Connector Pinout
The Art and Science of Assigning Connector Grounds

Scott McMorrow

Teraspeed Consulting Group LLC

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Abstract

- Crosstalk has a large effect on the electrical performance of a connector.
  - Heavily influenced by the locations of signals and grounds.
- Maximum density and bandwidth require a balance between the number of grounds and signals used in a connector.
- Over design reduces density and increases cost.
- Under design increases noise and chance of system failure.

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Abstract

- In this Webinar, we will show you how to develop pinouts that are appropriate to the signals being transferred.
  - We will use
    - IBIS models
    - Standard Samtec RF characterization reports
    - Samtec Final Inch™ documentation
    - Simple calculations

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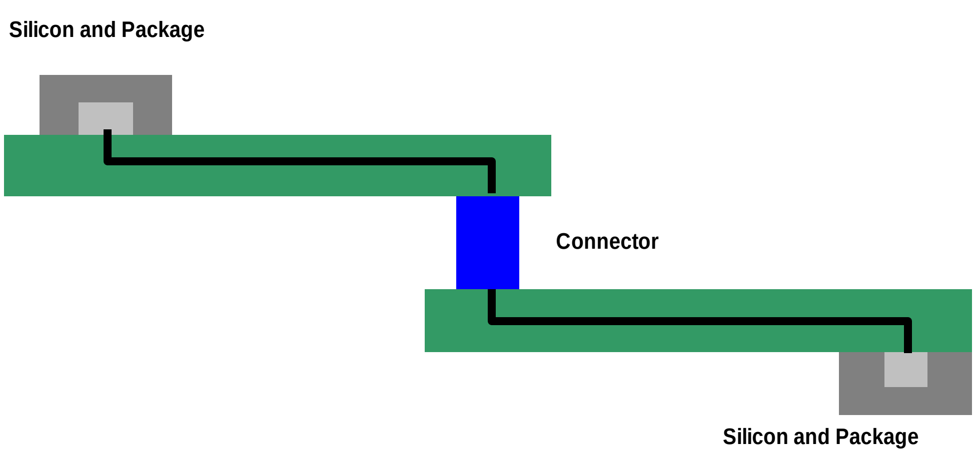
Typical Mezzanine Card Interconnect

- Includes traces and connectors.
  - Let's assume a mezzanine card with two boards and one connector.
  - Operating with a PCI-X bus signaling between the two cards.



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Steps Involved to Compute Connector Noise Margin

1. Determine bus operating margins.
2. Compute driver and receiver reflection coefficients.
3. Calculate required connector FEXT and NEXT limits.
4. Determine fastest risetime and highest bandwidth required.
5. Calculate total crosstalk from RF characterization and Final Inch^{TM} reports.

