

USB 3.1 Receiver Compliance Testing

Application Note

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Abstract

SuperSpeed USB (USB 3.1) is poised to become as popular and widespread as its predecessors. With a data rate up to 10 Gb/s, however, it is more than an order of magnitude faster than USB 2.0, posing challenges for physical layer testing and requiring bit error ratio (BER) testing for receivers. This paper reviews the requirements for receiver compliance testing with a comprehensive example using the Tektronix BERTScope family of products.

Introduction

The Universal Serial Bus (USB) is probably the best known computer peripheral interface today. It is ubiquitous in modern everyday life, connecting our various electronic devices such as mobile communication devices, flash drives, digital cameras, etc. to our computers.

As with any serial bus standard, it is evolving to accommodate the growing need for faster data transfer and more intelligent power consumption. For example, USB external storage devices are reaching the limits of their capable transfer speeds, and consumers' expectations of the speed at which large files, such as full resolution digital photos or entire movies, can be transferred to a host computer are rising.

The latest incarnation, USB 3.1, or "SuperSpeed USB," was designed to address such needs. Specificationsⁱ for USB 3.1ⁱⁱ were completed on July 31, 2013, and developers are gearing up to introduce products compliant with the new standard. Improvements from USB 3.0 include:

- Faster data rate (10 Gb/s vs. 5 Gb/s). This has a big impact on USB 3.0 receiver testing, as the higher data rate means a higher burden on the physical layer and more stringent compliance testing compared to USB 3.0. For example, receiver testing now requires a higher loss channel as well as more complex receiver equalization model.
- More power when needed and more power saving when not needed through the supplemental USB Power Delivery (PD) specification.
- <5% transfer overhead with more efficient coding of 128b/132b vs. 20% with 8b/10b.
- Improved connectors and cables, with backward compatibility to USB 3.0 as well as bandwidth scalability for the future.

The higher performance of the USB 3.1 standard has resulted in significant changes to the test requirement, including receiver testing as detailed in the following sections.

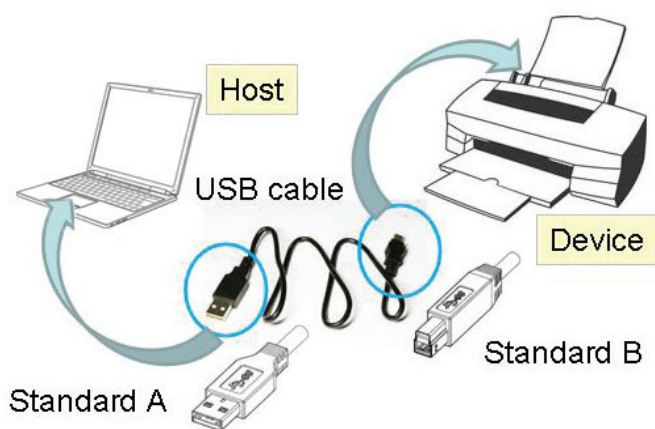


Figure 1. Standard A and Standard B USB connectors connect USB Hosts such as a PC to Devices such as a printer via a USB cable.

USB 3.1 Devices and Connectors

USB 3.1 products come in three flavors – Hosts, Devices, and Cables.

- **Hosts** are where the USB controller resides, for example, on a Personal Computer (PC), Notebook Computer or Tablet. It includes the CPU, buses, and operating system.
- **Devices** are USB hubs or peripheral devices, for example memory sticks, external disk drives, printers, digital cameras, cellular telephones/PDAs, etc.
- **Cables** are typically passive and provide data, power and control signals between a host and device.

The receiver test requirements are the same for both a Host and Device, but as we will see, the adapters and cabling needed for testing differ. Also multi-function products are also available such as Hubs and Docks but they are simply treated as both a Host and Device in terms of electrical testing.

There are four types of connectors defined in the USB 3.1 specification.

- The **Standard A** connector connects to the Host, and is the type of connector that is most familiar to consumers, as it is the type of USB port found on PCs and is the connector type found on the ubiquitous USB memory stick.

- The **Standard B** type of connector is typically used for stationary USB peripherals such as printers and external hard drives. It is usually found at the other end of a USB cable connecting the peripheral to the PC.
- The **Standard C** type connector is the same connector for both a Host and Device and allows for reversible connections as well as flipping of the plug (upside down or upside up). Additional pins provide dynamic port negotiation of host or device state as well as higher power transfer.
- The **Micro** connectors are used for small peripherals, such as digital cameras or phones.

While the SuperSpeed B side connectors on the cables (plugs) are incompatible with USB 2.0 B receptacles, the A side connectors are fully compatible. This allows USB 3.1 devices to plug into USB 2.0 hosts. All USB 3.1 receptacles accept both USB 2.0 and 3.1 plugs, so that USB 2.0 cables and devices can be used with USB 3.1 hosts.

The USB Type-C connector is not directly backwards compatible with the A and B connectors and requires an adapter for use with products that don't support Type-C. In addition, to fully utilize the unique capabilities of the Type-C connector (e.g., high power, role swapping, etc.) both the Host and Device need to include this functionality.

The Standard A, Standard B and Type-C connectors are used for receiver compliance testing.

