USB 3.1 ENGINEERING CHANGE NOTICE

Title: USB 3.1 CTLE
Applied to: USB_3_1r1.0_07_31_2013

Brief description of the functional changes:

1. Change to the reference CTLE transfer function for Gen 2 operation to add 3dB of amplification.
2. Define a single, normative transmitter equalization requirement for Gen 2 operation, along with compliance patterns (CP13, CP14, CP15) to allow measurement of the equalization coefficients.
3. Definition of the LFSR15 polynomial for CP12 in Table 6-13. We overlooked defining the polynomial.

Benefits as a result of the changes:

1. Allows SuperSpeed Gen 2 systems to support an additional 3dB of loss (10dB host/6dB cable assembly/7dB device) in order to minimize the need for re-timers.
2. Standardize the LFSR15 polynomial that is used and clarification on rate.

An assessment of the impact to the existing revision and systems that currently conform to the USB specification:

No existing systems exist.

An analysis of the hardware implications:

1. Will allow host system designs for Gen 2 operation to have up to 10dB of loss. Design impact is that Gen 2 transmitters must meet a normative specification, and Gen 2 receivers are expected to have at least 3dB of peak gain (per the reference CTLE transfer function). Both are small impact to designs.
2. Using a consistent polynomial assures that the LFSR15 pattern can be decoded if so desired.

An analysis of the software implications:

No software implications.

An analysis of the compliance testing implications:

The ECN results in changes to the Gen 2 reference CTLE that is used for transmitter compliance testing and receiver testing calibration, and change to the amount of transmitter equalization used in receiver compliance testing. The change will also require redesign of the load board for compliance testing of devices.

Actual Change

(a). Section 6.4.4, table 6-13, page 6-21

From Text:

In the table, patterns CP0 through CP8 are transmitted at Gen 1 rate, while CP9 through CP12 are transmitted at Gen 2 rate.

Table 6-13. Compliance Pattern Sequences

Compliance Pattern	Value	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/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	With 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.

Note: Unless otherwise noted, scrambling is disabled for compliance patterns.

To Text:

In the table, patterns CP0 through CP8 are transmitted at Gen 1 rate, while CP9 through CP16 are transmitted at Gen 2 rate.

Table 6-13. Compliance Pattern Sequences

Compliance Pattern	Value	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
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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	~~With~~ ~~w~~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.

Note: Unless otherwise noted, scrambling is disabled for compliance patterns.

(b). Section 6.7.1, Table 6-17, page 6-30

From Text:

6.7.1 Transmitter Electrical Parameters

Peak (p) and peak-peak (p-p) are defined in Section 6.6.2.

Table 6-17. Transmitter Normative Electrical Parameters

Symbol	Parameter	Gen 1 (5.0 GT/s)	Gen 2 (10 GT/s)	Units	Comments
UI	Unit Interval	199.94 (min) 200.06 (max)	99.97 (min) 100.03 (max)	ps	The specified UI is equivalent to a tolerance of ±300 ppm for each device. Period does not account for SSC induced variations.
$V_{TX-DIFF-PP}$	Differential p-p Tx voltage swing	0.8 (min) 1.2 (max)	0.8 (min) 1.2 (max)	V	Nominal is 1 V p-p
$V_{TX-DIFF-PP-LOW}$	Low-Power Differential p-p Tx voltage swing	0.4 (min) 1.2 (max)	0.4 (min) 1.2 (max)	V	Refer to Section 6.7.2. There is no de-emphasis requirement in this mode. De-emphasis is implementation specific for this mode.
$V_{TX-DE-RATIO}$	Tx de-emphasis	3.0 (min) 4.0 (max)	Not applicable	dB	Nominal is 3.5 dB for Gen 1 operation. Gen 2 transmitter equalization recommendations are described in section 6.7.5.2.
$R_{TX-DIFF-DC}$	DC differential impedance	72 (min) 120 (max)	72 (min) 120 (max)	Ω	
$V_{TX-RCV-DETECT}$	The amount of voltage change allowed during Receiver Detection	0.6 (max)	0.6 (max)	V	Detect voltage transition should be an increase in voltage on the pin looking at the detect signal to avoid a high impedance requirement when an "off" receiver's input goes below ground.
$C_{AC-COUPLING}$	AC Coupling Capacitor	75 (min) 200 (max)	75 (min) 265 (max)	nF	All Transmitters shall be AC coupled. The AC coupling is required either within the media or within the transmitting component itself.
$t_{CDR\_SLEW\_MAX}$	Maximum slew rate	10	Not applicable	ms/s	See the jitter white paper for details on this measurement. This is a df/ft specification; refer to Section 6.5.4 for details.
SSC_{dfdt}	SSC df/dt	Not applicable	1250 (max)	ppm/µs	See note 1.