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Example Noise Margin

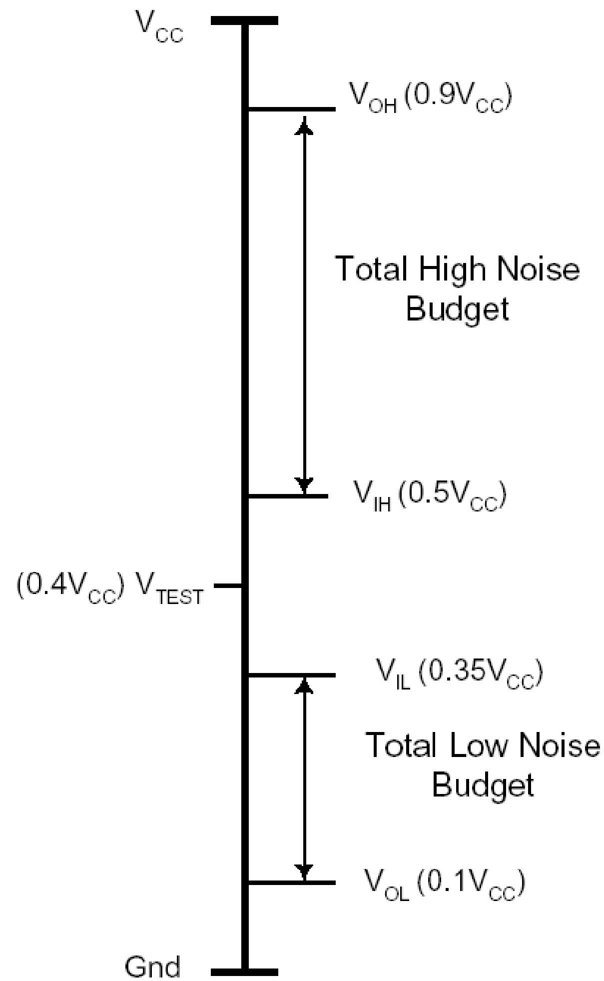
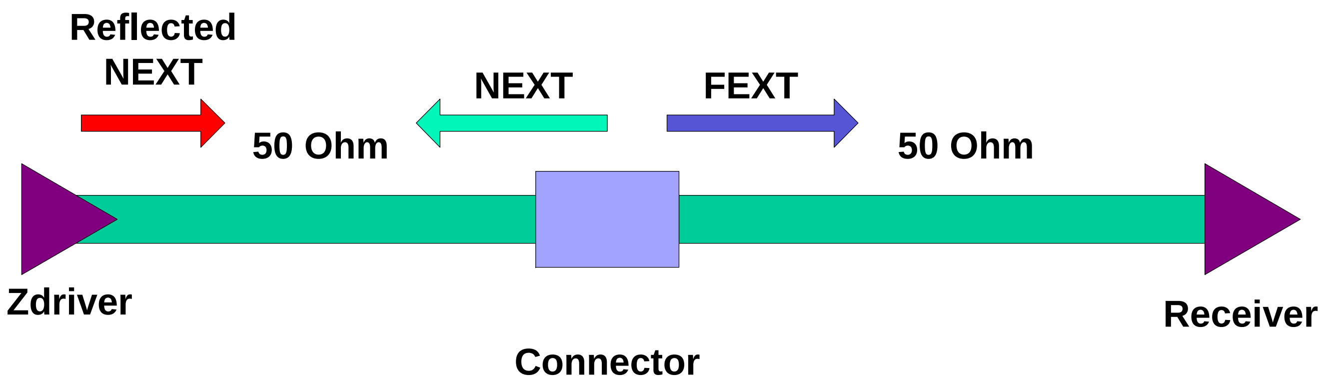


Figure 9-15: PCI-X Noise Budget

Connector Noise Contribution



Receiver sees FEXT and Reflected NEXT.

In general they may be treated separately, since they arrive out of phase and are not additive.

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Noise Budget

- PCI-X Noise Budget

Table 9-10: PCI-X System Noise Budget

Noise Source	Responsibility	High Noise Budget	Low Noise Budget
Reflective Noise	Platform	$0.30V_{CC}$	$0.15V_{CC}$
Crosstalk	Platform	$0.05V_{CC}$	$0.05V_{CC}$
Input Reference Offset	Device	$0.05V_{CC}$	$0.05V_{CC}$
Total		$0.4V_{CC}$	$0.25V_{CC}$

Vcc(max) = 3.465 V

260 mV reflected (.15 x 3.465 x 50%)

347 mV FEXT ((.05 x 3.465 + .15 x 3.465) x 50%)

Noise budgets are derated by 50% to account for other sources of reflective noise.

FEXT is time correlated with the signal driven through the connector and is of short duration. It will occur before reflected noise arrives and thus may be take up the entire crosstalk and reflected noise allocation.

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Driver Rise Time and Voltage Swing

- Driver edge rate and voltage swing can be computed using IBIS [Ramp Rate] data.

```
|*******************************************************************************
|
[Ramp]
R_load = 50.00Ohm
|            typ              min               max
|
dV/dt_r      1.479V/245.089ps   1.277V/439.827ps   1.671V/143.194ps
dV/dt_f      1.513V/152.684ps   1.342V/243.458ps   1.697V/100.848ps
```

20/80% rise time

20/80% voltage swing

2.83 V full swing

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Computing Output Impedance from IBIS model

[Model] **pcix_model_Rev1_1**

Model_type **I/O**

[Voltage Range] **3.300V** **3.135V** **3.465V**

Using driver voltage range and voltage swing, we can compute the output impedance as a voltage division between the driver and the 50 ohm load in the model.