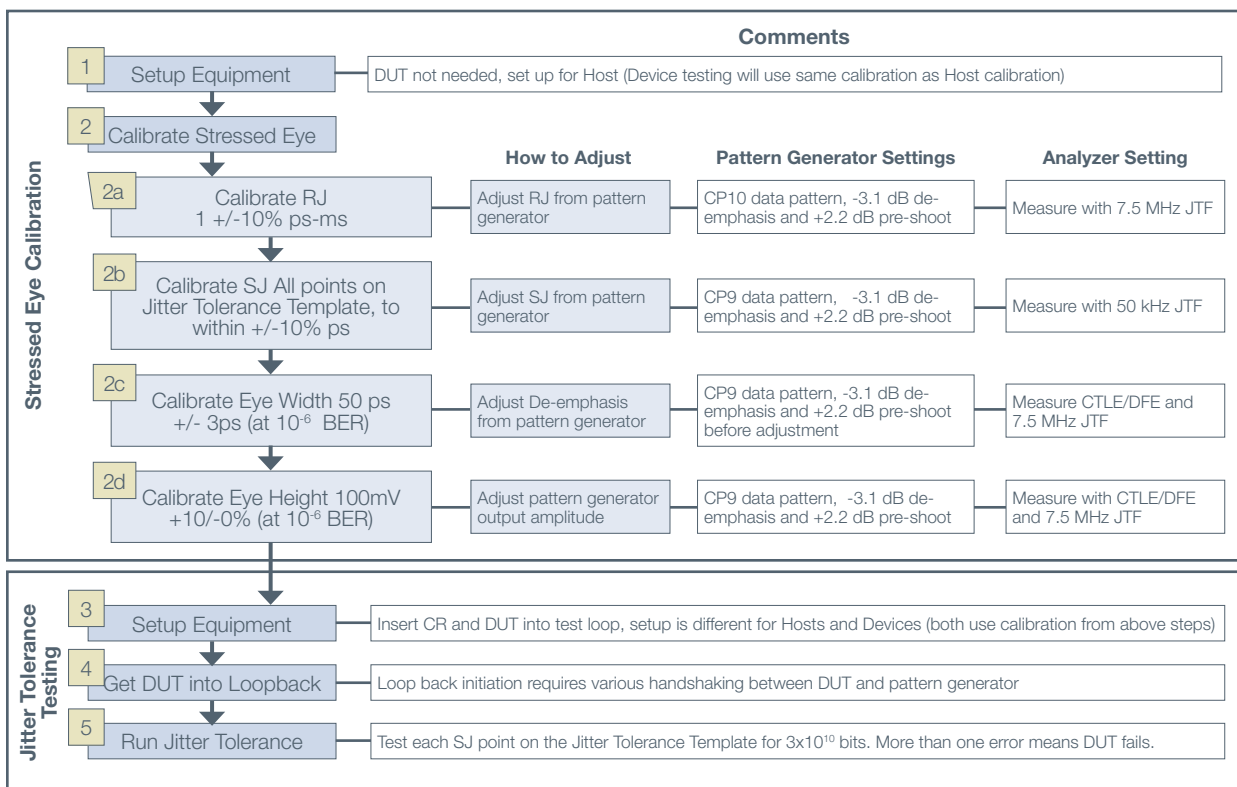


Figure 2. Steps 1 and 2 of Stressed Eye Calibration will be covered in Section 2.1. Steps 3-5 of Jitter Tolerance Testing will be covered in Section 2.2. All steps will be covered in the example in Section 3.

USB 3.1 Receiver Testing

Receiver testing for USB 3.1 is similar to other high speed serial bus receiver compliance testing, and is generally split up into two phases.

- **Stressed eye calibration** is the industry name for the procedure to create a worst case signal condition to test receivers. This worst case signal is usually impaired both horizontally by added jitter, and vertically, by setting the amplitude to the lowest a receiver would see when deployed. Stressed eye calibration must be performed when any of the test fixtures, cabling, or instrumentation have been changed.

- **Jitter tolerance** tests the receiver by using the calibrated stressed eye as input, and then applies additional sinusoidal jitter (SJ) of increasing frequency. This applied SJ exercises the clock recovery circuitry inside the receiver, so not only is the receiver being tested using worst case signal conditions, but its clock recovery is also explicitly tested. The magnitude and frequency of the applied SJ follows a template as prescribed by the standard. This jitter tolerance template covers the bandwidth of the clock recovery PLL; high amounts of applied SJ should be tolerated within the loop bandwidth since the clock recovery will track out this sinusoidal jitter, but only small amounts can be withstood beyond the loop bandwidth, since this jitter is not tracked out, and will affect the downstream receiver circuit.

Additionally, the long channel defined in USB 3.1 results in a closed eye at the receiver. A reference receiver model is used to open up the eye for Transmitter testing. With Receiver testing the receiver's equalizer, in addition to the clock recovery circuit, will be tested as signal conditioning is required to properly recover the data for BER testing.

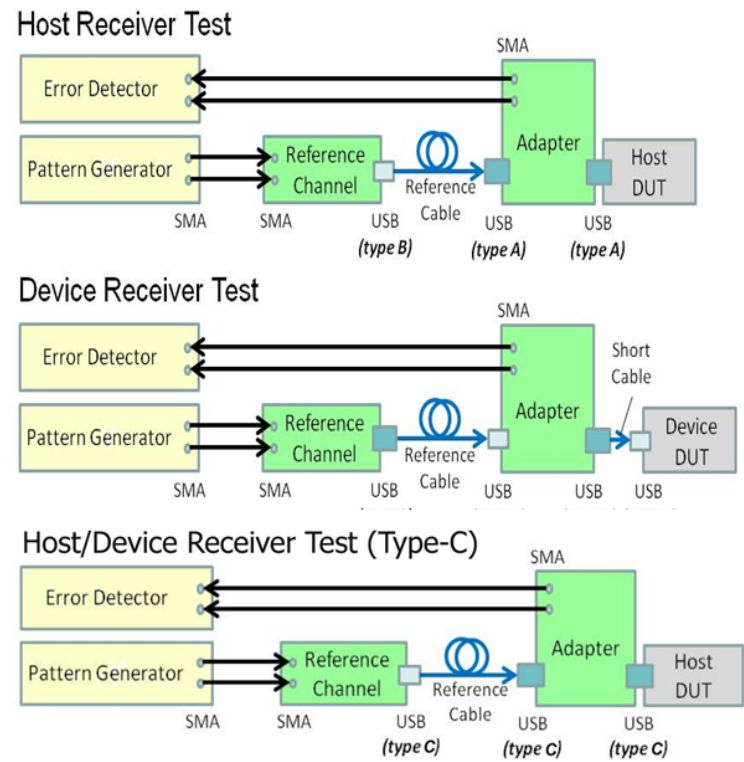


Figure 3. Setup for Stressed Eye Calibration for Hosts with the Type-A connector (top) Devices with the Type-B connector (middle), and Hosts or Devices with the Type-C connector.

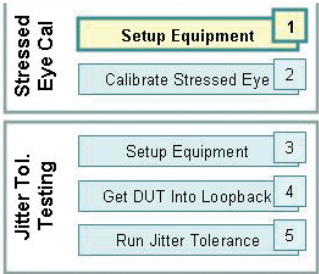
Stressed Eye Calibration

Stressed eye calibration involves first setting up the test equipment with compliant fixtures, cables, and channels, and then iteratively measuring and adjusting various types of applied stresses such as jitter. The calibration step is performed without the DUT, with compliant test fixtures and channels, and with specific data patterns generated by the test equipment.

