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T10/00-346r0

Ultra320 First Pulse Noise Margin

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First Pulse Amplitude Dependencies

- Target Vn
- Target fallback Vn level
- Tolerance of cutback current source
- Driver Va vs Vn equations (slope and offset)
- Bus resistance
- Terminator resistance and impedance
- Terminator bias cancellation current
- Backplane Impedance
- Cable impedance
- Signal attenuation

Target Vn

- Current allowed range is from 320 mV to 800 mV.
- A proposal has been made to raise the minimum to 500 mV (this could creep higher still).
- Quantum believes that a rise of about 50 mV to 370 mV is adequate.
- Operation of non-AAF systems with 500 to 800 mV drive levels is already permitted.
- Agreement on the spreadsheet equations is necessary for resolving the minimum drive level TBDs.

Target fallback Vn level

- The current SPI-4 document has limits on the ratio of $I_{fallback}$ to I_{full_drive} of 0.60 to 0.78.
- A proposal has been made to shift the range to: 0.50 to 0.66.
- First pulse amplitude can be assessed with a spreadsheet.

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Tolerance of Cutback Current Source

- The Cutback current source (or Boost current source) is generated with similar structures and in close proximity to the main signal current source.
- A tolerance of +/- 10% is proposed for the cutback current source, consistent with the 10% proposed for the slope of Va vs Vn (T10/00-319r0).

Limits on the Range of Fallback Ratio

- To avoid violating the specified range of fallback ratio, the target fallback ratio must be inside of the spec range.
- A range of +/- 10% for the cutback current corresponds to a range in fallback ratio (I_fallback/I_full_drive) of about +/- 0.06 for spec ranges of either 0.50 to 0.66 or of 0.60 to 0.78.

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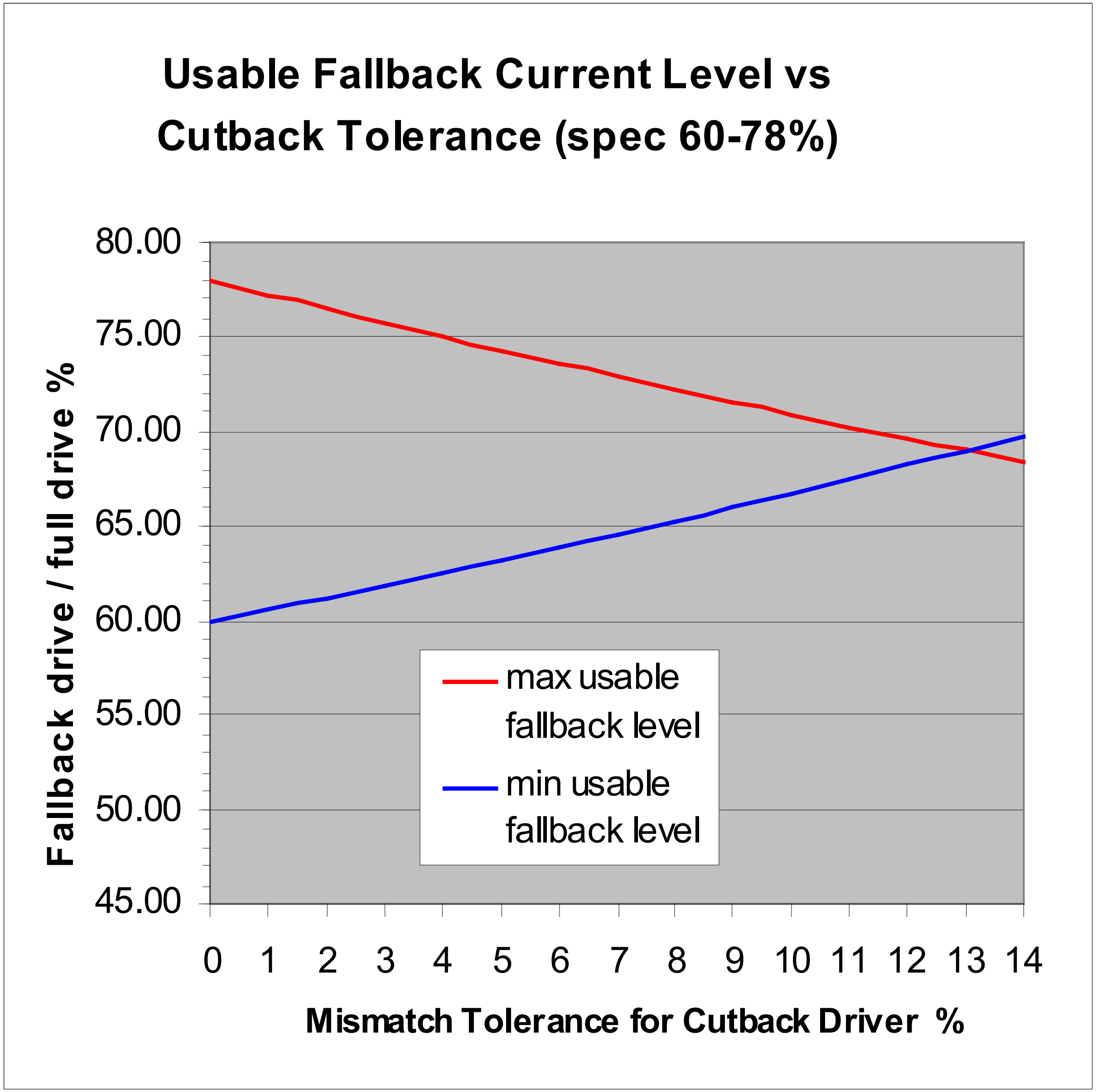
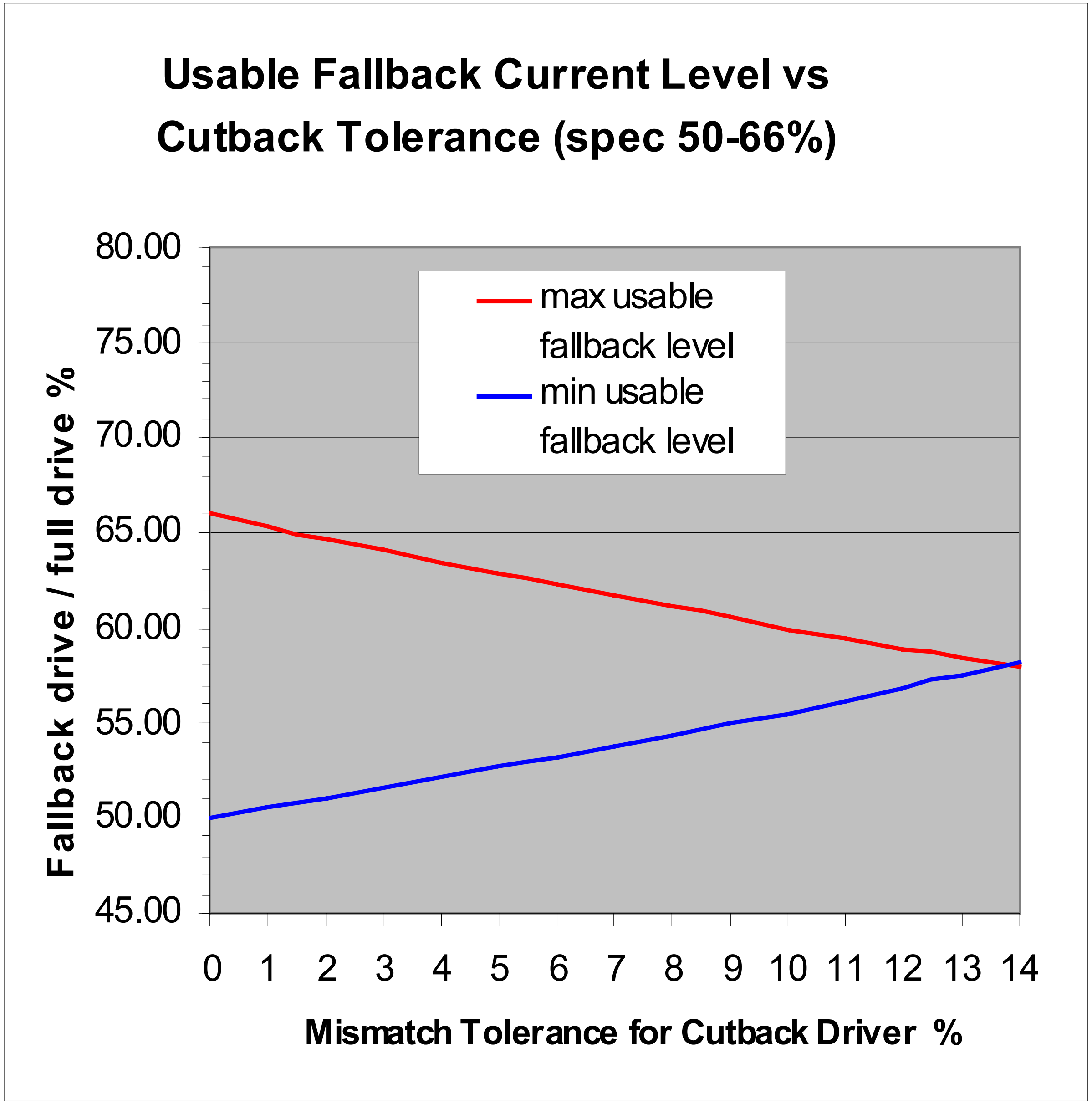
Range of Ratios for 60 - 78% spec