Notes:

1. Measured over a 0.5µs interval using CP10. The measurements shall be low pass filtered using a filter with 3 dB cutoff frequency that is 60 times the modulation rate. The filter stopband rejection shall be greater or equal to a second order low-pass of 20 dB per decade. Evaluation of the maximum df/dt is achieved by inspection of the low-pass filtered waveform.

To Text:

6.7.1 Transmitter Electrical Parameters

Peak (p) and peak-peak (p-p) are defined in Section 6.6.2.

Table 6-17. Transmitter Normative Electrical Parameters

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UI	Unit Interval	199.94 (min) 200.06 (max)	99.97 (min) 100.03 (max)	ps	The specified UI is equivalent to a tolerance of ±300 ppm for each device. Period does not account for SSC induced variations.
$V_{TX-DIFF-PP}$	Differential p-p Tx voltage swing	0.8 (min) 1.2 (max)	0.8 (min) 1.2 (max)	V	Nominal is 1 V p-p
$V_{TX-DIFF-PP-LOW}$	Low-Power Differential p-p Tx voltage swing	0.4 (min) 1.2 (max)	0.4 (min) 1.2 (max)	V	Refer to Section 6.7.2. There is no de-emphasis requirement in this mode. De-emphasis is implementation specific for this mode.
$V_{TX-DE-RATIO}$	Tx de-emphasis	3.0 (min) 4.0 (max)	See section 6.7.5.2.	dB	Nominal is 3.5 dB for Gen 1 operation. Gen 2 transmitter equalization ~~recommendations~~ requirements are described in section 6.7.5.2.
$R_{TX-DIFF-DC}$	DC differential impedance	72 (min) 120 (max)	72 (min) 120 (max)	Ω	
$V_{TX-RCV-DETECT}$	The amount of voltage change allowed during Receiver Detection	0.6 (max)	0.6 (max)	V	Detect voltage transition should be an increase in voltage on the pin looking at the detect signal to avoid a high impedance requirement when an “off” receiver’s input goes below ground.
$C_{AC-COUPLING}$	AC Coupling Capacitor	75 (min) 200 (max)	75 (min) 265 (max)	nF	All Transmitters shall be AC coupled. The AC coupling is required either within the media or within the transmitting component itself.
$t_{CDR\_SLEW\_MAX}$	Maximum slew rate	10	Not applicable	ms/s	See the jitter white paper for details on this measurement. This is a df/ft specification; refer to Section6.5.4 for details.
SSC_{dfdt}	SSC df/dt	Not applicable	1250 (max)	ppm/µs	See note 1.

Notes:

1. Measured over a 0.5µs interval using CP10. The measurements shall be low pass filtered using a filter with 3 dB cutoff frequency that is 60 times the modulation rate. The filter stopband rejection shall be greater or equal to a second order low-pass of 20 dB per decade. Evaluation of the maximum df/dt is achieved by inspection of the low-pass filtered waveform.

(c). Section 6.7.5, page 6-33

From Text:

6.7.5 Informative Transmitter De-emphasis

6.7.5.1 Gen 1 (5GT/s)

The channel budgets and eye diagrams were derived using a $V_{TX\text{-}DE\text{-}RATIO}$ of transmit de-emphasis for both the Host and the Device reference channels. An example differential peak-to-peak de-emphasis waveform is shown in Figure 6-20.