Equipment Setup

The setup for stressed eye calibration is shown in Figure 3 for Hosts and Devices.

The DUT is not needed for stressed eye calibration, but Figure 3 shows where the DUT would be placed during testing. Instead, the signal



is looped back to the analyzer through the adapters and cabling. The goal is to calibrate the signal as close to the input of the DUT when it is placed in the test loop. Note that the polarity of the reference cable is reversed between the two, whereas for Host testing, the Standard A type connector is connected to the adapter of the Host DUT, but the Standard B type connector is connected to the adapter of the Device DUT. There are different test fixtures for Hosts and Devices, and several adapters may be necessary to loop the generated signal back to the measurement instrument, as will be shown in the example. Note, the setup using a Type-C connector is the same for both the Host and Device. The connection to the analyzer should be as high quality as possible.

The test instrumentation should be capable of performing two functions – pattern generation with the ability to add various types of stresses, and signal analysis such as jitter and eye measurements.

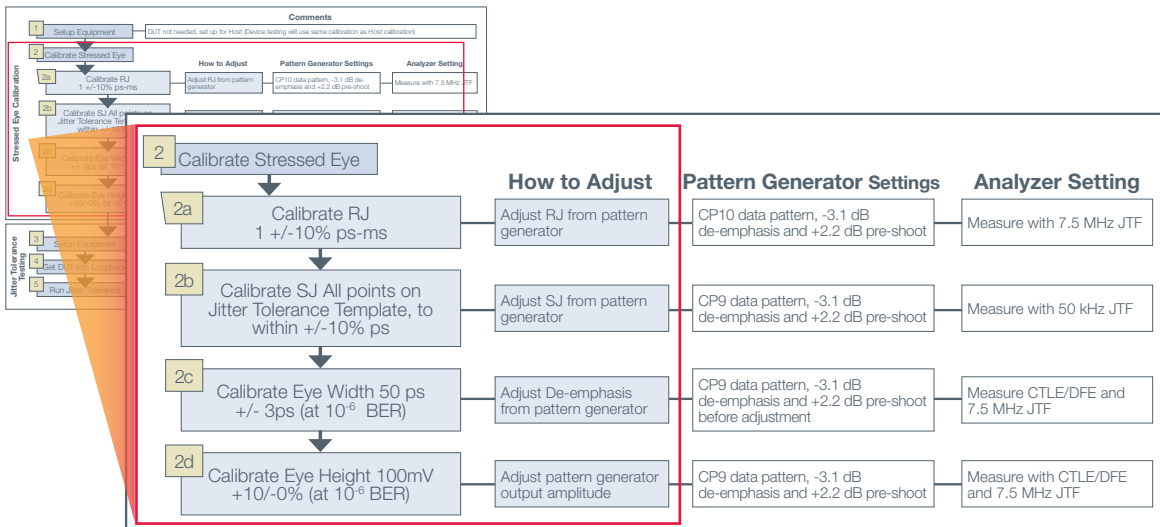
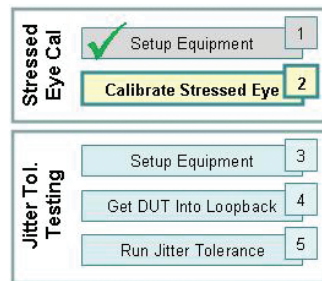


Figure 4. This figure shows the Stressed Eye Calibration (Step 2) of the overall flowchart in Figure 2.

How to Calibrate the Stressed Eye

The stressed eye recipe and how it can be achieved will be covered in this section. There are four impairment calibrations that must be made to calibrate the stressed eye, Random Jitter (RJ), Sinusoidal Jitter (SJ), eye width and eye height. Each of these requires particular settings on the pattern generator and analyzer, as listed in the flowchart in Figure 2. In this section, the stress components, the pattern generator settings, and the analyzer settings will be covered.

Stressed eye calibration must be performed once per set of cables, adapters, and instrumentation. Because they can use different sets of adapters and reference channels, Hosts and Devices will have different stressed eye calibrations. Once complete, the settings for the calibrated eye can be re-used and must be re-calibrated only if the equipment setup changes.



Stressed Eye Recipe Components

There are four “ingredients” in the stressed eye recipe, as shown in Figure 4. Each stress component should be calibrated in the order shown.

1. Random Jitter (RJ)

- **Definition:** RJ is unbounded jitter that is not correlated to the data pattern, which means that its measurement should be the same regardless of the data pattern used. Because it is unbounded, it grows with measurement depth; the deeper the measurement in terms of number of waveforms or BER measured, the larger the peak-peak RJ measurement becomes.
- **How to adjust:** To achieve the proper amount of RJ, the pattern generator must be able to adjust the amount of injected RJ.
- **How to measure:** Most analyzers (i.e. BERTs and oscilloscopes) provide automated RJ measurements.

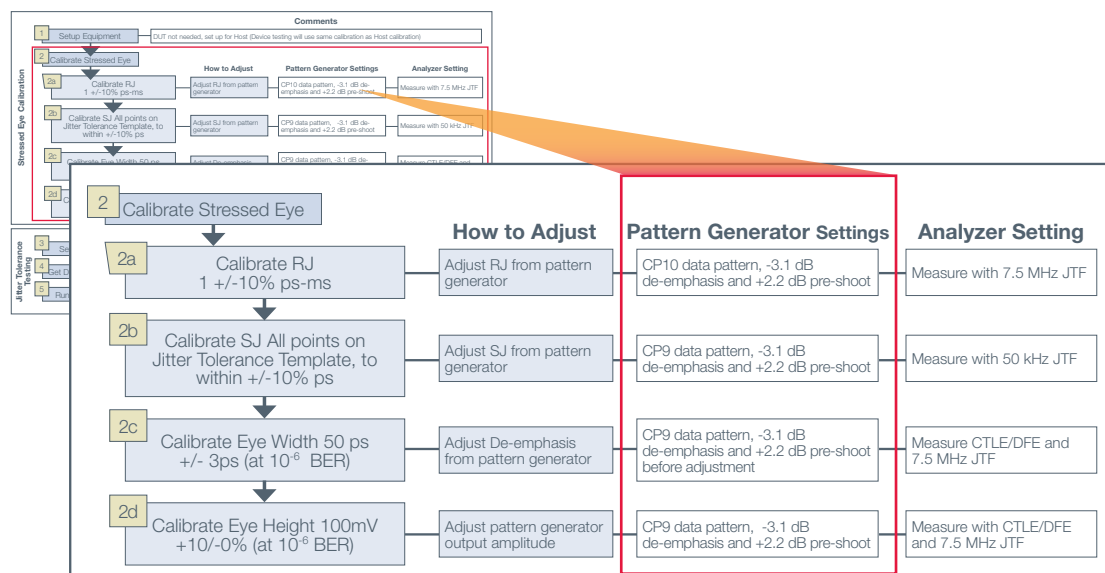
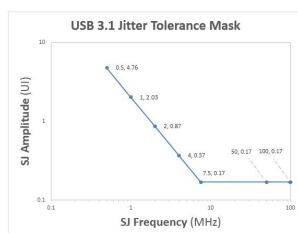