$$Rload/(Rload + Z) = Vswing/Vmax$$

$$Z = Rload(Vmax-Vswing)/Vswing$$

$$Vmax = 3.465\ V$$

$$Total\ Vswing = 1.697/60\% = 2.828\ V$$

$$Z = 10.88\ ohms$$

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Compute Reflection Coefficient for Driver

$$\Gamma = \frac{\text{Zdriver} - \text{Zo}}{\text{Zdriver} + \text{Zo}}$$

For our example:

Rdriver = 10.88 ohms

Zo = 50 ohms

Reflection coefficient = -0.63

63 % of NEXT from connector will be returned back to the receiver.

Note: series termination at the driver will reduce this reflection coefficient, thereby increasing the amount of allowable connector NEXT.

Compute Reflection Coefficient for Receiver

$$\Gamma = \frac{\text{Zreceiver} - \text{Zo}}{\text{Zreceiver} + \text{Zo}}$$

For our example:

Rreceiver = infinite

Zo = 50 ohms

Reflection coefficient = 1

100 % of crosstalk received will be reflected, causing an effective doubling factor at the receiver input.

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Putting It All Together

- Transmitted crosstalk (FEXT) allowed = 347 mV
- Reflected crosstalk allowed = 260 mV
- 20 %/80 % voltage = 1.697 V
- Percentage crosstalk
  - 20.5 % FEXT
  - 15.3 % reflected
- Compute connector NEXT percentage
  - NEXT = |15.3 % / reflection coefficient|
  - = 15.3 % /0.63 = 24.3 %
  - Derate for receiver impedance mismatch.
  - For unterminated receiver the reflection coefficient is 1, so voltages double.
    - Allowable FEXT and NEXT at connector are reduced by 2 due to the reflection at the receiver.
      - FEXT allowed = 10.2 %, NEXT allowed = 12.1 %