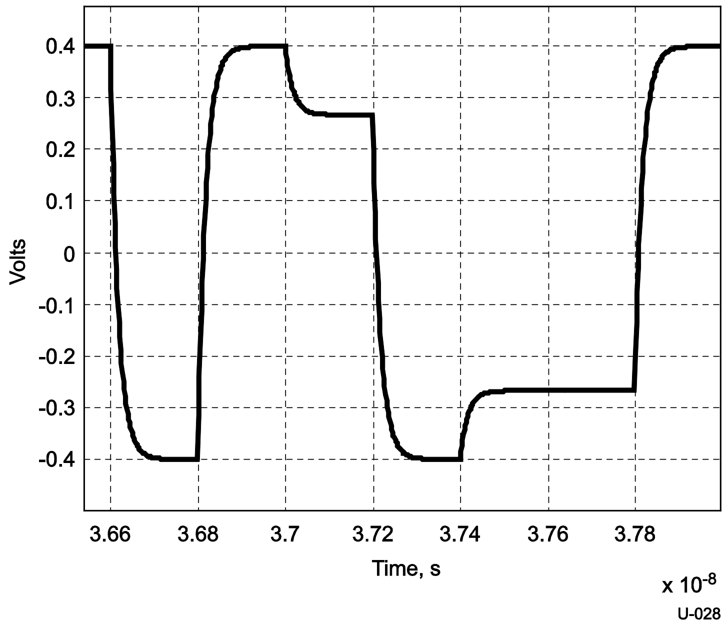


Figure 6-20. De-Emphasis Waveform

6.7.5.2 Gen 2 (10GT/s)

Gen 2 transmitters employ a 3-tap FIR-based equalizer, the structure of which is shown in Figure 6-21. An example waveform from the 3-tap equalizer is shown in Figure 6-22. In the figure, the pre-cursor (Vc) is referred to as pre-shoot, while the post-cursor (Vb) is referred to as de-emphasis. This convention allows pre-shoot and de-emphasis to be defined independently of one another. The maximum swing, Vd, is also shown to illustrate that, when both C+1 and C-1 are nonzero, the swing of Va does not reach the maximum as defined by Vd. Figure 6-22 is shown as an example of TxEQ and is not intended to represent the signal as it would appear for measurement purposes.

Table 6-20 provides recommended (informative) tap coefficient values (C_{-1} and C_1) along with the corresponding pre-shoot, de-emphasis and output amplitudes. The host/device loss referred to in the table refers to the differential insertion loss in the conductor path from the silicon die pad to the connector, and includes parasitic I/O capacitance, the chip package (routing, vias and I/O pins), and printed circuit board (routing and vias).

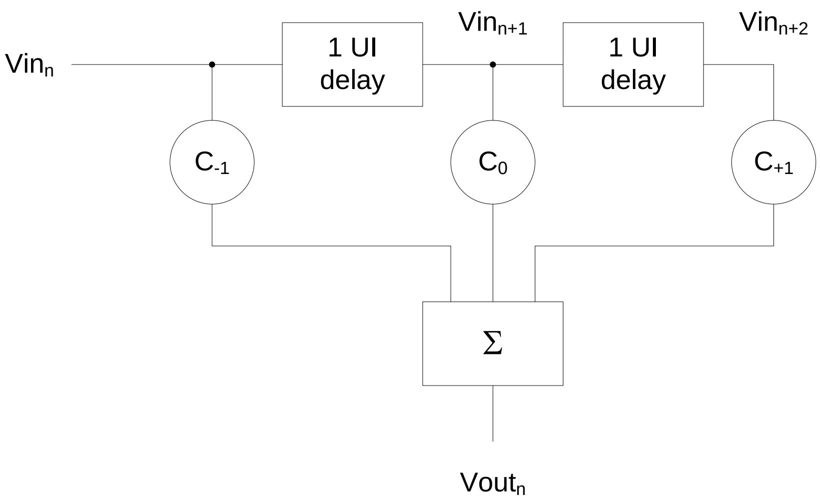
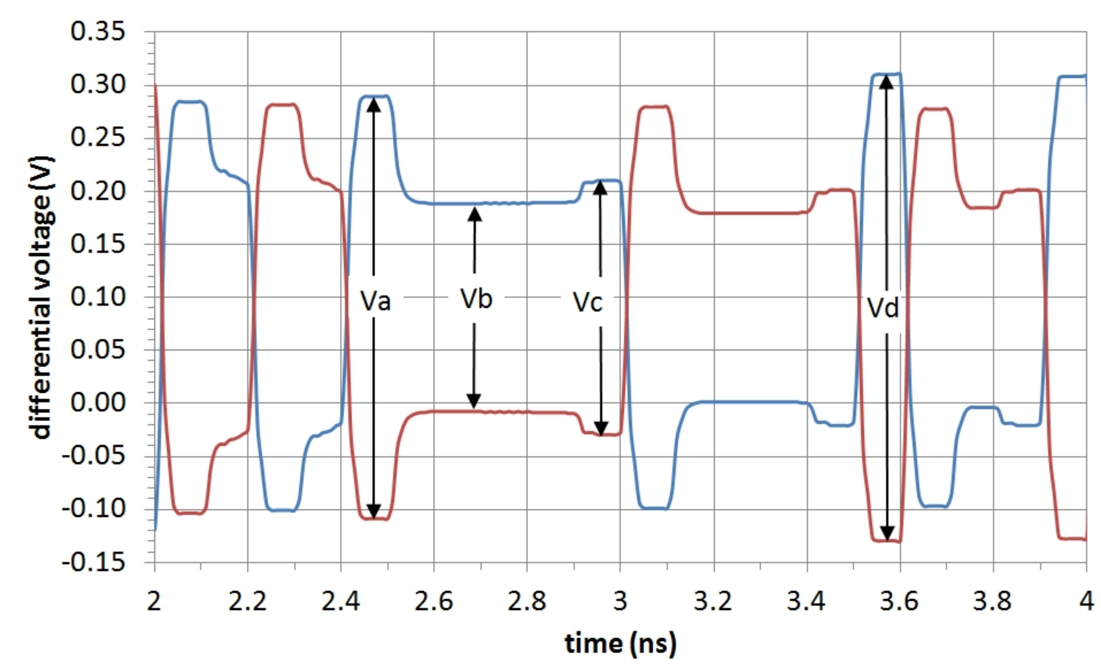


