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Transmitter Output Waveform Requirements

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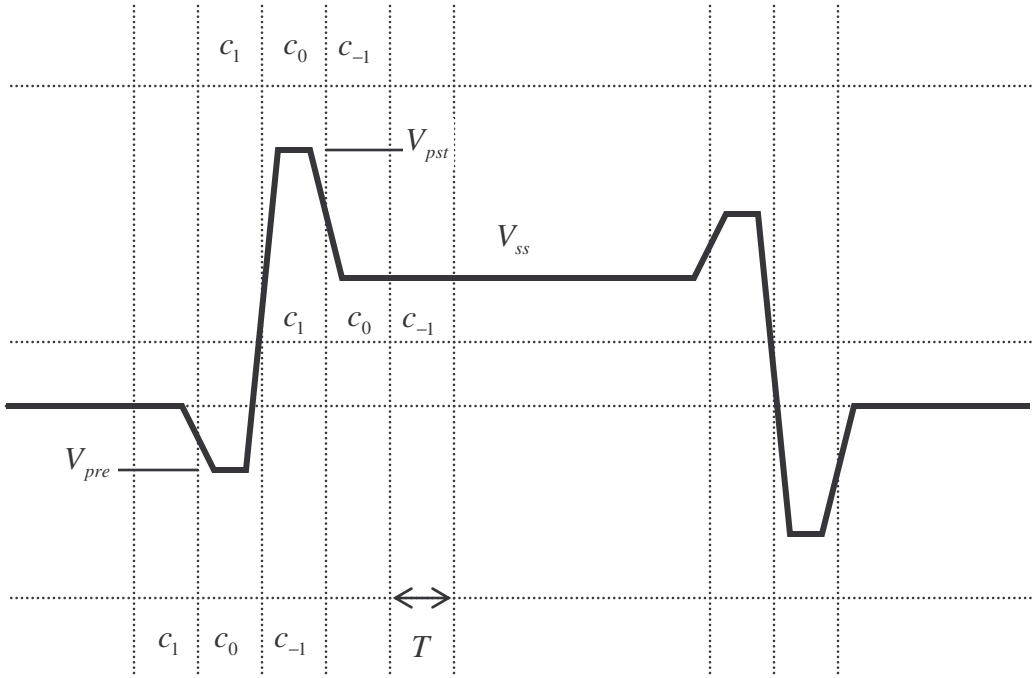
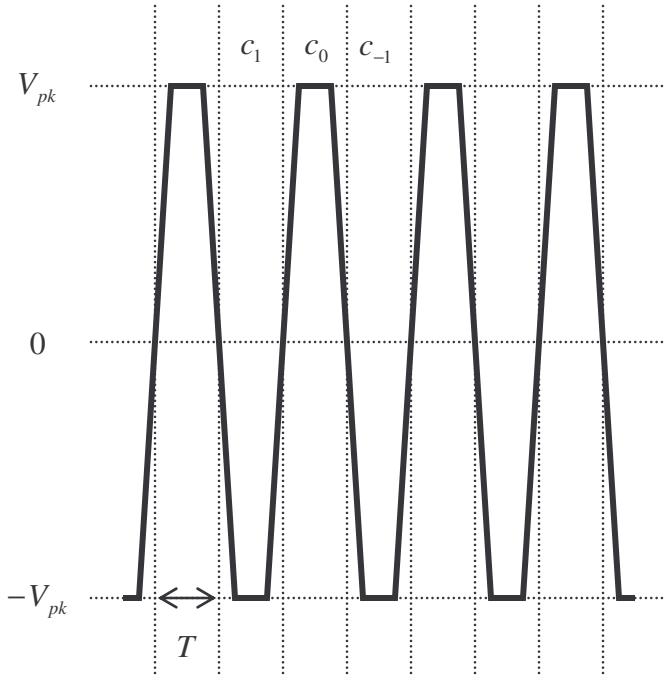
Transmit Equalizer Signal Shaping





$$V_{pre} = -c_1 - c_0 + c_{-1}$$

$$V_{pst} = -c_1 + c_0 + c_{-1}$$

$$V_{ss} = c_1 + c_0 + c_{-1}$$

$$V_{pk} = |c_1| + |c_0| + |c_{-1}|$$

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Transmit Equalizer Requirements

- Differential encoding of transmit equalizer updates (increment, decrement, hold)
- Performance requirements adopted via Motion #10 (Y: 26, N: 0, A: 9) at the May interim meeting (refer to brink_04_0505).