Figure 5. Pattern Generator Settings used for Stressed Eye Calibration, including specifications for data pattern, de-emphasis level, and spread spectrum clocking (SSC).

Sinusoidal Jitter (SJ)

- Definition:** SJ is bounded jitter that is periodic in nature, but usually not correlated to the data pattern (unless the SJ frequency just happens to be a multiple of the pattern repetition frequency), so like RJ, its measurement is the same regardless of data pattern. Unlike RJ, it does not grow with measurement depth due to its bounded nature.
- How to adjust:** Like RJ, the pattern generator must be able to adjust the amount of injected SJ to achieve the desired amount. The injected SJ must be of a particular frequency, with adjustable amplitude. All SJ frequencies and amplitudes in the USB 3.1 Jitter Tolerance Mask (above right) need to be calibrated.
- How to measure:** The USB 3.1 compliance test procedures specify that the amount of SJ should be measured by taking the difference in Total Jitter (TJ) between a signal with 0 amplitude of injected SJ, and the desired amount of injected SJ. TJ measurements can be found on most oscilloscopes.



- How to adjust:** The eye height is adjusted via the output amplitude of the pattern generator.
- How to measure:** Eye height can be measured on oscilloscopes, and should meet the 10⁶ waveforms requirement.

Eye Width

- Definition:** Eye width is the horizontal opening of the eye and is accompanied by a measurement depth, in this case, 10⁶ waveforms. The eye height is data pattern dependent because it is impacted by the amount of Data Dependent Jitter (DDJ) in the signal. The eye height specification is 50 ps +/-3 ps.
- How to adjust:** The eye width is adjusted via de-emphasis of the pattern generator.
- How to measure:** Eye width can be measured on oscilloscopes, and should meet the 10⁶ waveforms requirement.

Pattern Generator Settings

Now that we have covered “what” needs to be calibrated, we will discuss the additional requirements of the pattern generator for each step of the calibration, including:

1. The data pattern to be used.
2. The amount of de-emphasis and pre-shoot.
3. Whether or not spread spectrum clocking (SSC) should be enabled.

Eye Height

- Definition:** Eye height is the opening of the eye in the center of the unit interval and is accompanied by a measurement depth, in this case, 10⁶ waveforms. The eye height is data pattern dependent because it is impacted by the amount of Data Dependent Jitter (DDJ) in the signal.

Compliance Pattern	Value	Bit Sequence Description
CP0	D0.0 scrambled	A pseudo-random data pattern that is exactly the same as logical idle (refer to Chapter 7) but does not include SKP sequences.
CP1	D10.2	Nyquist frequency
CP2	D24.3	Nyquist frequency/2
CP3	K28.5	COM pattern
CP4	LFPS	The low frequency periodic signaling pattern
CP5	K28.7	With de-emphasis
CP6	K28.7	Without de-emphasis
CP7	50-250 1's and 0's	With de-emphasis. Repeating 50-250 1's and then 50-250 0's.
CP8	50-250 1's and 0's	Without de-emphasis. Repeating 50-250 1's and then 50-250 0's.
CP9		Pseudo-random data pattern (see section 6.4.4.1)
CP10	AAh	Nyquist pattern at 10Gb/s. This is not 128b132b encoded.
CP11	CCh	Nyquist/2 at 10Gb/s. This is not 128b132b encoded.
CP12	LFSR15	Uncoded LFSR15 for PHY level testing and fault isolation. This is not 128b132b encoded. The polynomial is $x^{15} + x^{14} + 1$
CP13	64 1's and 0's	With pre-shoot defined in section 6.7.5.2 (no de-emphasis). Repeating 64 1's and then 64 0's at 10Gb/s. This is not 128b132b encoded.
CP14	64 1's and 0's	With de-emphasis defined in section 6.7.5.2 (no pre-shoot). Repeating 64 1's and then 64 0's at 10Gb/s. This is not 128b132b encoded.
CP15	64 1's and 0's	With pre-shoot and de-emphasis defined in section 6.7.5.2. Repeating 64 1's and then 64 0's at 10Gb/s. This is not 128b132b encoded.
CP16	64 1's and 0's	No de-emphasis or pre-shoot. Repeating 64 1's and then 64 0's at 10Gb/s. This is not 128b132b encoded.

Table 1. USB 3.1 Gen1 and Gen2 Compliance Patterns (from table 6-13 of standard).

Data Pattern

There are two patterns, CP9 and CP10 listed in the stressed eye calibration recipe. For reference, all USB 3.1 compliance patterns are listed in Table 1.

- **CP9** is an 128b/132b encoded psuedo-random data pattern (the result of subjecting the 00h ddata symbol to scrambling and encoding in a USB 3.1 transmitter while including the SKP ordered set). After 128b/132b encoding, the 128-bit data block of repeated 00h is prepended with a data block header. This 132-bit packet is then scrambled using a Linear Feedback Shift Register (LFSR) with the following polynomial: $G(X) = X^{23} + X^{21} + X^{16} + X^8 + X^5 + X^2 + 1$. CP12 (see Table 1) is a pattern similar to the CP9 pattern in that it is scrambled but it is not 128b/132b encoded. This PRBS pattern is relatively easy to implement in a PHY design and is useful for debug.
- **CP10** is a clock pattern used for the RJ calibration. Many instruments implement a dual-Dirac method of random and deterministic jitter separation for the RJ measurement. Using a clock pattern circumvents one of the drawbacks of the dual-Dirac method, which is the tendency to report data dependent jitter (DDJ) as RJ, especially on long patterns. By using a clock pattern, DDJ as a result of Inter-symbol Interference (ISI) is eliminated from the jitter measurement, resulting in a more accurate RJ measurement. The CP11 pattern, which is an 1100 clock pattern, could also be used for RJ measurement.