Figure 6-21. 3-tap Transmit Equalizer Structure



Preshoot = 20log(Vc/Vb)
De-emphasis = 20log(Vb/Va)

Figure 6-22. Example Output Waveform for 3-tap Transmit Equalizer

Table 6-20. Informative Gen 2 Transmitter Equalization Settings

Host/Device Loss @ 5GHz (dB)	**<3.5**	**≥3.5**
C_{-1}	0.000	-0.100
C_1	-0.125	-0.125
Preshoot (dB)	0.0	2.7
De-emphasis (dB)	-2.5	-3.3
Va/Vd	1.000	0.800
Vb/Vd	0.750	0.550
Vc/Vd	0.750	0.750

To Text:

6.7.5 ~~Informative~~ Transmitter De-emphasis

6.7.5.1 Gen 1 (5GT/s)

The channel budgets and eye diagrams were derived using a $V_{TX\text{-}DE\text{-}RATIO}$ of transmit de-emphasis for both the Host and the Device reference channels. An example differential peak-to-peak de-emphasis waveform is shown in Figure 6-20.

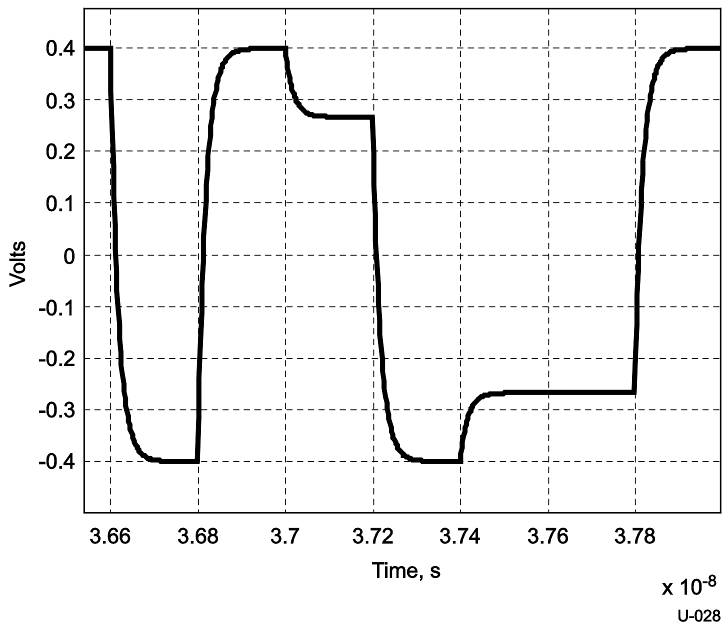


Figure 6-20. De-Emphasis Waveform

6.7.5.2 Gen 2 (10GT/s)

Gen 2 transmitters employ a 3-tap FIR-based equalizer, the structure of which is shown in Figure 6-21. An example waveform from the 3-tap equalizer is shown in Figure 6-22. In the figure, the pre-cursor (Vc) is referred to as pre-shoot, while the post-cursor (Vb) is referred to as de-emphasis. This convention allows pre-shoot and de-emphasis to be defined independently of one another. The maximum swing, Vd, is also shown to illustrate that, when both C_{+1} and C_{-1} are nonzero, the swing of Va does not reach the maximum as defined by Vd. Figure 6-22 is shown as an example of TxEQ and is not intended to represent the signal as it would appear for measurement purposes.

Table 6-20 provides the ~~recommended (informative)~~ normative pre-shoot and de-emphasis ~~tap coefficient~~ values ~~(C_{-1} and C_1)~~ along with the corresponding tap coefficient values (C_{-1} and C_1) ~~pre-shoot, de-emphasis~~ and output amplitudes. ~~The host/device loss referred to in the table refers to the differential insertion loss in the conductor path from the silicon die pad to the connector, and includes parasitic I/O capacitance, the chip package (routing, vias and I/O pins), and printed circuit board (routing and vias).~~

