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10GBASE-KR Transmitter Compliance Methodology Proposal

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Scope and Purpose

- Deficiencies of existing transmit template compliance methods are discussed.
- A proposal for a new compliance testing method capable of verifying a 10GBASE-KR transmitter is presented.
- Justification for tap range and tap resolution requirements will be presented separately.

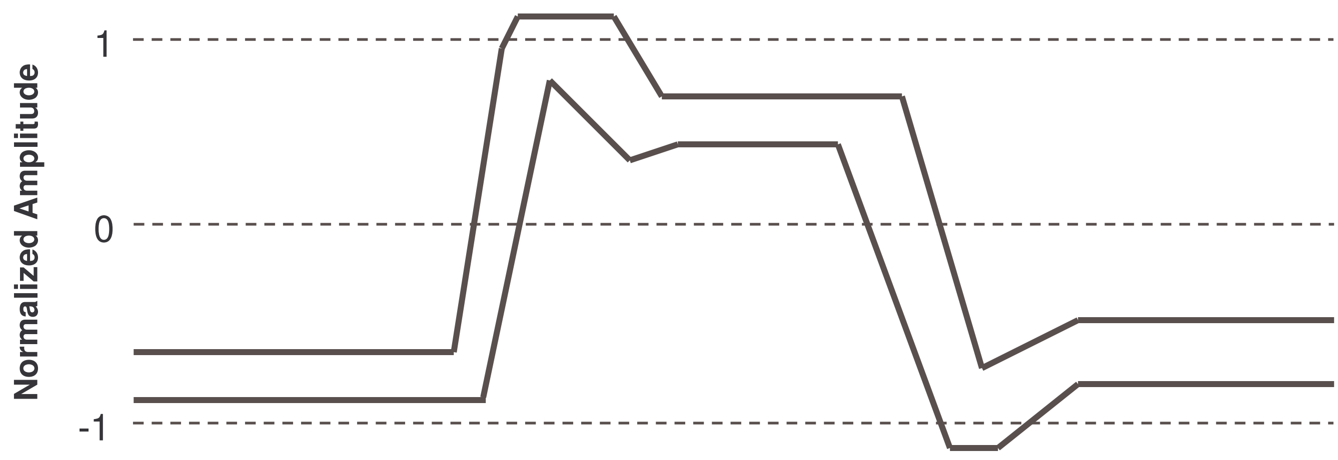
Agenda

- Transmitter Compliance Testing Wish List
- Template Testing Discussion
- Equalization Ratio Testing
  - Transmitter model
  - Transmit Equalizer Signal Shaping
  - Transmit Equalizer Solution Space
  - Proposed Specification Methodology
- Conclusions

Transmitter Compliance Testing Wish List

- Simple
  - Easy to implement with existing test equipment
- Repeatable
  - Should test transmitter, not test equipment
- Fast
  - Minimize time required for compliance testing
- Definitive
  - Should clearly identify a compliant transmitter

Template Testing Discussion



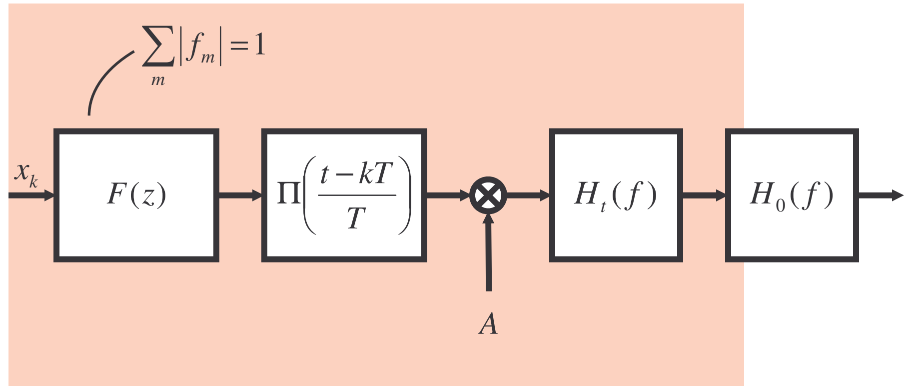
- Bounds rise/fall times, jitter (to some extent), over-/ undershoot and ringing, and relative amplitude.
- Bounds a single setting of pre- / de-emphasis (with tolerances).
- Documented as two voltage-time sequences (upper and lower bound).