- For a spec range of 60 - 78%:
- 63.2 - 74.3% for +/- 5% tol.
- 65.9 - 71.6% for +/- 10% tol.



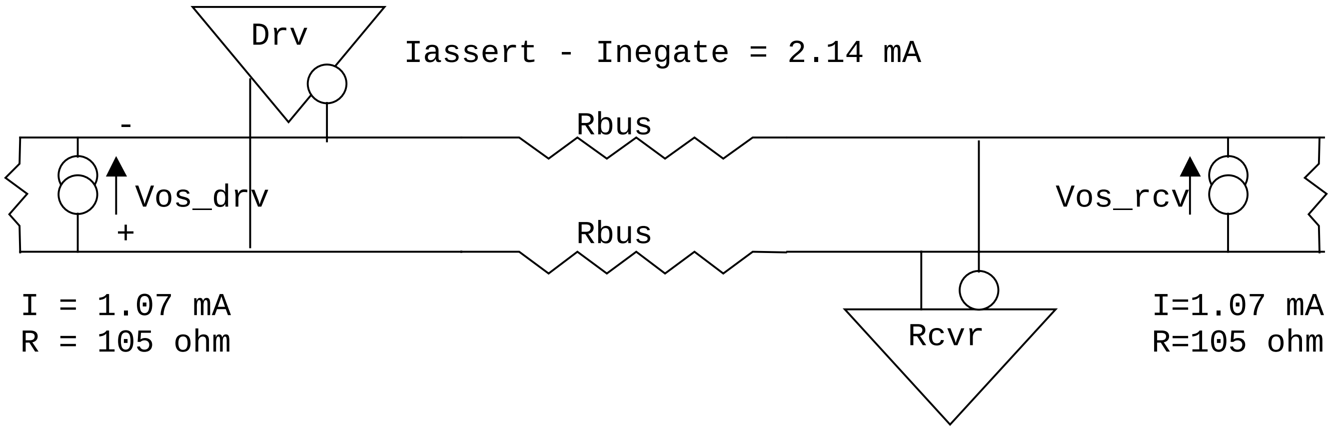
Range of Ratios for 50 - 66% Spec

- For a spec range of 50 - 66%:
- 52.6 - 62.9% for +/- 5% tol.
- 55.6 - 60.0% for +/- 10% tol.