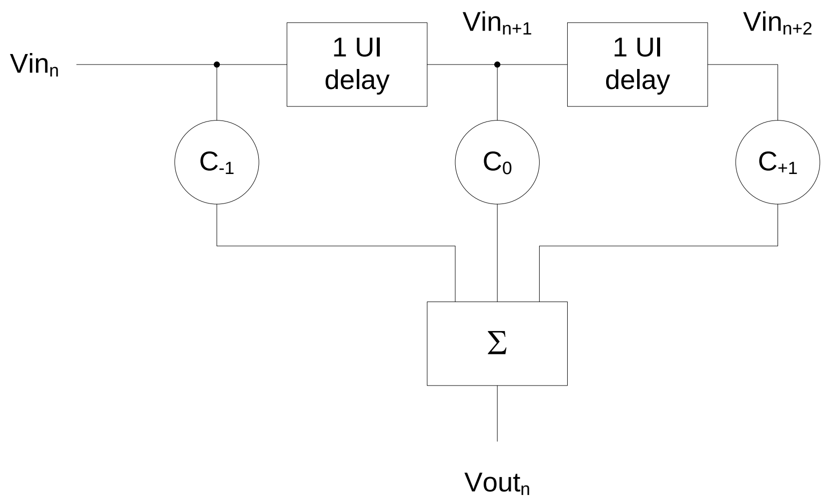
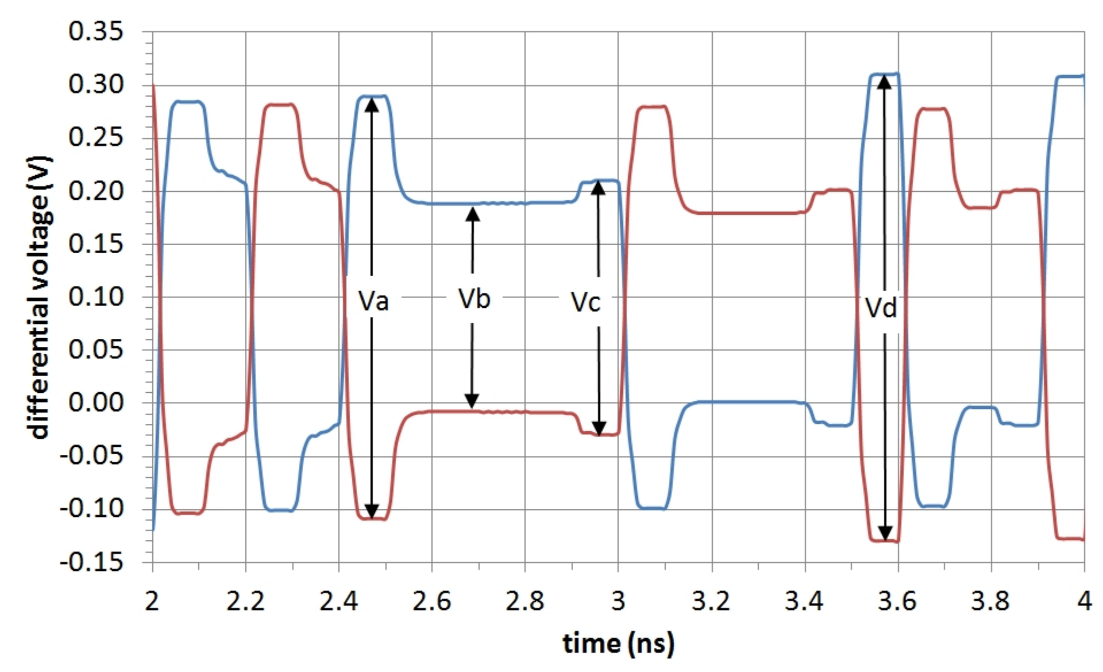


Figure 6-21. 3-tap Transmit Equalizer Structure



Preshoot = 20log(Vc/Vb)
De-emphasis = 20log(Vb/Va)

Figure 6-22. Example Output Waveform for 3-tap Transmit Equalizer

Table 6-20. ~~Informative~~ Gen 2 Transmitter Equalization Settings

Parameter	Value	Comments
Preshoot (dB)	2.2±1.0	Normative requirement
De-emphasis (dB)	-3.1±1.0	Normative requirement
C_{-1}	-0.083	Informative – for reference only
C_1	-0.125	Informative – for reference only
Nominal Boost (dB)	4.7	Informative – for reference only
Va/Vd	0.834	Informative – for reference only
Vb/Vd	0.584	Informative – for reference only
Vc/Vd	0.750	Informative – for reference only

Measurement of the preshoot and de-emphasis is done using CP13, CP14 and CP15. Va, Vc and Vb are obtained using CP13, CP14 and CP15 as shown in Figure 6-23. Preshoot and de-emphasis are calculated using equations (10) and (11).

$$(10) \qquad preshoot = 20\log_{10}\left(V_{CP14}/V_{CP15}\right) = 20\log_{10}\left(\frac{-C_{-1}+C_0+C_1}{C_{-1}+C_0+C_1}\right)$$

$$(11) \qquad deemphasis = 20\log_{10}\left(V_{CP15}/V_{CP13}\right) = 20\log_{10}\left(\frac{C_{-1}+C_0+C_1}{C_{-1}+C_0-C_1}\right)$$