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Computation of Bandwidth

$$\text{Bandwidth} = \frac{0.35}{\text{Risetime}}$$

$$\text{Bandwidth} = \frac{0.35}{100\ \text{ps}}$$

3.5 GHz

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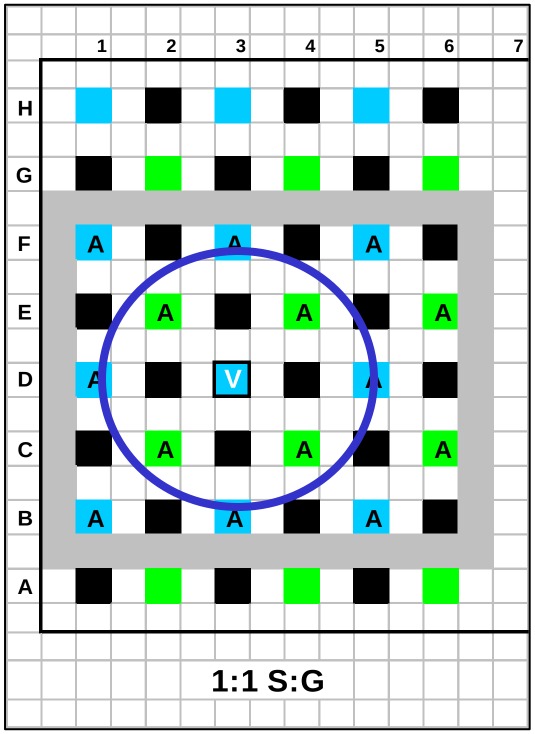
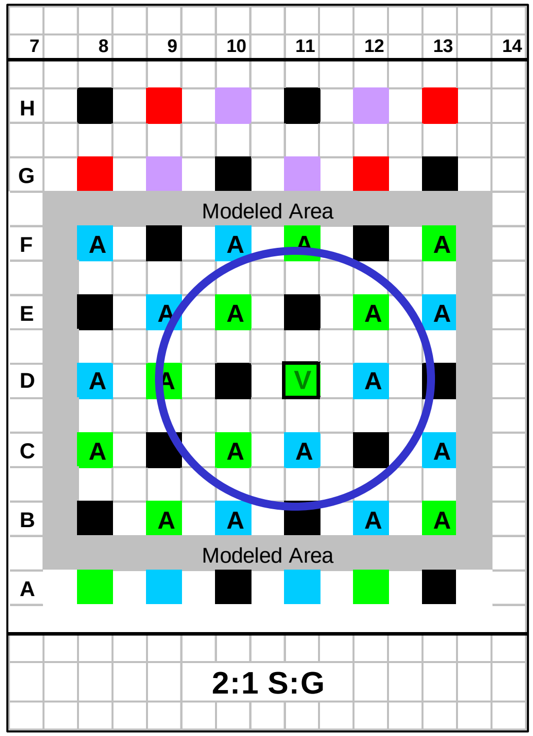
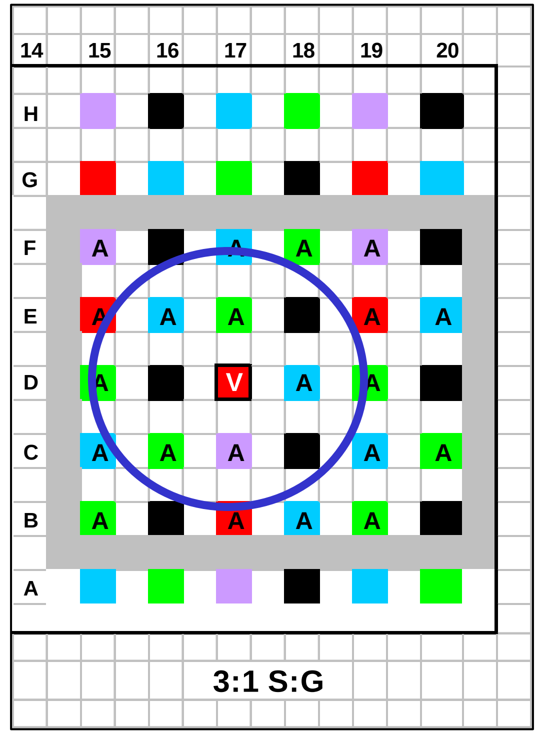
Design Requirements for Connector

- Allowable FEXT = 10.2 %
- Allowable NEXT = 12.1 %
- Rise time = 100 ps minimum.
- Bandwidth = 3.5 GHz maximum.

SamArray™ Final Inch™ Configurations







4 diagonal aggressors

3 diagonal aggressors

2 adjacent aggressors

2 diagonal aggressors

3 adjacent aggressors

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SamArray™ Crosstalk From RF Characterization Report

Best Case Single Ended Crosstalk Configuration 1

G	G	G	G	G
G	D	G	M	G
G	G	G	G	G

Signal Rise time	30 ps	100 ps	500 ps
NEXT	0.52 %	0.18 %	0.04 %
FEXT	0.74 %	0.22 %	0.06 %

Worst Case Single Ended Crosstalk Configuration 1

Adjacent Case

FEXT allowed = 10.2 %

NEXT allowed = 12.1 %

G	G	G	G
G	D	M	G
G	G	G	G

Signal Rise time	30 ps	100 ps	500 ps
NEXT	8.03 %	4.09 %	0.98 %
FEXT	3.03 %	0.71 %	0.09 %

Worst Case Single Ended Crosstalk Configuration 2

Diagonal Case

G	G	M	G
G	D	G	G
G	G	G	G

Signal Rise time	30 ps	100 ps	500 ps
NEXT	2.12 %	1.24 %	0.32 %
FEXT	0.95 %	0.40 %	0.11 %

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Crosstalk Summation with YFS RF Characterization Data

- Crosstalk from multiple aggressors may be summed at the victim.
- 1:1 S:G Final Inch™ (4 diagonal aggressors)
  - Total NEXT = 4 x 1.24 % = 4.96 % Meets Target
  - Total FEXT = 4 x 0.4% = 2.84% Meets Target
- 2:1 S:G Final Inch™ (3 diagonal, 2 adjacent aggressors.)
  - Total NEXT = 3 x 1.24 % + 2 x 4.09 % = 11.9 % Pass
  - Total FEXT = 3 x 0.4 % + 2 x .71% = 2.62 % Pass
- 3:1 S:G Final Inch™ (2 diagonal, 3 adjacent aggressors.)
  - Total NEXT = 2 x 1.24 % + 3 x 4.09 % = 14.75 % Fails
  - Total FEXT = 2 x 0.4 % + 3 x .71% = 2.93 %