Template Testing Discussion (continued)

- Difficult to guarantee across all possible process, voltage, and temperature conditions
- Masks are generally relaxed to the point that they become meaningless
  - If mask is tight enough to guarantee a given level of equalization most designs will fail somewhere else
- Susceptible to instrumentation noise, calibration and capability
- Each template specifies only one equalization setting
- Variable transmit equalization will require multiple templates
  - Multiple templates will need to be used in characterization testing
  - Difficult to implement and document
- An algorithmic method may alleviate this problem.

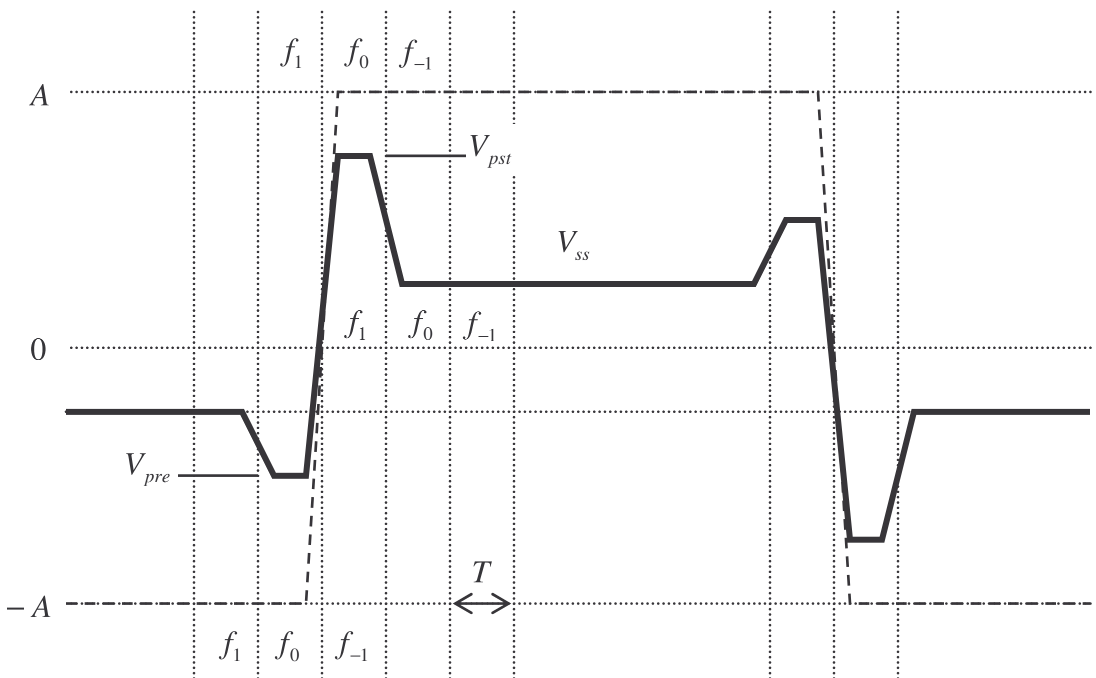
Transmitter Model

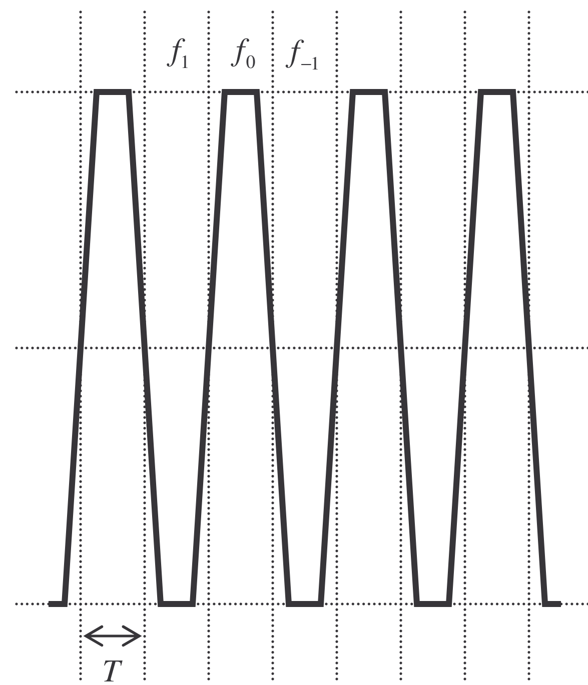
- F(z) is the 3-tap transmit FIR
- T is the symbol period
- A is the peak differential output amplitude
- $H_t(f)$ is the transmit pulse shaping filter