Parameter	Value		Units
	min	max	
Step Size (Δc)	0.00	2.50	%[1]
Tolerance (δ)	–1.25	1.25	%
Pre-cursor (c_{-1}) range	–17.50	0.00	%
Post-cursor (c_1) range	–37.50	0.00	%
Steady-State Amplitude (V_{ss})	10	100	%
Peak Amplitude (V_{pk})	400	600	mV_{pd}

[1] Units are expressed as a percentage of the full-scale amplitude (V_{pk}). The simulations presented in healey_01_0505 assumed a full-scale amplitude of 400 mVpd.

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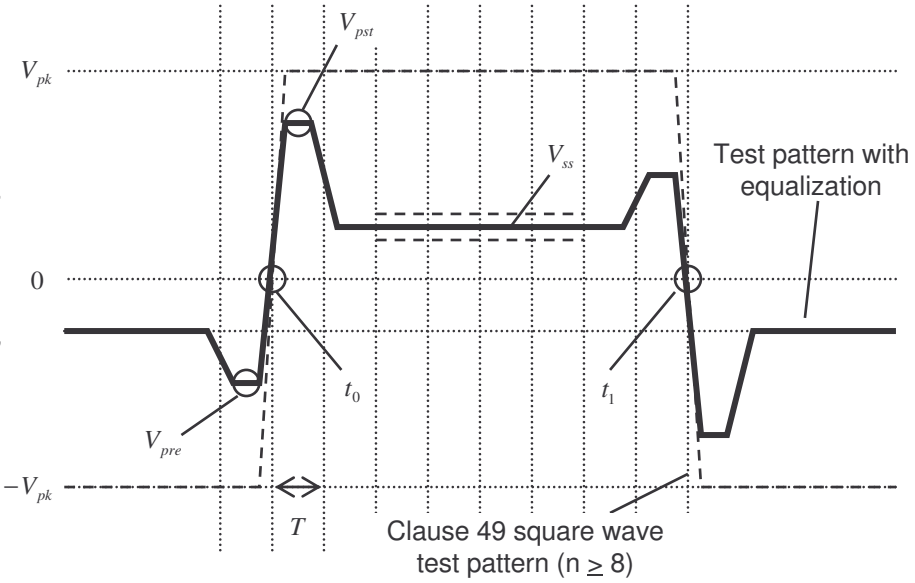
Notes on Requirements

- Requirements derived from MMSE analysis performed on 24 channel data sets provided by Tyco, Intel, and Molex (healey_01_0505)
- For each transmitter equalizer setting, sample phase and 5-tap DFE were optimized to minimize mean-squared error
- Simulations included jitter (but not DCD), crosstalk, and noise
- The performance metric was slicer signal-to-noise ratio
  - Acknowledged as a pessimistic estimate for slicer eye opening
  - However, serves as the basis for the majority of IEEE 802.3 link designs

Test Methodology: Range

- Define R_{pre} and R_{pst}
- Verified at the "rails"…
  - R_{pre}(min) with c_{-1} at *maximum* and c_1 at *maximum*
  - R_{pre}(max) with c_{-1} at *minimum* and c_1 at *maximum*
  - R_{pst}(min) with c_{-1} at *maximum* and c_1 at *maximum*
  - R_{pst}(max) with c_{-1} at *maximum* and c_1 at *minimum*
- Minimum levels of V_{ss} are also defined for no equalization and "full" equalization



