USB-IF USB 2.0 Electrical Test Specification

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Comments/questions to electrical@usb.org

Revision History

Revision	Issue Date	Comments
0.5	10/30/2000	Initial Revision – Intended For Review Purposes Only.
0.7	12/5/2000	Assertions added and test descriptions added
0.9	12/21/2000	Clean up and cross references added
0.91	3/2/2001	Minor updates.
1.00	3/29/2001	Release version
1.02	1/13/2005	Corrections to EL_27 and EL_28. Clarified that pre-emphasis is to be disabled in test description 3.3 Correct formatting of EL_15

1 Summary:

This document provides the compliance criteria and test descriptions for USB2.0 high-speed electrical testing. It is relevant for anyone building USB2.0 silicon, USB2.0 devices, USB2.0 hubs or USB2.0 hosts. The document is divided into two major areas. The first is compliance criteria and the second is test descriptions.

Compliance criteria are provided as a list of assertions that describe specific characteristics or behaviors that must be met. Each assertion provides a reference to the specification or other document from where the assertion was derived. Also each assertion provides a reference to the specific test description where the assertion is tested.

Test descriptions provide a high level overview of the tests that are performed to check the compliance criteria. The descriptions are provided with enough detail so that a reader can understand what a test does. The descriptions do not describe the actual step-by-step procedure to perform the test.

2 High Speed Electrical Compliance Criteria

2.1 General

EL_1 All high-speed capable devices must support the specified test modes for their ports.
Reference documents: *USB 2.0 Specification*, Section 7.1.20.
Test description: "Sections 3.1.1, 3.2.1, 3.3 ".

2.2 Transmitting

EL_2 A USB 2.0 high-speed transmitter data rate must be 480 Mb/s ±0.05%.
Reference documents: *USB 2.0 Specification*, Section 7.1.11.
Test description: "Section 3.1".

EL_3 A USB 2.0 downstream facing port must meet Template 1 transform waveform requirements measured at TP2 (each hub downstream port).
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Sections 3.1.2, 3.1.3".

EL_4 A USB 2.0 upstream facing port on a device without a captive cable must meet Template 1 transform waveform requirements measured at TP3.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Section 3.1.1".

EL_5 A USB 2.0 upstream facing port on a device with a captive cable must meet Template 2 transform waveform requirements measured at TP2.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Section 3.1.1".

EL_6 A USB 2.0 HS driver must have 10% to 90% differential rise and fall times of greater than 500 ps.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Sections 3.1.1, 3.1.2, 3.1.3".

EL_7 A USB 2.0 HS driver must have monotonic data transitions over the vertical openings specified in the appropriate eye pattern template.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Sections 3.1.1, 3.1.2, 3.1.3".

EL_8 When either D+ or D- is driven high, the output voltage must be 400 mV ±10% when terminated with precision 45 Ω resistors to ground.
Reference documents: *USB 2.0 Specification*, Section 7.1.1.3.
Test description: "Section 3.3".

EL_9 When either D+ or D- is not being driven, the output voltage must be 0V ±10mV when terminated with precision 45 Ω resistors to ground.
Reference documents: *USB 2.0 Specification*, Section 7.1.1.3.
Test description: "Section 3.3 and 3.4".

EL_10 The differential output impedance of a high-speed capable driver is required to be 90 Ω ± 10%.
Reference documents: *USB 2.0 Specification*, Section 7.1.1.3.
Test description: "Section 3.4".

2.3 Receiving

EL_11 A USB 2.0 high-speed receiver must be able to receive at 480 Mb/s ±0.05%.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Section 3.2.2".

EL_12 A USB 2.0 downstream facing port must meet Template 4 receiver sensitivity requirements when a signal is applied at TP2.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Section 3.2.2".

EL_13 A USB 2.0 upstream facing port on a device without a captive cable must meet Template 4 receiver sensitivity requirements when a signal is applied at TP3.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Section 3.2.1".

EL_14 A USB 2.0 upstream facing port on a device with a captive cable must meet Template 3 receiver sensitivity requirements when a signal is applied at TP2.
Reference documents: *USB 2.0 Specification*, Section 7.1.2.2.
Test description: "Sections 3.2.1, 3.2.2".