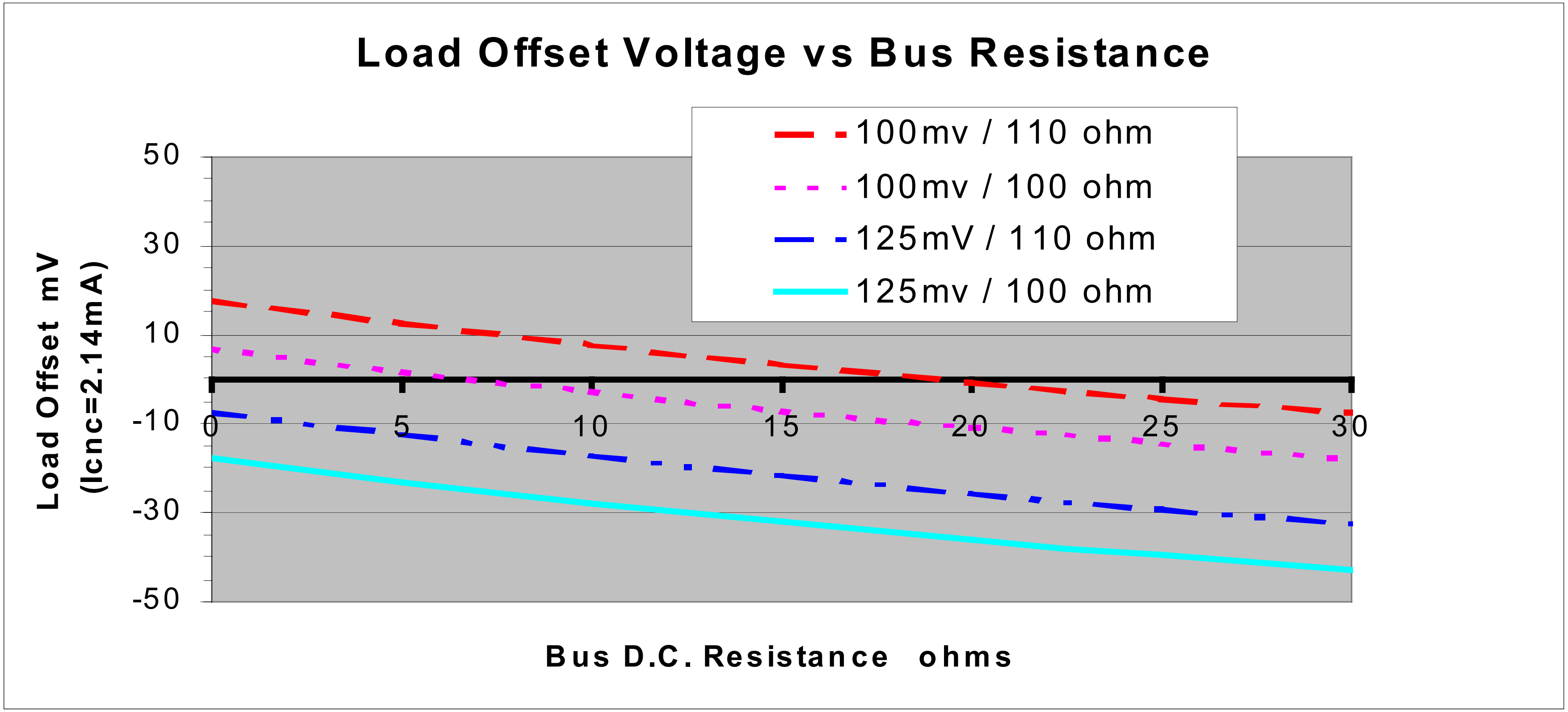
Bus Resistance causes DC Losses

- For initiator and targets on opposite ends of the bus, DC losses are a simple resistor ratio.
- F_dc_loss = Rterm / (Rterm + 2 * Rbus)
- DC loss factor is applied to both the start voltage and to the first step height.
- Other spreadsheets reported have used F_dc_loss = 0.90 which corresponds to about 6 Ω of bus resistance.



Bus Resistance Causes Offsets

- A bias cancellation current which provides perfect balance on a short bus will result in a negation bias at the load if there is a bus resistance between the source and the load (from 00-331r0 for the 4 corners of the terminator spec).
- At Rbus = 6 Ω, offsets range from +6 mV to -19 mV.



Terminator Characteristics

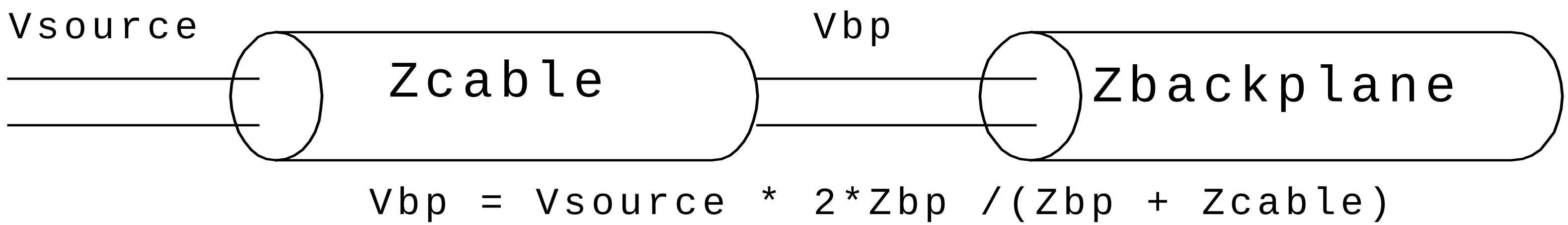
- Terminator resistances (with bus resistance) determines the start level for isolated (first) edges.
- Terminator impedances (with cable impedance) determine step height of the first transition.
- Terminator resistance, bias cancellation current, and bus resistance determine the DC bus offset.
- Quantum's spreadsheet accepts:
  - Near terminator resistance
  - Far terminator resistance
  - Bus resistance
- Spec range of terminator voltages are used to calculate offset errors.

DC Offset Errors

- +26 / -23 mV budget for canceling out the terminator negation bias current [$I_{cnc} = -I_{term} = (I_{assert} - I_{negate})$] when driving an ideal load, per Appendix A (also see 00-319r0).
  - Included in Figure A.2
- +/- 18 mV budget for differences between the ideal load and the terminator extremes of bias current.
  - Not included in Figure A.2
  - Use in calculating first pulse noise margins.
- +0 / -30 mV offset for bus D.C. resistance.
  - Not included in Figure A.2.
  - Use in calculating first pulse noise margins.

Losses at Impedance Discontinuities

- Cable impedance range 110 to 135 Ω.
- Backplane impedance range from 85 to 135 Ω.
- Ratio of the backplane amplitude to the cable amplitude is 2 * Zbp / (Zbp + Zcable).
- Maximum ratio is 1.10 = 2 * 135 / (135 + 110).
- Minimum ratio is 0.81 = 2 * 85 / (85 + 135).
- Reflection losses are included in AC losses in some other spreadsheets.
- This simple topology (single impedance discontinuity with no HBA etch) is optimistic.