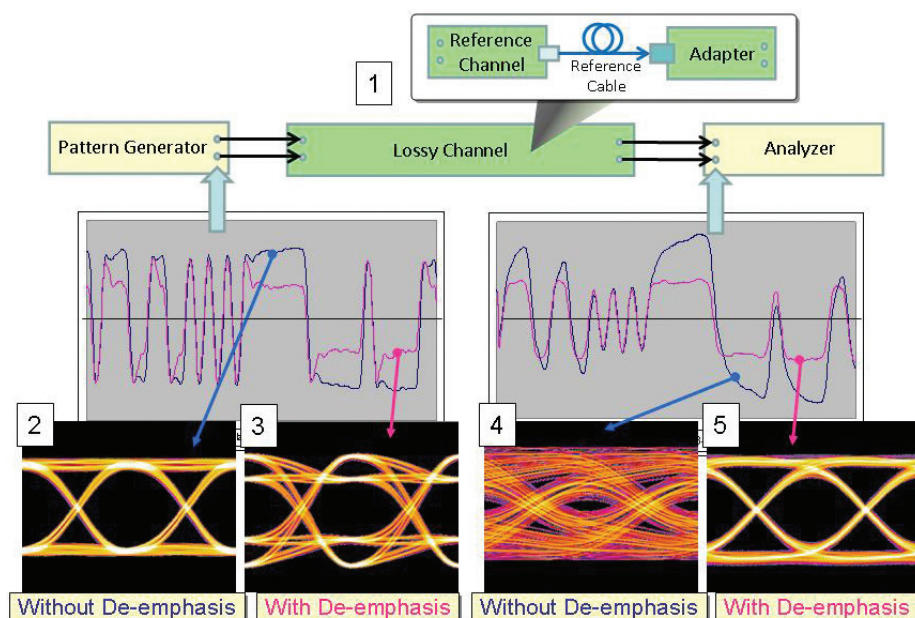


Figure 6. An example showing waveforms and eye diagrams demonstrating the effects of de-emphasis, using a PRBS-7 data pattern.

De-Emphasis

As shown in Figure 3 and replicated in Figure 6, there is a lossy channel (i.e. a USB 3.1 reference channel and cable) in between the pattern generator (transmitter) and the analyzer (receiver). This causes frequency dependent loss in the form of eye closure, both vertically and horizontally. To combat this loss, transmitter de-emphasis is used to boost the high frequency components of the signal so that the received eye is good enough for an operational link at a BER of 10^{-12} or better. De-emphasis is used for both gen1 and gen2 however gen2 uses a 3-tap reference equalization model including de-emphasis and pre-shoot.

In Figure 6:

1. A typical setup for measuring signals is shown, with a lossy channel in between the transmitter and receiver. The USB 3.1 reference channel, reference cable, and adapter are examples of components that constitute a lossy channel.
2. Without de-emphasis, all amplitudes are nominally the same.
3. With de-emphasis, transition bits have higher amplitude relative to non-transition bits, effectively boosting the high frequency components of the signal.
4. After passing through lossy channels and cables, the signal without de-emphasis suffers from Inter-Symbol Interference (ISI) and has more eye closure than the signal without de-emphasis.
5. The signal with de-emphasis is fully open.

As shown here, the amount of de-emphasis affects the amount of ISI and DDJ and therefore impacts the eye opening at the receiver.

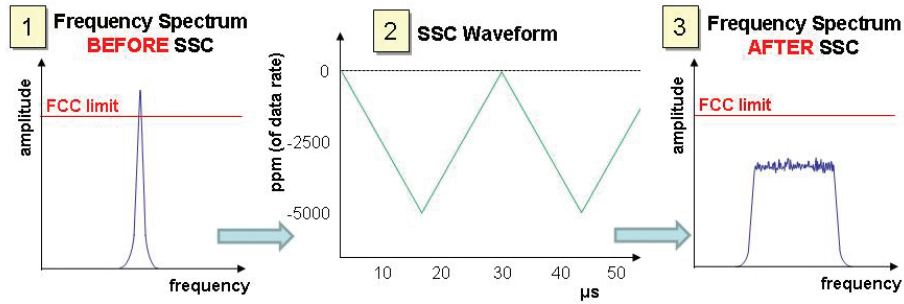


Figure 7. The effect of SSC on a frequency spectrum (single tone shown).

Spread Spectrum Clocking (SSC)

Spread spectrum clocking (SSC) is commonly used in synchronous digital systems (USB 3.1 included) to reduce electromagnetic interference (EMI). Shown in Figure 7:

1. Without SSC, the frequency spectrum of the digital stream would have a high magnitude sharp peak at the carrier frequency (i.e. 5 GHz) and its harmonics, possibly exceeding limits set by federal regulatory bodies such as the Federal Communications Commission (FCC) (in the United States).
2. To prevent this problem, SSC is used to spread out the energy of the frequency spectrum, keeping within the FCC limits. The carrier frequency is modulated, in this case by a triangle wave. The amount of frequency “spreading” for receiver testing is 5000 ppm, or 25 MHz, with the frequency modulation cycling at 33 kHz, or every 30 μ s, shown as one period of the triangle wave.
3. After SSC, the energy in the frequency spectrum is spread out, and no single frequency violates the FCC limits.