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

$$R_{pst} = \frac{V_{pst}}{V_{ss}}$$

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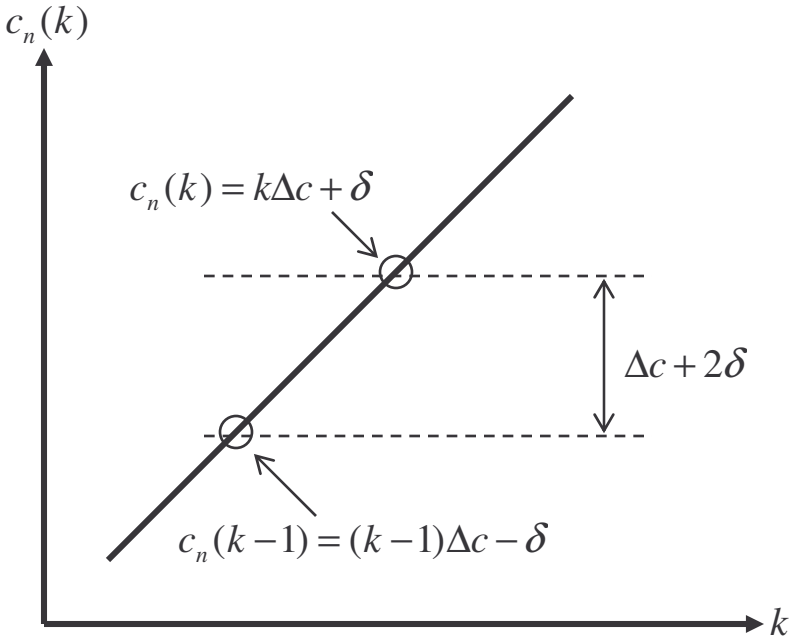
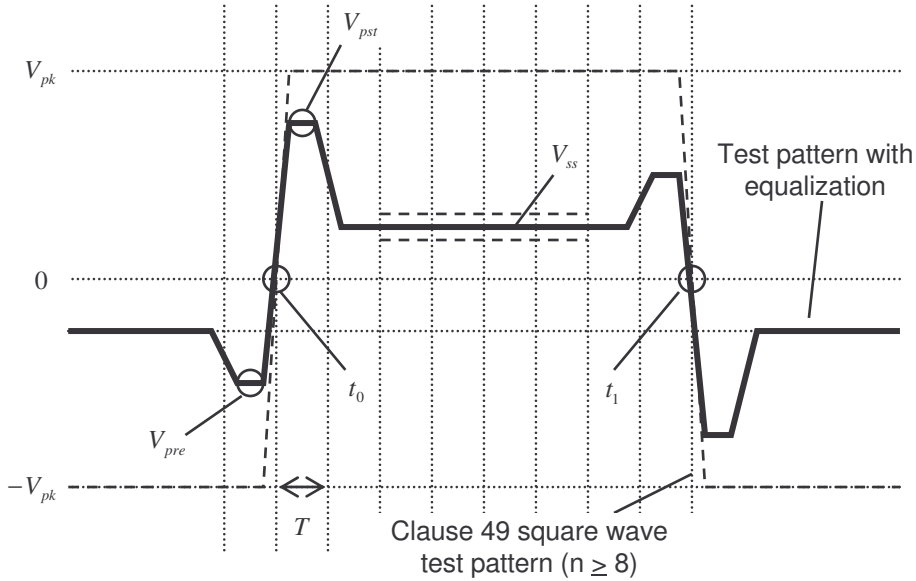
Test Methodology: Resolution

- Define D_{pre}, D_{pst}, and D_{main}
- Verified at all adjacent equalizer states, i.e. the results of a single *increment* or *decrement* on D_{pre}, D_{pst}, or D_{main}





$$D_{pre} = \frac{1}{2}\left|\frac{V_{pre}(k) - V_{pre}(k-1)}{V_{pst}(k) - V_{pre}(k) - V_{ss}(k)}\right|$$

$$D_{pst} = \frac{1}{2}\left|\frac{V_{pst}(k) - V_{pst}(k-1)}{V_{pst}(k) - V_{pre}(k) - V_{ss}(k)}\right|$$

$$D_{main} = \left|V_{ss}(k) - V_{ss}(k-1)\right|$$

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Notes on Test Methodology

- Methodology assumes the V_{pk} is kept constant for all transmit equalizer states
  - Defines c_0 for R_{pre} and R_{pst} testing
  - Fundamental assumption behind D_{pre} and D_{pst} definition (the equations no longer hold if V_{pk} is allowed to vary from state to state)
  - Under this assumption, *increment* / *decrement* operations on c_{-1} affect V_{pst} and vice versa (this is not intuitive, but true per the derivation on slide 14)
- Limits are a mix of ratios and absolute voltages
  - Ratios eliminate dependency on transmitter peak-peak output voltage.