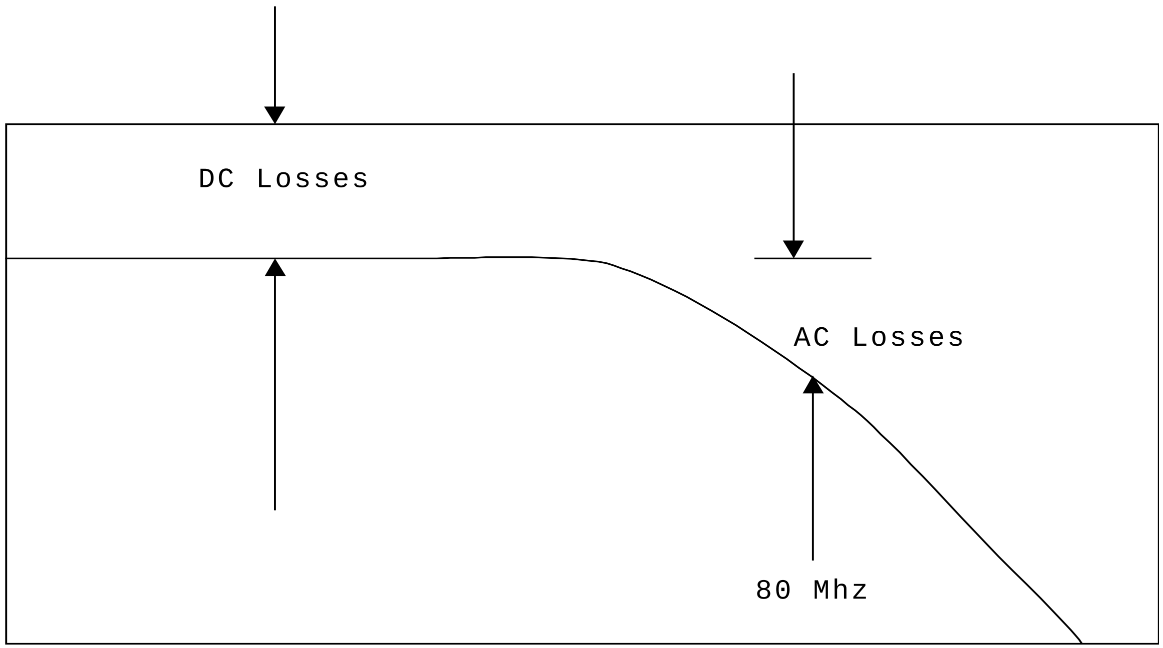


Complex Systems

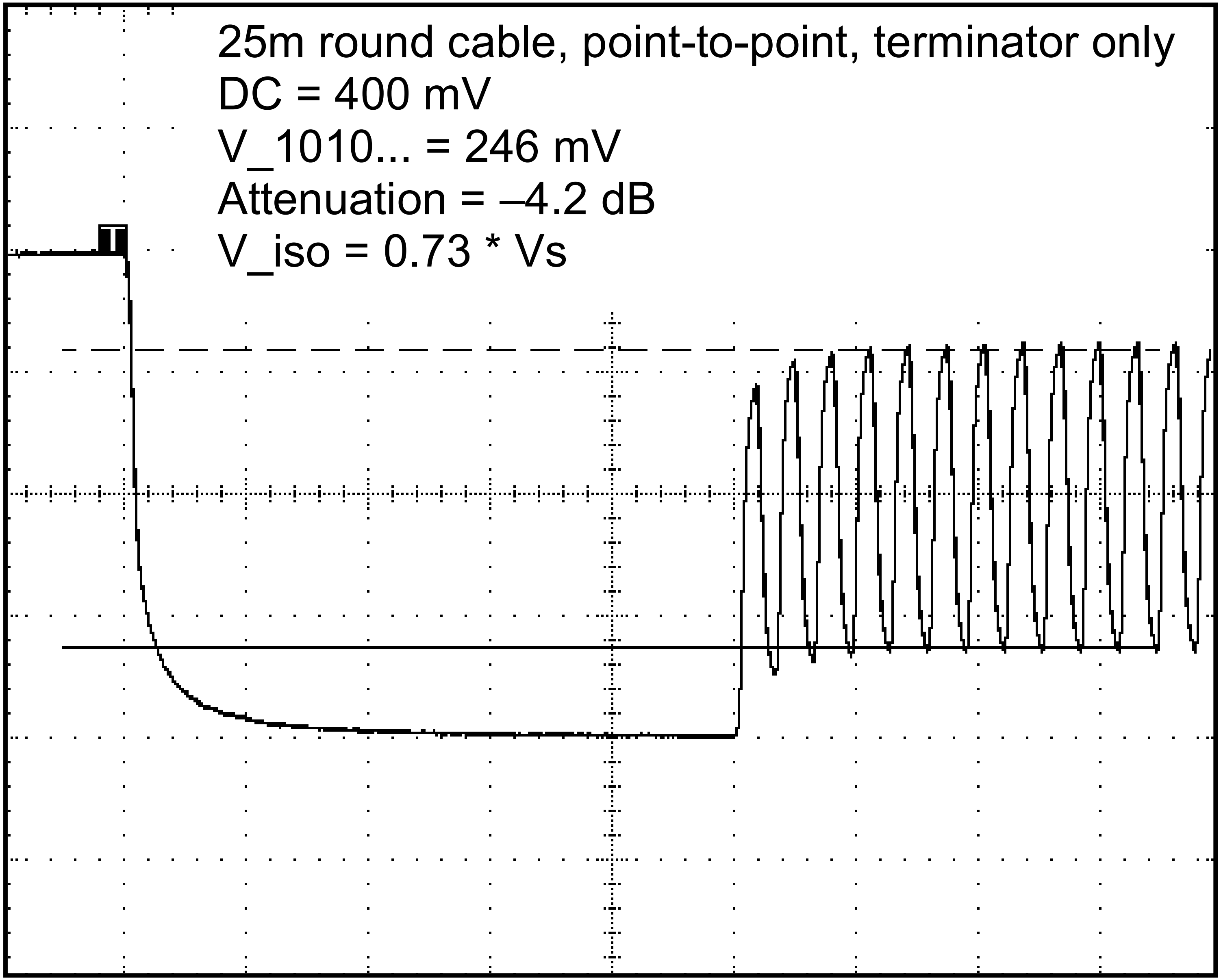
- Our spreadsheet considers only a first edge on a system with a single mid-bus reflection source.
  - This can be readily done in a spreadsheet.
  - Transmit PreComp can aid the first pulse.
- In a complex system, there are:
  - Multiple mid-bus reflection sources,
  - Interacting edges.
- Lab data from both Seagate and Quantum has shown examples of short complex buses in which noise margins degrade with the introduction of transmit PreComp.
- Spread sheet analysis of interacting edges in complex systems is beyond the capability of spreadsheet analysis.

Attenuation Losses

- In an accurate analysis, DC losses would fall out of the attenuation (dB) versus log frequency relationship and from the ISI effects.
- "AC losses" of 0.70 have been reported on legal cable plants without backplanes (00-235r0).



25m round, P-P (from 00-235r0)



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Non-DC Losses Summary

- Attenuation in a cable plant can be broken into a DC loss term and an AC loss term.
- Reflection losses occur at bus impedance discontinuities.
- A single edge in a system with a single discontinuity can readily be analyzed by spreadsheet, and can benefit from transmit precomp.
- Spreadsheets shown previously have lumped AC losses together with reflection losses.
- Quantum's spreadsheet treats reflection losses separately.

Worst Case Bus Parameters 1

- Model an HBA driving over a cable to a backplane.
- Choose HBA terminator to be 100 Ω (spec min) and the cable to be 135 Ω (spec max):
  - Maximum signal lost in local terminator,
  - Minimum signal sent down bus.
- Choose backplane to be 85 Ω (spec min):
  - Worst case cable / backplane reflection,
  - Minimize height of isolated edge.
- Use worst case **single** impedance discontinuity.
- Ignore buses with multiple impedance discontinuities (would be worse).

Worst Case Bus Parameters 2

- Choose Rbus as 6 Ω in each wire of pair.
  - No spec in SPI-2, 3, or 4.
  - 25 meter cable has about 8 Ω of resistance.
  - Backplanes range from 3 to 20 Ω of resistance.
  - 6 Ω corresponds to the 90% DC loss factor assumed in other T10 papers.
  - 6 Ω corresponds to –7 mV of added negation bias from the bias cancellation current.
- Choose far terminator as 110 Ω (max).
  - Force DC start level lower.