EL_15 High-speed receivers should be able to reliably receive in the presence of a common mode voltage component over the range of –50mv to 500mv.
Reference documents: *USB 2.0 Specification*, Section 7.1.4.2.
Test description: "Sections 3.2.1, 3.2.2".

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 100 mV differential amplitude.
Reference documents: *USB 2.0 Specification*, Section 7.1.
Test description: "Sections 3.2.1, 3.2.2".

EL_17 A high speed capable device must implement a transmission envelope detector that does not indicate squelch (i.e. reliably receives packets) when a receivers exceeds 150 mV differential amplitude.
Reference documents: *USB 2.0 Specification*, Section 7.1.
Test description: "Sections 3.2.1, 3.2.2".

EL_18 A high speed capable device's Transmission Envelope Detector must be fast enough to allow the HS receiver to detect data transmission, achieve DLL lock, and detect the end of the SYNC field within 12 bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.
Test description: "Sections 3.2.1, 3.2.2".

2.4 Input Characteristics

EL_19 The differential termination impedance of a high-speed driver must be between 80ohms and 100ohms.
Reference documents: *USB 2.0 Specification*, Section 7.1.6.2.
Test description: "Section 3.4".

EL_20 The 'Through Impedance' (described in the USB2.0 Specification) of a high-speed device must be between 70ohms and 110ohms, except for qualifying excursions within the 'Exception Window'.
Reference documents: *USB 2.0 Specification*, Section 7.1.6.2.
Test description: "Section 3.4".

2.5 Packet Parameters

EL_21 The SYNC field for all transmitted packets (not repeated packets) must begin with a 32 bit SYNC field.
Reference documents: *USB 2.0 Specification*, Section 8.2.
Test description: "Sections 3.6.1, 3.6.2".

EL_22 When transmitting after receiving a packet, hosts and devices must provide an inter-packet gap of at least 8 bit times and not more than 192 bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.18.2.
Test description: "Section 3.6.1".

EL_23 Hosts transmitting two packets in a row must have an interpacket gap of at least 88 bit times and not more than 192 bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.18.2.
Test description: "Section 3.6.2".

EL_24 A host or device expecting a response to a transmission must not timeout the transaction if the interpacket delay is less than 736 bit times, and it must timeout the transaction if no signaling is seen within 816 bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.19.2.
Test description: "Section 3.6.2".

EL_25 The EOP for all transmitted packets (except SOFs) must be an 8 bit NRZ byte of 01111111 without bit stuffing. (Note, that a longer EOP is waiverable).
Reference documents: *USB 2.0 Specification*, Section 7.1.13.2
Test description: "Section 3.6.1, 3.6.2".

EL_26 Receivers are required to interpret any bit stuff error as an EOP.
Reference documents: *USB 2.0 Specification*, Section 7.1.13.2
Test description: "Section 3.6.1, 3.6.2".

2.6 Speed Detection

EL_27 Devices must transmit a chirp handshake no sooner than 3.1ms and no later than 6.0ms when being reset from a non-suspended high-speed mode. The timing is measured from the beginning of the last uSOF transmitted before the reset begins.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_28 Devices must transmit a chirp handshake no sooner than 2.5us and no later than 6ms when being reset from a suspend state. Devices must transmit a chirp handshake no sooner than 2.5us and no later than 3ms when being reset from a full-speed state.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_29 The chirp handshake generated by a device must be at least 1ms and not more than 7ms in duration.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_30 A device must be able to detect a valid Chirp K-J-K-J-K-J (including Tfilt timing) sequence from a hub port.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_31 During device speed detection, when a device detects a valid Chirp K-J-K-J-K-J sequence, the device must disconnect its 1.5K pull-up resistor and enable its high-speed terminations within 500us.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_32 Downstream ports must detect a device chirp after it has seen the assertion of Chirp K for no less than 2.5us.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.2".

EL_33 Downstream ports start sending and alternating sequence of Chirp K's and Chirp J's within 100us after the device Chirp K stops.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_34 Downstream port Chirp K and Chirp J durations must be between 40us and 60us duration.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

EL_35 Downstream ports begin sending SOFs within 500us and not sooner than 100us from transmission of the last Chirp (J or K).
Reference documents: *USB 2.0 Specification*, Section 7.1.7.5.
Test description: "Section 3.5.1".