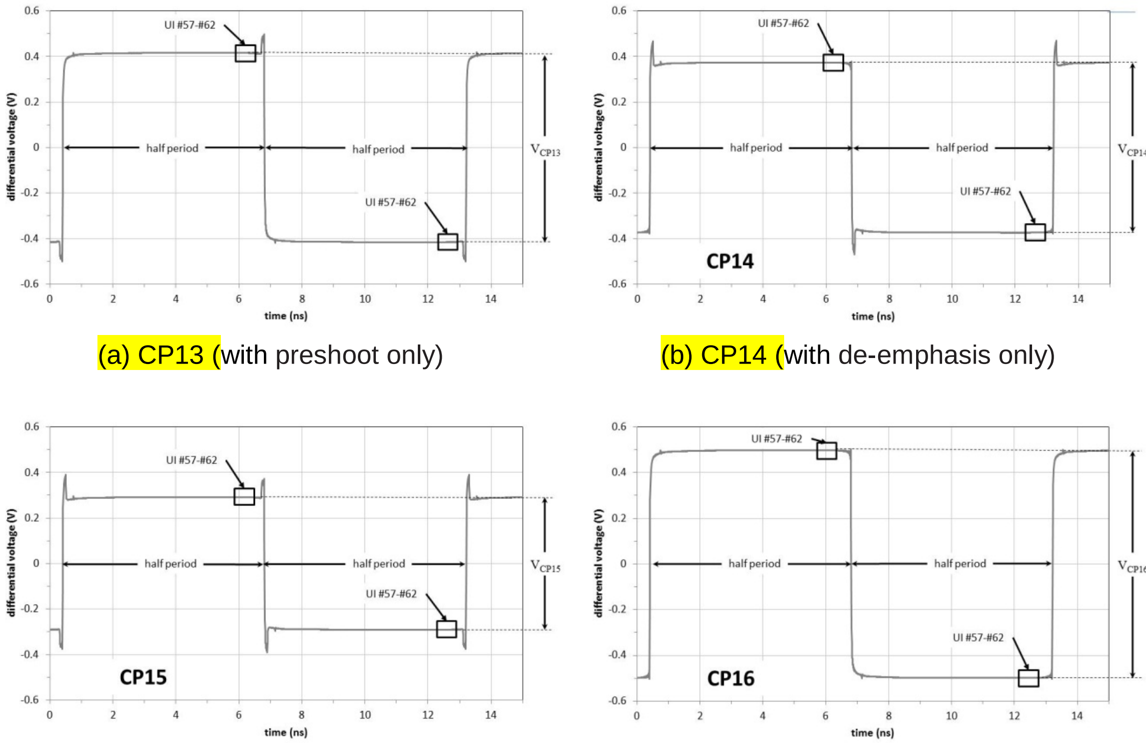
A transmitter must satisfy equation (12) during transmission of compliance patterns and during normal operation.

$$(12) \qquad |C_{-1}|+|C_0|+|C_1|=1$$

Satisfying equations (10) and (12) means that during transmission of the CP13 pattern, the transmitter moves the transistor legs for the de-emphasis tap (C_1) into the cursor tap (C_0). Similarly, during transmission of CP14, the transmitter moves the transistor legs for the preshoot tap (C_{-1}) into the cursor tap (C_0).

During measurement, ISI and switching effects are minimized by restricting the portion of the curve over which voltage is measured to the last few UI of each half cycle, as illustrated in the Figure 6-23. High frequency noise is mitigated by averaging over multiple readings until the peak-to-peak noise over the area of interest is less than 2% of the magnitude of the swing.

In addition, a transmitter's output voltage swing with no equalization is obtained by measuring the peak-to-peak voltage using the CP16 compliance pattern as shown in Figure 6-22.



(a) CP13 (with preshoot only)

(b) CP14 (with de-emphasis only)

(c) CP15 (with preshoot and de-emphasis)

(d) CP16(without preshoot or de-emphasis)

Figure 6-23. Example waveforms for measuring transmitter equalization

Note: all remaining figures in chapter 6 (Figure 6-23 and above) will require renumbering. The equations in subsequent chapters also require renumbering.

(d). Section 6.8.2.2.1, Figure 6-25, page 6-37

From Text:

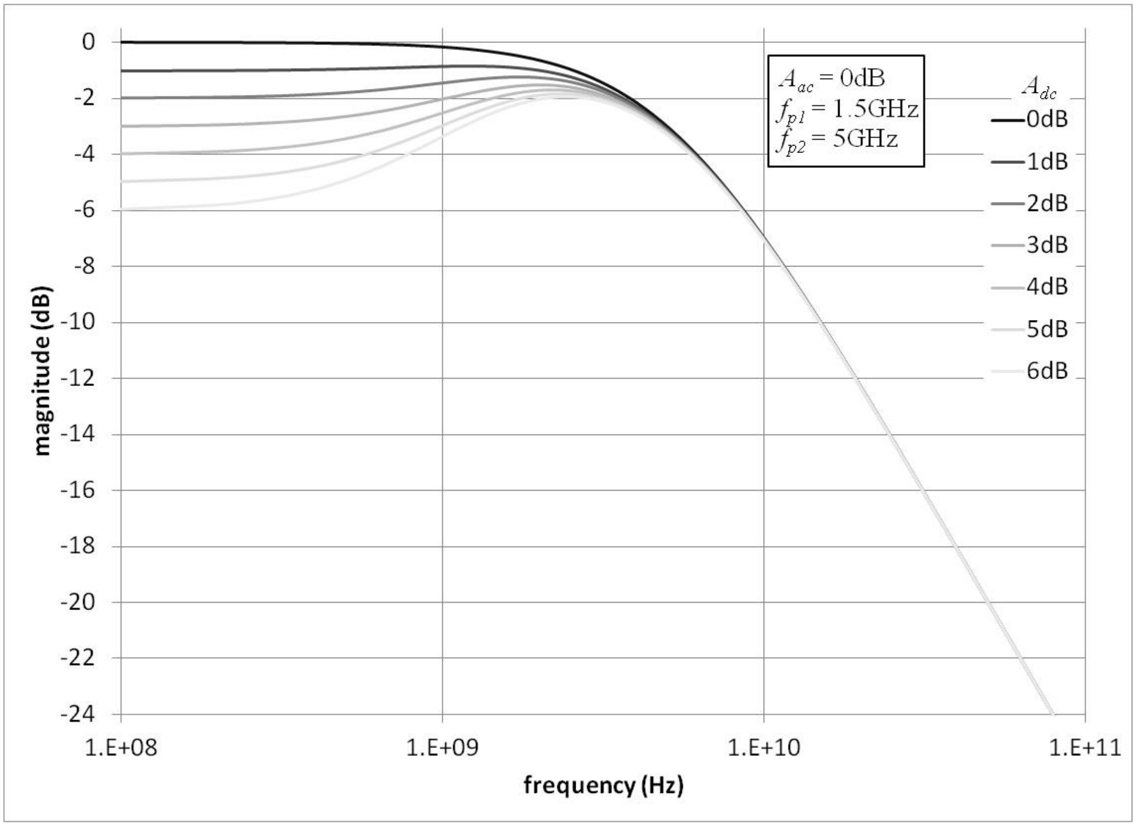


Figure 6-25. Gen 2 Compliance Rx EQ Transfer Function

To Text:

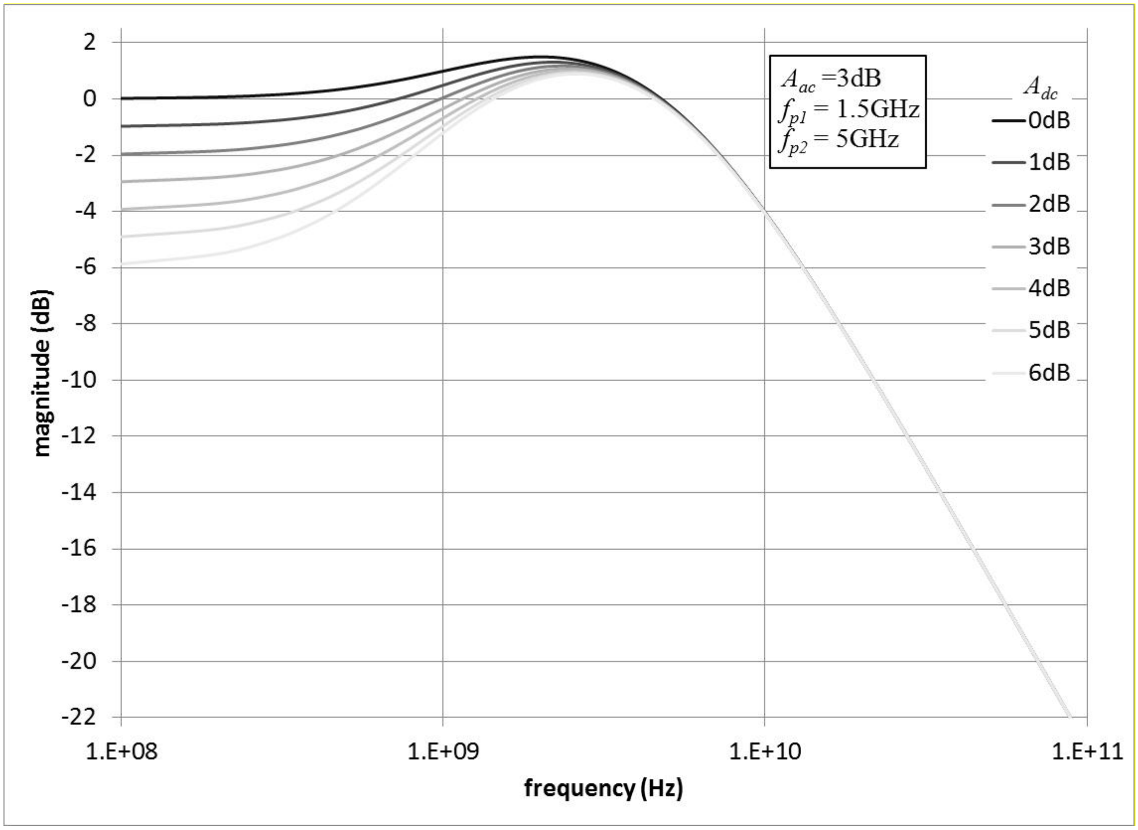


Figure 6-25. Gen 2 Compliance Rx EQ Transfer Function

(e). Section 6.8.2.2.1, Table 6-27, page 6-43

From Text:

Table 6-27. Input Jitter Requirements for Rx Tolerance Testing

Symbol	Parameter	Gen 1 (5GT/s)	Gen 2 (10GT/s)	Units	Notes
f1	Tolerance corner	4.9	7.5	MHz	
J_{Rj}	Random Jitter	0.0121	0.01308	UI rms	1
$J_{Rj\_p\text{-}p}$	Random Jitter peak- peak at 10^{-12}	0.17	0.184	UI p-p	1,4
J_{Pj_500kHZ}	Sinusoidal Jitter	2	4.76	UI p-p	1,2,3
J_{Pj_1Mhz}	Sinusoidal Jitter	1	2.03	UI p-p	1,2,3
J_{Pj_2MHz}	Sinusoidal Jitter	0.5	0.87	UI p-p	1,2,3
J_{Pj_4MHz}	Sinusoidal Jitter	N/A	0.37	UI p-p	1,2,3
J_{Pj_f1}	Sinusoidal Jitter	0.2	0.17	UI p-p	1,2,3
J_{Pj_50MHz}	Sinusoidal Jitter	0.2	0.17	UI p-p	1,2,3
J_{Pj_100MHz}	Sinusoidal Jitter	N/A	0.17	UI p-p	1,2,3
V_full_swing	Transition bit differential voltage swing	0.75	0.8	V p-p	1
V_EQ_level	Non transition bit voltage (equalization)	-3	Preshoot=2.7 De-emphasis= -3.3	dB	1

Notes:

1. All parameters measured at TP1. The test point is shown in Figure 6-19.
2. Due to time limitations at compliance testing, only a subset of frequencies can be tested. However, the Rx is required to tolerate Pj at all frequencies between the compliance test points.
3. During the Rx tolerance test, SSC is generated by test equipment and present at all times. Each J_{Pj} source is then added and tested to the specification limit one at a time.
4. Random jitter is also present during the Rx tolerance test, though it is not shown in Figure 6-20.
5. The JTOL specs for Gen 2 comprehend jitter peaking with re-timers in the system and has a 25dB/decade slope.

To Text:

Table 6-27. Input Jitter Requirements for Rx Tolerance Testing

Symbol	Parameter	Gen 1 (5GT/s)	Gen 2 (10GT/s)	Units	Notes
f1	Tolerance corner	4.9	7.5	MHz	
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$J_{Rj\_p\text{-}p}$	Random Jitter peak- peak at 10^{-12}	0.17	0.184	UI p-p	1,4
J_{Pj_500kHZ}	Sinusoidal Jitter	2	4.76	UI p-p	1,2,3
J_{Pj_1Mhz}	Sinusoidal Jitter	1	2.03	UI p-p	1,2,3
J_{Pj_2MHz}	Sinusoidal Jitter	0.5	0.87	UI p-p	1,2,3
J_{Pj_4MHz}	Sinusoidal Jitter	N/A	0.37	UI p-p	1,2,3
J_{Pj_f1}	Sinusoidal Jitter	0.2	0.17	UI p-p	1,2,3
J_{Pj_50MHz}	Sinusoidal Jitter	0.2	0.17	UI p-p	1,2,3
J_{Pj_100MHz}	Sinusoidal Jitter	N/A	0.17	UI p-p	1,2,3
V_full_swing	Transition bit differential voltage swing	0.75	0.8	V p-p	1
V_EQ_level	Non transition bit voltage (equalization)	-3	Preshoot=2.2 De-emphasis= -3.1	dB	1

Notes:

1. All parameters measured at TP1. The test point is shown in Figure 6-19.
2. Due to time limitations at compliance testing, only a subset of frequencies can be tested. However, the Rx is required to tolerate Pj at all frequencies between the compliance test points.
3. During the Rx tolerance test, SSC is generated by test equipment and present at all times. Each J_{Pj} source is then added and tested to the specification limit one at a time.
4. Random jitter is also present during the Rx tolerance test, though it is not shown in Figure 6-20.
5. The JTOL specs for Gen 2 comprehend jitter peaking with re-timers in the system and has a 25dB/decade slope.