$$f_0 = 1 - |f_{-1}| - |f_1|$$

Transmit Equalizer Signal Shaping





$$V_{pre} = A(-f_1 - f_0 + f_{-1})$$

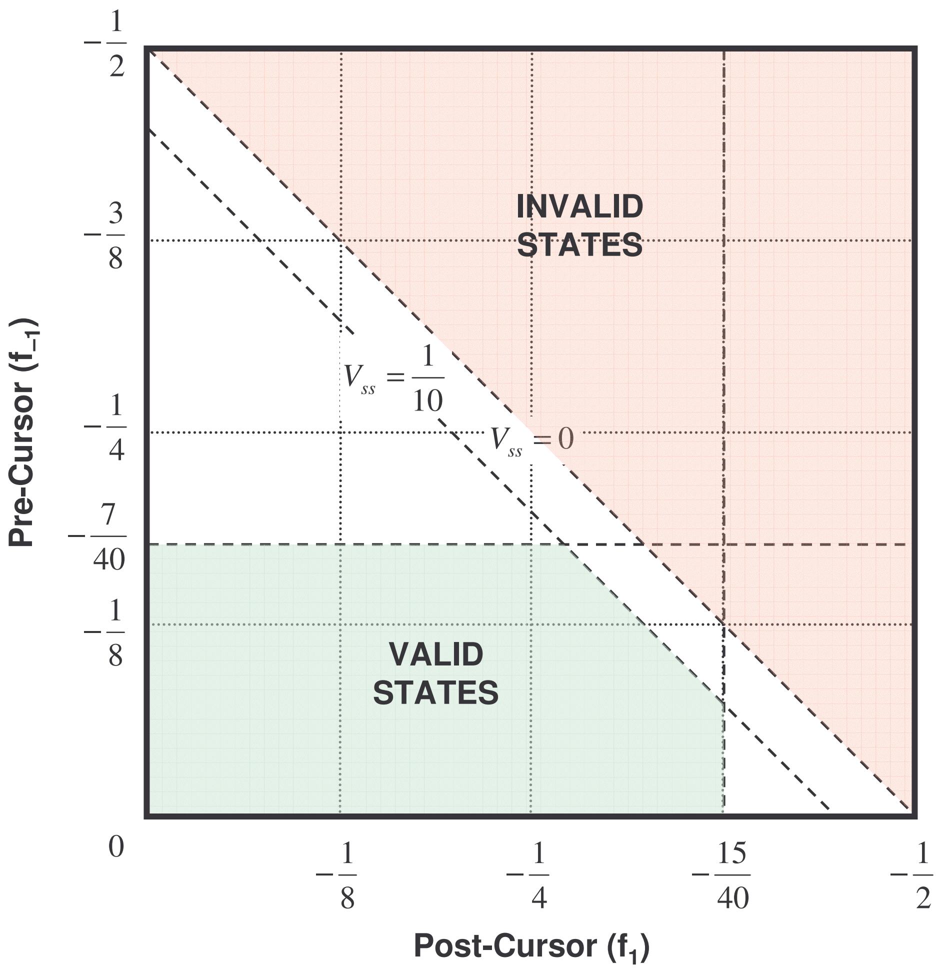
$$V_{pst} = A(-f_1 + f_0 + f_{-1})$$

$$V_{ss} = A(f_1 + f_0 + f_{-1})$$

$$-f_1 + f_0 - f_{-1} = 1$$

NOTE:
By convention, f_1 and f_{-1} are always negative and f_0 is always positive.