2.7 Disconnect Detection

EL_36 A USB 2.0 downstream facing port must detect the high speed disconnect state when the amplitude of the differential signal at the port is ≥ 625 mV.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.3.
Test description: "Section 3.7".

EL_37 A USB 2.0 downstream facing port must not detect the high speed disconnect state when the amplitude of the differential signal at the port is <= 525 mV.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.3.
Test description: "Section 3.7".

2.8 Suspend/Resume

EL_38 A device must revert to full-speed termination no later than 125us after there is a 3ms idle period on the bus.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.6.
Test description: "Section 3.8"

EL_39 A device must support the Suspend state.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.6.
Test description: "Section 3.8".

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 operation within two bit times from the end of resume signaling.
Reference documents: USB 2.0 Specification, Section 7.1.7.7.

Test description: "Section 3.8".

EL_41 After resuming a port, the host must begin sending SOFs within 3ms of the start of the idle state.
Reference documents: *USB 2.0 Specification*, Section 7.1.7.7.
Test description: "Section 3.8".

2.9 High speed repeater

2.9.1 Sync truncation

EL_42 Hub repeaters must not truncate more then 4 bits from from a repeated SYNC pattern.
Reference documents: *USB 2.0 Specification*, Section 7.1.10.
Test description: "Section 3.9.1".

EL_43 Hubs must not corrupt any repeated bits of the SYNC field.
Reference documents: *USB 2.0 Specification*, Section 7.1.10.
Test description: "Section 3.9.1".

2.9.2 EOP dribble

EL_44 A hub may add at most 4 random bits to the end of the EOP field when repeating a packet.
Reference documents: *USB 2.0 Specification*, Section 7.1.13.2
Test description: "Section 3.9.1".

EL_45 A hub must not corrupt any of the valid EOP bits when repeating a packet.
Reference documents: *USB 2.0 Specification*, Section 7.1.13.2
Test description: "Section 3.9.1".

2.9.3 Jitter

EL_46 A hub upstream repeater must meet Template 1 transform waveform requirements measured at TP3.
Reference documents: *USB 2.0 Specification*, Section 7.1.14.2.
Test description: "Section 3.1.1".

EL_47 A hub downstream facing repeater must meet Template 1 transform waveform requirements measured at TP2 (each hub downstream port).
Reference documents: *USB 2.0 Specification*, Section 7.1.14.2.
Test description: "Section 3.1.2".

2.9.4 Delay

EL_48 A hub repeater may not delay packets for more than 36 bit times plus 4ns.
Reference documents: *USB 2.0 Specification*, Section 7.1.14.2
Test description: "Section 3.9.1".

EL_49 The propagation delay of a hub repeater may not vary more than 5 HS bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.14.2
Test description: "Section 3.9.1".

2.9.5 SOF Timings

EL_50 A TT must generate a full-speed SOF within +/- 3 full-speed bit times from the occurrence of the zeroth high-speed SOF.
Reference documents: *USB 2.0 Specification*, Section 11.18.3.
Test description: "Section 3.9.4".

EL_51 Hub introduced microframe jitter must be less that 4 high-speed bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.12.
Test description: "3.9.1".

2.9.6 RWU Filter

EL_52 Hub downstream ports that are in the 'suspended' state do not leave that state when a 'K' is present at the port for a duration smaller than 2.5us.
Reference documents: *USB 2.0 Specification*, Section 11.5.1.10.
Test description: "Section 3.9.2".

2.9.7 EOF1 and EOF2 timing rules

EL_53 A hub repeater must tear down upstream connectivity at the EOF1 timing point.
Reference documents: *USB 2.0 Specification*, Section 11.2.5.
Test description: "Section 3.9.3".

EL_54 A hub repeater must disable any port that has upstream connectivity at the EOF2 timing point.
Reference documents: *USB 2.0 Specification*, Section 11.2.5.
Test description: "Section 3.9.3".".

2.10 Host requirements:

2.10.1 EOP length for SOFs

EL_55 Hosts transmitting SOF packets must provide a 40 bit EOP without bitstuffing where the first symbol of the EOP is a transition from the last data symbol.
Reference documents: *USB 2.0 Specification*, Section 7.1.13.2
Test description: "Section 3.6.3".