Worst Case Bus Parameters 3

- Choose Quantum proposed driver voltage balance with the standard load:
  - Max Va = 1.11 * |Vn| + 26
  - Min Va = 0.90 * |Vn| - 23
- Choose bias cancellation current as 2.14 mA (nominal).
  - Terminator caused offsets are +/- 13 mV.
- Choose AC loss factor as 0.70.
  - Ratio of training pattern first fast pulse height to DC level.

Worst Case Bus Parameters 4

- Choose tolerance of Cutback current as 10%.
  - Comparable to slope of Va vs Vn of figure A.2.
- Choose the TI proposed range of fall back ratios as 50% to 66%.
  - 50% results in the strongest first pulse.
  - 66% results in the weakest first pulse.
  - 78% (current spec) results in an even weaker first pulse.
- To accommodate 10% cutback current tolerance and 50 to 66% limits, the target fallback ratio is constrained to 55.6 to 60%.

Sample Calculation 1

- A signal strength of 500 mV, a fallback target of 60%, and a cutback tolerance of 10% would produce a weak negation of –320 mV = 0.64 * 500 mV , for an ideal load
- The start point is scaled to –289 mV for the DC loss term of 90%, a function of terminators and bus resistance
- This start point is scaled to –291 mV for the difference between the ideal DC load and the bus DC load

Sample Calculation 2

- The assertion pulse is the full negation strength modified by the equations of table A.2 leading to: 427 mV = 0.9 * 500 mV – 23 mV, for an ideal load.
- Swing into an ideal load is 427 mV - (-320 mV) = 747 mV.
- Swing is adjusted for DC losses 674 = 0.9 * 747
- Swing is scaled from ideal load to the AC impedance of the cable by the factor 1.06.
- AC loss factor of 0.70 is applied.
- Reflection loss factor of 0.77 is applied.
- Resultant step is 0.57 * 674 mV = 384 mV.

Sample Calculation 3

- The bus offset is calculated from bus resistance and terminator characteristics as +6 mV to –19 mV.
- Height of first edge is Vstart + Vswing + Voffset =
  V_{first} = -291 + 384 -19 = 75 mV minimum
- Taking all errors in the other direction produces a
  V_{first} = -254 + 443 + 6 = 195 mV maximum