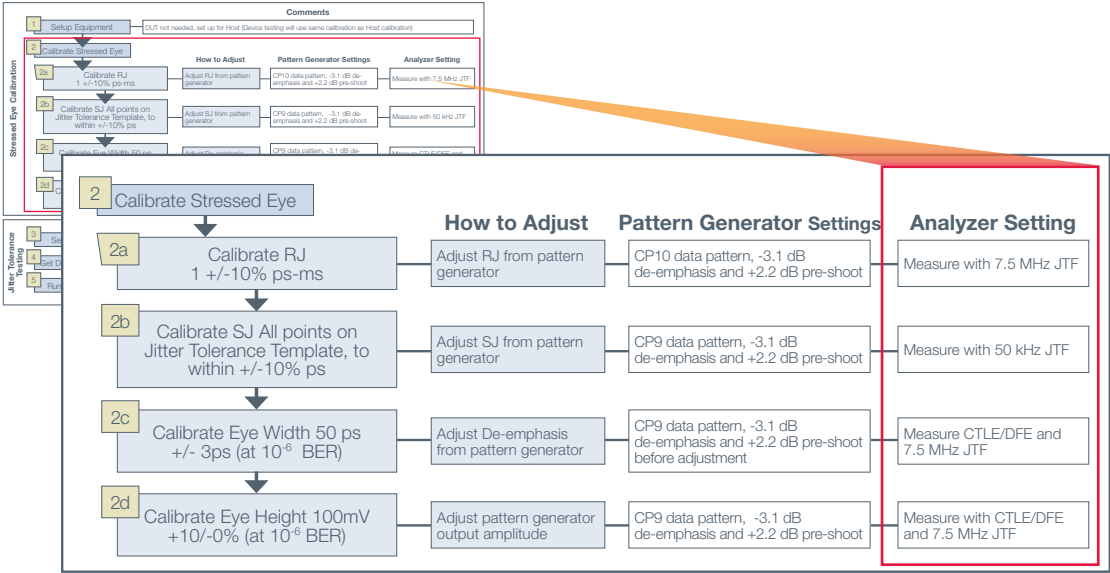


Figure 8. Analyzer Settings used for stressed eye calibration, including required use of the Continuous Time Linear Equalizer (CTLE), Decision feedback Equalizer (DFE) and Jitter Transfer Function (JTF).

Analyzer Settings

We have covered the stress recipe components, and the requirements of the pattern generator when calibrating the various stress components. This section covers the requirements of the analyzer, specifically the use of the Continuous Time Linear Equalizer, Decision Feedback Equalizer and Jitter Transfer Function when making jitter and eye opening measurements.

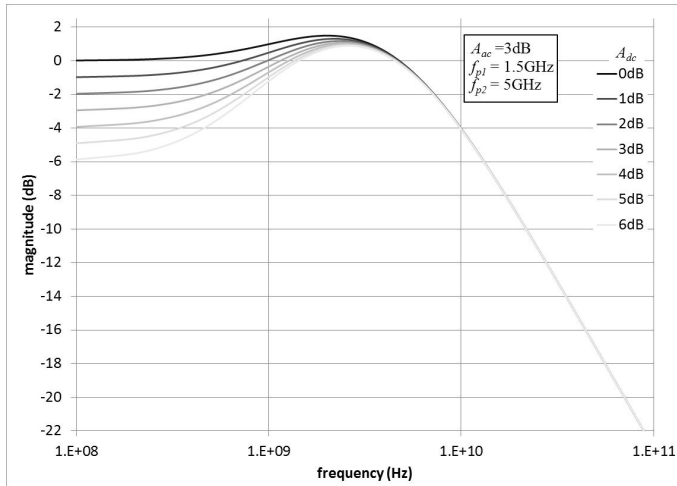


Figure 9. The CTLE function, from the USB 3.1 specification.

Continuous Time Linear Equalizer (CTLE) Function

In addition to transmitter de-emphasis and pre-shoot, receiver-side equalization is used to improve signals that have been impaired by ISI caused by frequency dependent loss from such elements as the reference channel and cabling. The concept is the same as for de-emphasis and pre-shoot – the high frequency components of the signal are boosted via signal processing methods.

Although receiver equalization circuitry in a Device or Host is implementation specific, the USB 3.1 standard specifies a Continuous Time Linear Equalizer (CTLE) to be used for compliance testing (Figure 9). This CTLE must be implemented by the reference receiver such as a BERT or oscilloscope prior to making compliance test measurements (both for transmitter testing, and in this case, receiver stressed eye calibration), often in the form of software emulation.

The use of CTLE emulation for jitter measurements mainly impacts jitter that is affected by signal processing methods, namely ISI. Jitter components that are not correlated to the data pattern such as RJ and SJ are not impacted by CTLE emulation, although the use of the CTLE is required for both of these measurements according to the CTS. On the other hand, eye height is directly impacted, since ISI contributes to its measurement.

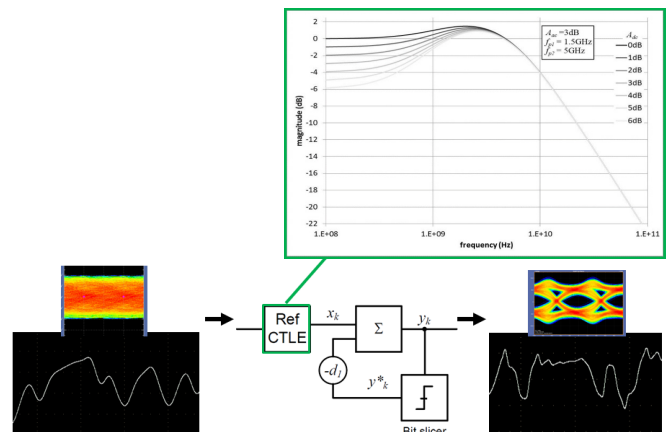


Figure 10. Waveform being processed with combined CTLE and DFE functions.

Decision Feedback Equalizer (DFE) Function

Figure 10 illustrates the reference receiver model as outlined in the USB 3.1 specification. In addition to the CTLE function, a 1-tap DFE is included. The combination of CTLE and DFE provides even more gain than previously used for USB 3.0. This extra "boost" is critical to ensure there is sufficient margin for proper data recovery. It was not uncommon for many 5 Gb/s designs to employ DFE and now DFE will be an even more important consideration in the receiver design.