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Measured Final Inch™ Crosstalk
with 14.5" of Trace

	Adjacent NEXT	Adjacent FEXT
1:1 Signal to Ground	2.0%	0.4%
2:1 Signal to Ground	4.6%	2.2%
3:1 Signal to Ground	4.8%	2.45%

FEXT allowed = 10.2 %
NEXT allowed = 12.1 %

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Crosstalk Summation With Final Inch™ Measurements

- Crosstalk from multiple aggressors may be summed at the victim, for connector noise, represents the worst possible case, including breakout trace and via crosstalk
- 1:1 S:G Final Inch™ (4 diagonal aggressors)
  - Total NEXT = 4 x 2 % = 8 % Meets Target
  - Total FEXT = 4 x 0.4% = 1.6% Meets Target
- 2:1 S:G Final Inch™ (3 diagonal, 2 adjacent aggressors.)
  - Total NEXT = 3 x 2 % + 2 x 4.6 % = 15.2 % Fails
  - Total FEXT = 3 x 0.4 % + 2 x 2.2% = 5.6 %
- 3:1 S:G Final Inch™ (2 diagonal, 3 adjacent aggressors.)
  - Total NEXT = 2 x 2 % + 3 x 4.6 % = 17.8 % Fails
  - Total FEXT = 2 x 0.4 % + 3 x 2.2% = 7.4 %

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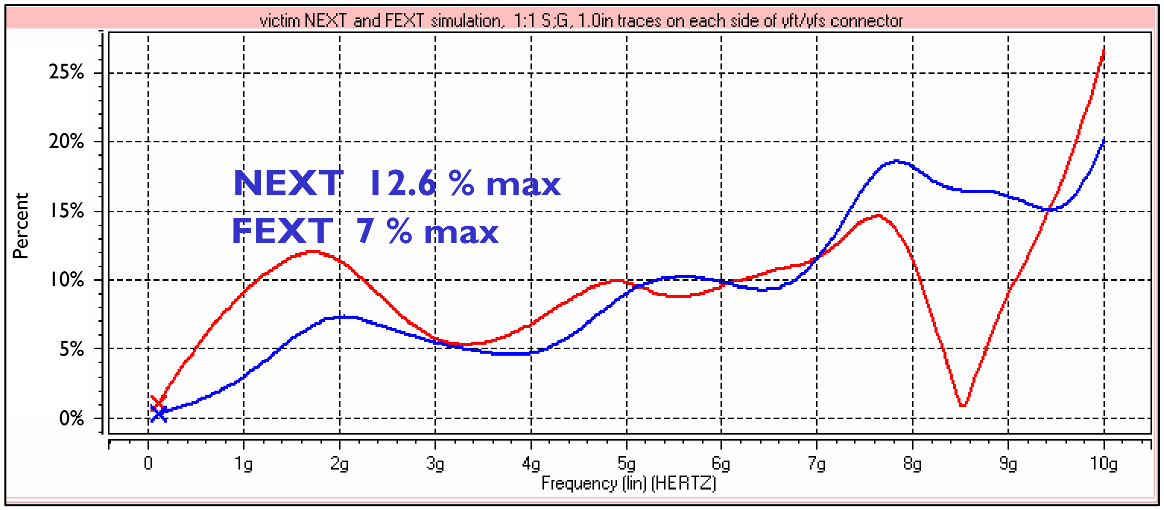
Crosstalk from 1:1 S:G SamArray™ Final Inch™ Simulations