EL_56 Host microframe interval must be 125us±62.5ns.
Reference documents: *USB 2.0 Specification*, Section 7.1.12.
Test description: "Section 3.6.4".

EL_57 Host microframe interval repeatability must be less that 4 high-speed bit times.
Reference documents: *USB 2.0 Specification*, Section 7.1.12.
Test description: "3.6.4".

2.11 Hub Transaction Translator requirements:

EL_58 Hub transaction translator 'think time' must be less than or equal to the value specified in the hub descriptor field *wHubCharacteristics* bit 5 and 6.
Reference documents: *USB 2.0 Specification*, Sections 11.18.2 and 11.23.2.1.
Test description: "3.9.5".

3 High Speed Electrical Test Descriptions

3.1 High Speed Signal Quality

These tests measure the ability of transmitters to do valid high speed signaling. High speed signal quality is measured on both upstream and downstream ports. A high speed scope with differential probes is used. Signaling data is captured with the scope and then translated to an eye pattern. The signal quality eye patterns obtained from the measurements must agree with the transmit eye patterns for Test Points 2 and 3 defined in the USB 2.0 Specification.

3.1.1 Upstream Port

This test is run for all devices and hubs on their upstream port. For devices that have a captive cable, measurements are taken at TP2 (instead of TP3 as stated below).

a. *Place port in Test Mode TEST_PACKET.*
b. *Isolate Device Under Test From System While Maintaining Bus Power.*
c. *Measure Transmitted Waveform With High Speed Oscilloscope and Differential Probe through Ideally Terminated Test Fixture. Make measurements at TP3.*
d. *Generate Eye Pattern Diagrams from Data.*
e. *Compare With USB 2.0 Specification Transmit Eye Patterns.*
f. *Check Rise/Fall Times To Make Sure They are not faster then minimum set in USB 2.0 specification.*
g. *Check for non-monotonic transitions.*

3.1.2 Downstream Port (hub)

This test checks the hub repeater capability to transmit properly when repeating downstream traffic.

a. *Place port in Test Mode FORCE_ENABLE.*
b. *Generate Test Packets From Upstream Source (Host).*
c. *Measure Transmitted Waveform With High Speed Oscilloscope and Differential Probe through Ideally Terminated Test Fixture. Make measurements at TP2.*
d. *Generate Eye Pattern Diagrams from Data.*
e. *Compare With USB 2.0 Specification Transmit Eye Patterns.*
f. *Check Rise/Fall Times To Make Sure They are not faster then minimum set in USB 2.0 specification.*
g. *Check for non-monotonic transitions.*

3.1.3 Downstream Port (host)

This test checks a host's capability to transmit properly.

a. *Place port in Test Mode TEST_PACKET.*
b. *Measure Transmitted Waveform With High Speed Oscilloscope and Differential Probe through Ideally Terminated Test Fixture. Make measurements at TP2.*
c. *Generate Eye Pattern Diagrams from Data.*
d. *Compare With USB 2.0 Specification Transmit Eye Patterns.*
e. *Check Rise/Fall Times To Make Sure They are not faster then minimum set in USB 2.0 specification.*
f. *Check for non-monotonic transitions.*

3.2 Receiver Characteristics

These tests check the receive characteristics of upstream and downstream ports.

3.2.1 Upstream Port Receiver Sensitivity

Testing for upstream ports and the criteria that will be tested are as follows:

a. *Place device under test in test mode SEO_NAK*
b. *Isolate device under test from USB Bus.*
c. *Connect Data Generator to Data Lines*
d. *Connect Oscilloscope*
e. *Generate IN Packets of minimum receivable amplitude (must meet appropriate receiver sensitivity template), with common mode voltage components ranging from –50mV to 500mV and with bit rate ranging from 480 Mb/s-0.05% to480 Mb/s+0.05%.*
f. *Verify that all packets are NAK'd while signaling is above the required voltage threshold.*
g. *Verify that no packets are NAK'd when signaling amplitude is below the squelch level.*
h. *Generate IN packets (of compliant amplitude) with a 12-bit SYNC field.*
i. *Verify that device responds*

