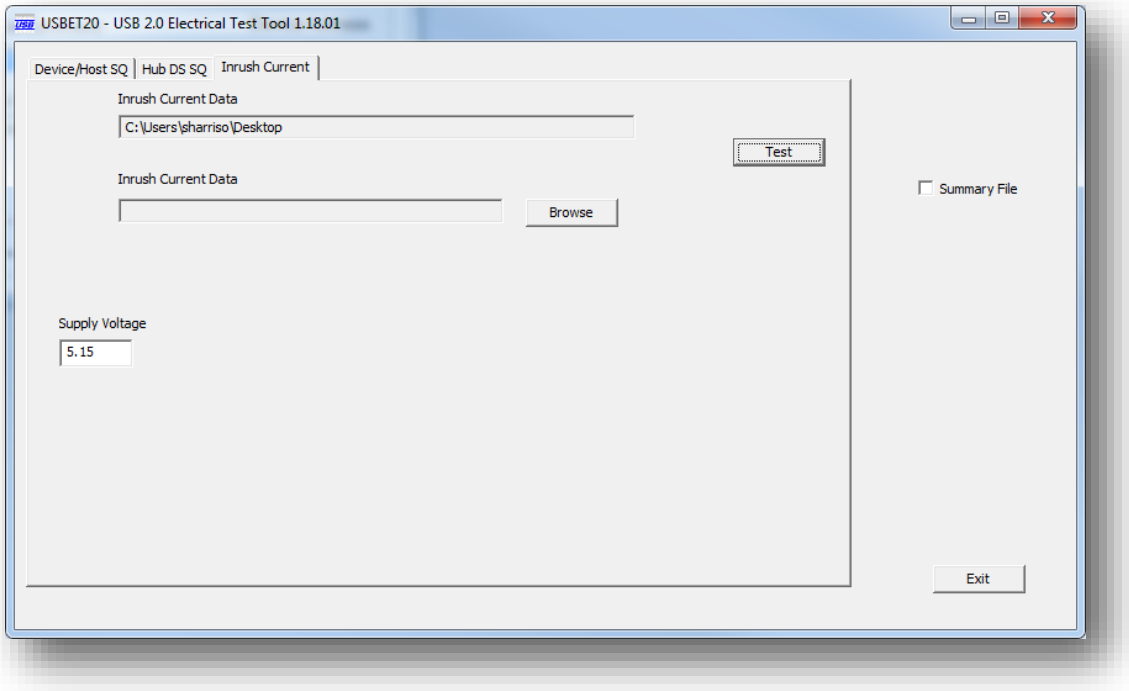


Figure 40: USBET20 Analysis Tool