Crosstalk

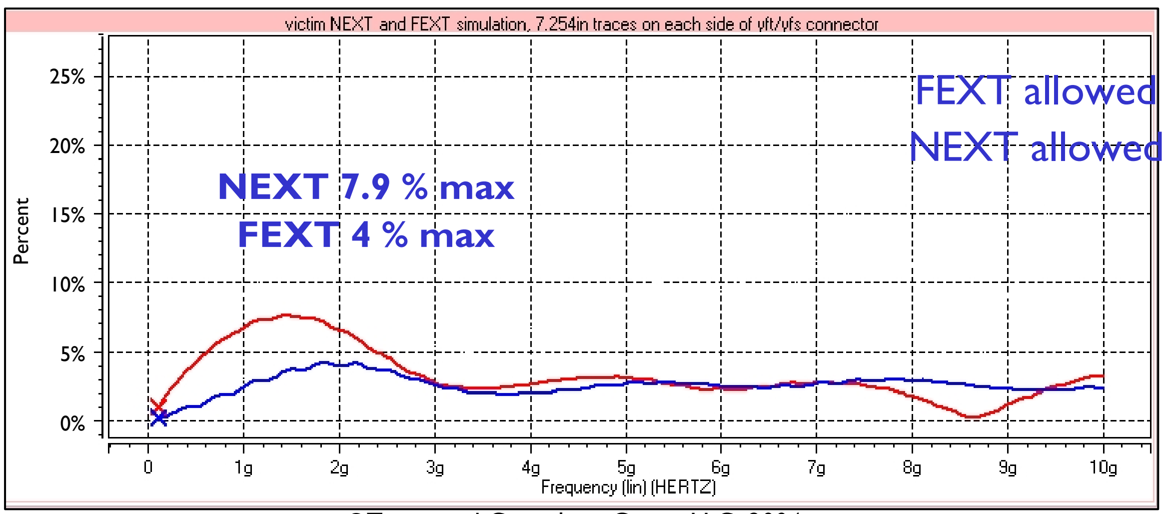
Red = NEXT

Blue = FEXT

1 inch Traces



7.254 inch Traces



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Final Inch Simulation vs. Measurement

- Comparing our calculations of NEXT vs. measurement for the 7.254" trace case (14.5" total) we arrive at:
  - NEXT
    - Measured NEXT 8 %
    - Simulated NEXT 7.9 %
  - FEXT
    - Measured FEXT 1.6 %
    - Simulated FEXT 4 %

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Crosstalk from 2:1 S:G SamArray™ Final Inch™ Simulations