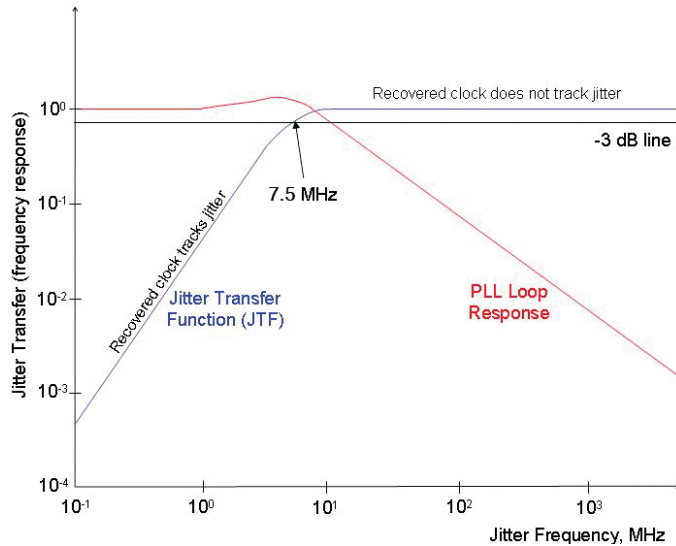


Figure 10. The JTF of the Golden PLL, adapted from figure 6-14 of the USB 3.1 standard.

Jitter Transfer Function (JTF)

Jitter calibration measurements must be made using a clock recovery Golden PLL with a compliant Jitter Transfer Function (JTF), as shown in Figure 10 (blue trace). The JTF dictates how much jitter is transferred from the incoming signal to the downstream analyzer. In this case, the -3 dB cutoff is 7.5 MHz.

- At lower SJ frequencies (along the sloped part of the JTF, and where the PLL Loop Response is flat), the recovered clock tracks the jitter on the data signal, and thus, the jitter in the data **relative** to the clock is attenuated according to the JTF.
- At higher SJ frequencies (where the JTF flattens out and the PLL Loop Response slopes downward), the SJ present in the signal is transferred to the downstream analyzer because the clock is a “clean” clock and does not track the jitter on the incoming data signal.

The use of a compliant JTF is specified for all measurements except for SJ during stressed eye calibration.

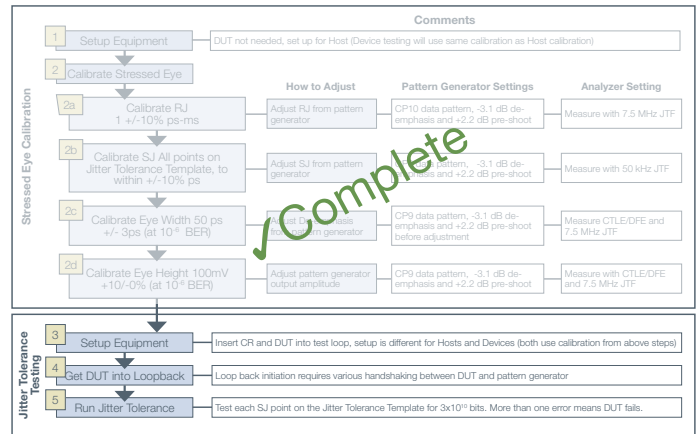


Figure 11. After Stressed Eye Calibration is complete, Jitter Tolerance tests the receiver using worst case signal conditions.

Jitter Tolerance Testing

Once the stressed eye has been calibrated, testing of the receiver can commence. As mentioned in the Introduction, USB 3.1 requires BER testing, unlike its 2.0 predecessor. Bit error ratio (BER) testing in the form of a Jitter Tolerance test is the **only** test required for receiver testing.

The Jitter Tolerance test exercises the receiver using worst case input signal conditions (the stressed eye calibrated in the previous section). On top of the stressed eye, a series of SJ frequencies and amplitudes covering the frequency range surrounding the -3 dB cutoff frequency of the JTF are injected into the test signal while the error detector monitors the receiver for mistakes or bit errors, and calculates the BER. Jitter Tolerance will be covered in detail after a review of the equipment setup and receiver loopback mode, a state in which the DUT's transmitter re-sends the bits it receives.

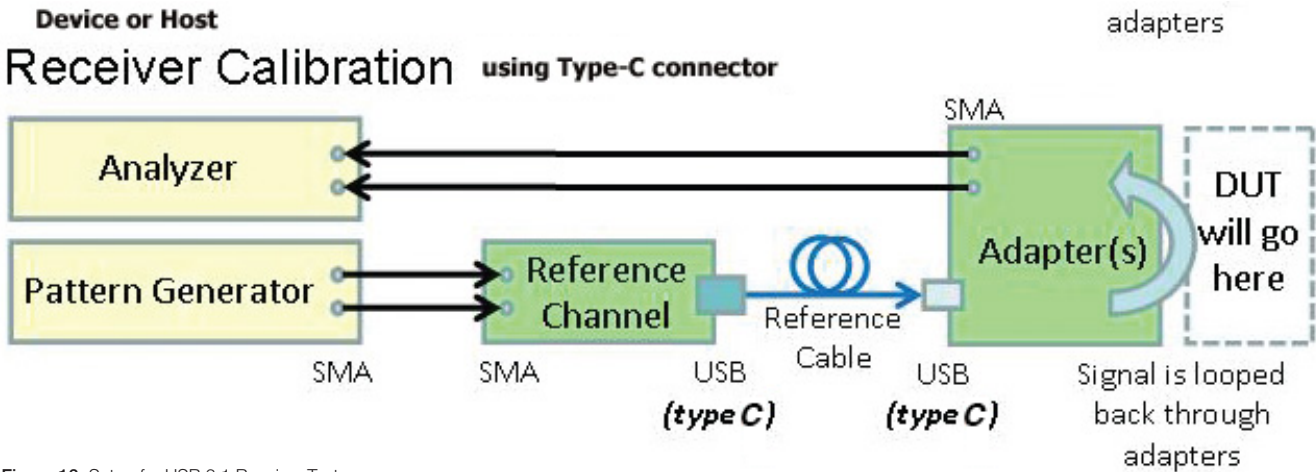
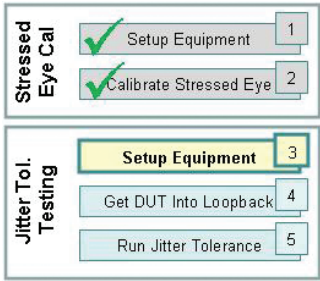


Figure 12. Setup for USB 3.1 Receiver Test.