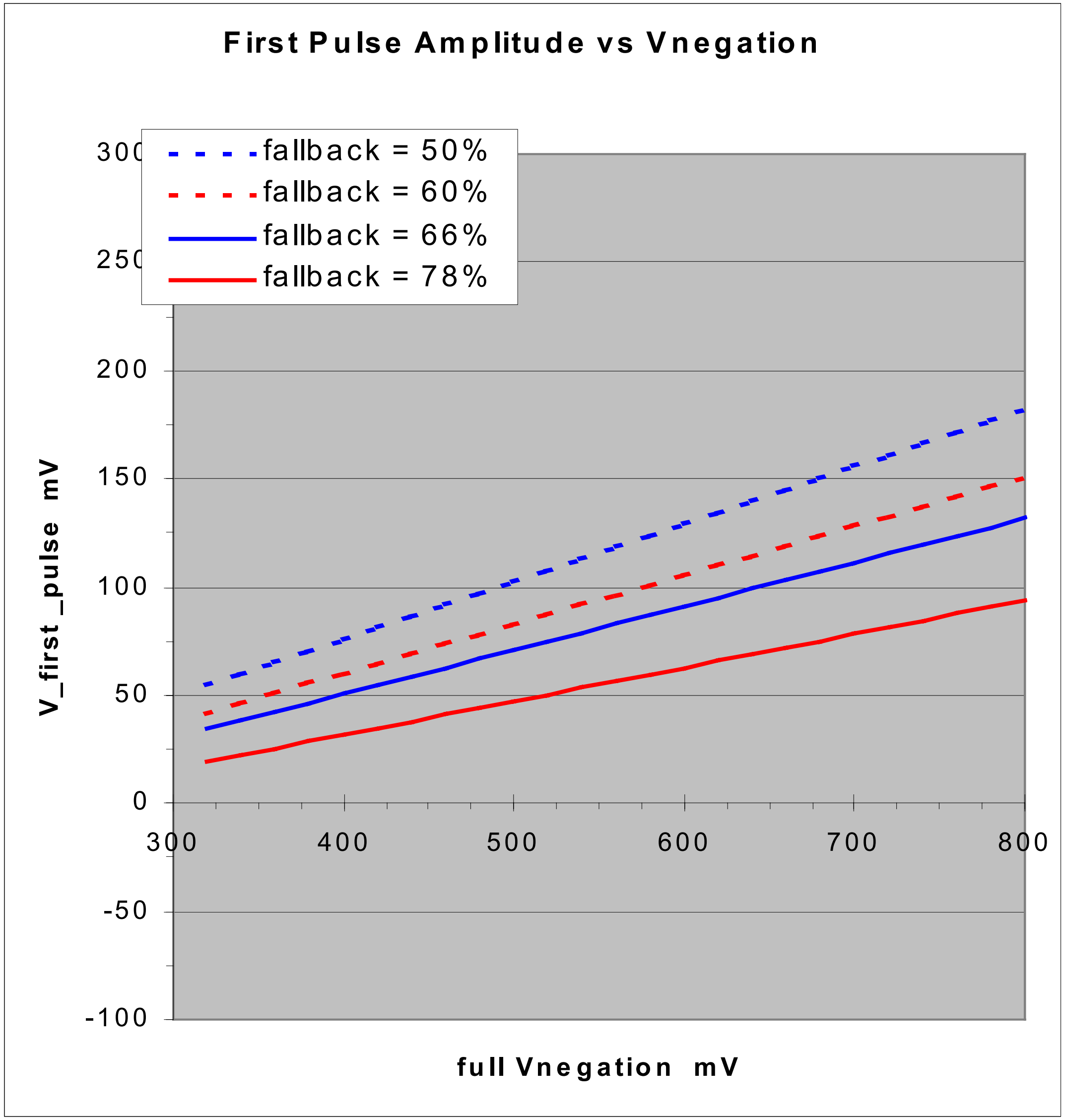
Sample Calculation 4

Driver parameters						short bus		adjusted for D.C loss	
500	mV Negation, full swing, Std load			320-800 spec		-500	Vneg std load		-451
60	% = (fallback swing / full swing)			60-78 or 50-66 spec		-280	Max cutback		**-252**
10	% tol. on Icutback / Idrive			10% ???		-320	Min cutback, on bus		**-289**
78	spec max % fallback			SPI4:78, TI:66		**64.0**	max fallback %		
50	spec min % fallback			SPI4: 60, TI:50		**56.0**	min fallback %		
1.11	Va vs Vn max slope			1.11 proposed		581	Vassert max		524
26	Va vs Vn max case offset			26 proposed		427	Vassert min		385
0.9	Va vs Vn min slope			0.90 proposed		861	Max step		**776**
-23	Va vs Vn min case offset			-23 proposed		747	Min step		**674**
Cable plant / term params									
2.14	mA bias compensation			2.14 mA is optimal compensation if bus is zero ohms					
6	ohms bus resistance			0 - 20 ohms		**6.0**	mV max term offset vs std load		
100	drvr R_term_near ohms			100 - 110 spec		**-19.0**	mV min term offset vs std load		
110	rcvr R_term_far ohms			100 - 110 spec		55.0	D.C. load resistance		
						0.90	D.C. loss ratio		
135	Z on cable ohms			110 - 135 spec		1.06	Vcable / Vstd_load ratio		
85	Z on backplane ohms			85-135 spec		0.77	Vload / Vcable ratio		
0.7	Cable loss factor			0.7		0.70	Cable loss factor		
1	Backplane loss factor			no spec		1.00	Backplane loss factor		
						0.57	Vload / std load ratio		
	Min step		**Max step**						
	-291		-254	mV Negation cutback on bus					
	-19		6	mv Terminator and R_bus offset					
	384		443	mV Assertion step voltage ratio x step height					
	75	**mV min**	**195**	**mV max**	**Step Height**				

Quantum™ Fallback Limits on Worst Case Bus

- First pulse height vs % Fallback vs Swing

1.11	Va vs Vn max slope	
26	Va vs Vn max case offset	
0.9	Va vs Vn min slope	
-23	Va vs Vn min case offset	
Cable plant / term params		
2.14	mA bias compensation	
6	ohms bus resistance	
100	drvr R_term_near ohms	
110	rcvr R_term_far ohms	
135	Z on cable ohms	
85	Z on backplane ohms	
0.7	Cable loss factor	



PreComp Driver for Worst Case Bus

- Using a fallback percentage of 78% (zero cutback tolerance) and 100 mV of swing beyond zero, the negation driver must be 840 mV, exceeding the SPI-4 max.
- Using a fallback percentage of 66% (proposed as a spec change), the negation driver must be 645 mV.
  - Greater than the proposed 500 mV minimum
  - This is a roughly 50% increase from typical SPI-3 drive levels
  - Driver strength range would be from 560-740 mV
- Transmit PreComp drivers can provide adequate first pulse margins on a bus with relaxed specifications

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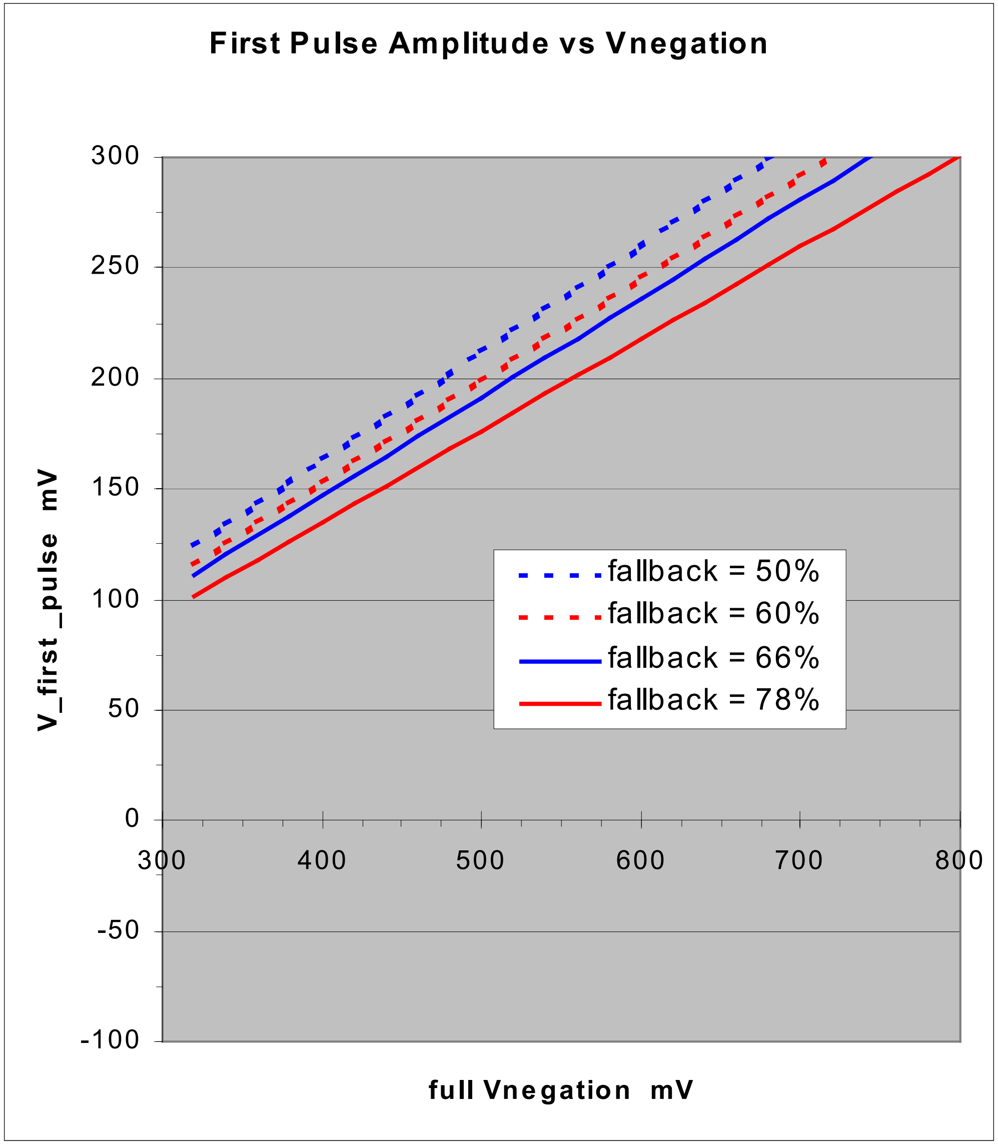
Fallback Limits on Constrained Bus