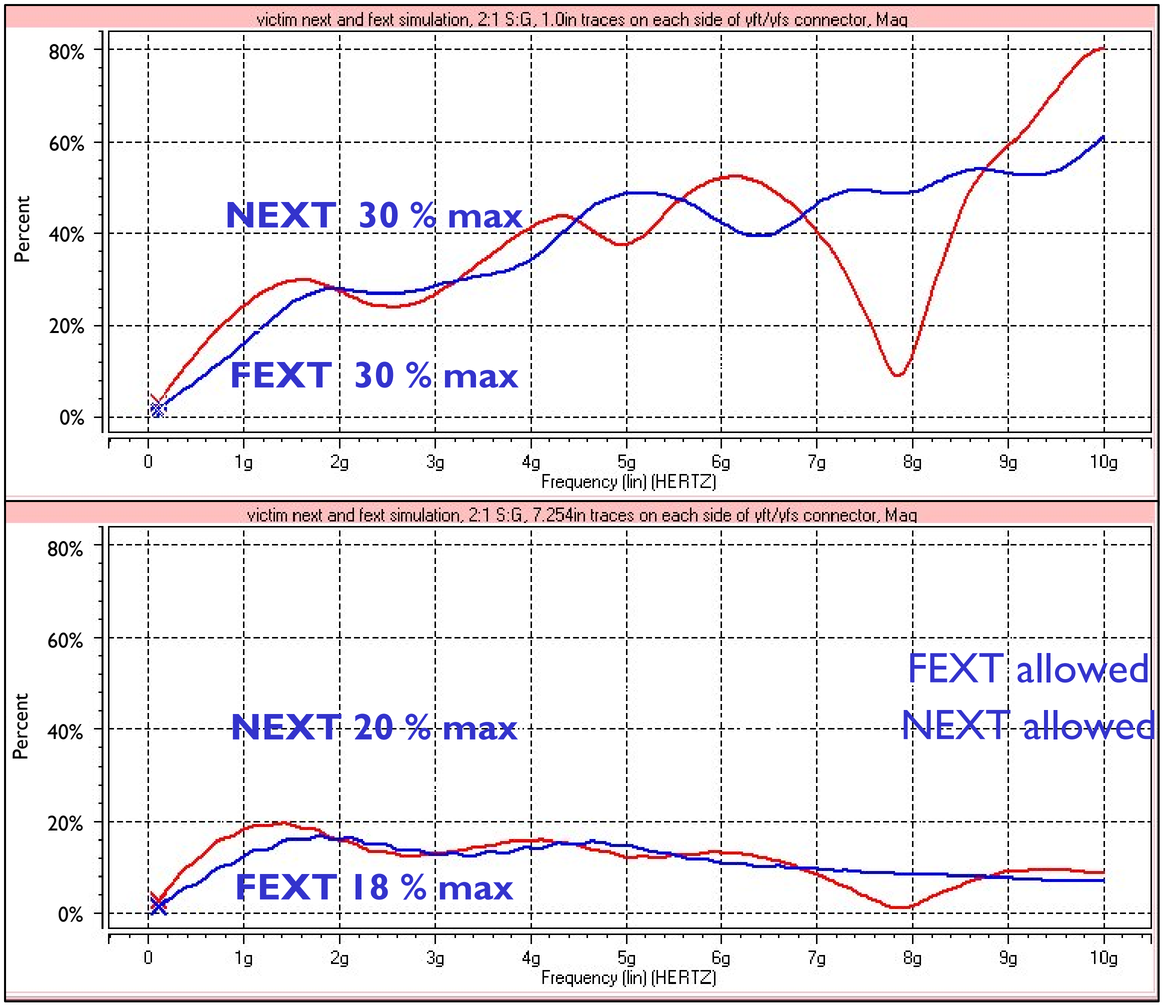
Crosstalk

Red = NEXT

Blue = FEXT

1 inch Traces

7.254 inch Traces



Fails

FEXT allowed = 10.2 %

NEXT allowed = 12.1 %

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Comparison of 1:1 to 2:1 Signal-to-Ground Ratio Pinouts

- 1:1 S:G Ratio
  - 1" Traces
    - NEXT 12.6 %
    - FEXT 7 %
  - 7.254" Traces
    - NEXT 7.9 %
    - FEXT 4 %
- 2:1 S:G Ratio
  - 1" Traces
    - NEXT 30 %
    - FEXT 30 %
  - 7.254" Traces
    - NEXT 20 %
    - FEXT 18 %
- Notice that crosstalk in the connector and breakout region decreases due to attenuation and edge rate reduction.

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Comparison of RF Characterization to Final Inch™

- Diagonal Coupling
  - RF characterization
    - NEXT 1.24 %
    - FEXT .4 %
  - Final Inch™
    - NEXT 2.0 %
    - FEXT 0.4 %
- Adjacent Coupling
  - RF characterization
    - NEXT 4.09 %
    - FEXT .71 %
  - Final Inch™
    - NEXT 4.6 %
    - FEXT 2.2 %

Differences between the Final Inch™ YFS design and RF characterization exist due to the break out region (BOR).

Direct connect measurements are used in RF characterization to eliminate all PCB breakout and via effects.

Final Inch™ designs include the BOR, which contributes additional crosstalk to the design.

For the purpose of crosstalk calculations, Final Inch™ numbers should be considered more like real PCB conditions, as RF characterization leaves out all effects of board attachment.

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Design Conclusions

- Based upon our calculated studies, a design using one SamArray^{TM} connector would fulfill the design requirements at a signal-to-ground ratio of 1:1.
  - Final InchTM data has shown the design to be robust across a large range of bus trace lengths.
  - A 64 bit PCI-X bus with approximately 100 active signals can be easily supported by a SamArray connector with greater than 200 contact pins or greater.

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Conclusion

- Using IBIS model data, Samtec RF characterization reports, Samtec Final InchTM documentation and simple calculations, we have demonstrated a powerful method for quickly determining the number of ground pins require in a connector, based upon noise criteria.
- In addition, we have shown strong correlation between measured and simulated data which lends confidence in the final choices made.

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