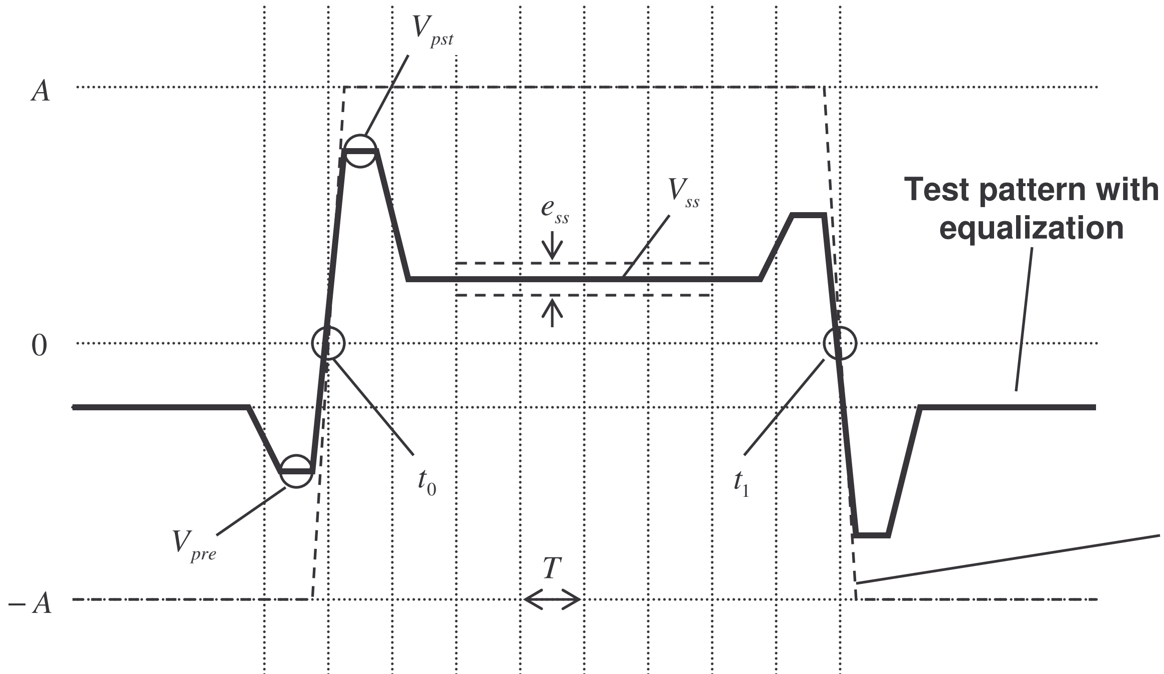
Transmit Equalizer Solution Space



f_{-1} : 8 steps from 0 to −7/40
f_1 : 16 steps from 0 to −15/40
V_{ss} : minimum value should be no less than 1/10

VERIFY EACH TRANSMITTER STATE

Proposed Specification Methodology



For each specified equalization setting, bound the following two ratios:

$$R_{pre} = \frac{V_{pre}}{-V_{ss}} \qquad R_{pst} = \frac{V_{pre}}{V_{ss}}$$

Definitions

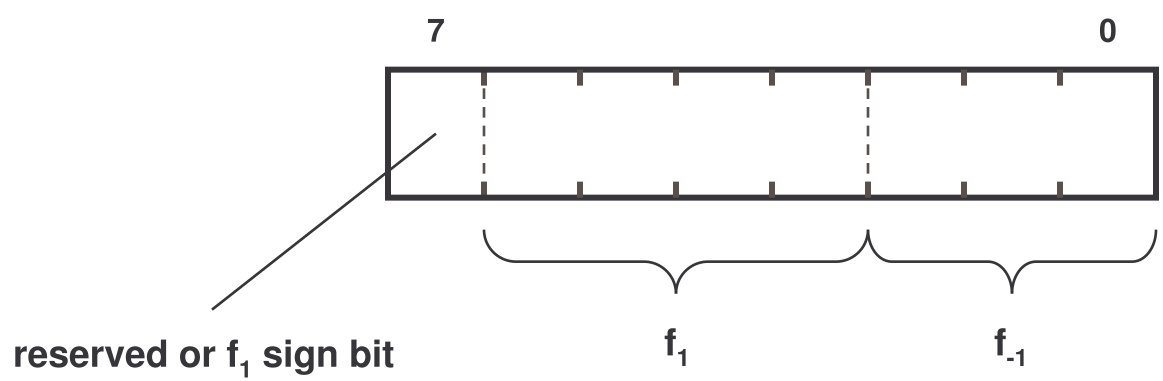
A = peak transmit differential output amplitude
T = symbol period
t_0 = zero-crossing point of the rising edge of the AC-coupled signal
t_1 = zero-crossing point of the falling edge of the AC-coupled signal
V_{pre} = peak voltage measured in the interval t_0–T to t_0
V_{pst} = peak voltage measured in the interval t_0 to t_0+T
V_{ss} = steady-state voltage measured as the average voltage in the interval t_0+2T to t_1–2T
e_{ss} = steady-state error measured as the deviation from V_{ss} in the interval t_0+2T to t_1–2T

Notes

- Use “equalizer off” setting and clause 49 waveform to validate rise time, jitter, and amplitude requirements.
- May also want to check peak-peak output amplitude with 1010… pattern (n = 1).