3.2.2 Downstream Port Receiver Sensitivity

Host and hub downstream ports are tested in the same way. In both cases, the host sends IN packets and a data generator will generate data packets in response. Software running on the host will cause the host to send INs and then the packet from the data generator will get to the host either through a hub port (if the hub is being tested) or directly to the host. If the port under test does not receive the packet, the host will see a timeout or CRC error and the host SW will detect this. The basic procedure is:

a. *Attach and enumerate device to port under test*
b. *Isolate port under test from USB Bus.*
c. *Connect Data Generator and oscilloscope to Data Lines*
d. *Run software on host that causes host to send IN tokens and expect a response*
e. *Use scope to detect INs and trigger data generator to transmit packets of minimum receivable amplitude (must meet appropriate receiver sensitivity template), with common mode voltage components ranging from –50mV to 500mV and with bit rate ranging from 480 Mb/s-0.05% to480 Mb/s+0.05%.*

f. Verify that host receives the packets.
g. Verify that no packets are received when signaling amplitude is below the squelch level.
h. Use data generator to generate packets (of compliant amplitude) with a 12-bit SYNC field.
i. Verify that host receives the packets.

3.3 J and K Voltage Levels

These tests measure the DC drive capabilities of the high-speed drivers using a voltmeter between the signal lines and GND. Tests should be conducted with pre-emphasis disabled on the device. These tests are performed on all ports.

a. Place port in Test Mode TEST_J when ideally terminated.
b. Measure D+ to be 400mV ±10%.
c. Measure D- to be 0V ±10mV.
d. Place port in Test Mode TEST_K when ideally terminated.
e. Measure D- to be 400mV ±10%.
f. Measure D+ to be 0V ±10mV.

3.4 Termination Impedance Tests

These tests measure the spatial impedance of the high speed signaling path and active terminations of the device under test. Differential TDR measurements are taken and then compared with spec requirements.

a. Place device under test in test mode SE0_NAK
b. Isolate device under test from system while maintaining bus power.
c. Measure D+ and D- to be 0V ±10mV.
d. Drive a 400ps (nominal) edge rate step to the device.
e. Observe the resulting waveform, making sure that the Termination Impedance and Through Impedance meet the spec requirements.

3.5 Speed Detection

These tests examine the chirp behavior for both upstream and downstream ports. For a hub, chirp must be tested both on the upstream (connecting the hub to a known good host) and all downstream ports device (connecting a known good device). All downstream port tests are done on hubs and host controllers. The procedure and criteria that will be analyzed are briefly as follows:

3.5.1 Chirp timing/voltage characteristics

This test examines the basic timings and voltages of both upstream and downstream ports during the speed detection protocol.

a. Connect Device Under Test To Host.
b. Measure signaling with single ended probes on both Data Lines.
c. Analyze data for the following:

Upstream Port (device reset from Full Speed)

1. *Full Speed Idle Voltage*
2. *Time from beginning of Reset to Chirp K (2.5us to 3ms)*
3. *Chirp K Amplitude (~800mV)*

4. *Chirp K Duration (1ms to not more than 7ms after start of Reset)*
5. *Number of KJ Pairs Before High-Speed Terminations Applied (at least 3 pairs)*
6. *Delay after KJKJKJ before Device Applies Terminations (<500us)*

Upstream Port (device reset from High Speed)

1. *Time from beginning of Reset(last SOF) to ChirpK (3ms to 6ms)*
2. *Chirp K Amplitude (~800mV)*
3. *Chirp K Duration (1ms to not more than 7ms after start of Reset)*
4. *Number of KJ Pairs Before High-Speed Terminations Applied (at least 3 pairs)*
5. *Delay after KJKJKJ before Device Applies Terminations (<500us)*

Upstream Port (device reset from Suspend after being in High-Speed)

1. *Full Speed Idle Voltage*
2. *Time from beginning of Reset to Chirp K (2.5us to 6ms)*
3. *Chirp K Amplitude (~800mV)*
4. *Chirp K Duration (1ms to not more than 7ms after start of Reset)*
5. *Number of KJ Pairs Before High-Speed Terminations Applied (at least 3 pairs)*
6. *Delay after KJKJKJ before Device Applies Terminations (<500us)*