Issues List (1/1)

- V_{pk} is unlikely to be constant for all transmit equalizer states
  - How to set c_0 for R_{pre} and R_{pst} testing?
- With no equalization (c_1 at *maximum* and c_{-1} at *maximum*), the lower limit of c_0 should need to be no less than 55% (refer to slide 16) of the full scale amplitude.
  - The lower limit is currently set to 100 mV_{pd} when 220 mV_{pd} is all that is required for a 400 mV_{pd} full-scale amplitude

Issues List (2/2)

- D_{pre} and D_{pst} values are not correct
  - Should be $\Delta c(max) + 2\delta(max)$ which is 0.0500 and not 0.0263
  - Must also factor in that V_{pk} may vary from state to state
- D_{main} requirements do not align with other requirements
  - Expressed as an absolute voltage, making percentage a function of the full-scale amplitude
  - Effective step size should not vary from D_{pre} and D_{pst} step sizes
    - 30 mV is appropriate for 600 mV_{pd} full-scale amplitude, 20 mV for 400 mV_{pd} full-scale amplitude
  - It is not clear that c_{-1} and c_1 are to be held constant as part of this test

Recommended Corrections

- Align specifications to what was adopted at the May interim
- Eliminate the requirement than V_{pk} be kept constant throughout the equalizer test
  - Acknowledge independent control of c_0
- Make test conditions for each requirement abundantly clear
- Note that, from the original requirements for pre- and post-cursor range:
  - $R_{pst}(max) = 1/(1–2*0.375) = 4.00$
  - $R_{pre}(max) = 1/(1–2*0.175) = 1.54$

Recommended Requirements

Coefficient Status			Requirements		
c_1	c_0	c_{-1}	R_{pre}	R_{pst}	V_{ss}
maximum	*minimum*	*maximum*	?	?	[220, 330] mV_d
maximum	*maximum*	*maximum*	?	?	[400, 600] mV_d
minimum	*minimum*	*maximum*		4.00 (min)	
maximum	*minimum*	*minimum*	1.54 (min)		

Coefficient Update			Requirements		
c_1	c_0	c_{-1}	$V_{pre}(k)-V_{pre}(k-1)$	$V_{pst}(k)-V_{pst}(k-1)$	$V_{ss}(k)-V_{ss}(k-1)$
increment *decrement*	*hold*	*hold*	(0, 20] mV_d [–20, 0) mV_d		
hold	*increment* *decrement*	*hold*		(0, 20] mV_d [–20, 0) mV_d	
hold	*hold*	*increment* *decrement*			(0, 20] mV_d [–20, 0) mV_d

- Any *decrement* update applied to any tap that results in $V_{ss} < 40$ mV_d shall return status *minimum*
- For all equalizer configurations, the sum $V_{pst}-V_{pre}-V_{ss}$ shall be no greater than 600 mV_d

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Implications of Proposed Requirements

- Continue to employ the waveform decomposition methodology in 72.6.1.11
- Eliminate the current D_{pre} and D_{pst} definitions and replace them with simple voltage differences
- Differential output voltage limits are covered by the tables on the preceding page, and additional definitions, including those in 72.6.1.4, are redundant

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Back-Up

D_{pre} and D_{pst} Derivation

- For each value of c_{-1} and c_1, assume that c_0 is adjusted to maintain a constant V_{pk}.
- Assume $c_{-1} \leq 0$ and $c_1 \leq 0$
  - $|c_{-1}| = -c_{-1}$ and $|c_1| = -c_1$
- Assume $c_{-1}(m) = m\Delta c$
- Assume $c_1(n) = n\Delta c$

$$c_0 = V_{pk} - |c_1| - |c_{-1}|$$

$$V_{pre} = -c_1 + c_{-1} - V_{pk} + |c_1| + |c_{-1}| = -V_{pk} - 2c_1$$

$$V_{pst} = -c_1 + c_{-1} + V_{pk} - |c_1| - |c_{-1}| = V_{pk} + 2c_{-1}$$

$$V_{ss} = c_1 + c_{-1} + V_{pk} - |c_{-1}| - |c_1| = V_{pk} + 2c_1 + 2c_{-1}$$

$$V_{pre}(n) - V_{pre}(n-1) = -V_{pk} - 2n\Delta c - \left(-V_{pk} - 2(n-1)\Delta c\right) = 2\Delta c$$

$$V_{pst}(m) - V_{pst}(m-1) = V_{pk} + 2m\Delta c - \left(V_{pk} + 2(m-1)\Delta c\right) = 2\Delta c$$

$$V_{pst} - V_{pre} - V_{ss} = \left(V_{pk} + 2c_{-1}\right) - \left(-V_{pk} - 2c_1\right) - \left(V_{pk} + 2c_1 + 2c_{-1}\right) = V_{pk}$$

$$\frac{1}{2}\left|\frac{V_{pre}(k) - V_{pre}(k-1)}{V_{pst}(k) - V_{pre}(k) - V_{ss}(k)}\right| = \left|\frac{\Delta c}{V_{pk}}\right| = D_{pre}$$

$$\frac{1}{2}\left|\frac{V_{pst}(k) - V_{pst}(k-1)}{V_{pst}(k) - V_{pre}(k) - V_{ss}(k)}\right| = \left|\frac{\Delta c}{V_{pk}}\right| = D_{pst}$$