Transmitter State Definition

- 8-bit encoding
- Pre- and post-cursor values encoded as N x step size (for example, –0.025)



Proposed Compliance Values

$State_{10}$	R_{pre} [dB] (min)	R_{pre} [dB] (max)	R_{pst} [dB] (min)	R_{pst} [dB] (max)	R_{pre} [V/V] (min)	R_{pre} [V/V] (max)	R_{pst} [V/V] (min)	R_{pst} [V/V] (max)
0	-0.6	0.7	-0.6	0.7	0.93	1.08	0.93	1.08
8	-0.7	0.7	-0.2	1.1	0.93	1.08	0.98	1.14
16	-0.7	0.7	0.2	1.6	0.92	1.09	1.03	1.21
24	-0.8	0.8	0.7	2.2	0.92	1.09	1.08	1.28
32	-0.8	0.8	1.2	2.7	0.91	1.10	1.15	1.37
40	-0.9	0.9	1.7	3.3	0.91	1.11	1.22	1.46
48	-0.9	0.9	2.3	4.0	0.90	1.12	1.30	1.58
56	-1.0	1.0	2.9	4.7	0.89	1.13	1.39	1.71
64	-1.1	1.1	3.5	5.4	0.88	1.14	1.50	1.86
72	-1.2	1.2	4.2	6.2	0.88	1.15	1.63	2.05
80	-1.3	1.3	5.0	7.2	0.86	1.17	1.77	2.28
88	-1.4	1.5	5.8	8.2	0.85	1.19	1.95	2.56
96	-1.6	1.7	6.7	9.3	0.83	1.21	2.17	2.93
104	-1.8	1.9	7.7	10.7	0.81	1.25	2.44	3.42
112	-2.1	2.3	8.9	12.3	0.79	1.30	2.79	4.10
120	-2.5	2.8	10.2	14.2	0.75	1.38	3.25	5.13
1	-0.2	1.1	-0.7	0.7	0.98	1.14	0.93	1.08
⋮	⋮		⋮		⋮		⋮	

Refer to spreadsheet for a complete list of values.

Conclusions

- An algorithmic method for compliance testing the 10GBASE-KR transmit equalizer across settings compatible with the channels of interest is described.
- The described method has the advantages of being algorithmic and therefore easily implemented and documented.

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Back-Up

Tolerance Analysis

$$V_{pre} = A(-f_1 - f_0 + f_{-1}) \longrightarrow V_{pre} = A(-1 - 2(f_1 + \Delta f_1))$$

$$V_{pst} = A(-f_1 + f_0 + f_{-1}) \longrightarrow V_{pst} = A(1 + 2(f_{-1} + \Delta f_{-1}))$$

$$V_{ss} = A(f_1 + f_0 + f_{-1}) \longrightarrow V_{ss} = A(1 + 2(f_1 + \Delta f_1) + 2(f_{-1} + \Delta f_{-1}))$$

$$\min(R_{pre}) = \frac{\max(V_{pre})}{\max(V_{ss})} \qquad \max(R_{pst}) = \frac{\max(V_{pst})}{\min(V_{ss})}$$

$$\max(R_{pre}) = \frac{\min(V_{pre})}{\min(V_{ss})} \qquad \min(R_{pst}) = \frac{\min(V_{pst})}{\max(V_{ss})}$$

$$\min(V_{pre}) = A(-1 - 2f_1 - 2|\Delta f_1|) \qquad \min(V_{pst}) = A(1 + 2f_{-1} - 2|\Delta f_{-1}|) \qquad \min(V_{ss}) = A(1 + 2(f_1 + f_{-1}) - 2(|\Delta f_1| + |\Delta f_{-1}|))$$

$$\max(V_{pre}) = A(-1 - 2f_1 + 2|\Delta f_1|) \qquad \max(V_{pst}) = A(1 + 2f_{-1} + 2|\Delta f_{-1}|) \qquad \max(V_{ss}) = A(1 + 2(f_1 + f_{-1}) + 2(|\Delta f_1| + |\Delta f_{-1}|))$$