Downstream Port

1. *Hub Chirp Response Time (100us)*
2. *Hub Chirp J Time (40us to 60us)*
3. *Hub Chirp K Time (40us to 60us)*
4. *Hub J and K Amplitudes (~400mV)*
5. *Time from end of Chirps to first SOF (100us to 500us)*

3.5.2 Chirp boundary conditions test for downstream port.

This test examines downstream port behavior when device behavior is at the boundary conditions for chirp timing. Boundary conditions consist of how quickly after Reset the device begins the Chirp K (either 2.5us or 3ms) and the duration of the device Chirp K (either 1ms or 4ms). Setup for the test is the same as the previous test. For each test case, the downstream port will be expected to properly detect the device chirp, respond with the alternating sequence of J's and K's, and enumerate the device.

a. *Device drives chirp K 2.5us after Reset with duration of 1ms.*
b. *Device drives chirp K 2.5us after Reset with duration of 7ms.*
c. *Device drives chirp K 3ms after Reset with duration of 1ms.*
d. *Device drives chirp K 3ms after Reset with duration of 4ms.*

3.6 Packet Parameters

There are several important packet characteristics for upstream and downstream signaling that are examined. They include the following.

3.6.1 Response Time

This test measures the amount of time it takes hosts and devices to respond. It also verifies device generated SYNCs and EOPs.

a. *Perform Get_Descriptor(Device)*

b. *Measure Device Response With Oscilloscope between Setup data packet and ACK and between IN token and Data from device (8 to 192 bit times)*
c. *Measure host interpacket gap between Setup packet and data packet (88 to 192)*
d. *Measure host response time between IN data packet and host ACK (8 to 192 bit times)*
e. *Count SYNC field bits on device data packet (32)*
f. *Count EOP bits on device data packet (not less than 8)*

3.6.2 Device/Host Response With Worst Case Interpacket Delay

This test verifies that devices and hosts can handle interpacket delays that are approaching the spec'ed maximum. Inserting the appropriate number of hubs in the communication path generates long interpacket delays. A scope is used to measure the actual interpacket delay. When testing a host, this will also check the host interpacket gap when transmitting consecutive packets as well as SYNC and EOP fields on host packets.

a. *Connect device, hub tree, and host. Connect scope at USB link closest to device or host being tested.*
b. *Perform Get_Descriptor(Device) in configuration where interpacket gaps are maximized (use intervening hubs).*
c. *Verify that transaction works correctly.*
d. *If testing a host, verify that the interpacket gap between Setup packet and Data packet correct (88 to 192 bit times).*
e. *If testing a host, count SYNC field bits on host setup data packet (32)*
f. *If testing a host, count EOP bits on host setup data packet (not less than 8)*

3.6.3 Host SOF Sync and EOP Bits.

This test verifies that a host generated the proper SYNC and EOP fields for SOF packets.

a. *Use scope to capture SOFs from host*
b. *Count SYNC field bits (32)*
c. *Count EOP bits (not less than 40)*

3.6.4 Host SOF Timing.

This test verifies that the host is generating high-speed SOFs at the right frequency and that the variability between any two SOFs is within spec. To measure this, the scope is set to trigger on an SOF and have enough trace depth so that two SOFs are captured. The scope is put into infinite persistence mode so that all trace captures show on the scope. After running for a while, the timing from the first SOFs to the second SOFs is measured, and the variance in the beginning of the second SOFs is measured.

a. *Use scope (set for infinite persistence) to capture many pairs of SOFs from host.*
b. *Measure time interval from first SOFs to second SOFs and verify that this time is 125us±62.5ns*
c. *Measure spread of the second SOFs and verify that it is less than 4 high-speed bit times.*

3.7 Disconnect Detection

This test verifies that downstream ports properly detect device disconnects. The test first verifies that the port does not detect a disconnect when it shouldn't, and then that the port does detect disconnect when it should.

a. *Place Ideal Terminations On Port Under Test*
b. *Place Port To Test in Test Mode FORCE_ENABLE*
c. *Change device terminations (without discontinuity) so that SOF EOP voltage is 500mV.*
d. *Verify that SOFs are still being transmitted.*
e. *Change device terminations (without discontinuity) so that SOF EOP voltage is just above 625mV.*
f. *Verify that SOFs stop and the port reports a disconnect.*