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D_{main} Derivation

- For each value of c_0, c_{-1} and c_1, remain constant (i.e. V_{pk} is not constant)
- Assume $c_0(k) = k\Delta c$

$$\left|V_{ss}(k) - V_{ss}(k-1)\right| = \left|\left(c_1 + k\Delta c + c_{-1}\right) - \left(c_1 + (k-1)\Delta c + c_{-1}\right)\right| = \Delta c = D_{main}$$

V_{ss} Limits Derivation

- Assume that V_{ss} needs to be no less than 10% of the full-scale amplitude (V_{pk})
- Assume $c_{-1} \leq 0$ and $c_1 \leq 0$
  - $|c_{-1}| = -c_{-1}$ and $|c_1| = -c_1$

$$V_{pk} = |c_1| + |c_0| + |c_{-1}|$$

$$V_{ss} = c_1 + c_0 + c_{-1} \geq \frac{V_{pk}}{10}$$

$$\frac{V_{pk} + V_{ss}}{2} = \frac{(-c_1 + c_0 - c_{-1}) + (c_1 + c_0 + c_{-1})}{2} = c_0$$

$$\frac{V_{pk} + V_{ss}}{V_{pk}} = \frac{2c_0}{V_{pk}} \geq 1.10$$

$$c_0 \geq 0.55 V_{pk}$$

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Updates to Requirements

Recommended Requirements (1/2)

Coefficient Status			Requirements		
c_1	c_0	c_{-1}	R_{pre}	R_{pst}	V_{ss}
maximum	*minimum*	*maximum*	[0.90, 1.10]	[0.90, 1.10]	[220, 330] mV_d
maximum	*maximum*	*maximum*	[0.95, 1.05]	[0.95, 1.05]	[400, 600] mV_d
minimum	*minimum*	*maximum*		4.00 (min)	
maximum	*minimum*	*minimum*	1.54 (min)		

Coefficient Update			Requirements		
c_1	c_0	c_{-1}	$V_{pst}(k)-V_{pst}(k-1)$	$V_{ss}(k)-V_{ss}(k-1)$	$V_{pre}(k)-V_{pre}(k-1)$
increment *decrement*	*hold*[1]	*hold*	[5, 20] mV_d [–20, –5] mV_d	[–5, 5][2] mV_d	[–5, 5] mV_d
hold	*increment* *decrement*	*hold*	[–5, 5] mV_d	[5, 20] mV_d [–20, –5] mV_d	[–5, 5] mV_d
hold	*hold*	*increment* *decrement*	[–5, 5] mV_d	[–5, 5] mV_d	[5, 20] mV_d [–20, –5] mV_d

1 Step size requirements to the tap under test shall apply regardless of the current value of the other two taps
2 Difference is measured relative to the value of the coefficient prior to assertion of the hold request

Recommended Requirements (2/2)

- For all equalizer configurations, V_{ss} shall be no less than 40 mV_d
- Any *decrement* update applied to any tap that results in $V_{ss} < 40$ mV_d shall return status *minimum*
- For all equalizer configurations, the sum $V_{pst}–V_{pre}–V_{ss}$ shall be no greater than 600 mV_d
- Any *decrement* update applied to c_{-1} or c_1 that results in V_{pk} greater than or equal to 600 mV_d shall return status *minimum*
- Any *increment* update applied to c_0 that results in V_{pk} greater than or equal to 600 mV_d shall return status *maximum*

Notes on Recommended Requirements

- Bounds applied to the change of held coefficients is based on $\pm\delta$
- Lower bound applied to coefficient step size is based on δ
- Range of R_{pre} and R_{pst} for max/min/max and max/max/max test cases based on c_{-1} and c_1 range of $\pm\delta$ and $c_0 = \min(V_{ss})$