Equipment Setup

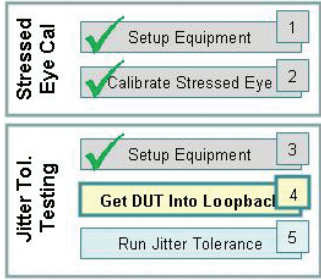
The setup of equipment for receiver testing is similar to that of stressed eye calibration, with the DUT now inserted into the test loop, as shown in Figure 12. The Host or Device DUT is connected to the adapter as displayed. Instead of the signal being routed straight back to the analyzer, the test signal from the pattern generator passes through the DUT's receiver, is "looped back" through its transmitter (hence, the term "loopback"), back through the adapter, and to the error detector. The connection to the error detector should be as high quality as possible.



For Jitter Tolerance testing, the test instrumentation must be able to perform error detection and keep track of the BER. Instruments such as BERTs and oscilloscopes are capable of this function.

Receiver Loopback

Loopback is one of the USB 3.1 link states in which the device sends the bits it receives back through its transmitter. If the receiver makes a mistake, the bit in error will be sent back through the transmitter and to the downstream analyzer for detection. To initiate loopback, a series of handshakes¹ must be performed between the pattern generator and DUT.



¹ A detailed description of loopback initiation is beyond the scope of this paper. See the USB 3.1 Specification, which includes link state diagrams and details on the bit sequences required for loopback initiation handshaking.

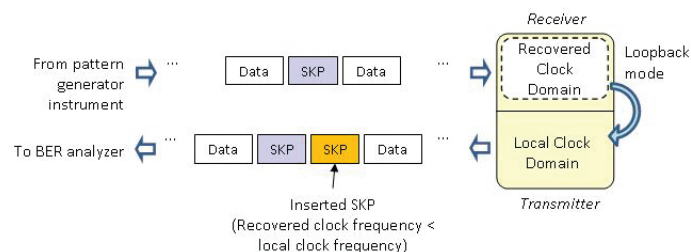


Figure 13. Example showing an inserted SKP when DUT is in loopback mode.

Asynchronous BER Testing

USB 3.1 uses 128b/132b encoding, and as is common in encoded systems, the receiver and transmitter may be on slightly different clock frequencies – the recovered clock of the received data stream may not be exactly equal to the clock frequency of the transmitter. When in loopback mode for receiver testing, this mismatch in frequencies poses a problem for the DUT; bits may be coming in faster than they can be sent back out, or vice versa. To compensate for the frequency mismatch, clock compensation symbols are used and either deleted or inserted into the data stream as it is passed from the receiver back through the transmitter. For example, symbols are added if the recovered clock frequency is less than (slower than) the transmitter clock frequency (as shown in Figure 13), and vice versa. USB 3.1 uses SKP symbols for clock compensation. The USB 3.1 gen2 SKP Ordered Set consists of variable length unscrambled symbols of CCh followed by a SKPEND symbol (33h), then 3 symbols that indicate LTSSM status.

The test equipment must be able to handle this non-deterministic number of clock compensation symbols in the incoming data stream, commonly termed **asynchronous BER testing**.

USB 3.1 Jitter Tolerance

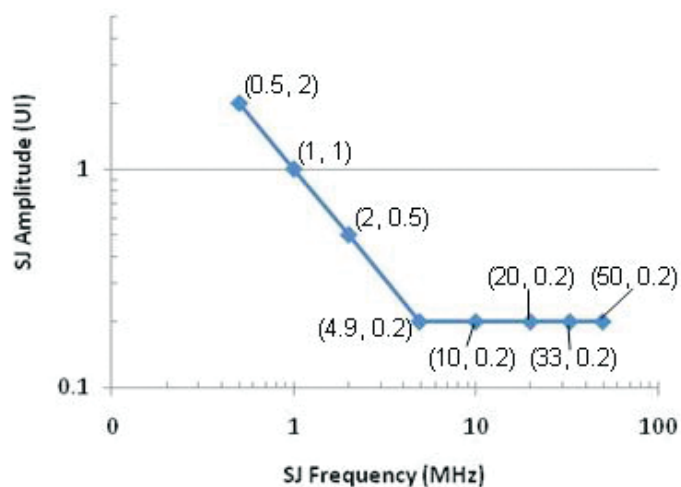


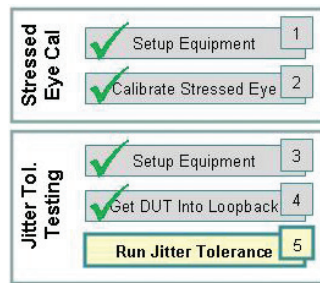
Figure 14. The USB 3.1 Jitter Tolerance Mask.

Stepping Through the Tolerance Mask

Once the stressed eye has been calibrated, the DUT and equipment have been set up for testing, and the DUT has been put into loopback mode, the DUT's receiver is ready to be tested.

Jitter tolerance testing applies varying levels of SJ amplitude at specific SJ frequencies to test the receiver. As shown in Figure 14, the lower SJ frequencies tend to have higher SJ amplitude, as these frequencies are well within the loop bandwidth of the receiver CR and will thus get tracked out. As the SJ frequency approaches the loop bandwidth and surpasses it, the SJ amplitude levels out at an amplitude less than 1 UI. Jitter above the loop bandwidth of the receiver will not get tracked out, and will be passed down to the receiver's decision circuit.

The USB 3.1 CTS specifies that each SJ point on the tolerance curve be tested using 3×10^{10} bits. The DUT fails if more than one error is detected at any SJ test point.



Summary

USB 3.1 promises to become a dominant computer peripheral bus standard, just as USB 2.0 has been for some time. Its signaling speed of 10 Gb/s is more than a magnitude faster than USB 2.0, and thus, signal integrity challenges cause a higher bar to be set for testing SuperSpeedPlus USB devices over the previous generation. For receiver testing, the test regimen is wholly based on Jitter Tolerance using a calibrated stressed eye input.

In this application note, all aspects of USB 3.1 receiver testing have been covered, including stressed eye calibration and jitter tolerance testing with measured device margin. An MOI demonstrating receiver testing using the BERTScope Family of Products is available on www.tektronix.com/usb. In this MOI, you'll see how the USB 3.1 Automation Software coordinates the operation of the following equipment to lead you through the receiver set-up and test process, including loopback initiation with a simple button click.

- BERTScope
- USB Switch
- De-emphasis Processor
- Clock Recovery

The BERTScope not only provides a straightforward solution for compliance testing, but also has the flexibility to troubleshoot difficult engineering problems if compliance tests fail.

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