3.8 Suspend and Resume

This test verifies that a device can be suspended and resumed while operating in high-speed and also that the device can be reset from the suspended state.

a. *Attach and enumerate the device.*
b. *Suspend the port where the device is attached.*
c. *Verify that the device reverts to full speed terminations (3000us to 3125us)*
d. *Resume the port where the device is attached.*
e. *Verify that device has high speed terminations on for first SOF.*
f. *Suspend the port where the device is attached.*
g. *Drive Reset from port where device is attached.*
h. *Verify time from beginning of Reset to device Chirp K (2.5us to 3ms)*

3.9 High Speed Repeater Tests

3.9.1 Repeater Packet/Timing Characteristics

This test looks at the hub repeater characteristics by attaching a differential probe on both the upstream and downstream ports. Data is captured as it goes through the repeater and sync truncation, EOP dribble and latency are checked.

a. *Connect hub to a host and connect a HS device to hub downstream port. Use scope to monitor both upstream and downstream port*
b. *Capture a packet moving in downstream direction.*
c. *Verify Sync truncation (not more than 4 bits), EOP dribble (not more than 4 bits) and latency through hub (not more than 36 bit times plus 4ns).*
d. *Capture a packet moving in upstream direction.*
e. *Verify Sync truncation (not more than 4 bits), EOP dribble (not more than 4 bits) and latency through hub (not more than 36 bit times plus 4ns).*
f. *Repeat steps d and e for each downstream port.*
g. *Capture multiple SOFs going through repeater (use infinite persistence on scope) and verify that delay variation is 5 bit times or less.*
h. *Capture multiple upstream packets through repeater (use infinite persistence on scope) and verify that delay variation is 5 bit times or less.*

3.9.2 RWU Filter

This test examines a hubs ability to ignore glitches on D+/D- on a suspended port. The test injects a small glitch on the data lines of a suspended device and verifies that the hub doesn't detect this as a remote wakeup.

a. *Attach high speed device to hub downstream port.*
b. *Suspend device*
c. *Inject glitch on data lines (K state for less than 2us).*
d. *Verify that port remains suspended.*
e. *Repeat steps a thru d for each downstream port.*

3.9.3 EOF1 and EOF2 Timing Rules

This test examines a hubs ability to detect and properly handle upstream traffic that is too close to the end of the microframe. The basic algorithm involves using a device that sends more data than the host is expecting (otherwise the host won't start the transaction). The host schedule is built so that the babbling device is polled late in the frame (ie. other isoch traffic is run early in the frame), so that when the device transmits it causes a frame babble. The port where the device is connected should be the only port that is disabled. If other upstream ports are also disabled, then it means that the hub did not properly stop upstream connectivity at the EOF1 point. This test should be run on both hosts and hubs.

a. *Connect babbling device to downstream port.*
b. *Generate traffic such that babbling device causes frame babble.*
c. *Verify that port where device is attached is disabled*
d. *Verify that no other ports in the path to the host are disabled.*

3.9.4 Full Speed SOF Generation

This test examines a hub's full-speed SOF generation timing. It uses scope data to make sure that the full-speed SOF happens within +/- 3 FS bit times of the zeroth high-speed SOF.

a. *Connect hub to host system and HS device to hub downstream port.*
b. *Use scope to capture FS SOF and HS SOFs.*
c. *Verify that FS SOF has proper timing relationship with zeroth HS SOF.*

3.9.5 Hub TT Think Time

This test looks at the amount of time it takes for a TT to start a pending FS transaction after a previous FS transaction has completed. It validates that this time is consistent with the time indicated in the hub descriptor. It is important that the actual time matches the descriptor values so that the budgeting algorithms can properly calculate the budget.

a. *Connect hub to host system and FS device to hub downstream port.*
b. *Send transfers to hub TT so that back-to-back transfers happen on FS bus. All combinations of transfer types (FS bulk, isoch, FS interrupt, LS control and LS interrupt) and ordering should be tested.*
c. *Use scope to measure time between back-to-back FS transactions*
d. *Verify that think time is less than or equal to values in hub descriptor.*