- First pulse vs % Fallback vs Swing

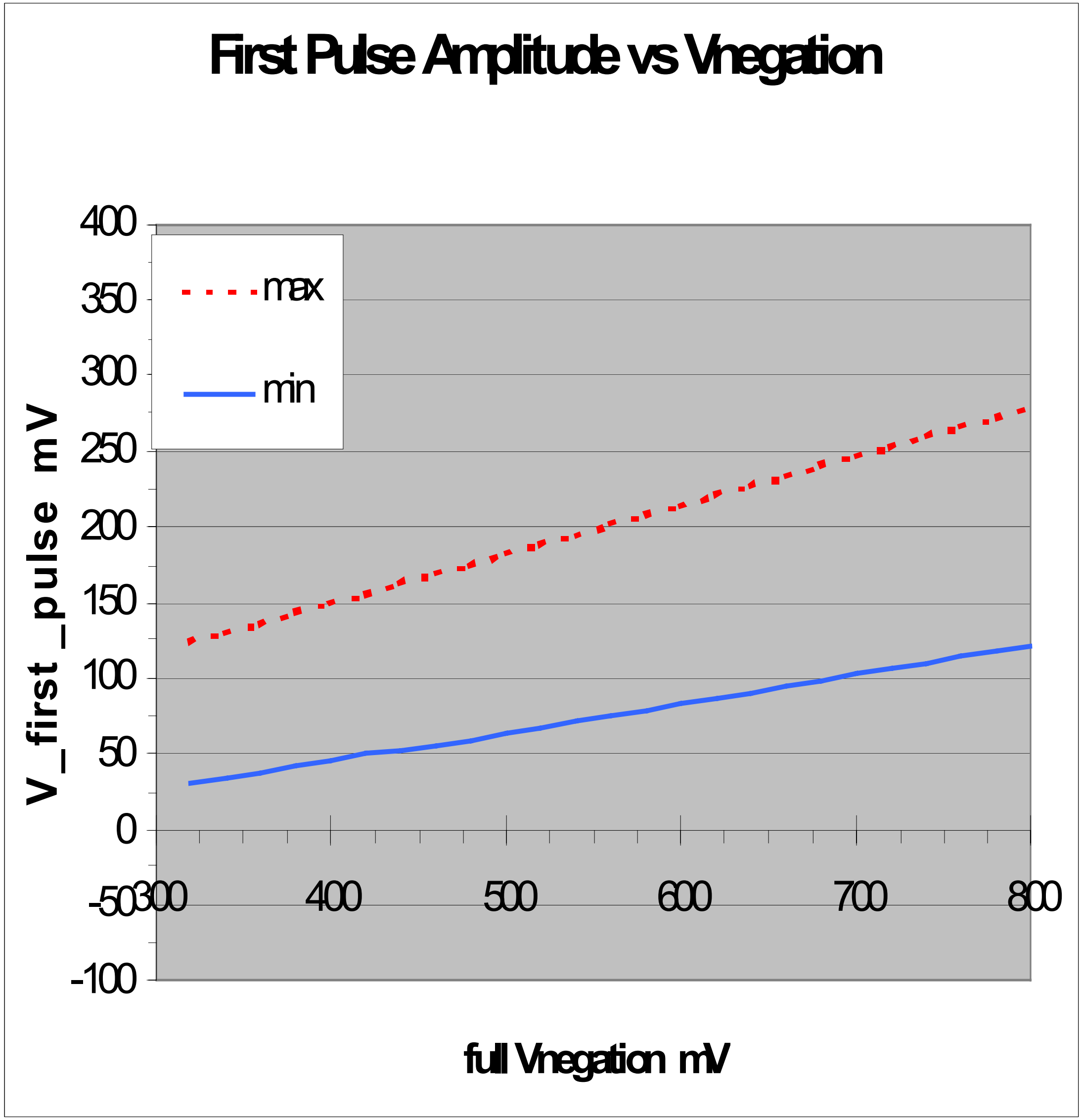
1.11	Va vs Vn max slope		
26	Va vs Vn max case offset		
0.9	Va vs Vn min slope		
-23	Va vs Vn min case offset		
Cable plant / term params			
2.14	mA bias compensation		
3	ohms bus resistance		
100	drvr R_term_near ohms		
110	rcvr R_term_far ohms		
135	Z on cable ohms		
100	Z on backplane ohms		
0.8	Cable loss factor		



Max / Min 1st Pulse, Worst Case Bus

- Max, min pulse heights vs swing

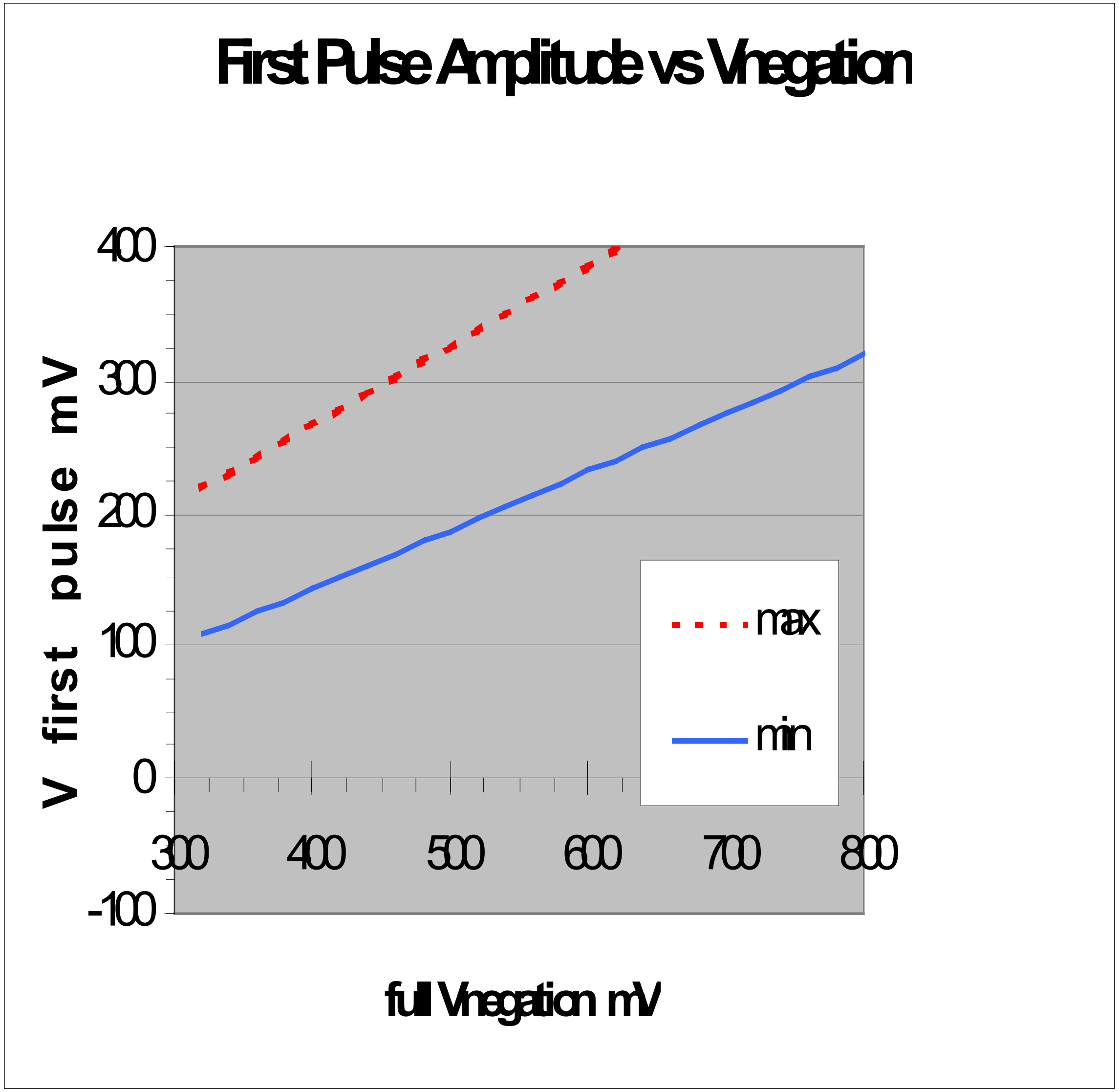
Driver parameters	
320	mV Negation, full swing, Std load
66	% = (fallback swing / full swing)
10	% tol. on Icutback / Idrive
78	spec max % fallback
50	spec min % fallback
1.11	Va vs Vn max slope
26	Va vs Vn max case offset
0.9	Va vs Vn min slope
-23	Va vs Vn min case offset
Cable plant / term params	
2.14	mA bias compensation
6	ohms bus resistance
100	drvr R_term_near ohms
110	rcvr R_term_far ohms
135	Z on cable ohms
85	Z on backplane ohms
0.7	Cable loss factor



Min / Max 1st pulse, Constrained bus

- Max and min amplitudes versus swing

Driver parameters	
320	mV Negation, full swing, Std load
66	% = (fallback swing / full swing)
10	% tol. on Icutback / Idrive
78	spec max % fallback
50	spec min % fallback
1.11	Va vs Vn max slope
26	Va vs Vn max case offset
0.9	Va vs Vn min slope
-23	Va vs Vn min case offset
Cable plant / term params	
2.14	mA bias compensation
3	ohms bus resistance
100	drvr R_term_near ohms
110	rcvr R_term_far ohms
135	Z on cable ohms
100	Z on backplane ohms
0.8	Cable loss factor



Sources of Max vs Min Variations

- Fallback min 62.6%, target 66%, max 69.4%
- Worst case bus

66	% = (fallback swing / full swing)
10	% tol. on Icutback / Idrive
78	spec max % fallback
50	spec min % fallback
1.11	Va vs Vn max slope
26	Va vs Vn max case offset
0.9	Va vs Vn min slope
-23	Va vs Vn min case offset
Cable plant / term params	
2.14	mA bias compensation
6	ohms bus resistance
100	drvr R_term_near ohms
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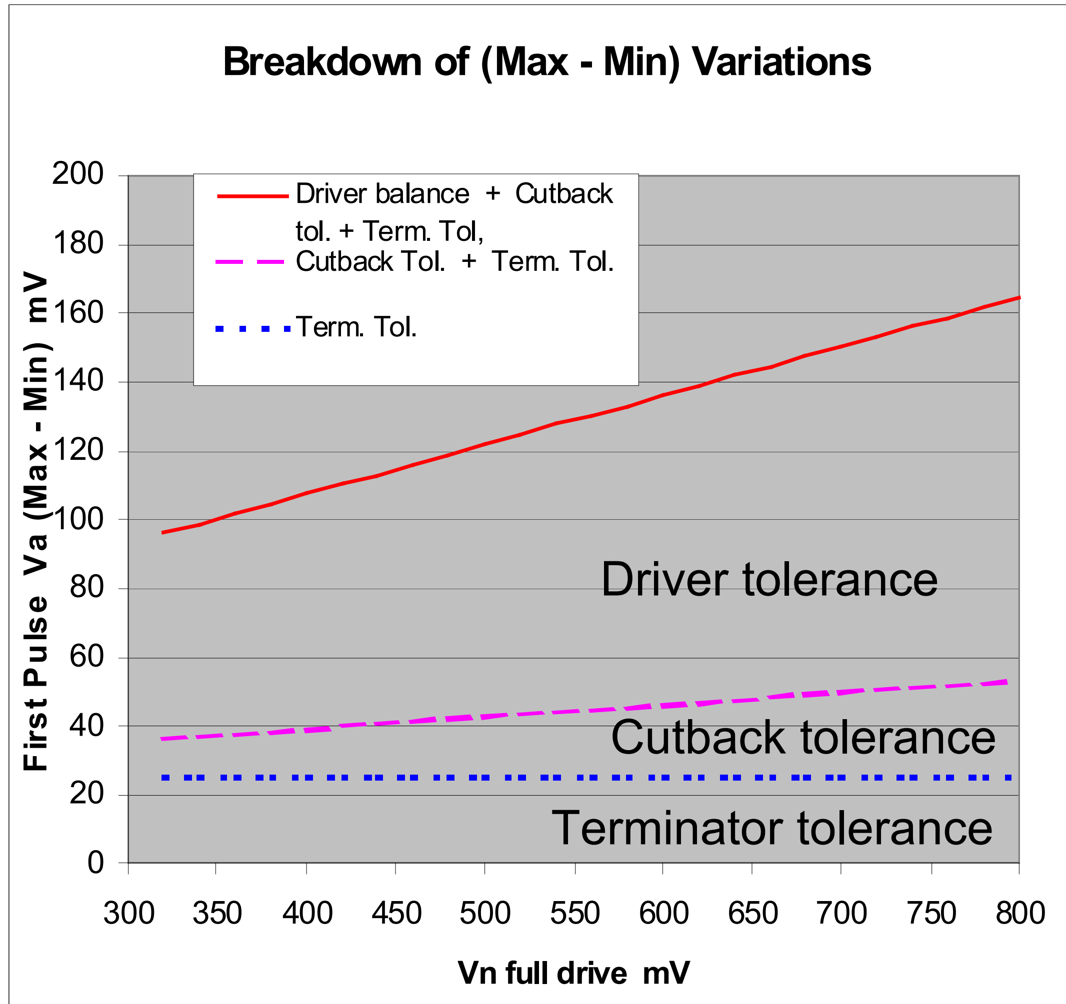

Summary 1

- Bus parameters affecting first pulse amplitude have been listed.
- Sample calculation of first pulse swings has been shown,
- On a worst case bus with a single impedance discontinuity, assuring 100 mV of margin requires some combination of:
  - Ratio of fallback current to full drive < 66%,
  - Full drive above 645 mV,
  - A relaxation of some spec parameters.
- A spread sheet can be used to show tradeoffs.

Summary 2

- With relaxed parameters, the bus can have over 100mv of margin with:
  - 78% fallback ratio,
  - < 400 mV swings.
- One possible set of relaxed specifications for non-AAF bus configurations is:
  - AC loss multiplier better than 0.80,
  - Backplane impedance minimum of 100 Ω.
  - Bus resistance end to end of 3 Ω max (DC loss factor of 0.95).

Conclusions

- For a worst case bus, signals at an AAF receiver have adequate margin.
- For a worst case bus, there is no feasible driver strength for which a non-AAF receiver will have adequate margin.
- If bus parameters are relaxed for non-AAF configurations, then there will be adequate signal margin at the receiver.
- Large increases in driver DC amplitudes only slightly increase the number of bus configurations which have adequate margins with only PreComp.